3. Decarbonization of Off-Road, Rail, Marine, and Aviation Technologies

The Vehicle Technologies Office (VTO) supports research, development, demonstration, and deployment (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well innovations in connected infrastructure for significant systems-level energy efficiency improvement); innovative powertrains to reduce greenhouse gas (GHG) and criteria emissions from hard to decarbonize off-road, maritime, rail, and aviation sectors; and technology integration that helps demonstrate and deploy new technology at the community level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), VTO advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The Decarbonization of Off-Road, Rail, Marine, and Aviation (DORMA) Technologies subprogram supports RDD&D to develop and deploy new propulsion and efficient vehicle technologies in off-road, rail, marine, and aviation applications that reduce GHG emissions and achieve a net-zero economy by 2050, all while creating good paying jobs with the free and fair chance to join a union and bargain collectively.

The goal of this portfolio is to conduct coordinated research with industry, universities, and the national laboratories through cooperative research and development agreements (CRADAs).This subprogram conducts industry-led RDD&D for off-road medium and heavy-duty (HD) vehicles, including engines used for marine, rail, and aviation, focused on electrified and hybrid systems as well as powertrains that can utilize renewable fuels, such as advanced biofuels, H_2, renewable diesel and e-fuels. The subprogram will coordinate with and utilize expertise from other Offices and VTO programs as needed.

The subprogram supports cutting-edge research at the national laboratories, in close collaboration with industry, while working closely with other agencies including the Environmental Protection Agency and Department of Transportation's Federal Railroad Administration (FRA) and Maritime Administration (MARAD), to achieve goals for decarbonization of these subsectors. It will use a multi-laboratory initiative, including high performance computing (HPC) and hardware in-the-loop resources, for research to optimize vehicle efficiency which also will be applicable to hard to electrify on-road HD vehicles.

The subprogram also supports industry needs to develop predictive, high-fidelity sub-models and simulation tools that are scalable and can leverage future exascale computing capabilities. The activity will fund research of renewable fuel properties utilizing chemical kinetics modeling of different molecules to determine their impact on combustion efficiency and emissions. It will also develop numerical routines and sub-models of complex chemical reactions that can reduce the computational time and increase the accuracy required for high-fidelity engine models, making them viable for use by industry.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (on a scale of 1.0 to 4.0). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 3-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
DORMA001	Heavy-Duty H_2 Combustion	Ales Srna (Sandia National Laboratories)	3-6	3.42	3.50	3.58	3.58	3.50
DORMA002	Off-Road Liquid Fuel Combustion	Dario Lopez-Pintor (Sandia National Laboratories)	3-12	3.29	3.43	3.43	3.36	3.38
DORMA003	High-Fidelity Simulations of Swirl-Stabilized Spray Flame with Sustainable Aviation Fuels	Bruno Souza Soriano (Sandia National Laboratories)	3-18	3.38	3.75	3.13	3.50	3.55
DORMA004	Ducted Fuel Injection	Chuck Mueller (Sandia National Laboratories)	3-23	3.60	3.60	3.60	3.60	3.60
DORMA005	Sprays and Spray Combustion	Lyle Pickett (Sandia National Laboratories)	3-27	3.75	3.75	3.75	3.58	3.73
DORMA006	LLCF combustion and emission models	Scott Wagnon (Lawrence Livermore National Laboratory)	3-32	3.58	3.58	3.50	3.42	3.55
DORMA007	Innovative NO_x Reduction Materials for Low Temperature Aftertreatment	Yong Wang (Pacific Northwest National Laboratory)	3-37	3.30	3.20	3.30	3.10	3.23
DORMA008	Slashing Platinum Group Metal (PGM) in Catalytic Converters: An Atoms-to-Autos Approach	Kevin Gu (General Motors)	3-41	3.10	3.10	3.60	3.00	3.15
DORMA009	NO_x Reduction with Low GHG Impact (N_2O Reduction for Off-road)	Feng Gao (Pacific Northwest National Laboratory)	3-45	3.20	3.10	3.20	3.00	3.13
DORMA010	Hardware in the Loop Toolkit for Off-Road and Marine	Muni Biruduganti (Argonne National Laboratory)	3-50	2.70	2.20	2.30	2.60	2.39

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
DORMA012	H_2 Combustion Research – CRADA with Wabtec	Muhsin Ameen (Argonne National Laboratory)	3-55	3.25	3.50	3.50	3.50	3.44
DORMA013	Experimental and Numerical Research on Biodiesel and Renewable Diesel Blends for Locomotive Engines	Chao Xu (Argonne National Laboratory)	3-57	2.75	2.75	3.25	2.75	2.81
DORMA014	Implementing low lifecycle carbon fuels on locomotive engines – CRADA with Wabtec	Dean Edwards (Oak Ridge National Laboratory)	3-59	3.50	3.25	3.50	3.00	3.31
DORMA015	Enabling H_2 and Methanol Combustion	Riccardo Scarcelli (Argonne National Laboratory)	3-62	3.00	2.67	2.17	3.00	2.73
DORMA016	Renewable methanol-fueled engines for marine and off-road applications	Jim Szybist (Oak Ridge National Laboratory)	3-65	3.33	3.67	3.33	3.50	3.52
DORMA017	SAF End Use Research	Sibendu Som (Argonne National Laboratory)	3-68	3.38	3.25	3.13	3.50	3.30
DORMA018	SAF Combustion & Soot Processes	Julien Manin (Sandia National Laboratories)	3-72	3.25	3.38	3.00	3.00	3.25
DORMA019	Multi-phase flow studies of SAFs for industry-relevant conditions and geometries	Brandon Sforzo (Argonne National Laboratory)	3-76	3.17	3.67	3.50	3.17	3.46
DORMA020	SAF Contrail Modeling	Matt McNenly (Lawrence Livermore National Laboratory)	3-80	3.63	3.13	3.50	3.13	3.30
DORMA021	Simultaneous Greenhouse Gas and Criteria Pollutants Emissions Reduction for Off-Road Powertrains	James McCarthy (Eaton)	3-85	3.67	3.33	3.33	3.67	3.46

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
DORMA022	Development of a Flex-Fuel Mixing Controlled Combustion System for Gasoline/Ethanol Blends Enabled by Prechamber Ignition	Adam Dempsey (Marquette University)	3-88	3.75	3.75	3.75	3.38	3.70
DORMA023	Improved Efficiency of Off-Road Material Handling Equipment through Electrification	Jeremy Worm (Michigan Technological University)	3-92	3.75	3.50	3.63	3.38	3.56
DORMA024	Reduced Cost and Complexity for Off-Highway Aftertreatment	Ken Rappe (Pacific Northwest National Laboratory)	3-96	3.50	3.50	3.83	3.33	3.52
DORMA025	Fully Electric Powered, Hydraulic Assisted, Compact Track Loader	Perry Li (University of Minnesota)	3-99	3.30	3.10	3.40	3.40	3.23
DORMA026	Articulated Dump Truck (ADT) Electrification – Greenhouse Gas Reductions and Commercialization of New Technology	Brij Singh (John Deere)	3-104	3.17	3.00	3.17	3.17	3.08
DORMA027	LLCF Effects on Emissions Control Catalyst Performance and Durability	Sreshtha Sinha Majumdar (Oak Ridge National Laboratory)	3-107	3.40	3.50	3.30	3.60	3.46
DORMA028	Comprehensive Integrated Simulation Methodology for Enabling Near-Zero Emission Heavy-Duty Vehicles	Andrea Strzelec (University of Wisconsin-Madison)	3-112	3.50	3.75	3.50	3.75	3.66
DORMA029	Fast Simulation of Real Driving Emissions from Heavy-duty Diesel Vehicle Integrated with Advanced Aftertreatment System	Hailin Li (West Virginia University)	3-115	3.33	2.83	3.50	3.50	3.13
DORMA030	Opposed-Piston 2-Stroke Hybrid Commercial Vehicle System	Fabien Redon (Achates Power)	3-118	2.83	2.83	3.33	2.83	2.90

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaboration	Future Research	Weighted Average
DORMA031	Dynamic Skip Fire (DSF) on a Heavy-Duty Natural Gas Engine	Jay Shah (Cummins)	3-121	3.50	3.25	3.00	3.00	3.25
DORMA032	High Efficiency, Ultra Low Emissions Heavy-Duty 10L Natural Gas Engine Project	Tim Lutz (Cummins)	3-125	3.50	3.50	2.13	3.50	3.33
DORMA033	High Pressure Fast Response Direct Injection System for Liquified Gas Fuels Use in Light-Duty Engines	William de Ojeda (WM International Engineering)	3-129	3.50	3.60	3.60	3.30	3.54
DORMA034	Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications	Qigui Wang (General Motors)	3-133	3.13	3.00	3.38	3.33	3.12
DORMA035	Next-Generation, High-Efficiency Boosted Engine Development	Michael Shelby (Ford)	3-136	3.88	3.63	3.50	3.33	3.64
DORMA036	SuperTruck 2 – PACCAR	Maarten Meijer (PACCAR)	3-139	3.70	3.60	3.70	3.60	3.64
DORMA037	SAF Specifications and Testing Protocols, Gina Fioroni, National Renewable Energy Laboratory	Gina Fioroni (National Renewable Energy Laboratory)	3-143	3.30	3.30	3.60	3.20	3.33
DORMA038	Towards Accurate Reacting Flow Simulations of SAFs	Debolina Dasgupta (Argonne National Laboratory)	3-149	3.20	3.40	3.00	3.30	3.29
Overall Average				**3.36**	**3.32**	**3.32**	**3.29**	**3.33**

Presentation Number: DORMA001
Presentation Title: Heavy-Duty H_2 Combustion
Principal Investigator: Ales Srna (Sandia National Laboratories)

Presenter

Ales Srna, Sandia National Laboratories

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

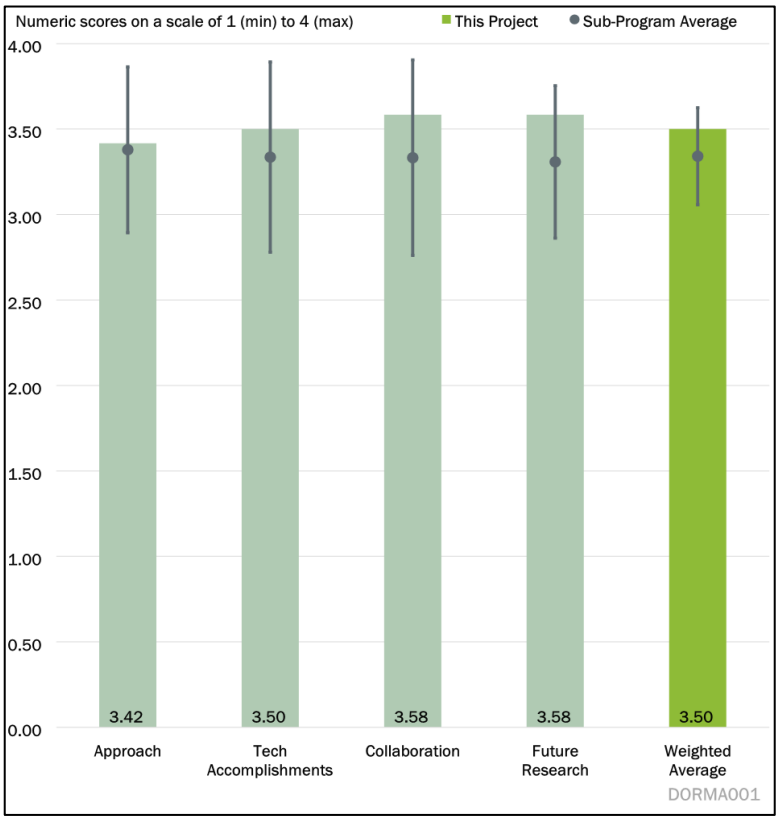

Figure 3-1 – Presentation Number: DORMA001 Presentation Title: Heavy-Duty H_2 Combustion Principal Investigator: Ales Srna (Sandia National Laboratories)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer believed this project was well designed and has the major barriers for hydrogen (H_2) internal combustion engine (ICE) systems identified. The reviewer stated that the gaps and barriers listed toward predictive H_2 combustion simulations are correct as well as the understanding that most original equipment manufacturers (OEMs) are pursing H_2 ICE heavily. The reviewer also said that the listing of knowledge gaps is a nice way to lay out the "why" behind the approach. Further, the Fiscal Year (FY) 2022 completed deliverables give evidence toward the excellent approach and feasibility.

Reviewer 2:

The reviewer stated that this is a very focused fundamental investigation of the mixing and combustion characteristics of H_2 in a heavy-duty (HD) engine, and it will provide foundational knowledge that could be very helpful in the refinement of H_2 use in the HD mobility sector. The phenomenon being investigated will be somewhat specific to the approach being taken. The reviewer commented that the researchers are likely aware of this and have plans to explore other approaches of introducing and burning H_2 in the engine, for example via prechamber systems.

Reviewer 3:

The reviewer said that this is a well-designed project with a reasonably planned timeline.

Reviewer 4:

The reviewer believed this project is a good start to close the fundamental research and development knowledge gaps by addressing some of the key technical barriers—from basic understanding of air management system requirements to the in-cylinder processes and predictive simulations of the combustion processes of H_2-fueled internal combustion engines.

Reviewer 5:

The reviewer believed that this project is focused on understanding the H_2 combustion in H_2 ICE. The reviewers stated that the researchers developed the single cylinder engine with several *in situ* measurement/characterization tools and used condition ranges similar to those in practical operations. The reviewer said that the key value of this project is that it provides visualization of the combustion (which they state is almost impossible in a real-life system), provides mechanical understanding of the process, and provides good data for modeling. The reviewer indicated that the project is well designed and the timelines are reasonably planned. The reviewer stated that there is a possibility that the project could have a Phase 2 depending on whether there are additional questions that need to be addressed based on the current work.

Reviewer 6:

The reviewer said that this this project has done an excellent job of defining and exploring the challenges of HD H_2 combustion, starting from the basics of injector and mixing behavior to including H_2 preignition.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said that quantitative measurements of H_2 concentration, H_2-air mixing, and ignition clearly achieved the deliverables listed toward overcoming the barriers. The quantitative output in the database is incredibly useful for internal combustion engine research and development, simulation validation, and physics understanding. The reviewer stated that the linkage of this data for 0-dimensional (0D) and 1-dimensional (1D) model development is very useful and the publication of this data and efforts on the Engine Combustion Network (ECN) website could bring broad dissemination. The reviewer commented that the cyclic variability of H_2-air mixture preparation is very important to understand (for preignition, operation limits, design influences, etc.) and encouraged the quantitative data to include as much variability and uncertainty understanding as possible. The reviewer pointed out that the preignition root cause work appeared to be coming along nicely with examples of how the phenomena can be grouped and what parameters impact the probability. The reviewer believed that the potential of this project is to use optical diagnostics to see what is happening, combine that new information with other analyses (like 0D kinetic calculations), and provide a better understanding of the combustion preignition. The reviewer advised that the researchers continue to focus on gaining knowledge and fully explaining the mechanisms on the full range of preignition root causes.

Reviewer 2:

The reviewer stated that the work completed so far (and reported in the first Annual Merit Review) is of very high caliber.

Reviewer 3:

The reviewer said that the researchers did a great job keeping the project on track. The reviewer also commented that the project has good methods to understand in-cylinder phenomena as well as promising findings (e.g., the importance of temperature for H_2 preignition).

Reviewer 4:

The reviewer stated that reasonable technical progress had been made based on the results from the optical engine in the areas of in-cylinder mixing, flame evolution, and hot-spot preignition mixing, which are critical to abnormal combustion challenges in H_2-fueled internal combustion engines, such as backfire. However, the moderate range of injection pressure (20–40 bar) being investigated is very limited since this will cover only low-pressure H_2 combustion concepts. The reviewer advised that the project scope be expanded to include high-pressure combustion concepts that require an injection pressure of 250–300 bar to reflect the long-term viable systems that will be required to meet diesel-like engine efficiency and ultra-low emissions for commercial implementation.

Reviewer 5:

The reviewer remarked that the research team had documented the database of cylinder H_2 direct injection mixture formation in HD optical engines. The reviewer also stated that the team established a connection between various parameters of engine operation, such as injection pressure on mixture formation and flame kernel evolution.

Reviewer 6:

The reviewer stated that there have been many valuable outcomes from this project, including correlations of nitric oxide (NO) and nitrogen dioxide (NO_2) formation and mixing, showing that preignition can be triggered and controlled, showing shock-like behavior during H_2 injection, and the origins of cyclic variability.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer stated that the collaboration between Sandia National Laboratories (SNL), the Advanced Engine Combustion (AEC) working group, industry, the European universities, and other U.S. national laboratories demonstrates the near maximum amount that could be achieved for a project of this size.

Reviewer 2:

The reviewer recommended that the researchers enlist the participation of injector suppliers, as the injection system is critical to the phenomena being investigated. The reviewer gave Westport as an example, given that the reviewer believed that Westport is developing direct injection H_2 systems.

Reviewer 3:

The reviewer stated that while the collaboration and coordination across the project team was outstanding, Principal investigators and DOE program managers should try to increase the participation of universities in the United States for such projects. The low level of government funding for academic research will result in more universities ending any research on decarbonization other than electrification (despite recognizing that there are many sectors difficult to electrify). The reviewer said that this could end any student training on decarbonization strategies other than electrification.

Reviewer 4:

The reviewer praised the fantastic collaboration and coordination work under the AEC working group between the national laboratories (Sandia National Laboratories and Argonne National Laboratory), academia (University of Duisburg-Essen, Polytechnic University of Valencia, and Danish Technical University), and industry (Borg Warner, Cummins, Caterpillar, Detroit Diesel Corporation, Mack Trucks, Volvo, GE, PACCAR, and Gamma Technologies).

Reviewer 5:

The reviewer said that the extent of the collaborations meets expectations and is appropriate for a DOE national laboratory-led project. There are built-in opportunities for sharing information and interaction with stakeholders through the AEC-memorandum of understanding group. The reviewer remarked that while collaborations were mentioned with two European universities, none were mentioned with any U.S. universities. This could be an area to expand with the growing interest in basic research on H_2 applications.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer remarked that future particle image velocimetry (PIV) measurements to aid in the flow field development and ignition/kernel development will be very powerful for physical understanding and computational fluid dynamics (CFD) model validation. The reviewer recommended continued addition of quantitative measurements to build a robust canonical H_2 internal combustion engine data set. The reviewer then stated that having "pre-chamber" on the list for future H_2 efforts is an excellent decision and it makes sense that the project budget and scope could not include everything in the initial stages. The reviewer went on to say that evaluation of the different H_2 ICE "combustion" and "injection technology" options, and how the physics are impacted, is desirable within the project. However, the reviewer encouraged the project to stay away from technology selection for H_2 ICE. The reviewer approved of the plans to add lubrication to the H_2 preignition understanding and stated that the addition of an oil injection device seems like a very reasonable way to reproduce interesting phenomena in a controlled manner in the skip-fired optical engine.

Reviewer 2:

The reviewer commented that the project is still in an early stage, though the team has interesting results already. The reviewer agreed with the team's assessment that the planned next phase of the research is the appropriate path to follow.

Reviewer 3:

The reviewer said that the team has done a very good job ensuring that the next milestones are achieved successfully.

Reviewer 4:

The reviewer stated that the future research plans to expand the scope to investigate ignition systems and wall-heat loss, as well as to upgrade the HD optical engine facility, should also factor into the exploration of higher injection pressures and other sources of preignition, like lubrication.

Reviewer 5:

The reviewer remarked on how the project team highlighted the work they planned for next year and based on the progress, should be able to achieve the project's goals in time.

Reviewer 6:

The reviewer said that the project's progress to date will be continued and expanded on in the future as well as in the long-term plans for the project. Considering optimization of the injection and mixing processes in concern with chamber geometry should lead to additional impactful outcomes. The reviewer remarked that the consideration of wall effects is a very good expansion and continuation of the project scope, as the literature has documented how sensitive H_2 ignition can be to surface interactions.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer commented that the project is 100% relevant and aligned to DORMA goals. The reviewer also stated that the project is nicely aligned to the industry need to quickly learn and develop H_2 ICE for customers who wish to show their intentions toward low carbon dioxide (CO_2) power systems.

Reviewer 2:

The reviewer acknowledged that the HD sector will be difficult to turn into an electric vehicle-only sector. H_2 has the potential to overcome many of the constraints impeding the adoption of battery electric vehicles in this sector. The reviewer stated that a detailed fundamental understanding of the subtleties of H_2 combustion in HD engines will help manufacturers decide if this is a viable option for their HD propulsion systems.

Reviewer 3:

The reviewer said that the project effectively addresses the VTO goals of reducing GHG emissions from off-road HD vehicles.

Reviewer 4:

The reviewer stated that this project supports the overall VTO objectives in DORMA.

Reviewer 5:

The reviewer commented that H_2 ICE is seen as the bridge between diesel, natural gas ICE, and fuel cell technology. As there are several logistical and durability challenges regarding the wide-scale implementation of fuel cell technology in HD transportation, H_2 ICE can fill the gap as the "engine" and "technology" are more familiar to the end customer, and service networks are more mature. In addition, there are several platforms where H_2 fuel cells would be difficult to make roads because of the thermal management constraints. The reviewer went on to say that there may be additional challenges for fuel quality due to the source of H_2 production and pipeline transport. Therefore, H_2 ICE can fill the gap and help in the decarbonization of HD transportation.

Reviewer 6:

The reviewer praised the project, stating that the outcomes are significant to date, and hopes for more to come.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that this project needs to expand to investigate additional types of H_2 combustion strategies, and faster. The reviewer went on to say that the project is underfunded and needs just as much effort as competing H_2 energy conversion programs, such as the fuel cell programs. The reviewer advised reallocation toward H_2 ICE projects like this, as ICE will be the first adopter of H_2 in many areas prior to fuel cells.

Reviewer 2:

The reviewer observed that the research team made a comment in passing that there were some aspects of the project that could have been pursued, but they were not included because of the resources. However, it appears that the resources are sufficient for the work that is planned.

Reviewer 3:

The reviewer remarked that it is difficult to comment on project resources when DOE funding for such projects is very limited.

Reviewer 4:

The reviewer stated that the resources for the project are sufficient based on the spend rate for completed work and the future work being planned.

Reviewer 5:

The reviewer said that the funding level seems consistent with expectations for a typical project using optical diagnostics in combustion research.

Presentation Number: DORMA002
Presentation Title: Off-Road Liquid Fuel Combustion
Principal Investigator: Dario Lopez-Pintor (Sandia National Laboratories)

Presenter

Dario Lopez-Pintor, Sandia National Laboratories

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

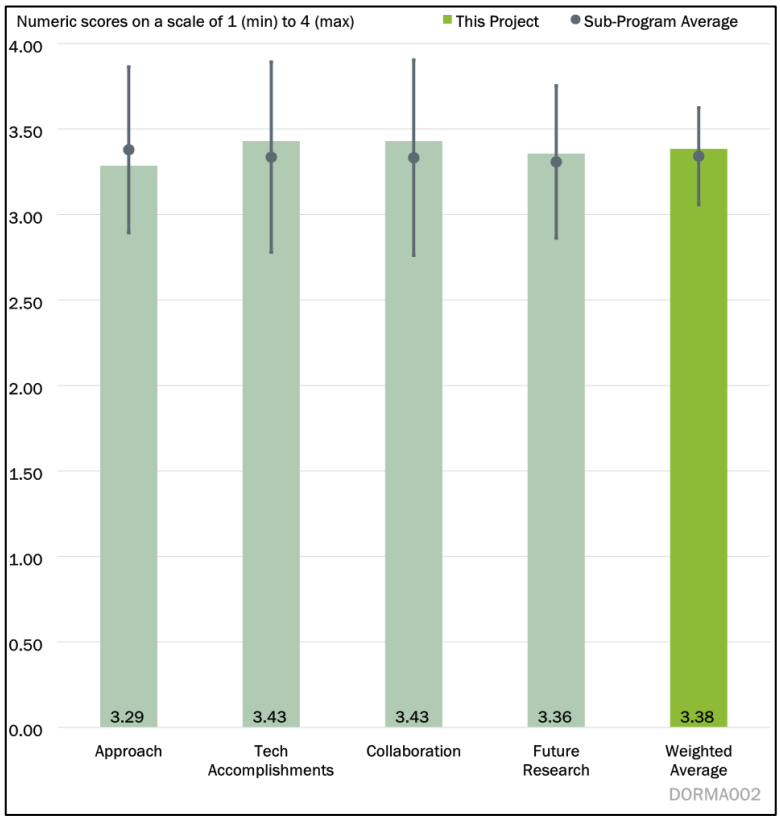

Figure 3-2 - Presentation Number: DORMA002 Presentation Title: Off-Road Liquid Fuel Combustion Principal Investigator: Dario Lopez-Pintor (Sandia National Laboratories)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the approach of utilizing existing laboratory capabilities for MD and HD mixing-controlled compression ignition (MCCI) engines allow for quick and flexible research and development. In addition, coupling optical engines to the research enables insight into the combustion processes not otherwise achieved through metal engines or simulations. The reviewer believed that the strategy used to compare alcohol fuels to diesel fuels is an excellent way to impart this knowledge to industry as well as internal combustion engine research and development collaborators. The reviewer also commented that consideration for retrofit and conversion of existing internal combustion engine architectures for low-carbon fuel MCCI combustion is critical for off-road, and this project has identified potential retrofitting concepts.

Reviewer 2:

The reviewer was unsure as to why this research is being done. There have been many studies published on the literature using ethanol and methanol with ignition improvers to achieve MCCI. The reviewer failed to see a difference between this work and what has already been reported in said literature.

Reviewer 3:

The reviewer's principal concern was with the high levels of ignition improvers that are needed to provide reasonable compression ignition (CI) combustion with the alcohol fuel. The reviewer stated that the potential cost of this approach in practice is concerning.

Reviewer 4:

The reviewer said that the project is well-designed with a reasonably planned timeline.

Reviewer 5:

The reviewer stated that the project is well designed with appropriate scope, focusing on ethanol and methanol, and is on track to address the listed technical barriers within the planned timeline.

Reviewer 6:

The reviewer expressed that improving the understanding of liquid injection, ignition, and combustion behavior for non-petroleum-based fuels is an important topic and has been a focus of DOE-funded research for quite some time. The connections between engine and vehicle companies are a strength, as are the broad collaborations that have been listed in the presentation. The justification that MCCI combustion is broadly essential in off-road applications, is consistent with the general viewpoint of the industry. The reviewer went on to say that there has already been quite a bit of work done in the past on ethanol and methanol in CI engines, so at the outset of the presentation, the reviewer wondered what new information is needed in this space for these short-chain alcohol fuels. Engines have been commercialized, and current efforts by companies such as ClearFlame are considering novel approaches to using ethanol in CI engines. The reviewer approved of the approach to better understand fuel mixing, air utilization, and pollutant formation. However, the reviewer noted that the additive enhanced approach that has been the focus of the first year is of limited practical value. The Scania approach of using a 5% or more additive mixture in ethanol has seemed to be a commercial dead end, though the ClearFlame approach seems much more likely to be effective in the long run.

Reviewer 7:

The reviewer affirmed that the project considers the technical challenges associated with the use of low-carbon fuels in attaining clean and efficient combustion in modern engines. The project focuses on the fuel property effects on nitrogen oxides (NO_x) and particulate emissions. The reviewer observed that the project team points out the need to improve the database for these fuels to support the existing simulation tools. The choice to focus on ethanol and methanol is reasonable, as they represent the most promising fuel candidates. The reviewer admitted that more work is needed to advance their use in model diesel engines due primarily to their low ignitability, especially as the target is to demonstrate superior performance with respect to diesel.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the achievement of stable and successfully robust combustion with 2-ethlyhexyl nitrate (2-EHN) doped ethanol is very clearly demonstrating quick and useful demonstration data for feasibility. The focus on low-load operation is very good, as ignition stability will be limited at the lower in-cylinder pressures and temperatures. The reviewer also stated that the initial progress on ozone (O_3) addition for ignition enhancement is interesting and demonstrates exploration into areas less researched. The reviewer praised the insight on the sensitivity difference between ethanol and methanol.

Reviewer 2:

The reviewer stated that while the experimental work appears sound, there does not appear to be any new knowledge being generated. To date, the results have been only a basic exploratory experimental effort. The reviewer commented that there are four collaborators who will do CFD work, but even though the project is approximately 50% complete there does not seem to be any results from these collaborators.

Reviewer 3:

The reviewer said that the experiments and modeling work provide very interesting results and advised that the project team prepare technical papers on these results. The reviewer also praised the extensions to higher compression ratios, ozone addition, and alternative cetane improvers.

Reviewer 4:

The reviewer stated that the principal investigator did a great job keeping the project on track and praised the methods to understand in-cylinder phenomena, remarking that these were promising findings.

Reviewer 5:

The reviewer praised the progress being made compared to the project plan, demonstrating promising results from ethanol MCCI combustion with different levels of ignition improver. The only suggestion the reviewer had for the project team was to generate similar results over a much broader operating range.

Reviewer 6:

The reviewer remarked that the accomplishments to date are limited in some respects by the scope of the initial efforts to focus on an extremely high-level of ignition improver addition. The reviewer went on to say that these levels of additives are extreme and impractical, though the fact that such mixtures perform well as CI fuels is a useful outcome.

Reviewer 7:

The reviewer stated that the use of ignition improvers to enable ethanol and methanol mixing control combustion in a diesel engine is an effective approach, proven commercially in a European application. The merit relies on no new hardware needed for the engine. The reviewer said that this work provides tests results with 2-EHN for the ignition improver on a single cylinder engine at two representative test points, with results showing potential to improve the diesel baseline. The reviewer commented that the results are very comprehensive, reporting thermal efficiency, particulate matter, and NO_x emissions.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer praised the excellent collaboration being demonstrated through the OEM) collaborations for the laboratory engine and the in-progress cooperative research and development agreement (CRADA). The reviewer also said that the simulation collaboration with five universities is excellent and quite substantial.

Reviewer 2:

The reviewer was unsure how to evaluate this question. The reviewer stated that there was no discussion of interaction with the collaborators, yet the list shows that there are multiple collaborators. The reviewer pointed out that the industry collaborators were not discussed in any detail and questioned whether they were technically engaged or just providing hardware and technical support.

Reviewer 3:

The reviewer commented that one slide describes collaborators, though the connections are not entirely clear.

Reviewer 4:

The reviewer stated that the project demonstrated very good collaboration and coordination across the project team.

Reviewer 5:

The reviewer said that that the collaboration and coordination between the national laboratories, universities, and industry stakeholders is well documented with clearly defined contributions from the project partners.

Reviewer 6:

The reviewer commented that the connections between engine and vehicle companies is a strength, as are the broad collaborations that have been listed in the presentation.

Reviewer 7:

The reviewer noted that the research team gathered industrial partners, national laboratories, and several universities, each contributing their own expertise to the project.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer indicated that the proposed future research is generally good and consistent with the off-road goals. Pulling in off-road OEM voices through the industry CRADAs will help orient the future research to off-road-unique requirements. The reviewer commented that the more generic the future research is, the better the accomplishments will be for the highly varied off-road ICE landscape (i.e., 1 L/cylinder to +20 L/cylinder engines).

Reviewer 2:

The reviewer stated that if the proposed work was accomplished it could be helpful, but according to the timeline provided, the reviewer was worried that the project team will not be able to complete the considerable work that lays ahead, especially the optical diagnostics and its collaboration with CFD.

Reviewer 3:

The reviewer observed that alternative ignition improvers are mentioned in the project and wondered if lower-cost compounds would provide acceptable performance. The reviewer noted that the “Future Research” slide mentioned studying the mixture preparation of ethanol/methanol in an optical engine, which appears to overlap with DORMA005, though no collaboration is mentioned.

Reviewer 4:

The reviewer praised the job done by the research team to ensure that next milestones are achieved successfully.

Reviewer 5:

The reviewer commented that the project is on track to meet the planned milestones, given its 55% completion rate. The purpose of the work to be completed as well as the proposed future research is clearly defined and will continue to enhance the fundamental understanding of the impact of low carbon fuels on combustion and emissions processes.

Reviewer 6:

The reviewer stated that the planned exploration of dimethyl ether (DME) and diethylene glycol diethyl ether as ignition improvers is a good expansion of the study, though this has already been done in the early 1990s (it was the first application of DME in an engine study). The reviewer commented that the mixed alcohol studies are a good extension of the work and stated that the practical ignition and tribological impacts of the alcohol mixtures need to be a part of this work if it is to yield valuable practical guidance. While much can be learned from the planned research, the reviewer questioned whether it would impact future engine design.

Reviewer 7:

The reviewer observed that the project effectually outlines concrete steps, including metal and optical engine testing, as well as CFD modeling.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer commented that the project is well aligned to the DORMA program objectives to help off-road ICE engines reduce CO_2 emissions as it is off-road focused with MCCI. However, the use of an MD on-road truck engine platform does bring in questions about applicability to off-road engines and the different operating regimes. The reviewer asked that the project team try to minimize the influence of on-road engine aspects and on-road input.

Reviewer 2:

The reviewer stated that in principle the work addresses the VTO program objective. Based on what was presented, the reviewer did not see that it will significantly advance the understanding from what is currently available in the literature. For example, the reviewer said, there was a very interesting paper presented at Thiesel 2020, "Renewable Energy to Power through Net-Zero-Carbon Methanol; R. Durrett and M. Potter, GM Global Research and Development, Warren, Michigan, USA," which lays out an engine configuration of an MCCI methanol engine and has some very interesting potential.

Reviewer 3:

The reviewer agreed that it would be great to use the lower alcohols directly in direct injection and ICE engines.

Reviewer 4:

The reviewer stated that the project addresses VTO goals of using sustainable fuels for reducing emissions from off-road HD engines.

Reviewer 5:

The reviewer affirmed that this project supports the overall VTO subprogram objectives for DORMA.

Reviewer 6:

While much can be learned from the planned research, the reviewer questioned whether it would impact future engine design. The reviewer commented that using extremely high treat rates if ignition improves is a dead end. Dual fuel combustion is already practical and can be implemented widely if desired. The reviewer recommended that the researchers consider a dual direct injection strategy to combine these alcohol mixtures with available biofuels for compression ignition engines.

Reviewer 7:

The reviewer stated that ethanol and methanol are promising candidates for decarbonization. Additionally, the reviewer said that the project focuses on "fundamental understanding" to enable MCCI combustion with these fuels and demonstrate equivalent, or superior, performance to that of petroleum diesel fuel.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer acknowledged that the funding and resources seem appropriate to keep the ICE laboratory functioning but encouraged DOE to equally fund research and development for ICE at similar levels to the less feasible efforts on electrification.

Reviewer 2:

The reviewer commented that there was no indication the project is constrained by resources.

Reviewer 3:

The reviewer stated that the resources appear fine.

Reviewer 4:

The reviewer said it was difficult to comment on project resources when DOE funding for such projects is very limited.

Reviewer 5:

The reviewer stated that based on the spend rate and work completed to date, as well as the work to be completed, the resources for the project should be sufficient.

Reviewer 6:

The reviewer believed the funding level seem appropriate for a typical engine research study at the national laboratories.

Presentation Number: DORMA003
Presentation Title: High-Fidelity Simulations of Swirl-Stabilized Spray Flame with Sustainable Aviation Fuels
Principal Investigator: Bruno Souza Soriano (Sandia National Laboratories)

Presenter

Bruno Souza Soriano, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

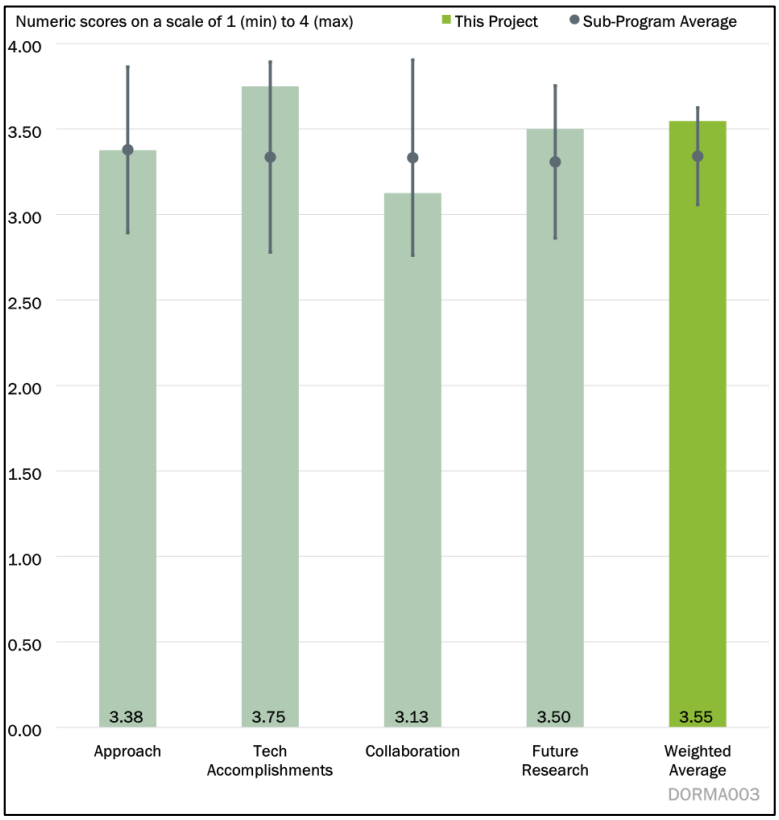

Figure 3-3 - Presentation Number: DORMA003 Presentation Title: High-Fidelity Simulations of Swirl-Stabilized Spray Flame with Sustainable Aviation Fuels Principal Investigator: Bruno Souza Soriano (Sandia National Laboratories)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the approach taken for the simulations is clearly effective and cutting edge. The reviewer believed that the project is following the right technical approach. However, the reviewer cautioned that the learnings from this project will be extremely sensitive to engine technology and operating conditions. For example, sprays at relevant compressor discharge conditions will be very different than at atmospheric conditions. Sprays and combustion physics in a rich-quench-lean (RQL) combustor will be very different than in a GE combustor. The reviewer praised the different corners of the space covered in the presentation and recommended an up-front "test matrix" that shows how different conditions and different hardware are explored, and what the research team aims to learn from each of these.

Reviewer 2:

The reviewer agreed that flame extinction and reignition are indeed a critical problem to address in the aviation industry. The reviewer commented that the project is correctly focusing on characterization of various jet fuels by performing large eddy simulations (LES) and direct numerical simulations (DNS). The reviewer also mentioned that this is not a big enough project to solve all the barriers, yet it is a critical step.

Reviewer 3:

The reviewer commented that the research team is using state-of-the-art computational methods to investigate swirl-stabilized spray flames.

Reviewer 4:

The reviewer pointed out that the timeline for this project was noted as having a start date of October 2022 and an end date of September 2023, though it is still not clear if this is the last year of the project. The reviewer said that the project involved modeling using the Pele computational framework to address (ultimately) multicomponent liquid evaporation, flame stabilization, and soot formation at high pressures in combustors relevant to the aviation industry. The configurations considered are a single-hole atomizer (SHA) and an LES of a lean direct injection (LDI) burner. The reviewer went on to make the following additional comments:

In practical burners, fuel is injected as a spray, and the SHA droplets will also be present. It was not clear how the presence of droplets and multicomponent evaporation would be considered for a fuel like Jet A or a sustainable aviation fuel (SAF) which will contain hundreds of components. A single component hydrocarbon seems not to be appropriate as a Jet A surrogate, as seems to be assumed here.

The most common approach is to pre-vaporize the liquid to rid the complication associated with coupling the chemistry of ignition with fuel droplet evaporation processes (e.g., shock tubes, flow reactors, etc.). The gas composition is the same as the originally prepared surrogate composition at the injection plane. The reality of the problem may be very different where the heat release at the flame evaporates the fuel, as in real combustors. While there may be conditions where the multicomponent SAF flash evaporates to create an initial fuel mixture of the same composition as the SAF at the injection plane, what those conditions are were not discussed in the presentation. One of the photos in the presentation clearly showed droplets well downstream of the fuel injection port.

Models for droplet evaporation typically consider an isolated droplet. It is not evident that such models would be applicable to configurations like a spray or even an SHA, because of droplet-to-droplet interactions that are typically present.

If the SHA does not produce monodispersed droplets, it was not clear how a distribution of droplets would be considered in the fuel evaporation analysis.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the project is highly accomplished. The major computational framework appears to be fully established. The reviewer also found the post-processing and data analysis to be well matured and insightful.

Reviewer 2:

The reviewer commented that performing a DNS study of a laboratory-scale combustor provides invaluable information to understand the combustion dynamics better. The reviewer said that this is an excellent attempt and progress report. The reviewer also stated that more complex geometry with LES was a natural and reasonable choice.

Reviewer 3:

The reviewer praised the technical progress and stated that while the modeled configurations do not have all the characteristics of gas-turbine swirl-stabilized combustors, there is a lot to be learned from the computation results.

Reviewer 4:

The reviewer stated that the lift-off length simulations for Jet A and C1 showed substantial differences for the probability density function and robust capabilities of the model. The reviewer also commented that the simulations of the mixing lengths were shown and were quite interesting. The reviewer did not think it was clear whether the fuel phase was pre-vaporized gas with no liquid droplets present. If details at the level of individual droplets were not possible to incorporate in the simulations, the reviewer wondered if the future work would consider how droplets alter the results. The reviewer was intrigued by the fact that the simulation results (white boundaries in Slide 7) seem to follow the trajectories of the flame edge and diffusion flame boundaries. The reviewer noted that the project is shown to be 70% complete, which is a good place to be at this point.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer said that the presentation did a nice job laying out the various partners and collaborators up front and identifying their areas of contribution. The reviewer remarked that the partners nicely covered the DNS for near-field combustion dynamics experiments, soot modeling, and kinetics. The reviewer was particularly fascinated by the edge-flame dynamics. In the reviewer's opinion, there is a gap with the spray modeling, though the reviewer also observed that the project is producing its own contributions on that front. Overall, the reviewer believed that this is a good team with good partners, but the "checks and balances" of the spray model was a weakness.

Reviewer 2:

The reviewer had nothing to criticize, stating that the collaboration is well organized with essential parties.

Reviewer 3:

The reviewer approved of the collaboration with Cambridge University and the experimentalists at Sandia National Laboratories (SNL). The reviewer also noted that there appears to be some collaboration with modeling efforts at other institutions as well.

Reviewer 4:

The reviewer affirmed that the project team includes five partners: NREL, The University of Cambridge, Princeton University, The University of Illinois Urbana-Champaign (UIUC), and Stanford University. The reviewer stated that the Cambridge collaboration was the easiest to follow in the presentation. The reviewer noted that UIUC and Stanford were both to provide a "chemical mechanism," but they were not clear on what this chemical mechanism was and how it would be developed. The reviewer also stated that it was not clear what the Princeton soot modelling effort would provide, where it fits, and how it would be used in the project. The reviewer recommended that any future presentations articulate the deliverables of each of the collaborators to make it clear how the parts effectively contribute to the whole.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the proposed future research nicely covers the gaps seen as the accomplished work was being presented. In particular, the measurements of soot and spray will be critical to validate and refine this work. In the reviewer's opinion, the project has identified the right future work to validate the contributions of the project.

Reviewer 2:

The reviewer commented that the extension of the current accomplishments to more complex geometries while scaling up the physical domain is a natural and plausible choice.

Reviewer 3:

The reviewer stated that the proposed future research looks very interesting. Improvement of flamelet models and better modeling of the spray are very important and the reviewer approved of them being included in the future work plan. The reviewer also noted that SHA experiments are not representative of sprays for aviation gas turbines, but are interesting, nonetheless.

Reviewer 4:

The reviewer observed that the future work plan notes several challenges and barriers that would be addressed, including the need for improved kinetic mechanisms, incorporation of soot chemistry, and additional information to characterize the spray boundary. The reviewer stated that these are logical and appropriate, and being cast in such general terms, the overarching way forward is evident. However, the reviewer said, any one of the above can require a substantial effort, and details of the approach for future modeling was not clear. As the reviewer noted, this study would have significant separation from the "state of the art" on fuel spray injection if the liquid and gas were considered as a fully coupled system. The reviewer further noted that this approach has only been possible for isolated droplet burning with capabilities to incorporate soot, radiation, and a plethora of other factors, but evidently not for a SHA or spray flame.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that soot formation is a highly relevant component of SAF end use. In fact, according to the reviewer, many speculate that it might even be an advantage to SAFs, with environmental and heat transfer (durability) benefits. However, the reviewer noted, the ability to simulate gas turbine soot emissions is relatively immature today. The reviewer went on to say that this project is directly filling the need not only for SAFs, but also for the combustion system engineering community as a whole. Additionally, the insight that this project is producing on flame stabilization details is valuable and the reviewer hoped that it will be fed over to Dasgupta (DORMA038).

Reviewer 2:

The reviewer believed that the project supports the objective of reducing emissions by adopting alternative jet fuels.

Reviewer 3:

The reviewer stated that this project supports the objectives for the DORMA subprogram.

Reviewer 4:

The reviewer remarked that the project is quite relevant from a broad perspective, with renewed interest in combustion technologies using SAFs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the resources for this project look appropriate, so long as the partners are bringing sufficient cost share and doing relatively few new experiments. The reviewer noted that the project identified a need for future work to obtain spray and soot data, and the reviewer agreed with this need, but anticipated a higher funding level will be needed for those partners to conduct those types of tests.

Reviewer 2:

The reviewer stated that the resources are sufficient.

Reviewer 3:

The reviewer remarked that the research team has performed a great deal of work for the annual budget of $150,000.

Reviewer 4:

The reviewer believed that a budget of $150,000 is quite modest for the work being carried out. The reviewer said that the research team appears to already have significant computational infrastructure, allowing them to produce the results presented in a short amount of time. The reviewer also mentioned that it was not noted how the five other collaborators were supported in the project.

Presentation Number: DORMA004
Presentation Title: Ducted Fuel Injection
Principal Investigator: Chuck Mueller (Sandia National Laboratories)

Presenter

Chuck Mueller, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

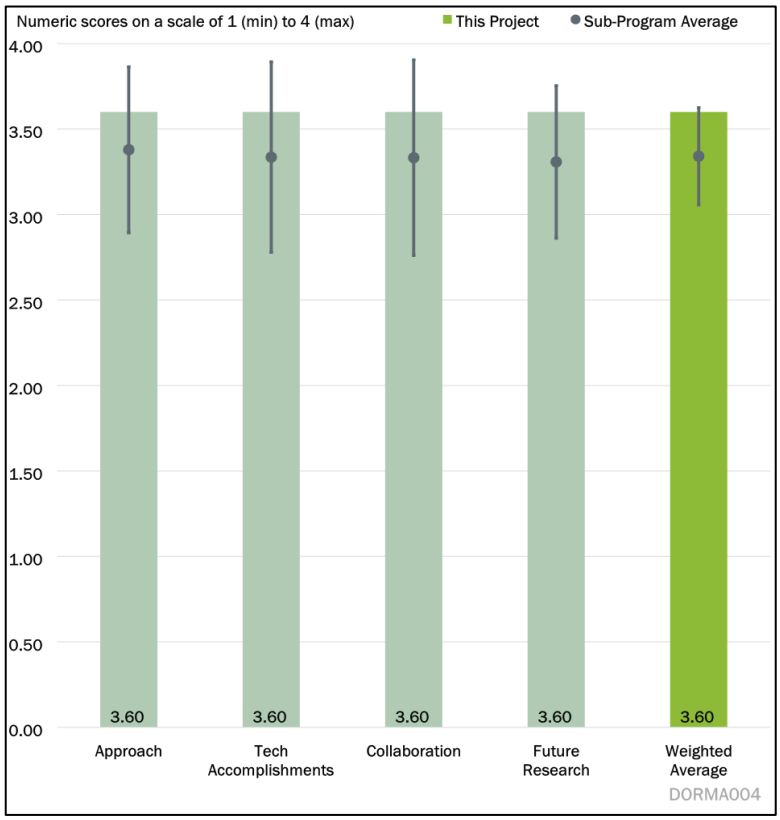

Figure 3-4 - Presentation Number: DORMA004 Presentation Title: Ducted Fuel Injection Principal Investigator: Chuck Mueller (Sandia National Laboratories)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the alignment of ducted fuel injection (DFI) to low carbon fuels makes sense in relation to DOE goals. The reviewer commented that the traditional diesel fuel DFI needs just as much focus as the low carbon fuels, as diesel will continue to be used for decades in long-life offroad power systems. To aid the approach, the reviewer suggested making comparisons to continuous-fired single cylinder engines and state-of-the-art diesel engine combustion and emissions, as it is sometimes hard to tell the real relevance of the DFI emissions results.

Reviewer 2:

The reviewer praised the project, saying it is potentially game-changing work. The reviewer said it represents a project which is moderate risk with a huge potential payoff. For a transportation sector that will be difficult to convert to electric vehicles (EVs), this technology, if proven to be applicable, will be a game changer. The reviewer stated that not only will there be a reduction in the CO_2 associated with carbon reduction in the fuel, but it could also yield improved performance of the engine, as well as significantly reduce criteria pollutants with less expensive aftertreatment systems.

Reviewer 3:

The reviewer commented that the project presented an interesting technology. The reviewer stated that the higher-load optical operation with DFI provides excellent insights. The reviewer also said that some extended (metal engine) operation would be useful in order to understand longer operation durability.

Reviewer 4:

The reviewer stated that this was a well-designed project with a reasonably planned timeline and an outstanding approach to understanding the issues.

Reviewer 5:

The reviewer commented that this project, which mainly focuses on DFI technology, has been well designed and has made a significant impact to the overall understanding of clean combustion, in particular the reduced engine-out NO_x and particulate emissions, as well as fuel effects on soot formation and oxidation processes. However, the reviewer stated, with only 70% of the project completed it might be quite a challenge to meet the planned project completion timeline.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that upgrading the optical engine to allow for higher peak cylinder pressures demonstrates very clear delivery and accomplishment. This is critical to move into the relevant state space for HD ICEs and future research and development. The reviewer approved of the quantitative soot reduction with DFI compared to conventional diesel combustion as well as the move toward including the rest of the combustion system (e.g., piston bowl) into the DFI optimization, which the reviewer said is well warranted. The reviewer also stated that the understanding of heat-loss increase from DFI shows good progress toward a holistic understanding of how DFI impacts combustion, emissions, and engine efficiency. The reviewer then commented that the heat transfer impact should be investigated with an entire combustion system DFI optimization and stated that it is unclear what the Wabtec FOA2197 technical progress is, or if it should even be reported in this project review.

Reviewer 2:

The review praised the results, saying that the fundamental understanding of the results is yielding insight into the enhanced potential of DFI and possible further improvements. The reviewer also stated that demonstrating the potential of DFI at high load was a great accomplishment.

Reviewer 3:

The reviewer noted that the project had made excellent progress and stated that the misalignment and design variable study would be important to complete and publish.

Reviewer 4:

The reviewer stated that the research team did a great job keeping the project on track. The reviewer praised the methods to understand in-cylinder phenomena as well as the promising findings (e.g., the use of DFI and oxygenated fuels can reduce aftertreatment requirements).

Reviewer 5:

The reviewer praised the accomplishments and progress that had been made compared to the project plan, with successful demonstration of large reductions in engine-out soot, NO_x, and CO_2 emissions with sustainable oxygenated fuels in an optical engine over a broad range of full-load conditions.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer said that the collaboration between U.S. and international entities shows excellent engagement and interest in the ICE and combustion community.

Reviewer 2:

The reviewer observed that the groups who have been brought into the collaboration effort are exploring a deeper understanding of the fundamentals as well as its use in multi-cylinder operation and its integration into a production engine.

Reviewer 3:

The reviewer stated that the collaboration appears good, and there was not much discussion during the presentation.

Reviewer 4:

The reviewer commented that while collaboration and coordination across the project team was outstanding, principal investigators and DOE program managers should try to increase the participation of U.S. universities in such projects. The low level of government funding for academic research will result in more universities ending any research on the decarbonization topic other than electrification (despite recognizing that there are many sectors difficult to electrify). According to the reviewer, this could end student training on any decarbonization strategies other than electrification.

Reviewer 5:

The reviewer praised the collaboration and coordination between national laboratories (Sandia National Laboratories), academia (Bandirma University–Turkey, and Georgia Tech–USA), and industry stakeholders (Aramco, British Petroleum, Chevron, Clean Fuels Alliance America, Coordinating Research Council, Cummins, Daimler Truck, Denso, ExxonMobil, Ford, General Motors, Honda, John Deere, Mercedes, Phillips 66, Shell, Toyota, Wabtec, and Southwest Research Institute). The reviewer commented that these were very well done.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the proposed idea to reduce NO_x and particulate matter formation without exhaust gas recirculation (EGR), but with DFI and oxygenated fuels is very interesting. Efforts made towards quickly evaluating the real feasibility of this would be beneficial, as the physics of NO_x mitigation seem highly challenging but would be more impactful than solely soot reduction. The reviewer stressed the need for this project to continue moving towards understanding and demonstrating multi-hole DFI performance across the ICE operating range. This could be with diesel or low carbon fuels. The reviewer went on to say that strategies, as well as a fundamental DFI mechanism understanding for real HD MCCI systems, are needed to go from optical/canonical combustion systems to real world systems. These would need to work at many different ambient and boundary conditions (e.g., what happens when starting a DFI engine at –40°C?).

Reviewer 2:

The reviewer affirmed that the project team is aware of the challenges that lay ahead and acknowledged that the team has laid out a coherent plan to address them.

Reviewer 3:

The reviewer stated that the companion CFD modeling would be useful to aid in the understanding of design variable effects (e.g., number of holes and diameter).

Reviewer 4:

The reviewer praised the work done by the project team to ensure that the next milestones are achieved successfully.

Reviewer 5:

The reviewer commented that the proposed future research has a clearly defined purpose and will likely achieve its targets based on the results that have been demonstrated so far. For successful commercial implementation, the reviewer recommended that the scope of future work include an understanding of cold start capability with DFI technology.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the project is relevant, given that it continues progressing DFI in case there are any breakthroughs. The reviewer also admitted that it seems to be a stretch to tie low carbon fuels to DFI given that many of the fuels are already oxygenated and produce a low amount of soot, or zero soot.

Reviewer 2:

The reviewer reiterated that the project represents potentially game-changing work, stating that it presents only moderate risk with a huge potential payoff.

Reviewer 3:

The reviewer was fascinated by the approach to lower soot, and perhaps increased maximum engine loads.

Reviewer 4:

The reviewer commented that the project addresses the VTO goal of reducing emissions from off-road HD engines.

Reviewer 5:

The reviewer stated that the project supports the overall VTO subprogram objectives for DORMA.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the funding is at an appropriate level to continue observing the project for breakthroughs.

Reviewer 2:

The reviewer stated that the work appears to be proceeding well with the resources available, though the reviewer wondered what might happen if more resources were directed at the practical implementation. The reviewer asked if it was possible to know if this is a candidate for production engines at a sooner date?

Reviewer 3:

The reviewer remarked that the resources appear to be sufficient.

Reviewer 4:

The reviewer noted that it is difficult to comment on project resources when DOE funding for such projects is very limited.

Reviewer 5:

The reviewer stated that the resources for this project are sufficient based on the spend rate for completed work and the proposed future research.

Presentation Number: DORMA005
Presentation Title: Sprays and Spray Combustion
Principal Investigator: Lyle Pickett (Sandia National Laboratories)

Presenter

Lyle Pickett, Sandia National Laboratories

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

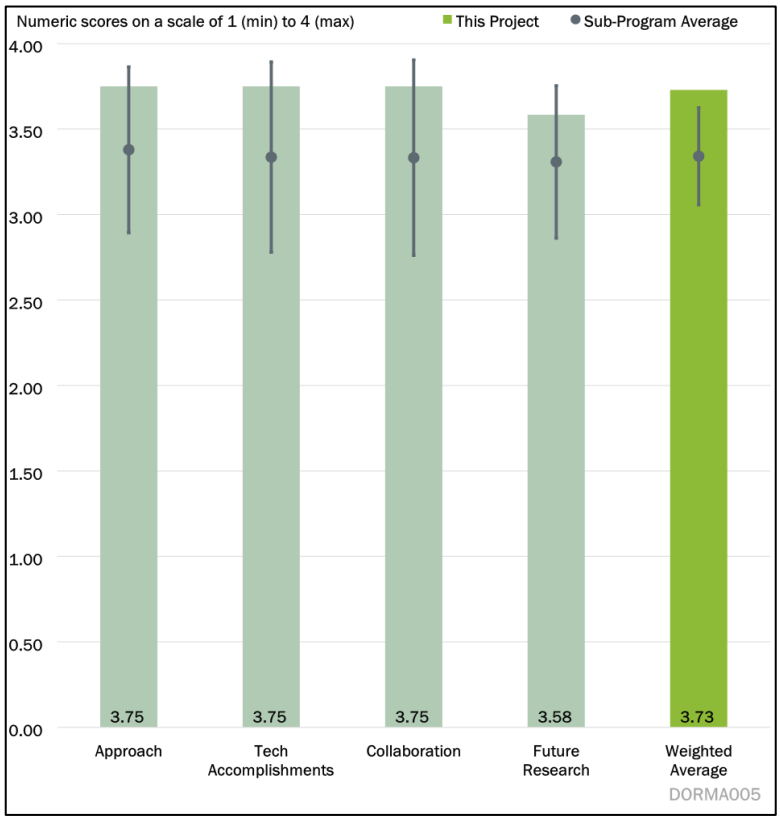

Figure 3-5 - Presentation Number: DORMA005 Presentation Title: Sprays and Spray Combustion Principal Investigator: Lyle Pickett, (Sandia National Laboratories)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said that the approach of multiple industry CRADAs, Advanced Engine Combustion (AEC) working group oversight, and worldwide engagement via ECN activities enables multiple pathways and resources to tackle the project goals. The reviewer commented that the discussion of the motivation for this work makes sense, and the methodical thinking aids in the excellence of the approach. The reviewer agreed with the decision to continue using the ECN approach to build quantitative datasets from world class laboratories and resources, as this drives broad ICE community learning. The reviewer praised the approach to move sprays from single isolated jets to multi-jets and more realistic combustion chambers, as more complicated physics can be understood.

Reviewer 2:

The reviewer observed that the project had been reconfigured to use the accumulated knowledge from the ECN to consider the behavior of low carbon fuel in spray combustion systems.

Reviewer 3:

The reviewer stated that most of the presentation focused on the excellent experimental work, and the only piece that appeared to be missing was the feedback-connection from the empirical work to the spray modeling. The reviewer also commented that the multiple spray plume interaction observation was very interesting. The reviewer expressed interest in how the physics of this effect are, or may be, captured by the modeling.

Reviewer 4:

The reviewer said that the project is well-designed with a reasonably planned timeline.

Reviewer 5:

The reviewer said that the project is well designed with a reasonable timeline to address some of the barriers associated combustion systems optimized for sustainable fuels with particular emphasis on methanol, renewable, diesel, and H_2.

Reviewer 6:

The reviewer commented that project relies on an outstanding experimental capability that has helped to improve the understanding of injection and combustion processes and, in the present work, is continuing to make important observations to address future engine design.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the demonstration of a sootless methanol HD MCCI spray/flame is an outstanding quantitative result that pushes the traditional understanding of a fuel-rich jet's sooting propensity. The reviewer commented that this aids in computational validation efforts greatly, and it also illuminates technology strategy comparisons to other ICE investigations, like ducted fuel injection (DFI). The reviewer further stated that liquid length quantification of methanol is another critical point of understanding for combustion and fuel system development. The investigation of the sprays for port or low-pressure direct injection (DI) low-carbon fuel combustion systems is, according to the reviewer, very useful for fundamental injector design understanding. The reviewer also commented that the quantitative learning here can be applied broadly. The reviewer noted that it was very interesting to see how the methanol sprays differ from gasoline-like fuels, and the addition of heat flux measurements and wall impingement adds outstanding capability. Finally, the reviewer praised the technical accomplishments, stating that they are coming along quickly in this multifaceted project.

Reviewer 2:

The reviewer remarked that the project represents very fundamental work. The reviewer also commented on how the research team not only explained the fundamental findings—they also explained the implications of these findings in more general take-aways. For example, the differences in spray behavior between methanol and gasoline and what this means in terms of oil dilution, wall wetting, crankcase ventilation, and soot formation.

Reviewer 3:

The reviewer believed that this newer area of characterizing and understanding DI methanol injection will be very important for future HD low-carbon methanol fueled engines. The reviewer also stated that this project's technical experimental work, with its various diagnostics, provides an outstanding comprehensive picture of the DI methanol spray.

Reviewer 4:

The reviewer stated that the research team did a great job keeping the project on track. The reviewer praised the methods used to understand spray phenomena, stating that the findings were promising.

Reviewer 5:

The reviewer approved of the technical progress made compared to the project plan, stating that the results were very promising, providing insights on critical spray combustion metrics that will enable improvements in modeling and commercial implementation of sustainable fuel injection.

Reviewer 6:

The reviewer commented that this project has provided key new insights on the injection behavior of renewable diesel fuel. Given the enormous commercial interest in renewable diesel fuel, this is an outstanding combination of developing fundamental measurements to help support the development of clean, low-GHG, and practical solutions.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer stated that modeling the ECN framework and adding multiple CRADAs demonstrates a benchmark for DOE programs. There is no higher standard than this.

Reviewer 2:

The reviewer was impressed by the list of collaborators and their contributions.

Reviewer 3:

The reviewer noted that the presentation appeared to focus mainly on the Sandia Spray Groups' contributions. Partners were mentioned (on one slide), but the degree of interaction was not immediately clear.

Reviewer 4:

The reviewer commented that while collaboration and coordination across the project team was outstanding, Principal investigators and DOE program managers should try to increase the participation of U.S. universities in such projects. The low level of government funding for academic research will result in more universities ending any research on the decarbonization topic other than electrification (despite recognizing that there are many sectors difficult to electrify). According to the reviewer, this could end student training on any decarbonization strategies other than electrification.

Reviewer 5:

The reviewer praised the collaboration and coordination between national laboratories, academic institutions, and industry stakeholders. The reviewer commented that the contributions from all project partners were clearly defined and very well done.

Reviewer 6:

The reviewer stated that this project supports excellent collaborations and enables broad interactions with groups and industry around the world. This is a model for how to maximize impact.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that adding a move toward H_2 injection makes complete sense as the liquid low-carbon fuel research is already covered by the program. The reviewer remarked that the H_2 injection likely depends highly on the injector technology as well as the strategy. The usefulness of the H_2 quantitative spray data for modelling, including 1D/3D, CFD, etc., is invaluable. However, the reviewer believed that trying to get away from injector design-specific behavior would benefit the ICE community most.

Reviewer 2:

The reviewer commented that the work discussed and the assessment of what should be done in the future represents a coherent path for continuing to enhance the fundamental understanding of the phenomena

governing combustion behavior of low carbon fuels, while also giving insight into what the practical challenges for engine development will be.

Reviewer 3:

The reviewer said that the future work section mainly focused on the upcoming H_2 fuel injection work. The reviewer also stated that the methanol spray results were outstanding and encouraged the researchers to finish and publish this part of the project.

Reviewer 4:

The reviewer stated that the research team did a very good job up to this point, ensuring that the next milestones are achieved successfully.

Reviewer 5:

The reviewer remarked that purpose of the remaining challenges and barriers, as well as the proposed future research, are clearly defined and the project is on track to achieve its stated targets. The reviewer praised the team, asking that they continue the good work.

Reviewer 6:

The reviewer commented that the move to consider H_2 is highly topical and should provide important insights into how to improve H_2 fuel injections systems, engines, and combustion processes.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that this project is completely relevant for the DORMA goal of enabling low-carbon sustainable fuels for ICE and combustion systems.

Reviewer 2:

The reviewer commented that this work will inform engine developers and combustion system researchers trying to use low-carbon fuels in the transportation sector which will not be easily converted into electric vehicles.

Reviewer 3:

The reviewer said that the project is quite relevant to current engine and fuel development trends and efforts.

Reviewer 4:

The reviewer stated that the project addresses the VTO goal of reducing GHG emissions from off-road HD, while also supporting the production of sustainable fuels.

Reviewer 5:

The reviewer said that the project supports the overall VTO subprogram objectives for DORMA.

Reviewer 6:

The reviewer commented that this work has impact and is highly relevant to the application of low-carbon intensity fuels.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that ICE will be the fastest way to reduce carbon emissions and move toward a sustainable energy source. The reviewer encouraged DOE to add resources and funding to this ICE research and not put all hopes into electrification.

Reviewer 2:

The reviewer said that there was no indication that the resources were limiting the progress of this project.

Reviewer 3:

The reviewer remarked that the resources appear to be sufficient.

Reviewer 4:

The reviewer noted that it is difficult to comment on project resources when DOE funding for such projects is very limited.

Reviewer 5:

The reviewer stated that the resources for this project are sufficient based on the spend rate for completed work and the proposed future research.

Reviewer 6:

The reviewer said that the resources seem appropriate for this type of optical fuel injection and combustion research.

Presentation Number: DORMA006
Presentation Title: LLCF combustion and emission models
Principal Investigator: Scott Wagnon (Lawrence Livermore National Laboratory)

Presenter

Scott Wagnon, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

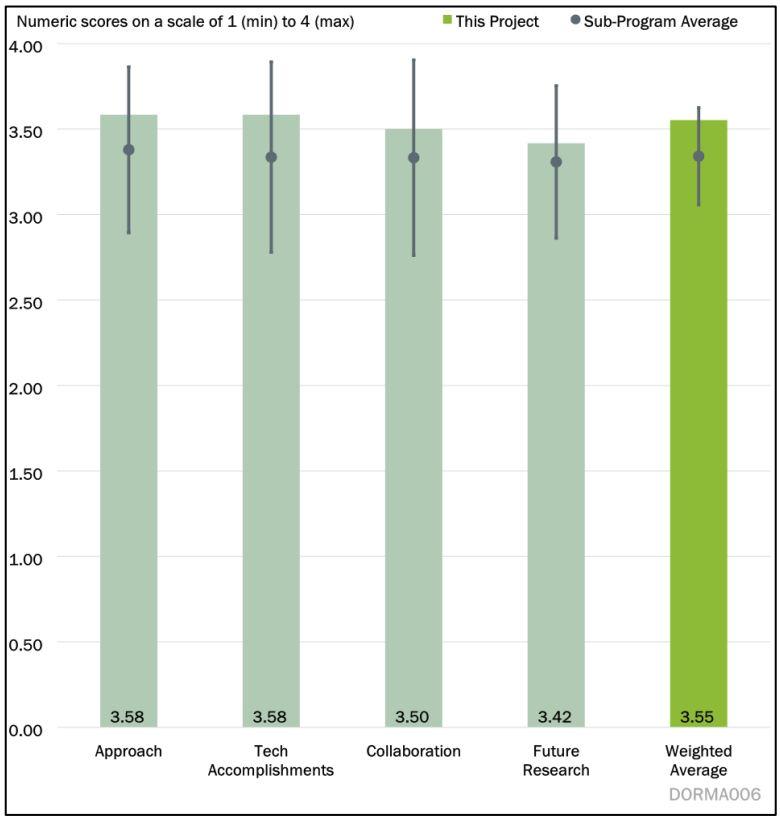

Figure 3-6 - Presentation Number: DORMA006 Presentation Title: LLCF combustion and emission models Principal Investigator: Scott Wagnon (Lawrence Livermore National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the project's approach continues the time-tested kinetic mechanism development process that Lawrence Livermore National Laboratory (LLNL) has pioneered, among others, throughout the decades. The reviewer saw the approach as likely to deliver the goals and address the barriers identified. The reviewer approved of the focus on solvers as well as the focus on both kinetic models for oxidation and emissions.

Reviewer 2:

The reviewer stated that this is important work. The researchers are following an established and proven approach to increasing the kinetic understanding and fidelity of the resultant models for simulation of the ignition and flame characteristics of low-lifecycle carbon fuels.

Reviewer 3:

The reviewer agreed that LLNL does excellent work in this area, expanding the mechanisms for various hydrocarbons (HCs). However, the reviewer also wondered if part of the research team's future effort should include some "automated" mechanism generation tool development. That being said, the reviewer was not sure if this is possible from first principles. The reviewer also stated that there are so many HCs, and now hydrogen-based molecules, that perhaps a way to auto-generate would be more efficient in the future.

Reviewer 4:

The reviewer stated that the project is well-designed and has a reasonably planned timeline.

Reviewer 5:

The reviewer commented that the project is reasonably well-designed to address some of the technical barriers to meet the stakeholder's need for chemical kinetic models that accurately predict combustion models and can run quickly in CFD simulations. However, the reviewer said, the approach for performing the work is based on current best practices of traditional approaches, but in order to achieve the desired simulation speeds, the team should also investigate non-traditional approaches. This could include neural network and machine learning algorithms that have shown "order of magnitude" efficiency improvement when employed in the characterization of material properties.

Reviewer 6:

The reviewer observed that this project continues a long-term effort of improving the understanding and characterization of combustion chemistry. The reviewer stated that the application to improving kinetic mechanisms for SAF is highly topical and important for the present push to roll out low carbon intensity aviation. The reviewer commented that this is extremely useful work with demonstrated impacts in the science and engineering of combustion and fuels.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the progress on utilization of unique universal identifiers seems quite good to standardize the pallets of surrogate components within the kinetics research community. The focus on methyl alkane is clear in its relation to low-lifecycle-carbon fuel (LLCF) and sustainability. The reviewer commented that the ignition delay comparisons seem adequate for the current state (26% complete) of the project but noted that it would be good to link the ignition delay errors to relevant ICE error success criteria to precisely know the needed accuracy for ICE combustion modeling. The reviewer further stated that the agreement in asymptotic behavior of C8-C80 methyl alkanes for flame speed seemed to agree quite well with the qualitative behavior or the data in the literature, which is very powerful for showing the correct physics prediction behavior. Similarly, the reviewer said, the soot model work and comparisons to soot volume fraction data from the University of Connecticut looked very good, as soot modeling is incredibly difficult. In closing, the reviewer commented that the end-users of many of the developed mechanisms rely on reduced mechanisms, so the progress on an automated reduction process demonstrated great progress toward adoption and impact of this project's mechanism efforts.

Reviewer 2:

The reviewer observed that the researchers are systematically developing, and updating, the needed kinetic mechanisms for detailed modeling on LLCFs.

Reviewer 3:

The reviewer said that these are very useful mechanisms that are made publicly available and encouraged the team to publish the physical basis for mechanism reductions.

Reviewer 4:

The reviewer stated that the research team did a great job keeping the project on track and accomplishing the goals.

Reviewer 5:

The reviewer commented that the technical progress made compared to the project plan is reasonable but the number of LLCFs in scope may be too broad for the project timeline.

Reviewer 6:

The reviewer observed that the project has updated and rolled out surrogate fuel formulations and kinetic mechanisms for design and development of SAF, which may be comprised of lightly methylated compounds.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer stated that the multiple collaborations with other national laboratories, universities, and software companies demonstrates excellent collaboration which will drive adoption and use by the ICE community.

Reviewer 2:

The reviewer observed that the research team is interacting with the international community to discuss, evaluate, and improve their kinetic models.

Reviewer 3:

The reviewer commented that the collaboration efforts appear to be fine.

Reviewer 4:

The reviewer said that the researchers demonstrated excellent collaboration and coordination across the project team.

Reviewer 5:

The reviewer stated that the project shows broad collaboration and coordination between national laboratories, academic institutions, and industry stakeholders.

Reviewer 6:

The reviewer praised the broad and impactful collaborations, stating that the project is a model for how to maximize the impact of combustion chemistry research.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the proposed future research seems good and agreed with the question about adding efforts to gain validation data and model development at high pressures and with EGR. They said that this could be added to the future scope of work with specific tasks.

Reviewer 2:

The reviewer observed that the research team had identified the important chemistry subgroups, C8–C20 2-methylalkanes, that need to be incorporated into the kinetic models to facilitate the modeling effort of low-carbon fuel simulation. The reviewer also observed that the research team would continue with the reduction of the more complex models into reduced models, which could be to shorten the computational time. This gives the modelers the latitude of choosing the appropriate model based on the needed fidelity and/or computational time. The reviewer commented that the work on soot modeling is also an important component of the team's activities.

Reviewer 3:

The reviewer advised that the research team continue to stay aware of current develops in commercial SAFs, as it would be great to have relevant mechanisms available as newer fuels develop.

Reviewer 4:

The reviewer stated that the research team did a great job ensuring that the next milestones are achieved successfully.

Reviewer 5:

The reviewer commented that the proposed future research work was too vague.

Reviewer 6:

The reviewer stated that the proposed work will continue to push this project toward significant outcomes and impacts. The plan to work to develop and deliver effective reduced kinetic models will benefit design simulations of new fuels and combustor designs.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer commented that this is clearly relevant and relates strongly to the DORMA goals, as the kinetic models are imperative for engineering of ICEs with LLCFs.

Reviewer 2:

The reviewer reiterated that this is important work, referencing their previous comments on the project.

Reviewer 3:

The reviewer stated that this is very useful work, being both detailed and with reduced mechanisms.

Reviewer 4:

The reviewer said that the project addresses the VTO goal of reducing GHG emissions from off-road HD by producing the kinetic models for developing the next generation engines.

Reviewer 5:

The reviewer commented that the project supports the overall VTO subprogram objectives for DORMA.

Reviewer 6:

The reviewer stated that the proposed work will continue to push the project toward significant outcomes and impacts. The plan to develop and deliver effective reduced kinetic models will benefit design simulations of new fuels and combustor designs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that given the goals and the costs (which are mainly labor and computational costs), the resources and budget seem appropriate. The reviewer also noted that if additional experimental data or scope is pursued then the resources may be insufficient, but this could be mitigated by adding more direct tasks to other relevant DOE funded projects.

Reviewer 2:

The reviewer did not see any indication that the resources were insufficient.

Reviewer 3:

The reviewer stated that the resources appear to be fine.

Reviewer 4:

The reviewer noted that it is difficult to comment on project resources when DOE funding for such projects is very limited.

Reviewer 5:

The reviewer commented that the resources are sufficient for the FY 2022 and FY 2023 project milestones listed but will not be sufficient for the long-term project objectives beyond FY 2023.

Reviewer 6:

The reviewer stated that the funding level seems appropriate for such impactful work, given the scope.

Presentation Number: DORMA007
Presentation Title: Innovative NO_x Reduction Materials for Low Temperature Aftertreatment
Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Presenter

Yong Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

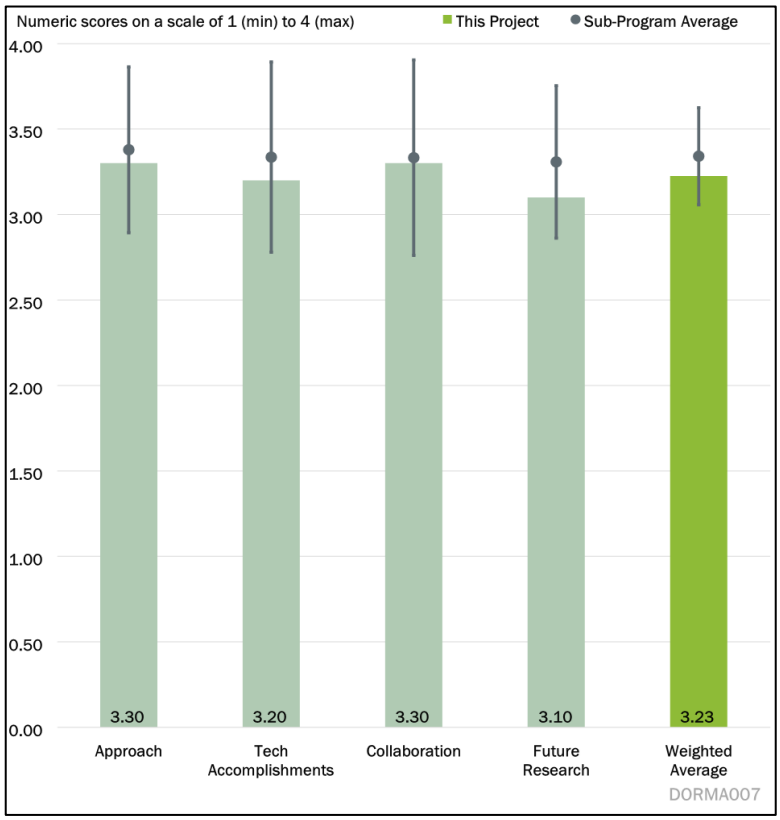

Figure 3-7 - Presentation Number: DORMA007 Presentation Title: Innovative NO_x Reduction Materials for Low Temperature Aftertreatment Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said that this team has addressed the barrier in cost-effective and sustainable NO_x emissions control. The project has been well designed, and the proposed work has been completed as scheduled. For example, the data in Slide 9 clearly show the storage of NO in the system.

Reviewer 2:

The reviewer stated that the approach has been excellent with appropriate tools used to study and characterize the catalyst. These include highly relevant theoretical density functional theory (DFT) studies as well as experimental work that is getting at the issues for this catalyst.

Reviewer 3:

The reviewer was confused as to this CRADA with Stellantis, who has no presence in the off-road market. The major problem with passive NO_x adsorbers (PNAs) is the repeated storage and release cycles that they are exposed to, which leads to capacity loss. The approach to this work does not include any repeated cycles, and without that, none of the results are going to be relevant to real world application. The reviewer stated that industry has essentially "stuck a fork in" this technology, so this project seems ill-advised.

Reviewer 4:

The reviewer commented that single-atom catalysts have been studied for a few years now and this study extends the field to a new specific catalyst formulation, so this is a well-focused study.

Reviewer 5:

The reviewer stated that the project is on track to the timeline, but key issues of poisoning and production are still required for future work.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said that this team has demonstrated the storage of NO and its reduction by carbon monoxide (CO) with data shown in Slide 12. The data shown in Slide 11 demonstrated the super-low temperature performance of rhodium (Rh), ruthenium (Ru), and ceria over other candidates, which is the key achievement in this project.

Reviewer 2:

The reviewer stated that there has a been discovery in the project that Ru-ceria can have an excellent role as a PNA. This would be most useful in a diesel application if it was determined it was needed. The main benefit is the high NO_x to Ru ratio (as high as 14:1). The aging done in the project has always been for lean exhaust conditions and the lower temps in diesel exhaust make this a possibility durable formulation. The reviewer commented that the fact that Ru-ceria is a good NO-CO catalyst has been well-known for more than thirty years, but it has not been well studied, because ruthenium oxide (RuO_2) forms a toxic oxide. When it is heated, it is volatile enough to leave the catalyst under regular driving conditions, so OEMs have not chosen to use Ru. Many studies have shown it leaves the catalytic converter (e.g., SAE Paper #920846, 1992). However, the reviewer stated, there is a potentially different catalyst, a single-atom catalyst, whose durability has been examined by the usual aging conditions, but it would seem good for stoichiometric use to have its durability tested under rich-lean cycling conditions. In rich exhaust, Ru may turn metallic and form agglomerates and then perform more like typical catalyst preparations that volatilize at high temperatures. The reviewer suggested that be done, since if it durable under those conditions, it would be very interesting. For the equally interesting PNA system using Ru-ceria, this same testing is important in a more limited way, since it would be most likely used in remediating diesel exhaust in non-road emissions.

Reviewer 3:

The reviewer said that the approach to this project is missing work on the significant technical barrier for this technology.

Reviewer 4:

The reviewer stated that this is a good finding. Ru is shown to have a surprisingly high NO uptake for PNA applications. Highly stable (under hydrothermal aging) Ru/ceria catalysts are shown, though stability of the PNAs is a key bottleneck for application. The catalyst will also be about 20 times cheaper than state-of-the-art palladium (Pd)/zeolite catalysts. The reviewer commented that the results are well supported by DFT theoretical calculations.

Reviewer 5:

The reviewer remarked that the data showed that Ru/ceria-based PNAs can outperform traditional formulations. More discussion on where PNA technology can be used in industry would be helpful and how this new technology can help overcome PNA challenges such as performance in different use cases such as

extended low-load operation and interaction with other species in the exhaust (water [H_2O], reducing gas species, poisoning agents such as sulfur).

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer remarked that Stellantis is an industry partner of this project. As indicated in Slide 14, Stellantis have provided/will provide aging, steady state, and Federal Test Procedure (FTP) dynamometer testing in the future. The reviewer is confident that Stellantis has provided input/guidance to this project as industry partner.

Reviewer 2:

The reviewer said that the way the project is moving, there must be good collaboration between these two strong teams. If the Ru-ceria catalyst is durable under high temperature cycling conditions, then a catalyst manufacturer would be a good addition to the team (presumably an interested supplier to Stellantis) that would build even further on this outstanding collaboration.

Reviewer 3:

The reviewer stated that collaboration with an on-road OEM for an off-road project seems to be an unusual choice.

Reviewer 4:

The reviewer noted that it is was mentioned that BASF Corporation (BASF) is involved which is great, though the team needs to take this research to a more practical level soon.

Reviewer 5:

The reviewer stated that there is good synergistic collaboration between the Pacific Northwest National Laboratory (PNNL) and Stellantis.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer said that the purpose of the future work has been clearly defined. As shown in Slide 16, the future work includes the slurry preparation, core sample, demonstration, and final evaluation.

Reviewer 2:

The reviewer commented that the future plan items look well thought out, although including ways to improve resistance to phosphorus poisoning is very difficult and of lower immediate pay off. However, if PNNL has a previous record of building P-resistance of their catalysts, then this would also be of interest. The reviewer said that, as mentioned above, the durability of the Ru-ceria catalyst should have durability testing under a wider range of conditions, including lean-rich cycling at relevant temperatures added to its list of future deliverables.

Reviewer 3:

The reviewer stated that PNAs are essentially a dead technology. Based on the approach taken in this project, they will not address the technical barriers to the technology, so future research is of questionable value.

Reviewer 4:

The reviewer said that in addition to phosphorus, it will be important to consider the effect of sulfur. It is not clear if the plan includes full size monolith coatings and engine testing. It will be important to test the new catalysts under practical conditions if this is to reach commercialization. The reviewer remarked that there is a

need to address the challenge of Ru volatilization. Some challenges with respect to practical application were discussed—stability with two metals, high temperatures, etc. The project should investigate these factors.

Reviewer 5:

The reviewer stated that future work on poisoning and viability of large-scale production are the key issues. The reviewer further stated that they are looking forward to seeing this work.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said that the project supports DORMA as aftertreatment is a key system in engine technology.

Reviewer 2:

The reviewer stated that this project has already found a new catalyst that could lead to a much lower cost for emissions control in the DORMA area. It presumably falls in a category (e.g., IV-10) of projects that make these kinds of improvements possible for diesel and non-road systems and stoichiometric systems.

Reviewer 3:

The reviewer stated that this project seems a bit lost and out of place in the portfolio.

Reviewer 4:

The reviewer said that upcoming regulations will require light-duty vehicles to comply with super-ultra-low emissions vehicle 30 (SULEV30) or tighter standards. Reducing platinum group metal use will be critical to doing so cost-effectively.

Reviewer 5:

The reviewer commented that any technology that can improve NO_x reductions and lower cost is of great interest to industry. The reviewer hoped that this project would continue.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that PNNL has extensive facility in catalyst preparation and sample evaluation. The engine test cell facility is available in Stellantis.

Reviewer 2:

The reviewer said that the resources available have, with good researchers, made excellent progress on the project.

Reviewer 3:

Given the tight funding in the VTO area, the reviewer commented that they are disappointed with this project. There are so many other areas that have been cut back, or entirely, that would make better use of this money.

Reviewer 4:

The reviewer stated that resources are sufficient for now but need to add engine testing.

Reviewer 5:

The reviewer said that the project seems to have adequate resources between PNNL and Stellantis.

Presentation Number: DORMA008
Presentation Title: Slashing Platinum Group Metal (PGM) in Catalytic Converters: An Atoms-to-Autos Approach
Principal Investigator: Kevin Gu (General Motors)

Presenter

Kevin Gu, General Motors

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

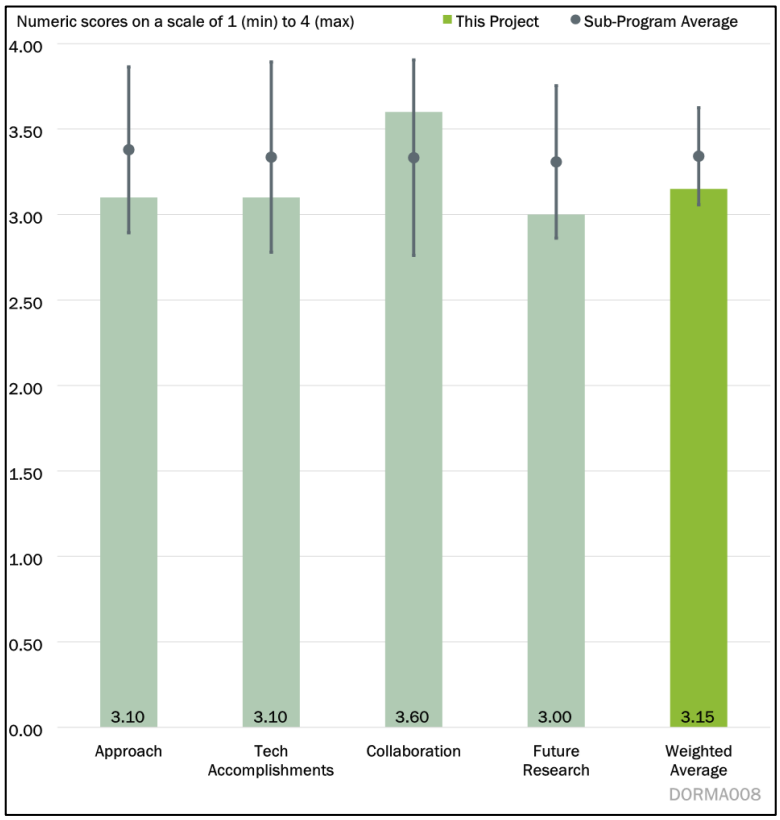

Figure 3-8 - Presentation Number: DORMA008 Presentation Title: Slashing Platinum Group Metal (PGM) in Catalytic Converters: An Atoms-to-Autos Approach Principal Investigator: Kevin Gu (General Motors)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer said that reducing platinum group metal (PGM) applications help to reduce the cost of three-way catalyst (TWC) in light-duty industry—a barrier in the auto-industry. The reviewer stated that the project was well planned but has been delayed due to foreign national (FN) participant approval. FN participant is super important for classified work but seems unnecessary for application work like DOE funded research. Unless specified by industry, the research data generated in DOE must be, or will be, made to public. The long process in FN check is delaying the progress of research in the U.S. and may put American industry in a difficult time in competing with other countries (e.g., from Europe, Japan).

Reviewer 2:

The reviewer stated that the approach has gotten some very interesting data of improved catalyst durability and activity. The reviewer also stated that they had heard somewhat more in the June 14 presentation than is captured in the slides submitted earlier that made clear that the preparation method using an intermediate metal oxide layer between the Rh or Pd catalyst material led to its ability to maintain small particle size and good activity using roughly 40% of the active catalyst material in the baseline commercial catalyst. Hence, the reviewer said, this approach is strongly supported.

Reviewer 3:

The reviewer stated that the atoms to autos approach seems ambitious—the idea of going to nearly atomic dispersion of PGMs to reduce PGM loading is wonderful in theory, but has many, many practical challenges, especially when it comes to poisoning and flaking. The reviewer said that the approach makes sense as a way to combat the sintering impacts of aging, as less total surface area loss occurs without big particles. However, there is not enough evidence that substantial activity is not lost over longer times, and this is only one part of the issue—mechanical failure (flaking of these fine catalyst layers) and poisoning are still large barriers to overcome.

Reviewer 4:

The reviewer said that the project has addressed the key barriers of making new catalysts with higher dispersion and stability, for potentially reduced PGM loadings. Experiments done using core and powder samples in laboratory conditions, but a key barrier of exploring performance under real-world engine conditions with full size parts is not addressed.

Reviewer 5:

The reviewer commented that there is a project start delay due to participant approvals.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer said that this team has made notable progress in catalyst preparation and characterization in laboratory at a delayed schedule. The time needed in transform powder and core samples to full size, fully formulated catalyst, and system demonstration on engine dynamometer or vehicle may take much longer time than planned.

Reviewer 2:

The reviewer commented that the accomplishments to obtain operational catalysts were done successively and successfully over a period of years to prepare durable, active catalysts. The details of the materials are not mentioned in the slides, since they are proprietary, so it is hard to comment in detail on what is new in this preparation, but it clearly improved the catalysts performance over baseline preparation methods. The reviewer stated that the goals so far appear to have been well met.

Reviewer 3:

The reviewer remarked that the technical accomplishments are generally good but have some weaknesses and may contribute to overcoming some barriers. The reviewer noted that while the team has demonstrated that they can in fact make these nearly atomic dispersion catalysts—and that there is some positive impact in the first round of synthetic gas testing—this is still quite a way off from demonstrating that this could lead to real reductions in PGM use and cost on the actual in-use devices. The reviewer rated this satisfactory not as a derogatory rating, but because it is “fine”—the progress is reasonable based on the timeline of the project and the budget period (BP) goals.

Reviewer 4:

The reviewer noted that the new catalysts are developed with improved dispersion and stability. The results for catalyst light-off under laboratory conditions and model gas composition show good promise with similar light-off at 60% reduced PGM. The reviewer commented that improvements in light-off are not clear since there are no numbers on the Y-axis. The catalysts are shown to lose dispersion after lean/rich aging. Some of this is irreversible depending on exposure time to lean/rich. This needs to be addressed.

Reviewer 5:

The reviewer commented that this was good progress, but the most important work is still ahead, confirming performance of aged catalysts via testing.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer said that this team presented extensive collaboration work with industry partners, as shown in Slide 17. Very strong support from partners is the key to success for this project. The reviewer also noted that GM has done an excellent job in coordinating the research in this project.

Reviewer 2:

The reviewer stated that the team assembled in this project is excellent, including excellent researchers from five institutions (GM, University of Central Florida, University of Virginia, PNNL, and BASF). The excellent results suggest excellent collaboration between these five research groups that come from universities, national laboratories, and industry.

Reviewer 3:

The reviewer noted that there are clear roles for all collaborators on the project.

Reviewer 4:

The reviewer said that collaboration is very good across the team. The reviewer also noted that it was good to see participation of academia and industry bringing in understanding at fundamental and applied levels.

Reviewer 5:

The reviewer remarked that the very strong team of OEMs, suppliers, national laboratory, and universities gives this project a high chance of success.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer commented that this team has clearly defied the purpose of future work. The future work can be achieved with the assumption that GM will put more resources, especially researcher time and facility, to this project. This is possible but challenging with the research and development work shifted from traditional engines to electric vehicles.

Reviewer 2:

The reviewer said that this project has had target dates extended for many deliverables for several reasons, including approval of foreign nationals. The project also started about the time of the beginning of the COVID-19 pandemic in the U.S. The project is 1 year from completion and its projected activities are important to get closer to possibly commercializing the improvements. For example, the reviewer noted, the Pd catalyst has been validated for its core performance and Rh needs to reach the same level.

Reviewer 3:

The reviewer commented that BP 3 has some incredibly ambitious goals—the idea of translating this very fundamental (to-date) study to actual devices to be put on vehicle and demonstrating performance on engines seems like a large hill to climb from where things are now. The transformation from powder and core samples to full sized bricks is difficult, so the reviewer was quite skeptical and wished the team much luck.

Reviewer 4:

The reviewer stated that the results need to be evaluated using full size catalysts and using engine testing, and it is good to see this in the plan. The reviewer also stated that the team needs to include chemical aging in the project plan. It is not quite clear how the deactivation under lean rich aging will be addressed. It will be good to demonstrate stability under a wide range of real-world operating conditions.

Reviewer 5:

The reviewer said that future work is critical, confirming the aged performance, overall cost savings, and potential for production.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said that this project is closely relevant to DORMA. The reviewer also stated that it is the most relevant project of the six projects they reviewed this year.

Reviewer 2:

The reviewer commented that, more than many projects, this one clearly meets the goal of lowering the cost of emission control systems based on its ability to match baseline performance with 60% less catalyst material, which is important in the DORMA area.

Reviewer 3:

The reviewer said that this is relevant to VTO goals.

Reviewer 4:

The reviewer stated that reducing PGM is critical to enable improved emissions control at reduced cost.

Reviewer 5:

The reviewer commented that with unstable PGM prices, this is an important project. The reviewer highly recommended that the team continue this work.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the research has more hardware resources and facility than the delivery of this project. However, the reviewer suggested GM put more human research resources to this project as the work in the last year could be very challenging and needs more time and effort to get the work completed.

Reviewer 2:

The reviewer stated that over the past several years the researchers have made great strides finding a catalyst and have had the resources sufficient to meet their goals.

Reviewer 3:

The reviewer remarked that this is interesting fundamental research that is normally in the purview of Basic Energy Sciences (BES) or the catalyst suppliers and seems a bit out of place in the VTO portfolio.

Reviewer 4:

The reviewer commented that the resources look sufficient. It remains to be seen how much of the engine testing is done with a wide range of full-size catalysts.

Reviewer 5:

The reviewer stated that the team is strong and well-rounded.

Presentation Number: DORMA009
Presentation Title: NO_x Reduction with Low GHG Impact (N_2O Reduction for Off-road)
Principal Investigator: Feng Gao (Pacific Northwest National Laboratory)

Presenter

Feng Gao, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 60% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 40% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

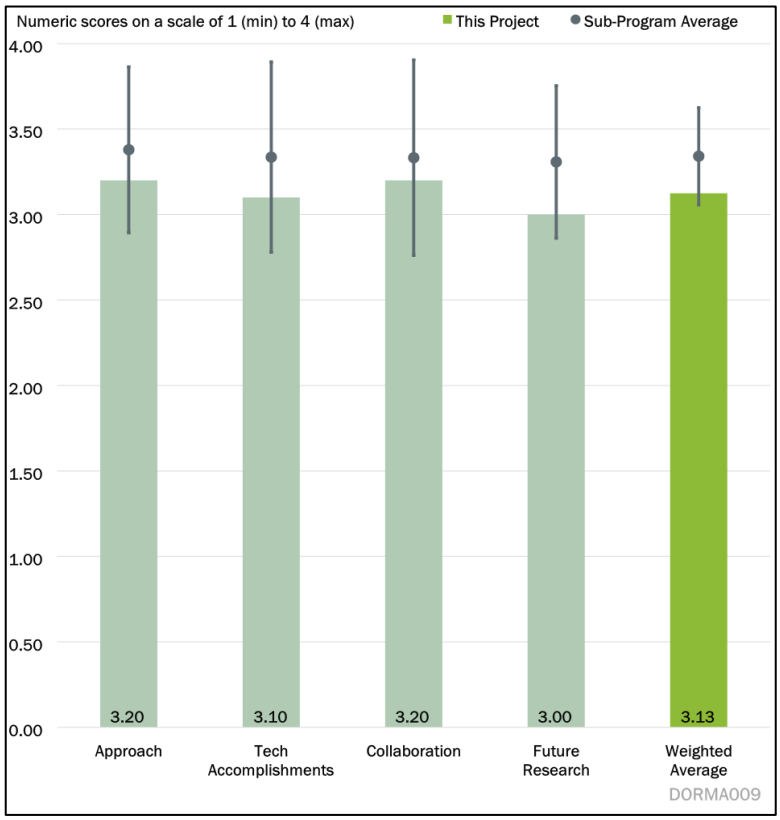

Figure 3-9 - Presentation Number: DORMA009 Presentation Title: NO_x Reduction with Low GHG Impact (N_2O Reduction for Off-road) Principal Investigator: Feng Gao (Pacific Northwest National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

Nitrous oxide (N_2O) emissions gained increasing importance in the years past as regulations for GHG emissions were implemented. The reviewer found this project to have been well-designed. The timeline, as depicted in Slide 4, was well planned. Based on the reviewer's understanding of the time required to complete the remaining work, they were confident that the team could meet the established deadlines.

Reviewer 2:

The reviewer noted that the approach employed in this study to enhance NO removal without causing an increase in N_2O emissions, a potent GHG, was notably comprehensive, covering a wide range of issues related to using selective catalytic reduction (SCR) catalysts for NO_x control in off-road diesel vehicles. The exploration of various catalyst compositions and their impact on N_2O emissions, along with a focus on mechanistic issues, was highly commendable.

Reviewer 3:

The approach described primarily served as early-stage research for clarifying barriers (as seen in Slide 3) rather than directly addressing them. Therefore, the reviewer believed it might have been more suitable for funding by organizations like BES or the National Science Foundation (NSF), rather than DOE VTO. Given the tight financial constraints in this research area, it was somewhat surprising to encounter a project that

appeared to fall outside the portfolio's scope. The project's objectives were relatively general, making it challenging to discern a clear connection between the ongoing work and these objectives.

Reviewer 4:

The reviewer stated that a fundamental understanding of N_2O formation was crucial, as it remained less comprehensively understood. Consequently, the study's emphasis on fundamental research across various practical catalysts was highly significant and addressed an essential need.

Reviewer 5:

While the project was commendable for its work on N_2O reduction and its substantial impact on global warming potential, the reviewer stated it could have benefited from additional efforts aimed at improving low-temperature activity, extending useful life, and reducing costs.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer observed that the team successfully completed the design of the catalyst and evaluated N_2O formation characteristics in December 2022. At that time, the team was engaged in characterizing the side requirements for N_2O formation through catalyst characterization. The reviewer noted that N_2O formation at low temperatures had been thoroughly examined, as evidenced by Slide 12.

Reviewer 2:

The reviewer recognized notable achievements within the project concerning the understanding of how N_2O formed on Cu-SCR catalysts. Specifically, it was observed that N_2O was generated from ammonium nitrate (NH_4NO_3) as one source and was promoted under conditions where NO_2 was produced during the reaction. The reviewer also noted the exploration of the role of Brønsted acid sites in this promotion. Furthermore, it was highlighted that high NO conversion catalysts could be a significant source of N_2O production. As far as this reviewer could discern, the strategy for simultaneously optimizing NO conversion while minimizing N_2O formation remained elusive. Consequently, achieving this balance would constitute a significant milestone for the project in addressing non-road NO_x and GHG emissions.

Reviewer 3:

As indicated in Slide 3, the reviewer understood that the primary goal of this work was to clarify, rather than solely overcome barriers. Thus, while this work might have helped overcome some barriers, it did not appear to be its primary focus.

Reviewer 4:

The reviewer noted that testing had been conducted with aged catalysts, including both hydrothermal and chemical aging. Overall, there had been commendable progress in enhancing the fundamental understanding of N_2O formation. The reviewer gleaned from the work that N_2O formation was a complex process that could not be attributed to a single step. It was likely that N_2O formation proceeded through nitrates, which could be formed either directly or indirectly, with or without NO_2 involvement. The outcome also appeared to depend on the type of SCR catalyst utilized (Cu, silicon/aluminum (Si/Al) ratio, etc.). The reviewer further appreciated the work's elucidation of how N_2O could form even in the absence of NO_2, as the latter could be formed *in situ* and directly through nitrates, bypassing the need for NO_2.

Reviewer 5:

The reviewer observed that, thus far, the work had placed a strong emphasis on N_2O reduction.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer found this project was supported by four industry partners and two universities. It appeared that the primary contribution of the industry partners was to provide valuable input regarding the research direction, as the majority, if not all, of the work was conducted at PNNL. Therefore, the reviewer recommended that the team specifically report on the contributions of each partner, with a particular emphasis on the industry partners.

Reviewer 2:

The reviewer stated the collaborators in this project included two companies that supplied engines for non-road vehicles, an active catalyst supplier, a zeolite manufacturer, Postech, and PNNL. These collaborators brought diverse backgrounds and strengths to the project, and there was strong interaction among them.

Reviewer 3:

While collaboration with John Deere, Cummins, Zeolyst, and BASF existed, the reviewer deemed the presentation did not provide a clear delineation of the specific roles of each participant and how coordination among them operated.

Reviewer 4:

The reviewer acknowledged the active participation of industry partners at various levels, encompassing equipment, engine, and catalyst manufacturers.

Reviewer 5:

The project had a strong team in place. However, the reviewer suggested that the team should place more focus on some of the other stated objectives, such as improving fuel utilization, reducing costs, and enhancing low-temperature performance. This would enhance the project's overall effectiveness.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the project clearly defined the purpose of future work, as illustrated on Slide 17. The inclusion of theoretical calculations to enhance comprehension of NH_4NO_3 formation pathways in NH_3-SCR was deemed highly important and held significant promise for the advancement of SCR simulation, offering academia an opportunity to make substantial progress in SCR development.

Reviewer 2:

The reviewer remarked that there were specific research goals with evident utility. It was observed that proficient NO conversion catalysts often generated higher levels of N_2O, a phenomenon influenced by the roles of Brønsted acid sites and Cu loading. The proposal to investigate whether this applied to low carbon fuel vehicle emissions control was considered a promising direction. Furthermore, the reviewer suggested that taking a broader, system-level view could yield fruitful results and pave the way toward achieving this objective. The potential for utilizing machine learning to explore the extensive results for further research directions was also acknowledged.

Reviewer 3:

The reviewer commented on the proposed future work, stating that it seemed to align more with BES/NSF than with an applied office primarily focused on overcoming barriers. The outlined tasks, which included proposing pathways to mitigate or circumvent N_2O formation in NH_3-SCR, stabilizing NH_4NO_3 to facilitate the NH_4NO_3

+ NO reaction, balancing boron arsenide (Bas) and Cu density, and engaging in theoretical calculations to better understand NH_4NO_3 formation pathways in NH_3-SCR, were found to be better suited for such a context.

Reviewer 4:

The reviewer affirmed the importance of considering the trade-off between N_2O and NH_3 slip, suggesting that studying N_2O formation with varying ammonia-to-NO_x ratios could be beneficial. Although this might be perceived as beyond the project's initial scope, it was deemed a valuable avenue to explore. Additionally, the reviewer encouraged the inclusion of work with iron (Fe)-zeolite catalysts.

Reviewer 5:

In alignment with the previously mentioned objectives, the reviewer stressed the need for greater focus on enhancing low-temperature efficiency, improving FUL, reducing costs, and reducing N_2O emissions. These aspects were seen as pivotal in enhancing the overall success of the project.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that this project played a crucial role in assisting the diesel engine industry in enhancing the performance of SCR systems, a critical aspect for next-generation diesel engines, particularly HD diesel engines.

Reviewer 2:

The reviewer observed that this set of project goals clearly aligned with the broader objective of identifying pathways to reduce the GHG emissions impact of emissions control systems.

Reviewer 3:

In general, the reviewer pointed out that the project's focus on catalyst material knowledge supported its goals. However, it was noted that this work appeared to be at a relatively low technology readiness level for VTO.

Reviewer 4:

The reviewer emphasized the importance of reducing N_2O, a potent GHG agent, and highlighted the significance of obtaining fundamental understanding to develop effective solutions.

Reviewer 5:

The reviewer stated that the project's objectives, including cost reduction, improving FUL, and enhancing low-temperature performance, were highly important and useful. However, it was noted that most of the project's efforts had concentrated on N_2O reduction. The reviewer suggested that addressing all the stated objectives would significantly enhance the project's overall impact and effectiveness.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that PNNL possessed ample resources, including facilities, to support the project team in achieving the project's objectives.

Reviewer 2:

The reviewer acknowledged that the collaborators, particularly PNNL, brought substantial and well-suited resources to investigate the matter at hand.

Reviewer 3:

The reviewer expressed the view that this work could be categorized as “nice to have” rather than being a necessity for addressing barriers.

Reviewer 4:

While recognizing the presence of sufficient resources, the reviewer suggested that extending the scope to include Fe-zeolite or hybrid Fe-Cu systems would be highly beneficial.

Reviewer 5:

The reviewer praised the project for having a competent team in place and encouraged the pursuit of all the project’s objectives.

Presentation Number: DORMA010
Presentation Title: Hardware in the Loop Toolkit for Off-Road and Marine
Principal Investigator: Muni Biruduganti (Argonne National Laboratory)

Presenter

Muni Biruduganti, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 60% of reviewers felt that the resources were sufficient, 40% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

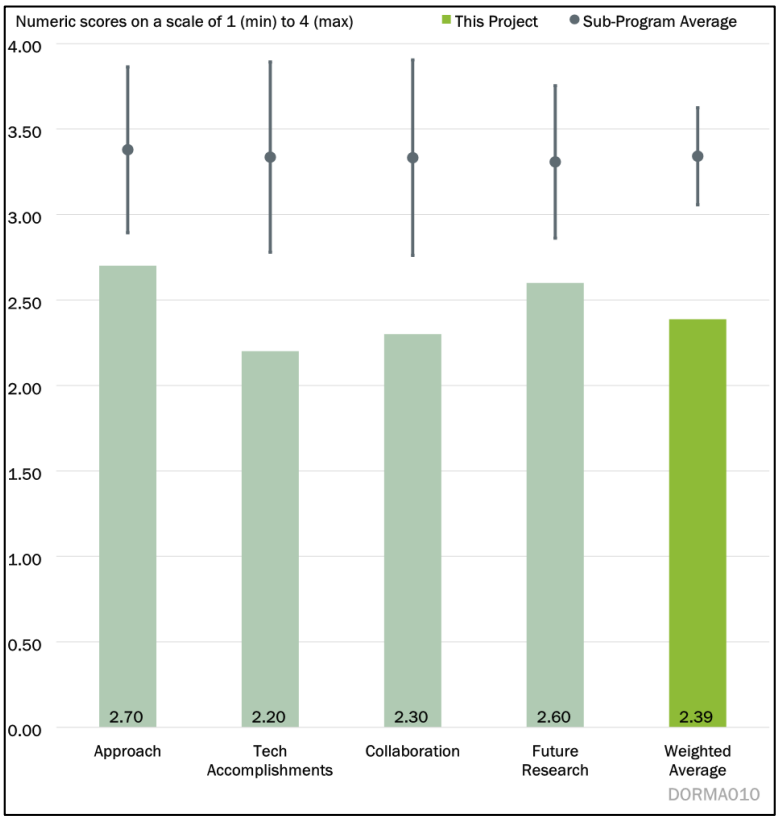

Figure 3-10 - Presentation Number: DORMA010 Presentation Title: Hardware in the Loop Toolkit for Off-Road and Marine Principal Investigator: Muni Biruduganti (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked that the project allowed Argonne National Laboratory (ANL) to develop a toolset already existing within the industry. Two industrial exemplars, AVL (https://www.avl.com/en/development-speed-and-methodology) and FEV Test Systems (https://www.fev-sts.com/testing-solutions/simulation-and-hil-solutions.html), were cited. While acknowledging the soundness of the approach, the reviewer pointed out the presence of commercially available hardware-in-the-loop (HIL) solutions, including real-time plant models capable of simulating engine testing on a dynamometer. The reviewer inquired about the unique contributions this project brings to the engine development community.

Reviewer 2:

The reviewer questioned whether it was necessary for these components to operate in real-time sync, as it is not a common practice in the commercial vehicle sector, and even less so in the marine sector. The reviewer suggested the need for a more comprehensive elaboration on the anticipated outcomes and benefits of the integrated approach. Additionally, concerns were raised regarding the project's ambitious timeline to test a H_2 ICE in December 2023, just one month after its expected delivery. The reviewer sought clarification on any ongoing efforts to ensure the feasibility of this tight schedule.

Reviewer 3:

The reviewer praised the project as a valuable initiative providing real-world assessments for the use of low-emission engines in various off-road vehicle applications, encompassing a range of propulsion system types, from mechanical to hybrid configurations. The output of the project was emphasized as critical for evaluating potential impacts on GHG emissions and fuel consumption in future applications. The project's comprehensive approach, addressing both steady-state and transient aspects of mobility, was noted for its potential benefits in the development of low-emission engine subsystems. The reviewer, while acknowledging the project's challenges arising from its commencement during supply chain disruptions and shutdowns, questioned the project's timeline relative to its funding level and project type.

Reviewer 4:

The reviewer found the execution of the project to be lacking, even though the approach was considered acceptable. The primary approach was seen as using an existing HIL laboratory to verify off-road vehicles using a conventional diesel engine, with a transition to an H_2 ICE.

Reviewer 5:

The reviewer highlighted a significant weakness in the project, the absence of involvement from an industrial partner. The project was noted for lacking a defined engine platform for utilization, which was seen as a potential explanation for the limited progress achieved since October 1, 2021. Additionally, the reviewer questioned why the authors had not devised a backup plan for an H_2 test platform and mentioned potential distractions posed by the commissioning of a large diesel engine.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the team's progress was not satisfactory, given that they were halfway through the period of performance but had only completed 20% of the work. Delays in the delivery of the real-time controller from dSPACE and in the development of a production H_2 ICE from Cummins appeared to be the main factors for the slow progress.

Reviewer 2:

The reviewer observed that the infrastructure for H_2 fuel supply appeared to be set up and complete, although it was not clear what validation of this had been done. This aspect should be clarified. The demonstration of an off-road duty cycle with the Navistar engine was in progress, with a completion date expected by June 31, 2023. Powertrain models had been completed in Autonomie for off-road applications.

Reviewer 3:

The reviewer commended the principal investigators for being able to reconfigure their test facility for H_2 use and for being in a position to benchmark a legacy engine, recognizing these as critical steps toward reaching the ultimate goals of the project. However, the reviewer also noted that the project appeared to have progressed slowly and acknowledged that the timing of shutdowns and supply chain issues may have played a major role.

Reviewer 4:

The reviewer pointed out that the project was significantly behind schedule, likely due to personnel changes. Currently, the project was only 20% complete, and it should be closer to 50% complete. The reviewer expressed uncertainty about how the team planned to catch up.

Reviewer 5:

The reviewer emphasized the lack of technical information in the project. They noted that the team needed to promptly determine which H_2 ICE they would use and expedite their efforts to install it on the dynamometer.

The reviewer considered the effort reported on the H_2 infrastructure upgrades or on the transient dynamometer capabilities upgrades to be minor contributions, as these were standard capabilities in most engine laboratories. Furthermore, the reviewer pointed out that the authors had not discussed H_2-like operation approaches, such as the use of traditional spark ignition or stoichiometric three-way catalyst. The reviewer sought information on whether there was a plan to run homogeneous charge compression ignition-like operations, aiming at low heat losses and low NO_x emissions, and inquired about their anticipated efficiencies.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commented it looks like ANL is the only member of the project team, which is unusual for a VTO-funded project. Dr. Biruduganti explained that there are two different ANL departments involved in this project. The two engine manufacturers identified in the project—Navistar and Cummins—are only weakly collaborating with ANL on the project.

Reviewer 2:

The reviewer stated the project is dependent upon collaboration with Cummins or other engine supplier. The success of the project is ultimately dependent upon this. Slide 16 further states that an un-calibrated Cummins H_2 ICE is needed. Calibration of the engine seems out of scope in this project. Is the intent that the project needs an open controller for this and has Cummins agreed with suppling such a controller with the engine.

Reviewer 3:

The reviewer was not clear as to the level of involvement of the two engine OEMs in this project. Nevertheless, they are supplying at least two engines of which one is a legacy product for HIL benchmarking while the other is an advanced low emission engine with the possibility of a third engines which will be an advanced low emissions engine. It is assumed the engine OEMs will ensure proper communication/controls are in place within the HIL and also will be involved in possible calibration change work as necessary.

Reviewer 4:

The reviewer commented the major task is to obtain a H_2 ICE from Cummins, but the reviewer did not see a commitment in writing that this is going to happen. It sounds like the engine is not available and will not be for some time. Not sure what the contingency plan is. The overall project needs more communication among the collaborators.

Reviewer 5:

The reviewer felt the team needs significant industrial support to move forward effectively.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer pointed out that there was uncertainty regarding whether the proposed Future Research outlined on Slide 17 was intended for this specific project or for broader, overall research initiatives. If intended for this project, the reviewer expressed concerns about its ambitious nature, particularly for a national laboratory, given the limited remaining time (18 months) and budget.

Reviewer 2:

The reviewer highlighted the project's dependency on acquiring the appropriate H_2 ICE. They requested clarification on whether this engine needed to be calibrated, un-calibrated, or if the calibration could be modified.

Reviewer 3:

The reviewer stressed the significance of future work for the project's progress. They noted the industry's need for assessments of various propulsion system architectures, including power source evaluations and power transfer evaluations. The reviewer emphasized the central role of hybridization in these assessments and saw the HIL as a valuable resource for evaluating different propulsion system options. The reviewer anticipated that this future work would successfully meet its assessment targets, providing valuable propulsion system evaluations for off-road applications.

Reviewer 4:

While acknowledging the overall soundness of the research plan, the reviewer raised concerns about the project's ability to proceed in the absence of the required H_2 ICE.

Reviewer 5:

The reviewer expressed doubts about the project's ability to run an H_2 ICE and suggested that a significant change in approach was needed.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that the project's primary objective is to examine H_2 ICEs as a means to address GHG emissions associated with traditional ICEs. Nevertheless, the reviewer pointed out the ongoing challenges related to NO_x and other criteria pollutants, underscoring that H_2 ICEs do not align with the California Air Resources Board's definition of zero-emission power units.

Reviewer 2:

The reviewer acknowledged the project's particular focus on the ability to operate HD off-road and marine H_2 engines, highlighting its alignment with the broader goals of the VTO programs.

Reviewer 3:

From the reviewer's perspective, the project strongly supports the objectives laid out by DOE's VTO programs. The project holds the potential to serve as a valuable experimental and modeling/simulation tool aimed at reducing emissions in future off-road applications. Moreover, it is poised to enhance fuel consumption characteristics through the incorporation of advanced low heat rejection engines and advanced propulsion systems, potentially involving various levels of hybridization and electrification. The reviewer stressed the pivotal role of the project's experimental component and the need for heightened attention to this aspect in the coming year.

Reviewer 4:

The development of more efficient H_2-powered off-road vehicles aligns with the overarching objectives of the VTO program.

Reviewer 5:

The reviewer contended that the project represents a potential pathway towards achieving decarbonization in off-road applications through the use of ICE.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the ANL team had most of the necessary components at the project's outset, including the Navistar engine and the foundational models in Autonomie, indicating that they possess the required

resources to complete the project. However, the primary challenge faced by the ANL team appears to be time constraints.

Reviewer 2:

The reviewer did not express any particular concerns but suggested considering the engine sizes that are targeted and needed for the project. The project's scope involves both a 6.7 L and a 15 L engine, and it should be noted that doubling the engine displacement would likely increase the overall cost of operation.

Reviewer 3:

The reviewer found the project's funding to be somewhat insufficient relative to the level of effort and facility upgrades required to conduct this experimental work. The project entailed infrastructure upgrades, extensive testing hours, and significant post-processing and interpretation of results. The allocated budget of $1.2 million was considered somewhat low for this type of effort.

Reviewer 4:

The reviewer noted that if the project team were on schedule, the funds would likely be adequate. However, given the current 20% completion status, it was suggested that the budget would only have been 20% spent at this point.

Reviewer 5:

The project was identified as in need of an industrial partner to provide guidance, particularly in terms of validating the engine platform or directing the retrofitting of existing engines to run on H_2. The reviewer indicated that the current team did not appear to possess the necessary technical capabilities and resources to accomplish these objectives.

Presentation Number: DORMA012
Presentation Title: H2 Combustion Research - CRADA with Wabtec
Principal Investigator: Muhsin Ameen (Argonne National Laboratory)

Presenter

Muhsin Ameen, Argonne National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

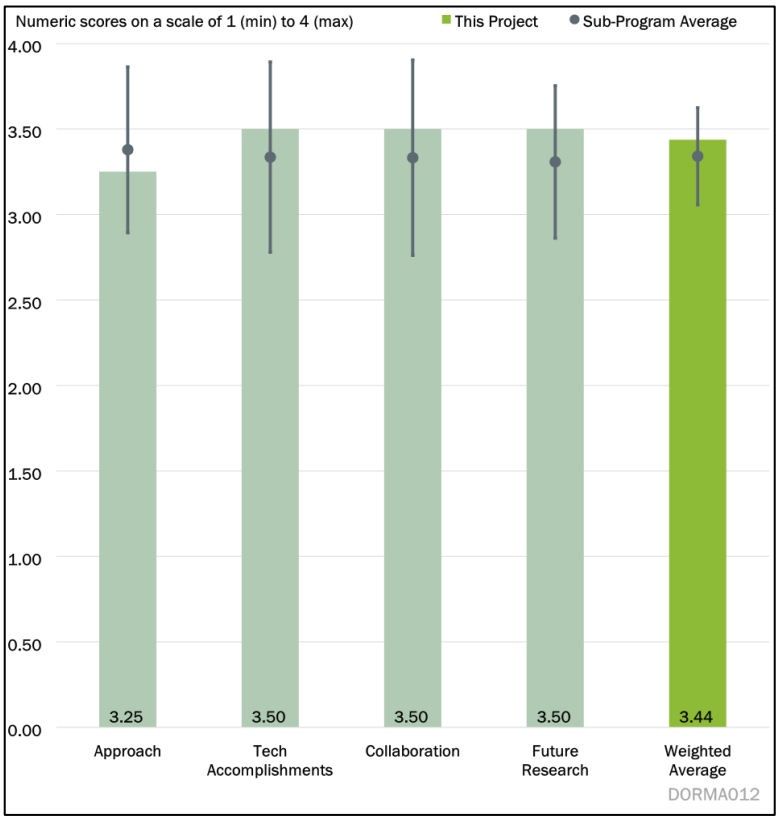

Figure 3-11 - Presentation Number: DORMA012 Presentation Title: H2 Combustion Research - CRADA with Wabtec Principal Investigator: Muhsin Ameen (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer comprehended that the project encompasses both traditional dual fuel and high-pressure direct injection (HPDI) approaches. The reviewer expressed concern that these two combustion approaches are considerably different and might pose a challenge to address simultaneously. The reviewer indicated a preference for selecting one approach, particularly favoring HPDI due to its potential for achieving high substitution rates.

Reviewer 2:

The timeline was deemed reasonable, with the reviewer emphasizing that the key to making progress would involve support from Oak Ridge National Laboratory (ORNL) and successfully getting the single-cylinder engine up and running, first using diesel and then transitioning to dual-fuel with H_2. The reviewer also noted that the Approach slide highlighted support for H_2 engine development, starting with port injection and aiming for a 90% substitution goal with direct injection. The reviewer inquired about the presence of direct injection work in the current plan and whether it was reserved for FY 2024 efforts. The reviewer assumed that the ORNL engine test would also be a parallel effort with direct injection in the test engine and pointed out the absence of any mention of spark plugs in the project's scope.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer, while not a modeling expert, found the project's approach to be reasonable.

Reviewer 2:

The reviewer saw the team as making a good start, particularly in terms of validating the model with diesel and natural gas dual-fuel engine data.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer also noted a strong alignment between the team members' backgrounds.

Reviewer 2:

The reviewer acknowledged that the team appeared to be making progress but anticipated potential challenges in this area. The reviewer reiterated that the key to success would be timely data input and parallel progress from ORNL.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer believed that the modeling aspect had a good potential to assist in transitioning to test cell operation of the single-cylinder research engine.

Reviewer 2:

The transition to direct injection with a 90% substitution and reaching 100% with spark ignition was highlighted as an essential step. The reviewer pointed out that NO_x predictions would be crucial for both the port injection and direct injection studies.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer recognized that the project aligned with several objectives but did not encompass all aspects, such as materials, batteries, and electrification.

Reviewer 2:

The reviewer emphasized the importance of H_2 internal combustion engines (H_2 ICEs) as a pathway for exploring decarbonization in the rail industry.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the team had made a good start and appeared to have a plan for completing the project. However, the reviewer expressed a limitation in fully assessing the team's ability to meet milestones without attending their weekly meetings.

Reviewer 2:

The reviewer found the funding through FY 2023 to be reasonable but requested more details regarding funding for FY 2024–FY 2026 to provide an overall assessment of project funding.

Presentation Number: DORMA013
Presentation Title: Experimental and Numerical Research on Biodiesel and Renewable Diesel Blends for Locomotive Engines
Principal Investigator: Chao Xu (Argonne National Laboratory)

Presenter

Chao Xu, Argonne National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

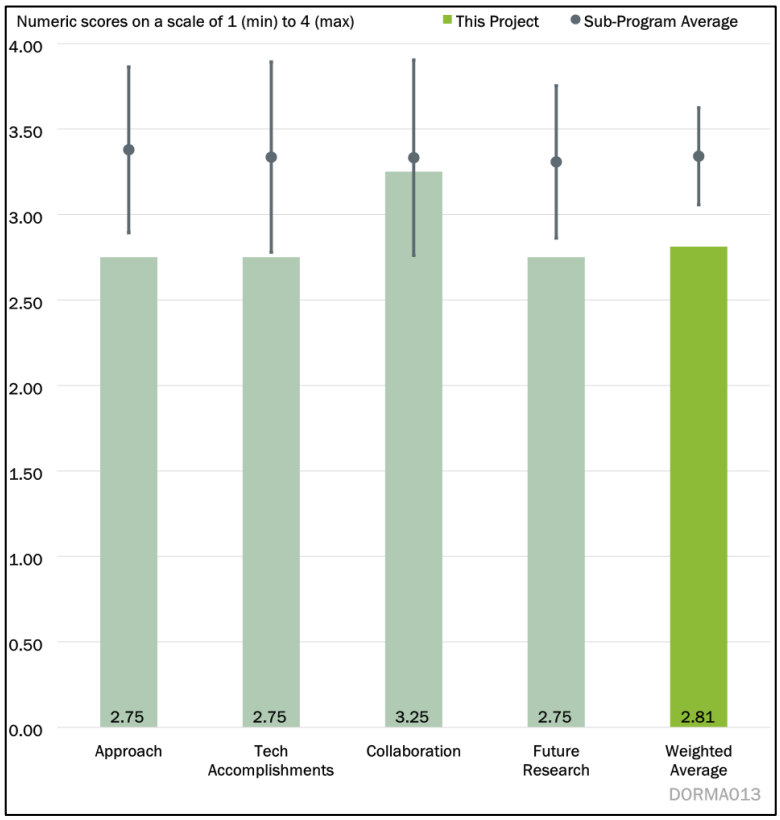

Figure 3-12 - Presentation Number: DORMA013 Presentation Title: Experimental and Numerical Research on Biodiesel and Renewable Diesel Blends for Locomotive Engines Principal Investigator: Chao Xu (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer found the project's approach reasonable but expressed concerns about the timeline, considering it to be too long.

Reviewer 2:

The "Barriers and Technical Targets" slide raised questions for the reviewer regarding the inclusion of reliability, as it was not evident in the project's scope. The reviewer acknowledged that understanding engine performance and emissions was essential before delving into field reliability testing.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer questioned the extended timeframe for obtaining engine data with different fuel blends, given that the single-cylinder research engine (SCRE) was already installed at Argonne National Laboratory. The reviewer also sought clarification on the prolonged duration for modeling work, considering that the engine already existed and there should have been accurate models in place for designing the original engine's fuel system. The project's alignment with liquid fuels further raised questions regarding the need for an extended timeline.

Reviewer 2:

The milestone chart was commended for reflecting good progress, particularly in getting the SCRE up and running, conducting baseline diesel CFD analysis on the injector, and developing the engine model.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer did not identify any issues in the provided presentation.

Reviewer 2:

The reviewer noted that the team appeared to be making progress with the support of various organizations, including Progress Rail, Chevron Renewable Energy Group, and Convergent, as well as coordination with the Federal Railroad Administration and DOE.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed a degree of skepticism about the project's timeline and its potential to provide industry-advancing insights due to the existing field tests with similar fuels.

Reviewer 2:

The reviewer anticipated that future research focus would likely emerge from the findings of the current work and underscored the importance of validating models with various biofuel blends tied back to engine data.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

While the project was viewed as relevant to DORMA, the reviewer believed it should have been completed over 2 years ago.

Reviewer 2:

The reviewer commented that biofuels were recognized as a crucial technology in the context of rail decarbonization, especially considering the extended timeframes for H_2 and battery options in the rail sector.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

In terms of resources, the reviewer deemed the project sufficiently resourced, primarily because the SCRE was already installed, and Argonne National Laboratory had access to the OEM's existing models.

Reviewer 2:

The reviewer described the funding as "barely sufficient" noting the challenges associated with conducting laboratory work on locomotive engines, which are heavy and expensive.

Presentation Number: DORMA014
Presentation Title: Implementing low lifecycle carbon fuels on locomotive engines – CRADA with Wabtec
Principal Investigator: Dean Edwards (Oak Ridge National Laboratory)

Presenter

Dean Edwards, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

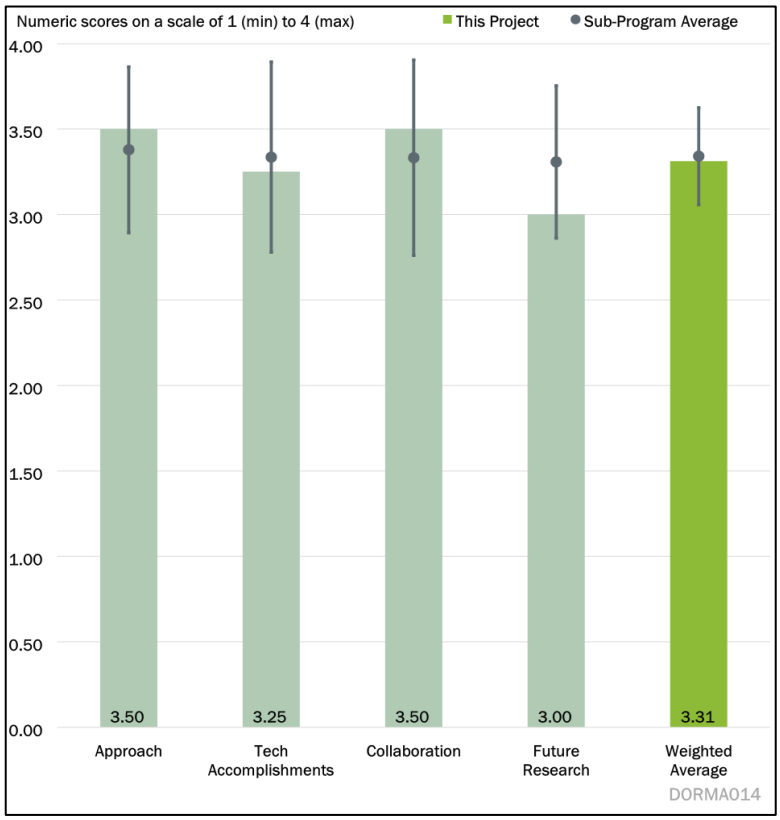

Figure 3-13 - Presentation Number: DORMA014 Presentation Title: Implementing low lifecycle carbon fuels on locomotive engines – CRADA with Wabtec Principal Investigator: Dean Edwards (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer highlighted the potential of the single cylinder engine (SCE) as a valuable resource for validating models without the complexities associated with operating a multi-cylinder engine. However, the reviewer expressed concerns about the time and cost required for installing the necessary infrastructure, as well as the significant challenges involved in setting up and maintaining the safety systems for the test cell.

Reviewer 2:

The project was seen as a crucial endeavor requiring a substantial amount of research and development work to develop H_2 ICEs for locomotive engines. The reviewer believed the project had the essential components to make a strong start in this regard.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The progress achieved thus far was considered reasonable, but the reviewer anticipated potential issues in obtaining approvals to operate the test cell. The reviewer emphasized the need for extensive upfront work to facilitate the transition from an infrastructure upgrade and SCRE installation project to the operational phase.

Reviewer 2:

Given the project's status approximately 1 year in, the 18% completion figure was seen as appropriate by the reviewer.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer acknowledged that the team appeared to be working cohesively, which was viewed as a significant factor in enhancing the project's likelihood of success.

Reviewer 2:

The project received good support from Wabtec, along with the Oak Ridge National Laboratory team. However, there was limited discussion in the slides about ANL and Convergent CFD status, support, and collaboration. The reviewer suggested that including information about the funding allocation and effort distribution between ANL and Convergent in future briefings would be beneficial.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the outlook for the project was expected to brighten significantly once the test cell was commissioned and the SCRE became operational.

Reviewer 2:

The reviewer noted that the presentation lacked specific details beyond achieving 50% H_2 substitution with port injection. This emphasis on facilities-related matters was deemed understandable given the project's current focus. Future research aspects, as highlighted on Slide 10, included compression ratio, dilution (presumably related to turbocharger simulation), and EGR. The reviewer recognized the need to "turn all those knobs" to optimize the system, although it was acknowledged that maintaining 100% diesel capability would be a challenge. The direct injection work was characterized as somewhat of a fresh start but considered worthwhile to maximize substitution.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the project was categorized under DORMA.

Reviewer 2:

The reviewer noted that H_2 ICE could be a crucial bridge technology for decarbonization in long-life locomotives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer emphasized that only time would determine whether the level of effort and funding was adequate. Having the engine OEM available and an active team member was seen as factors that could reduce the likelihood of the SCRE becoming a bottleneck in achieving the project's milestones.

Reviewer 2:

Regarding funding, the reviewer considered it to be robust, which was deemed necessary for the work involved. The budget, as presented in Slide 2, was presumed to be linear. However, the reviewer pointed out

that expenses would escalate rapidly as the team began purchasing expensive H_2 and conducting extensive engine operating hours with high substitution rates. Additionally, the cost of operating the facility was anticipated to be significant, with the electricity bill for the turbocharger simulation system noted as a potential source of high expenses.

Presentation Number: DORMA015
Presentation Title: Enabling H_2 and Methanol Combustion
Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

Presenter

Riccardo Scarcelli, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

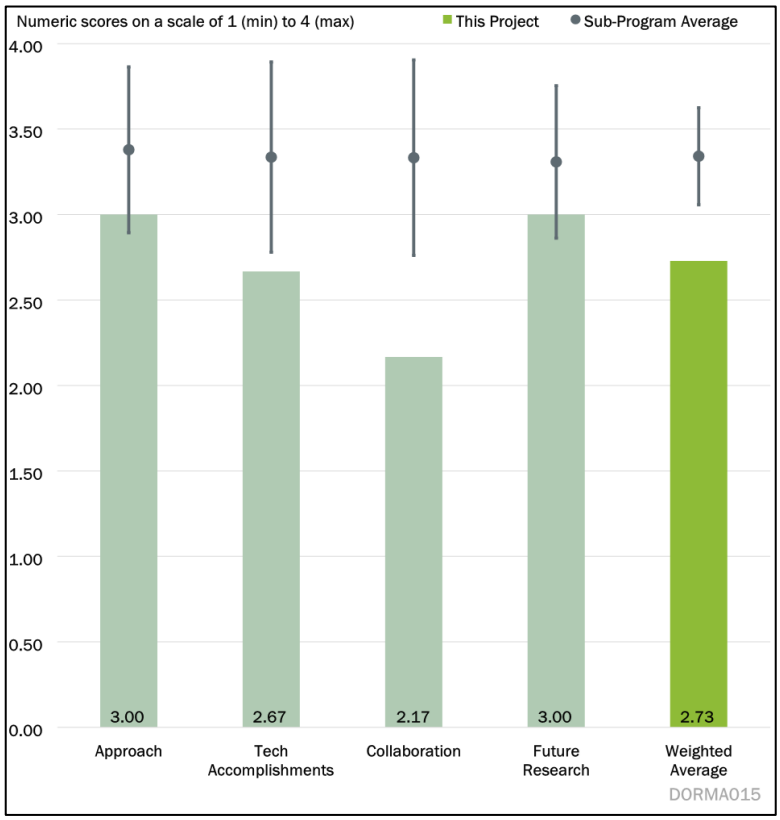

Figure 3-14 - Presentation Number: DORMA015 Presentation Title: Enabling H_2 and Methanol Combustion Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer expressed uncertainty about why the H_2 work would commence first, speculating that it might be because existing models were available and that lessons learned from other methanol projects would be applied when the methanol (MeOH) work began. The two project objectives appeared somewhat disconnected, lacking clear linkages between the H_2 and methanol components. The reviewer pointed out that many methanol engines were currently being designed and produced, and the delay in starting this aspect of the project for 2 years was considered a missed opportunity. The suggestion was made to work on the tasks related to H_2 and methanol in parallel.

Reviewer 2:

The reviewer noted that the project could not be fully initiated due to the unexpected loss of some partners, and the rating of "satisfactory" was considered a placeholder. Overall, the adoption of low-carbon fuels was viewed as a valid approach to decarbonization throughout the product's life cycle. The reviewer recommended providing a one-to-two-page summary that supports the remaining barriers and unknowns, particularly in light of the extensive literature and prior work on the combustion of methanol and H_2 in engines. The availability of low-carbon H_2 and methanol should also be discussed.

Reviewer 3:

The project plan was commended by the reviewer for addressing technical barriers and being well designed and planned.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer expressed uncertainty about how to evaluate the project since it had not yet started. A "satisfactory" rating was given, with the hope that this score would not be included in the overall project rating.

Reviewer 2:

The reviewer noted that the project could not be effectively evaluated at this stage, and the "fair" rating was considered a placeholder. The reviewer suggested that a "not applicable" rating might be more appropriate.

Reviewer 3:

Despite the project not having started, the reviewer acknowledged that it was well planned.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted the difficulty in evaluating the project since it had not yet commenced, and project team members were not publicly known. A "satisfactory" rating was assigned, with the hope that this score would not be factored into the overall project rating.

Reviewer 2:

The reviewer highlighted that the project was unable to proceed due to the loss of a partner.

Reviewer 3:

Despite the inability to disclose all project collaborators publicly, the reviewer acknowledged that the level of collaboration appeared to position the project for success.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed a desire to see a Diversity, Equity, and Inclusion (DEI) SMART milestone included in the project's scope. Additionally, the reviewer reiterated the importance of reconsidering the project's task sequence, specifically in terms of advancing the timing for MeOH work. This adjustment was seen as beneficial for the industry, given the current focus on MeOH over H_2 ICEs.

Reviewer 2:

The reviewer recommended revisiting the project once partnerships were re-established, indicating that the absence of key partnerships had impacted the project's evaluation.

Reviewer 3:

The reviewer commented that as the project had not yet begun, future work had not been extensively addressed at this stage.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer agreed with the relevance of the project.

Reviewer 2:

The reviewer affirmed that the successful deployment of net-low carbon fuels is a viable approach to carbon reduction. The reviewer suggested that the project should focus on addressing key barriers and inquired whether there had been a workshop involving engine and fuel stakeholders.

Reviewer 3:

The reviewer noted that the project was considered relevant to the broader VTO program objectives, particularly within the scope of DORMA.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that it was challenging to assess the project fully, primarily due to the inability to disclose project team members. However, the current suite of models and planned models were considered highly relevant.

Reviewer 2:

The reviewer recommended revisiting the budget in light of the inclusion of new partners.

Reviewer 3:

The reviewer stated that the budget was adequate to support the project in achieving its milestones.

Presentation Number: DORMA016
Presentation Title: Renewable methanol-fueled engines for marine and off-road applications
Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

Presenter

Jim Szybist, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

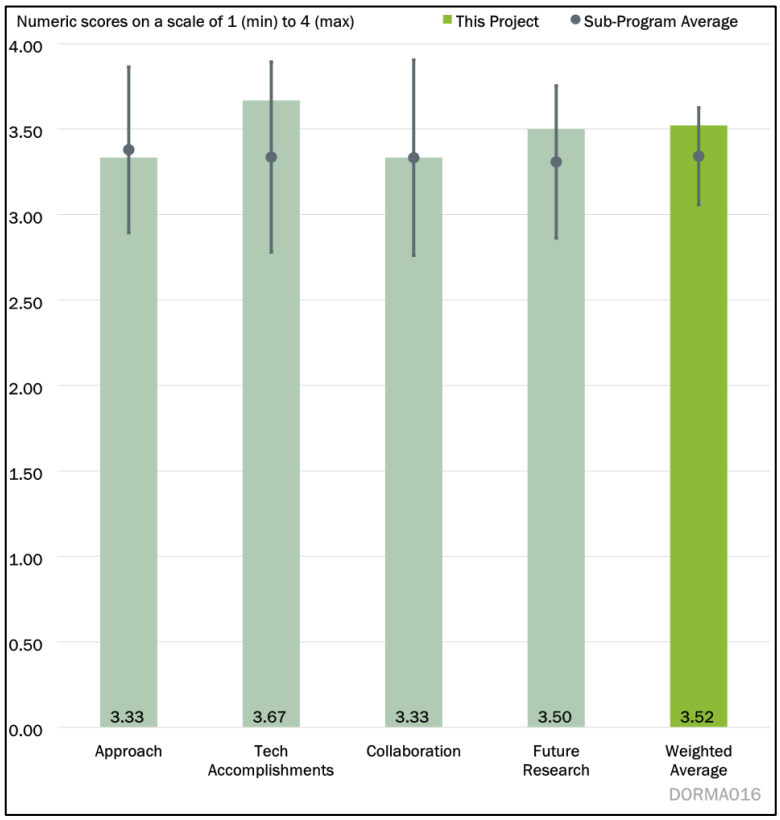

Figure 3-15 - Presentation Number: DORMA016 Presentation Title: Renewable methanol-fueled engines for marine and off-road applications Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer appreciated that the technical barriers were presented and discussed in the project. The three different ignition types being investigated were viewed positively. However, the reviewer raised the following points for consideration: catalyst lifespan/poisoning; water handling; methanol quality; and state of industry assessment. Regarding catalyst lifespan/poisoning, the reviewer inquired if catalyst lifespan and potential catalyst poisoning would be investigated. Concerning water handling, it was unclear to this reviewer how the water produced during the reforming process with zeolite would be stored onboard and managed. Separation of water from the produced H_2 could be an important aspect, and optimization of this separation process would be interesting. Thew reviewer suggested more investigation into the quality of methanol, particularly in relation to new green methanol production pathways (e.g., bio-methanol, e-methanol) as opposed to commodity methanol. This data could be valuable in scenarios where lower-quality green methanol might be a more cost-effective option. Finally, the reviewer noted the project team was encouraged to conduct a state-of-industry assessment to ensure that their data could be utilized or compared with other engine types in the marine engine sector, such as those produced by MAN Energy Solutions, ABC-Engines, Daihatsu, and Wartsila.

Reviewer 2:

The project's three-pronged approach to investigating methanol combustion was commended, along with the successful pivot and leverage of previous prechamber spark ignition work. The modification of the diesel platform to accommodate both methanol and dimethyl ether was also viewed positively.

Reviewer 3:

Overall, the reviewer found that the project effectively addressed technical barriers, was well designed, and had a reasonably planned timeline. The delay in the installation of the intake manifold modifications on the prechamber engine was not seen as a significant challenge to project completion within the planned timeline.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer commended the project's substantial progress made within the first six months of work. Despite missing the Q2 milestone, the project was noted to be on track to meet the Q4 milestone.

Reviewer 2:

The reviewer pointed out that significant advancements had been achieved in both the single-cylinder and multi-cylinder engine modification aspects of the project.

Reviewer 3:

Overall, the reviewer observed solid progress relative to the project plan, with full awareness of the remaining challenges.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer acknowledged that it was still early in the project's development but noted that the team appeared to be working effectively with project partners, particularly Caterpillar, in the area of engine design.

Reviewer 2:

The reviewer also highlighted the presence of clear roles and responsibilities for all project partners, which was seen as a positive aspect of the project's organization.

Reviewer 3:

Overall, the reviewer commended the project team for demonstrating a high level of collaboration, with a particular emphasis on the valuable collaboration with Caterpillar.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer acknowledged that the project had a well-structured plan with many valuable components. The reviewer suggested that some additional areas, alluded to in the first question, could further strengthen the planned work. This included a tank-to-wheel/wake life-cycle assessment comparison of the three different combustion scenarios, as well as the inclusion of a project-specific DEI SMART milestone, rather than relying solely on the national laboratory's DEI plan. The suggestion of engaging project interns and creating an outreach program for underserved high schools was also made.

Reviewer 2:

The reviewer appreciated that the remaining barriers were clearly defined and noted that there was a detailed plan in place for accomplishing seven tasks over a 4-year period, involving three engine platforms and bench flow reactor experiments.

Reviewer 3:

The reviewer felt the project's detailed plan for future tasks was setting it up for successful contributions.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer indicated agreement with the project's relevance to all current and potential stakeholders and how it aligns with the multi-agency blueprint on decarbonizing hard-to-electrify sectors.

Reviewer 2:

The project was considered relevant to the interests of the VTO by the reviewer.

Reviewer 3:

The reviewer stated that project was supportive of overall VTO subprogram objectives, particularly within the scope of DORMA.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found that the project's resources were aligned with its scope.

Reviewer 2:

The project was viewed by the reviewer as being aligned with the goal of de-fossilization, which is important for both DOE and the U.S. Department of Transportation. Investing in renewable and sustainable liquid fuels was seen as a key objective.

Reviewer 3:

The budget for FY 2023 and beyond was considered sufficient by the reviewer to support the achievement of the project milestones.

Presentation Number: DORMA017
Presentation Title: SAF End Use Research
Principal Investigator: Sibendu Som (Argonne National Laboratory)

Presenter

Sibendu Som, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

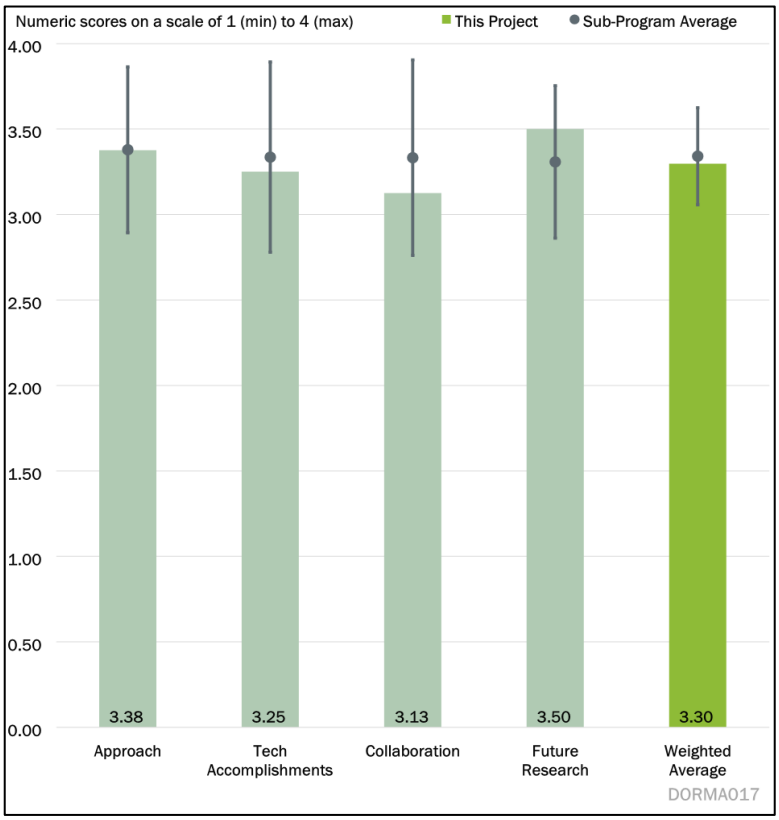

Figure 3-16 - Presentation Number: DORMA017 Presentation Title: SAF End Use Research Principal Investigator: Sibendu Som (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer praised the project for addressing the right technical barriers and noted that the presentation provided a comprehensive list of technical barriers in the roadmap. However, the reviewer suggested the inclusion of a master timeline that highlights the interdependencies of various project components.

Reviewer 2:

The timeline for the project was considered reasonable, and the study was seen as addressing important technical challenges associated with fuel property variations, fuel characterizations, chemical kinetics modeling, and data generation. The reviewer emphasized the importance of model validations with real systems, engagement with OEMs, and post-test refinement of models and mechanisms using relevant engine combustion and field data.

Reviewer 3:

The reviewer indicated that their rating considered the combined impact of multiple DORMA projects, covering a wide range of topics related to sustainable aviation fuels and their usage. The reviewer also highlighted the clear linkage between these projects and the SAF Grand Challenge goals, as well as their relevance to increasing SAF usage, particularly in addressing issues related to contrails.

Reviewer 4:

The reviewer commented that overall, the presentation was viewed as a good overview of DOE program on SAFs.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the presentation teed up several sub-projects. The principal investigator presentations were effective in demonstrating the technical progress of each component of the plan. However, the presenter could have provided a quick indication of the progress of each project, highlighting areas with significant learnings and those with open questions and challenges to address.

Reviewer 2:

The reviewer observed significant progress in critical property characterization, soot kinetics, soot models, and ice nucleation models, as well as initial fuel spray characterization studies. The modeling activity appeared to have progressed at an impressive pace. However, the reviewer found that the progress of the experimental spray and turbine combustion studies at relevant engine conditions depended on a larger vision yet to be set by DOE and Argonne National Laboratory and/or communicated to the reviewers. There was a lack of clarity on the clear path forward and the timeline for either an infrastructure build within Argonne to support this plan or identifying a non-Argonne capability.

Reviewer 3:

In their rating, the reviewer considered the combined impact of the following DORMA projects: 03, 17, 18, 19, 20, 37, and 38. This set of projects, in the reviewer's assessment, had made excellent progress in terms of testing conducted, models developed, simulations performed, and processing of experimental data across a wide range of processes crucial to understanding and utilizing sustainable aviation in aircraft engines.

Reviewer 4:

The reviewer clarified that their evaluation was more of an assessment of the overall program rather than focusing solely on the specific presentation. In their view, the overall program was making substantial progress, particularly in the computational modeling of SAF combustion processes.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer observed that the presenter effectively portrayed the various projects and their integration into the larger framework. The reviewer also commended the presenter for outlining the involvement of various laboratories and illustrating coordination among industry, government, and academia. However, the reviewer noted the absence of identification of academic partners and collaborators.

Reviewer 2:

The reviewer highlighted the necessity for a clearer definition of OEM participation. They questioned the level of coordination in combustion modeling activities, specifically in terms of knowledge and data sharing between Argonne and the National Renewable Energy Laboratory. Additionally, the reviewer expressed a desire to see more utilization of the Air Force Research Laboratory's legacy work and closer collaboration.

Reviewer 3:

In the reviewer's rating, they considered the combined impact of the following DORMA projects: 03, 17, 18, 19, 20, 37, and 38. The reviewer acknowledged a wide range of collaborations within DOE and with external

partners. The reviewer suggested improving the coordination of CFD efforts within DORMA 037, 038, and 003. They raised concerns about potential overlap in simulated cases and the absence of simulations for the same geometry/condition with consistent fuel properties and chemistry models between these projects, particularly DORMA 037 and 038.

Reviewer 4:

The reviewer commended the collaboration and coordination within the overall program, noting effective cooperation among its different components. However, the reviewer expressed disappointment regarding the limited participation of academia, acknowledging that this perspective may be influenced by their academic background.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer found that the proposed future work aligns with the current needs. The presenter appropriately recognized the imperative of addressing end-use issues related to drop-in fuels, a major obstacle to the widespread use of SAFs. The reviewer commended the presenter for assembling an excellent roadmap addressing this critical concern. Acknowledging the inherent risks associated with combustion testing, the reviewer acknowledged that it might be challenging for this project to achieve all of its targets but emphasized that the roadmap is correctly oriented toward essential research.

Reviewer 2:

The reviewer identified certain hurdles that must be overcome, including effectively navigating the participation of OEMs, generating pertinent data at conditions meaningful for model validations, and successfully implementing such models within the OEM community to demonstrate their impact.

Reviewer 3:

The reviewer highlighted that all projects commenced in FY 2022 and are assumed to extend through FY 2027, contingent on funding. The presentations provide summaries of the work accomplished up to this point and typically outline the plans for FY 2024 or, at times, describe it as "future work" without specifying a timeline. While the purpose of the future work is evident, the reviewer noted that the actual work planned beyond FY 2024 is generally not clearly stated.

Reviewer 4:

The reviewer noted that the future research proposed by various team members addresses issues related to the use of SAFs for aircraft propulsion. The proposed work in computational simulation of SAF sprays and combustion leverages the unique capabilities of DOE, aligning with the specific expertise and resources available within DOE.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer assessed this project as highly relevant. They emphasized the critical importance of decarbonization in today's context and highlighted SAFs as the aviation sector's best opportunity for achieving this goal. Additionally, the reviewer noted that SAFs hold significance as a strategy for various land and marine-based systems. The presentation effectively outlined a roadmap to address the most pressing issues and challenges associated with SAF implementation, earning the highest possible relevance rating in the reviewer's opinion.

Reviewer 2:

The reviewer stressed the project's vital role in accelerating and advancing the adoption of drop-in SAFs within the aviation sector. They acknowledged the project's value in addressing field challenges and establishing a framework for potential non-drop-in fuels of the future.

Reviewer 3:

The reviewer recognized the relevance of the work being conducted in DORMA projects 03, 17, 18, 19, 20, 37, and 38, as it contributes directly to the increased understanding and utilization of sustainable aviation fuels, thereby supporting the overarching goal of decarbonizing aviation.

Reviewer 4:

The reviewer pointed out that the project aligns with objectives within the DORMA subprogram, further underscoring its relevance and alignment with broader strategic goals.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The presentation lacked clarity regarding the overall resources allocated to this roadmap. The reviewer noted an issue with the budgets presented by the principal investigators, as it was unclear whether these figures represented yearly or total budgets. Furthermore, there was a lack of transparency regarding how much of the budget was allocated to other laboratories, partners, or contractors. The reviewer expressed the view that the budgets, especially if they include portions directed to numerous collaborators and partners, seemed generally low given the extensive scope of work outlined in the presentation.

Reviewer 2:

Regarding computational resources, the reviewer found them to be adequate. However, the reviewer identified a deficiency in experimental resources, particularly for high-pressure and high-temperature gas turbine facility upgrades at Argonne and recommended addressing this issue.

Reviewer 3:

With the exception of DORMA038, the reviewer believed that the resources allocated to DORMA projects 03, 18, 19, 20, 37, and 38 appeared sufficient for both current work and work planned for FY 2024. Nevertheless, the reviewer pointed out that assessing the adequacy of resources for achieving the full set of project goals beyond FY 2024, for which limited details were provided in most cases, remained a challenge.

Reviewer 4:

The reviewer concluded that the resources devoted to the project as a whole were sufficient.

Presentation Number: DORMA018
Presentation Title: SAF Combustion & Soot Processes
Principal Investigator: Julien Manin (Sandia National Laboratories)

Presenter

Julien Manin, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

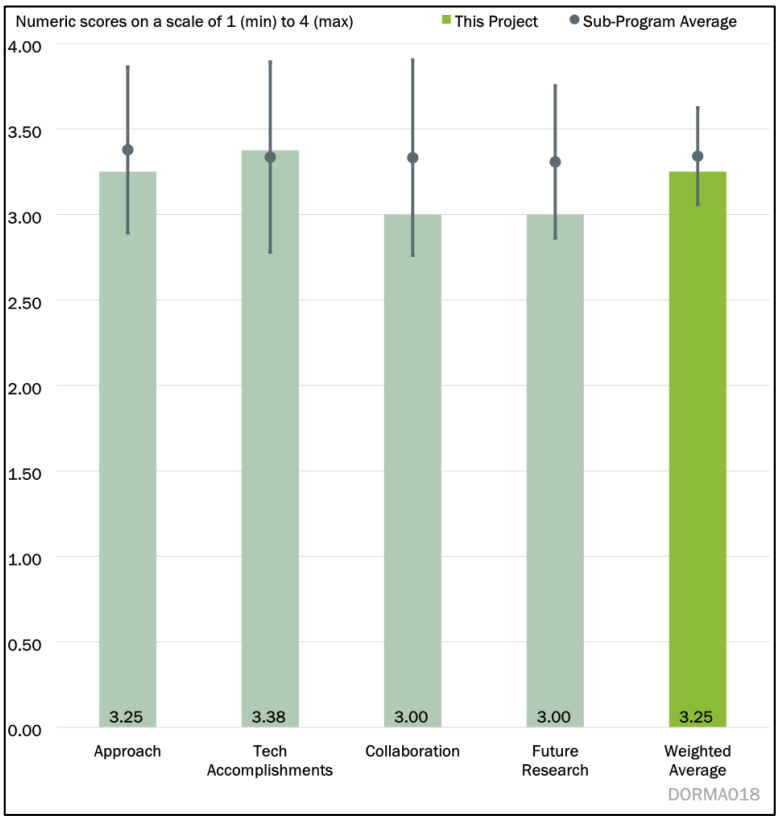

Figure 3-17 - Presentation Number: DORMA018 Presentation Title: SAF Combustion & Soot Processes Principal Investigator: Julien Manin (Sandia National Laboratories)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The approach appears to be a well-thought-out strategy, focusing on applying the established optical diagnostic laboratories and capabilities of Sandia National Laboratories to study SAF combustion in gas turbines. However, the reviewer raised concerns about the relevance of non-turbine test chambers and facilities, suggesting that a more specific alignment with gas turbine combustor designs would be valuable. While there is likely immediate progress to be made, the reviewer expressed the limitation of relying on a single-hole spray originating from reciprocating engines and highlighted the importance of considering gas turbine applications. The combination of spray experiments, soot experiments, and kinetics and CFD was commended as a comprehensive approach to leverage all available capabilities for achieving the project's goals.

Reviewer 2:

The reviewer found the technical approach sound and consistent with other spray research in the literature, although not necessarily focused on SAFs. The reviewer emphasized the appropriateness of the combined study of non-reacting and reacting sprays. However, they sought clarification on how the team targeted droplet sizes and whether these sizes align with specific nozzle types or manufacturers. The reviewer cautioned about potential variability in droplet sizes across the industry and emphasized the importance of diligence in selecting an appropriate range of droplet sizes. Additionally, they expressed curiosity about the altitude condition, particularly regarding the feasibility of testing at a higher altitude, such as 35,000 feet, considering the significance of auxiliary power unit (APU) start at altitude conditions.

Reviewer 3:

The reviewer recognized the team's excellent progress and found the timeline reasonable. They acknowledged that while the choice of a SHA may not be directly relevant to real engine interpretation, the team is addressing a critical gap in fundamental fuel chemistry, soot study, and model development for SAF implementation.

Reviewer 4:

The approach was considered interesting and likely to yield new insights into sprays and soot formation for SAFs. However, the reviewer pointed out that the experimental systems for spray measurements appeared more suitable for internal combustion engines, such as diesel engines, rather than aviation gas turbine engines. The team itself acknowledged this challenge and barrier, specifically highlighting the need to enhance mixing to better match conditions found in modern aero-engines, as indicated on Slide 18.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer commended the completion of databases for SAF mixing, ignition delay, and lift-off length, considering it an excellent contribution to advancing SAF knowledge rapidly. Similarly, the successful completion of a reduced kinetic mechanism for C4 fuel was acknowledged as excellent progress. The reviewer noted that many facets of the project appeared to be making excellent progress, especially considering that the project is in its second year of a 5-year timeline. They anticipated more robust accomplishments as the groundwork laid in the early stages of the project matured. The reviewer also found the altitude chamber for contrail research to be an intriguing and valuable addition, as it has the potential to build new fundamental datasets related to soot and SAF. They requested that the researchers continue to demonstrate how all project tasks could be more fully integrated toward the distinct goals of SAF combustion, soot processes, and contrails.

Reviewer 2:

The reviewer found the technical accomplishments to be strong, particularly in demonstrating the capability to acquire non-reacting and reacting spray data, which they considered a challenging aspect of this work.

Reviewer 3:

The reviewer noted the team's good initial progress in acquiring and interpreting data related to fuel evaporation regimes and analysis at trans-critical conditions, an area less investigated in the aero-engine community. They also recognized the team's efforts in characterizing flame liftoff and ignition delay times, encouraging further investigation into lean-and-rich blowoff and flashback characteristics. The reviewer suggested conducting a parametric study over a broader range of conditions, beyond just take-off and cruise conditions, to benefit the community.

Reviewer 4:

The reviewer stated that the technical accomplishments achieved thus far were impressive and were expected to provide valuable insights into spray dynamics and ignition, despite differences with aviation gas turbine conditions. The development of a new altitude chamber for contrail formation study was highlighted as a significant achievement.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commended the excellent collaboration observed within the project, emphasizing the engagement across government laboratories, universities, and relevant industrial partners. They encouraged continued engagement and integration of the perspectives and input of industrial OEMs, recognizing the importance of their involvement.

Reviewer 2:

The reviewer noted the identification of a strong team and mentioned that a few bullet points were dedicated to the partners. However, they expressed that it was not entirely clear what the partnerships were contributing to the work. They urged the team to provide clearer insight into the specific contributions and roles of their partners.

Reviewer 3:

The reviewer further encouraged the team to collaborate with relevant engine OEMs for combustion research and develop a plan for model and technology transfer to facilitate industry validations.

Reviewer 4:

The researchers were acknowledged for their excellent work in identifying issues of interest to the aerospace community, particularly through interactions with OEMs and National Aeronautics and Space Administration (NASA) Glenn Research Center.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer found the proposed research promising for advancing the three areas of spray mixing, soot, and contrails. They encouraged continued engagement with gas turbine OEMs and suggested that their insights should guide the project's direction within reasonable bounds. While acknowledging the validity of using the SHA for fundamental physics understanding, the reviewer recommended that future efforts consider building, developing, or utilizing specific combustors and injectors for turbines. The reviewer proposed the idea of establishing a project similar to Engine Combustion Network's "Spray-A/B/C/D" but focused on a canonical "Spray-SAF."

Reviewer 2:

The reviewer supported the proposed future work as the right path but expressed concerns about the level of risk involved. The reviewer emphasized the need for the project to fully utilize its altitude capability and conduct diagnostic tests in the altitude chamber. Additionally, the reviewer suggested increasing the altitude, if possible, to better capture the low-pressure, low-temperature atomization characteristics of SAFs, with specific implications for APU altitude start conditions.

Reviewer 3:

The reviewer inquired about the team's coordination with other computational aero-engine SAF research activities at Argonne and the National Renewable Energy Laboratory. The reviewer pointed out that combustion in industrially relevant configurations spans a wide spectrum of length and time scales and suggested exploring studies on the impact of turbulence, fuel temperature, and additives on SAF fuel combustion.

Reviewer 4:

In conclusion, the reviewer considered the proposed future research efforts on spray atomization and mixing to be logical. The reviewer noted that the value of the work for aero-engines might be somewhat limited by the current experimental systems' constraints. However, the reviewer found the combustion and soot formation research to be valuable for exploring SAF properties, and the contrail formation research to provide interesting fundamental data.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer acknowledged the clear alignment of the research with decarbonization objectives in the context of SAF and aerospace gas turbines. The research was considered highly relevant, particularly as alternative propulsion sources may not be feasible in the near term.

Reviewer 2:

This research addresses gaps left by the National Jet Fuel Combustion Program (NJFCP) and is highly relevant. The significance of the work on soot modeling and contrail formation modeling that can build upon this foundation was also noted. Overall, this project is seen as highly relevant and impactful.

Reviewer 3:

The reviewer pointed out that topics related to fuel mixing, fuel chemistry, soot, and contrail modeling for alternate fuels are of industrial relevance and require substantial research efforts. The critical nature of this research for the successful down selection of fuels and combustor systems for future aircraft platforms was emphasized.

The project was confirmed to be relevant to DORMA, reinforcing its alignment with broader program objectives.

Reviewer 4:

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources at hand were deemed sufficient for leveraging the existing laboratories and staff that traditionally focused on reciprocating internal combustion engines. However, the reviewer emphasized that if a shift is made toward gas turbine-specific laboratories, the current resources would be vastly insufficient. They expressed support for such a shift but stressed the need for commensurate increases in funding to adequately support the transition.

Reviewer 2:

The reviewer found that the project appears to be sufficiently funded, although they noted that the depth of partner involvement and the allocation of the budget to partners were not entirely clear. Nevertheless, the budget was considered sufficient for the scope of work presented, which included the development of altitude capability.

Reviewer 3:

The reviewer saw both experimental and computational resources as adequate for the project's activities.

Reviewer 4:

The resources available for the project were viewed as sufficient by the reviewer for making progress with the current experimental systems.

Presentation Number: DORMA019
Presentation Title: Multi-phase flow studies of SAFs for industry-relevant conditions and geometries
Principal Investigator: Brandon Sforzo (Argonne National Laboratory)

Presenter

Brandon Sforzo, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 33% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

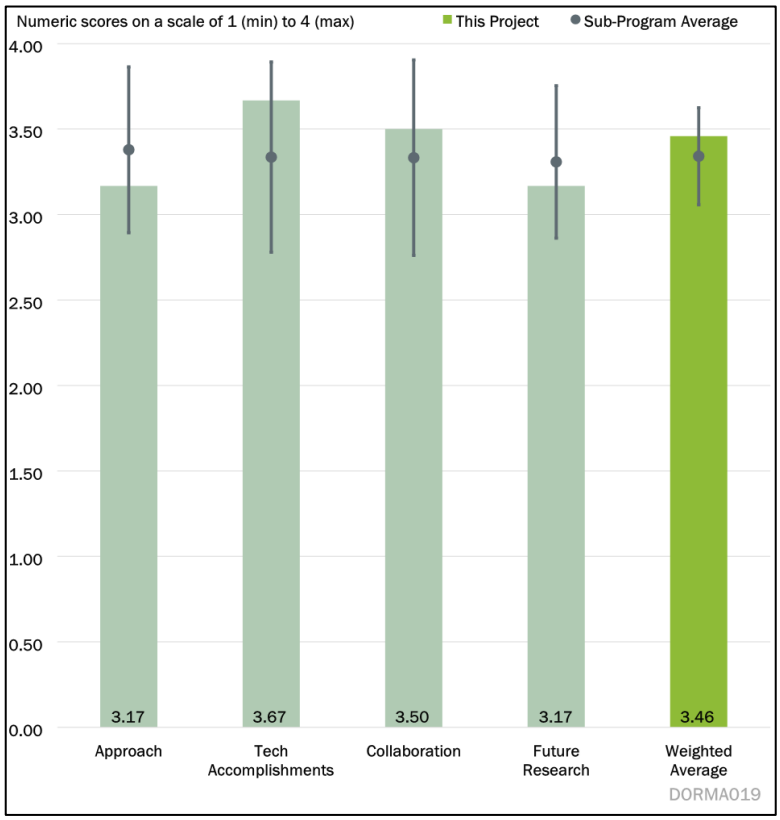

Figure 3-18 - Presentation Number: DORMA019 Presentation Title: Multi-phase flow studies of SAFs for industry-relevant conditions and geometries Principal Investigator: Brandon Sforzo (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer found that the project presented a clear roadmap for understanding fuel spray through the use of X-ray imaging. It was noted as a novel and one-of-its-kind approach. The reviewer expressed curiosity about the omission of sub-atmospheric conditions, given that a previous presentation had identified altitude re-light as a critical aspect of SAF research, with implications for the spray.

Reviewer 2:

In the reviewer's assessment, the absence of high-pressure continuous flow capability at Argonne raised concerns about schedule risks. It was emphasized that measurements should be conducted and analyzed under the relevant pressure and temperature conditions and, ultimately, under the relevant reacting conditions. The reviewer also recommended that Argonne explore additional diagnostic methods, including X-ray-based techniques, to acquire quantitative data for comparisons.

Reviewer 3:

From the reviewer's perspective, future testing under higher temperature and pressure conditions holds the potential to uncover differences in fuel injection and atomization, or transcritical behavior, between conventional Jet-A and various SAFs. The detailed X-ray imaging data was seen as having strong potential to enhance fuel injection and atomization models for any hydrocarbon fuels, whether Jet-A, SAF, or blends. The reviewer noted that the real fluid modeling and CFD tasks aligned with the overall objectives of this work.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer remarked that this project ranks at the top of accomplishments. The implementation of X-ray imaging in industry-relevant fuel injectors with different fuels is considered a major achievement. The reviewer expressed a wish that this presentation had more time to delve into the takeaways from these images but acknowledges the significant value of this dataset to the SAF certification and acceptance community and its stakeholders.

Reviewer 2:

The reviewer commented that the initial spray assessment of jet fuel vs. SAF fuel results offers insights into expected performance. Trends were also demonstrated to be consistent with previous NJFCP studies and in line with industrial experience.

Reviewer 3:

The reviewer stated that experiments with X-ray imaging have been completed for an NJFCP referee injector and a Woodward non-proprietary injector, including two approaches for liquid atomization in aircraft engine combustors. Progress was also demonstrated in the real fluid modeling and atomization CFD.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the presentation showed a strong team of collaborators and even highlighted instances where partners had contributed hardware or offered cost-sharing. For instance, the NASA funding of the Woodward injector, designed specifically for X-ray imaging, was cited as a demonstration of a strong team. The reviewer mentioned that it would have been desirable to see the contributions of the many other team members mentioned at the beginning but recognized that time constraints may have prevented that.

Reviewer 2:

The reviewer acknowledged that Brandon and the Argonne team have had excellent collaborations with NASA, Air Force Research Laboratory, Office of Naval Research, OEMs, and select universities. However, the reviewer also encouraged Argonne to consider opening this study and expanding collaboration with other laboratories, such as Sandia and the National Renewable Energy Laboratory.

Reviewer 3:

The reviewer pointed out that this project involves participation by multiple engine OEMs and other government agencies, which appears to be instrumental in guiding this work toward conditions and injectors of practical interest.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer affirmed that the proposed future work is appropriate. The phased approach introduced at the beginning makes sense, and transitioning from atmospheric conditions to more challenging conditions is a logical progression. However, the reviewer noted potential risks and suggested that it would be beneficial to illustrate how this transition will be achieved with the Advanced Photon Source (APS). Additionally, some justification for the focus on high-power conditions for the spray as opposed to altitude conditions would be warranted. The reviewer commented that the proposed analysis and modeling are well-suited to the project's

objectives. The reviewer also pondered, albeit recognizing it might be beyond the scope of this presentation, whether it would be possible to simulate the effects of radiation heating the spray or pre-heat the fuel nozzle.

Reviewer 2:

The reviewer observed that addressing Argonne's facility needs is essential for the lasting impact of this effort.

Reviewer 3:

The reviewer mentioned that this work began in FY 2022, and the presentation outlines future work up to FY 2024, although a specific timeline is lacking. The reviewer recognized the significance of addressing high-temperature and high-pressure conditions and stated that this would likely yield valuable test data. The plans for real fluid modeling and CFD of liquid atomization were deemed reasonable.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that this project holds high relevance to the certification and acceptance of SAFs and is of great importance to stakeholders such as OEMs. The utilization of the APS to image the fuel spray in relevant hardware under realistic conditions with actual fuels is truly pioneering and represents a unique endeavor in this field. The reviewer expressed the belief that this work will be exceptionally valuable to modeling and simulation teams and will serve to refine their understanding of the effects of fuel properties on sprays. The reviewer commended the project for producing such challenging yet rewarding data.

Reviewer 2:

The reviewer stressed the imperative nature of this project for future OEM technology development with SAF fuels, underlining the absence of such capability elsewhere.

Reviewer 3:

The reviewer noted that simulations exploring the impact of fuels on combustor operability or emissions will require spray atomization models, and the results of this work are expected to enhance these models. The reviewer anticipated that experiments conducted at higher temperatures and pressures with X-ray imaging, in close proximity to the fuel injector exit, would yield new insights into the influence of fuel variations on liquid atomization. This, in the reviewer's opinion, is a crucial element in advancing the understanding of the use of SAFs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer acknowledged that the resources allocated appear appropriate. They appreciated how the presentation meticulously delineated the budget allocation between experiments and modeling tasks. Furthermore, the presentation effectively outlined where cost-sharing contributions from partners were being utilized. The reviewer expressed anticipation that the high-temperature, high-pressure conditions might strain the budget but remained confident in the project's achievability.

Reviewer 2:

The reviewer noted that the absence of high-pressure, high-temperature, and high-flow capabilities represents a significant challenge, both in terms of schedule and cost for this endeavor.

Reviewer 3:

The reviewer concluded that the current resources are sufficient but foresaw a likely need for an increase or the incorporation of funding from other partners to attain test conditions approaching 50 bar and 1300°F combustor inlet conditions.

Presentation Number: DORMA020
Presentation Title: SAF Contrail Modeling
Principal Investigator: Matt McNenly (Lawrence Livermore National Laboratory)

Presenter

Matt McNenly, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

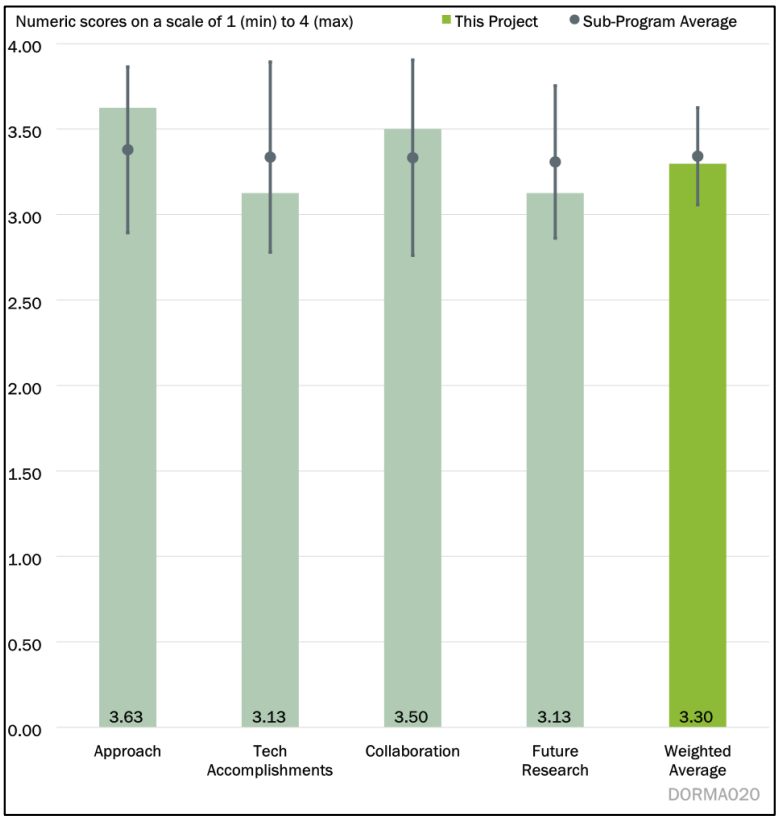

Figure 3-19 - Presentation Number: DORMA020 Presentation Title: SAF Contrail Modeling Principal Investigator: Matt McNenly (Lawrence Livermore National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer pointed out that this is a new project and commended the explanation of its motivation. The significant impact of contrail formation on the radiative forcing function and potential climate change consequences was well articulated. The project's goal to simulate the potential impact of SAF on contrail formation was highlighted.

Reviewer 2:

The reviewer found that the project is well-aligned with addressing technical barriers and providing a structured approach to overcoming them. The 2-year project was deemed to be well-planned with appropriate milestones, and the timelines were considered suitable.

Reviewer 3:

The approach to extend the LLNL chemical kinetic modeling of combustion and soot processes to ice nucleation in contrails was seen as a very promising solution to a complex problem.

Reviewer 4:

The project, according to the reviewer, covers various processes involved in contrail formation, and the team effort is well-developed. However, several comments and questions were raised by the reviewer as detailed below.

The importance of the chemical kinetic mechanism in determining the formation of precursor species and solid impurities (soot) for contrail formation and its impact on global climate change were acknowledged. The reviewer noted that while there is an abundance of literature on this topic, the project focuses on developing chemical kinetic models for the formation of species and reaction routes leading to solid impurities in SAFs.

The reviewer raised concerns about the consistency of rate constants for overlapping reactions from different component kinetic mechanisms in SAF surrogates. The reviewer recommended addressing this issue or clarifying the approach taken.

Differences between soot formation from SAFs and gasoline or diesel fuels and the process for surrogate development were queried. The reviewer suggested exploring and discussing these differences.

The inclusion of characterization of particle morphology from SAF combustion and comparisons with studies on soot particles from gasoline and diesel fuel combustion was recommended.

The reviewer sought clarification on the term "ice nucleation" and suggested that the process should involve supersaturated water vapor condensing on particle surfaces, followed by ice formation as nuclei freeze.

The simulation of heterogeneous nucleation was deemed important, but the reviewer expressed concerns about the lack of detail in its description. The reviewer recommended addressing key properties related to the energetics of the nucleation process and discussing challenges related to the irregular shapes of soot aggregates serving as condensation nuclei.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer acknowledged the thorough literature review and the focus on ice formation processes for contrail simulation in the project. The use of a self-consistency approach developed by Westbrooke and Ptiz was noted. However, the reviewer raised questions regarding the potential impact of differences in temperature and pressure conditions between the ambient cruise conditions in this research and ground-based engine combustion systems, for which the self-consistency approach was initially developed. The reviewer also inquired about whether the researchers would be using kinetics for SAF, as the presentation mainly showed standard hydrocarbons. The reason for not using SAF kinetics, if applicable, was requested.

Reviewer 2:

The reviewer expressed concerns about the progress made in the project, particularly with only two tasks completed halfway through the timeline, which were verification of kinetics and literature reviews. While the remaining milestones were marked as "On track," the reviewer suggested a more thorough tracking of progress and resource allocation.

Reviewer 3:

The reviewer acknowledged that the project is still in its early stages, with the mechanism development for computing ice nucleation in progress.

Reviewer 4:

The reviewer recognized the significant work accomplished by the research team in the first year of the project. The reviewer highlighted the importance of the literature review and requested clarification on whether the analysis and experiments would be carried out under sub-atmospheric conditions. Regarding the computational aspects of the project, the reviewer suggested that future presentations should provide more details on the nature of the computations and the computational platform used. The reviewer also emphasized the need for a surrogate-based approach for modeling SAF and soot, and requested information on the specific

SAF surrogate used, its development, and validation. The reviewer noted the significant improvements in soot volume fraction estimates from the new model and recommended a clear strategy for closing the gap. Lastly, the reviewer sought clarification on the term "homogeneous" in the context of nucleation without the presence of solid particles (soot).

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the project demonstrates collaboration with relevant individuals and organizations.

Reviewer 2:

The reviewer deemed the level of collaboration and partner selection to be reasonable.

Reviewer 3:

The collaboration with different teams at LLNL was perceived as very solid. However, the reviewer inquired about the plan to collaborate with Julien Mann at Sandia, particularly regarding the development of an altitude chamber for contrail formation research (DORMA 018). The reviewer pointed out that the presentation mentions collaborations with national laboratories, including Sandia, but does not reference the LLNL contrail modeling effort in the presentation from the Mann group. The reviewer suggested exploring and potentially strengthening this collaboration.

Reviewer 4:

The reviewer found that the collaborations include competencies covering most of the major processes involved in forming contrails, with the exception of the nucleation problem. The reviewer mentioned that it was not entirely clear how the collaborations would be coordinated. The presentation briefly mentioned various aspects such as experiments, theoretical calculations, model reduction development, and surrogate fuel recommendations, but lacked specific details. The reviewer recommended that future presentations clarify how these collaborations are integrated to meet the project's goals.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that the project has laid out a logical progression of tasks to move from the current state to the completion of the project. However, the reviewer raised concerns, particularly in response to the discussions of other reviewers, that the scope of the problem might be more substantial than what is being addressed in this research. There is a suggestion that the current project might serve as a preceding step to a larger project.

Reviewer 2:

The reviewer recognized the value of further model validation and suggested that the current project may serve as a preliminary step to a more extensive initiative.

Reviewer 3:

The approach to modeling ice nucleation and contrail formation was considered highly promising, even though it was acknowledged that this is an incredibly complex problem.

Reviewer 4:

The reviewer observed that the future work was outlined but noted that it appeared somewhat non-specific. For example, the development of nucleation and cloud physics models for homogeneous and heterogeneous processes was mentioned, but it was not clear which theoretical framework would be used (e.g., classical

nucleation theory, density functional theory, molecular dynamics simulations). The reviewer also expressed interest in understanding the nature of the experiments at Sandia and their expected outcomes, as well as the SAF and soot kinetic mechanism effort. The reviewer raised concerns about obtaining property data for nucleation models, especially given the potential challenges associated with classical theory and the lack of data for properties such as surface energy on non-circular solids and the rate of condensation. The reviewer pointed out that it may be difficult to obtain these properties until the team starts developing the models. The reviewer requested more details on the SAF surrogate to be used in the simulations. The reviewer suggested the potential value of testing the capabilities developed in the project in the field, such as by fueling an aircraft and monitoring performance during a flight test. Collaboration with partners from the aviation industry or government entities like commercial airlines or the Air Force was recommended to provide real-world flight tests to assess soot emissions and contrail formation and to evaluate how well the methodologies and simulation capabilities of the project perform in practice. The reviewer highlighted the challenge of understanding the energetics of condensation nuclei formed on soot aggregates and called for a clearer explanation of how ice nucleation models would be validated, as well as clarification on the experiments to be conducted at Sandia to provide validation data.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized the importance of understanding the potential impact of SAFs on contrails.

Reviewer 2:

The project was seen as supporting the project objective, which involves building a better foundation to accurately capture the effect of SAF composition.

Reviewer 3:

The project's relevance to the DORMA subprogram was acknowledged.

Reviewer 4:

From a broader perspective, the project was considered highly relevant, especially with the renewed interest in combustion technologies using SAFs. The reviewer underscored the critical concern of contrail formation in the context of global climate change, and how this project addresses the processes involved in their formation.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that it seems that they have sufficient funds to complete the tasks associated with the research. While the resources were deemed adequate, the scope of the problem was perceived as potentially larger than what the current research was addressing, leading to the suggestion that a more extensive project might be worth considering.

Reviewer 2:

The reviewer commented that the resources look sufficient.

Reviewer 3:

The reviewer stated that the resources seem to be significant.

Reviewer 4:

The reviewer commented that while the resources were deemed adequate, the scope of the problem is potentially larger than what the current research was addressing, suggesting that a more extensive project

might be worth considering. In terms of resource sufficiency, the reviewer agreed that the project had the necessary resources, but more detailed information is needed, such as overhead rates, salaries for scientists and technicians, equipment costs, etc., to provide a more comprehensive assessment. The reviewer suggested that an ultimate judgment of cost-effectiveness would require a cost/benefit analysis based on DOE investment relative to the commercialization potential and the distribution of costs among the collaborators.

Presentation Number: DORMA021
Presentation Title: Simultaneous Greenhouse Gas and Criteria Pollutants Emissions Reduction for Off-Road Powertrains
Principal Investigator: James McCarthy (Eaton)

Presenter

James McCarthy, Eaton

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

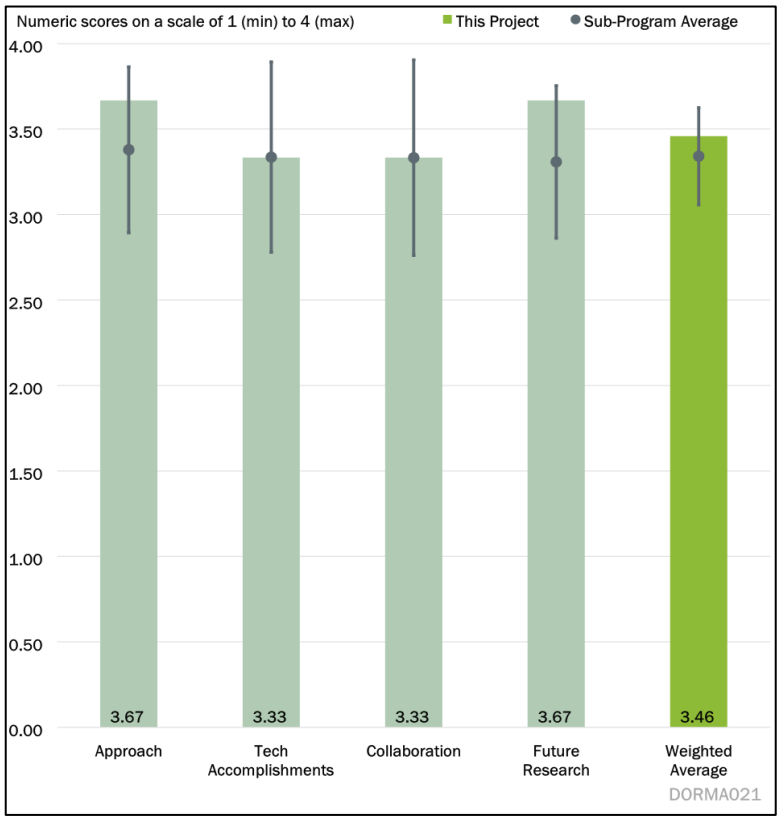

Figure 3-20 - Presentation Number: DORMA021 Presentation Title: Simultaneous Greenhouse Gas and Criteria Pollutants Emissions Reduction for Off-Road Powertrains Principal Investigator: James McCarthy (Eaton)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the project is well designed to address the technical barrier at hand. They found the timeline to be well planned yet advised the team to remain vigilant about the work at ORNL, acknowledging that work in DOE laboratories may sometimes proceed more slowly due to government structural factors.

Reviewer 2:

Another reviewer expressed admiration for the project's outstanding approach, which goes beyond the original scope by including additional tasks to deepen the understanding of the underlying science. They particularly praised the modular, single-pass aftertreatment system concept, which allows for comprehensive analysis at each stage of the system. The plan to compare the modular system with a commercial aftertreatment system was seen as a clever move and evidence of effective collaboration within the team. The utilization of external and international collaborations was also seen as a positive aspect.

Reviewer 3:

The reviewer commented that the key barriers were adequately addressed and appreciated the project's modular approach and transient testing across multiple cycles, enabling the assessment of a wide range of system configurations. The project's timeline was viewed as reasonably planned. The reviewer suggested considering additional barriers not currently addressed, specifically cost and space constraints.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer expressed concern about the project's progress, noting that it has experienced delays. However, with the granted six-month no-cost extension, the reviewer expressed trust that the team will be able to complete BP 1 by November.

Reviewer 2:

In terms of technical progress, the reviewer commended the project, describing the progress made to date as excellent.

Reviewer 3:

The reviewer found the technical progress to be good and on track. They highlighted the positive development of advanced engine components such as the EGR pump, cylinder deactivation (CDA), and others, along with the aging of aftertreatment parts.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer said that the team has active collaboration among team partners. The role of Southwest Research Institute (SwRI) in this project seems not clear, and there is no report about data from SwRI in period 1.

Reviewer 2:

The reviewer mentioned that the project has clear team member roles, with good coordination between organizations.

Reviewer 3:

The reviewer understood that the progress made so far required collaboration across teams and is therefore satisfactory.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed confidence in the clearly defined future work for the project, anticipating that it will likely achieve its target. They acknowledged that the testing work proposed for ORNL might take longer than planned but had trust in ORNL's ability to accomplish it with strong support from other team members.

Reviewer 2:

Another reviewer found the future work plan for BP 2 and BP 3 to be clearly defined and purposeful, and they were impressed with the project.

Reviewer 3:

The reviewer appreciated the inclusion of testing five different aftertreatment configurations over multiple transient test cycles and under aged conditions, describing it as excellent. They suggested adding chemical aging for at least one system, as it could reveal differences in performance loss and desulfation needs among the systems. Furthermore, the reviewer recommended considering modeling or sensitivity studies to show the impact of changing component designs once the results for the five systems are available. Space constraints and cost considerations were also suggested as topics to be addressed.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that the project is closely relevant to DORMA.

Reviewer 2:

The reviewer noted that building clean, high-efficiency off-road engines is directly in line with the VTO objectives.

Reviewer 3:

The reviewer commended the project for addressing the critical need to reduce NO_x and CO_2 from non-road engines.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the team has sufficient resources to complete this project. They suggested that ORNL might need to make more effort and provide additional resources to retain its engine research team. Overall, the team was considered to have sufficient resources.

Reviewer 2:

The reviewer remarked that the resources appeared sufficient, especially since industrial partners were willing to provide more cost share.

Reviewer 3:

The reviewer stated that the resources appeared sufficient but recommended revising them in light of the earlier recommendations to add modeling, cost considerations, space constraints, and additional tests to assess the sensitivity of results to changed component designs. The reviewer also suggested allocating resources for chemical aging, as previously mentioned.

Presentation Number: DORMA022
Presentation Title: Development of a Flex-Fuel Mixing Controlled Combustion System for Gasoline/Ethanol Blends Enabled by Prechamber Ignition
Principal Investigator: Adam Dempsey (Marquette University)

Presenter

Adam Dempsey, Marquette University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

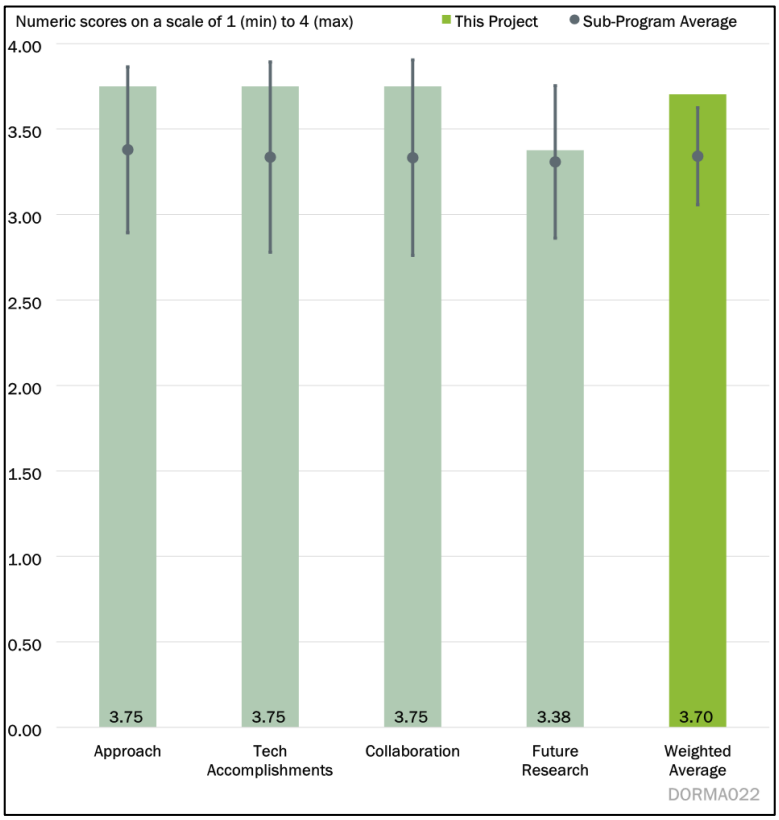

Figure 3-21 - Presentation Number: DORMA022 Presentation Title: Development of a Flex-Fuel Mixing Controlled Combustion System for Gasoline/Ethanol Blends Enabled by Prechamber Ignition Principal Investigator: Adam Dempsey (Marquette University)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer commented that the project is well-planned and thorough, incorporating a combination of simulation and experiments (SCE). They noted that the first demonstration on SCE is sensible. The reviewer affirmed that the questions posed by previous reviewers from the prior year remain relevant, and it appeared that the project would respond to them, including a comparison to more conventional spark ignition engines. They requested that the project should follow through with a reaction to reviewer comments. Additionally, they suggested including consideration/comments of renewable diesel or biodiesel for its impact on CO_2. The reviewer questioned whether the focus on ethanol is in line with regional availability and regional interests, pointing out that CO_2 reduction with renewable diesel might yield more significant results. The reviewer further requested a discussion on the need or lack thereof for NO_x aftertreatment.

Reviewer 2:

The reviewer expressed that the researchers are very good. They praised the principal investigator for assembling an excellent, highly qualified team and acknowledged that the work is appropriately focused in areas where their strengths lie.

Reviewer 3:

The reviewer observed that it is a well-designed project with a reasonably planned timeline.

Reviewer 4:

The reviewer remarked that the project is well-laid out and has leveraged previous research using the Caterpillar single-cylinder engine. They verified that the project aims to apply these learnings to the John Deere 9 L engine. The reviewer noted that the researchers have systematically tested various low carbon fuels and pre-chamber locations, leading to the identification of the best locations for the pre-chamber. The ultimate goal, the reviewer clarified, is to be able to maintain the diesel torque curve while achieving up to a 50% reduction in life-cycle carbon emissions.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer affirmed that the overall team is strong and has made excellent progress in the design of the pre-chamber, as well as in conducting simulations and experiments pertaining to operating strategy, soot formation, and blend effects.

Reviewer 2:

The reviewer observed that very good progress has been made, and the team's future plans have been well laid out.

Reviewer 3:

The reviewer praised the principal investigator and the team for their exceptional efforts in keeping the project on track, even in the face of challenging questions that arose during the design phase.

Reviewer 4:

The reviewer noted that the project has successfully completed its first year, with estimates indicating that it is over 38% complete. The reviewer highlighted that a substantial amount of data was collected and meticulously analyzed, revealing favorable results. This, in turn, instilled confidence that the technology transfer to the multi-cylinder engine should be a successful endeavor.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer stated that the contributions of the team members are clearly explained and highly collaborative.

Reviewer 2:

The reviewer remarked that the presenter clearly articulated the work and progress of the collaborators.

Reviewer 3:

The reviewer affirmed that the presented results would not have been possible without very good collaboration among all team members.

Reviewer 4:

The reviewer observed that the project lists a total of seven collaborators, with each providing significant contributions. They clarified that these collaborators are all essential for the success of the project, encompassing an engine manufacturer, two universities, a power cylinder supplier, a fuel system supplier, an ethanol supplier, and Clear Flame. The reviewer emphasized that each collaborator will be able to provide valuable input on what needs to be addressed to bring the technology to production.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed surprise at finding no summary slide for future research, except where it is included in the project timeline chart on Slide 5. They suggested considering the addition of a specific "future work" slide near the end of the slide deck, noting that it might have been overlooked by the reviewer. Additionally, the reviewer brought up the question about the need for NO_x aftertreatment, pointing out that while it might not be required by current regulations, there is a societal push for achieving emissions levels as close to zero as possible, or at least as low as the electric grid NO_x per kilowatt-hour.

Reviewer 2:

The reviewer commended the researchers for making intelligent adjustments to their planned research based on the results obtained thus far. An example provided was the adjustments made in response to results demonstrating the potential benefits of the side-mounted ignition prechamber.

Reviewer 3:

The reviewer praised the team for doing a very good job in ensuring that the next milestones are set to be successfully achieved.

Reviewer 4:

The reviewer noted that the project is well laid out, with well-thought-out project milestones for BP 2 and BP 3. They expressed confidence that as long as the project stays on schedule, it should be a success.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the project has the potential to result in an effective approach to CO_2 reduction in off-road applications, potentially with a retrofit option. The reviewer emphasized that the technology utilizes readily available fuels and fuel distribution, making it impactful in the near and mid-term.

Reviewer 2:

Reducing engine CO_2 emissions through lower carbon fuels was noted by the reviewer as a critical aspect of meeting CO_2 reduction goals in the transportation sector, especially in scenarios not conducive to electrification.

Reviewer 3:

The reviewer pointed out that the project effectively addresses the VTO goal of reducing GHG emissions from off-road HD vehicles while also supporting the production of sustainable fuels.

Reviewer 4:

The reviewer highlighted that one method to reduce the lifecycle CO_2 emissions from hard-to-electrify off-road vehicles is to convert them to a low life-cycle carbon fuel, such as green ethanol. The project enables the conversion of diesel engines to run on ethanol with similar efficiency to diesel engines. The reviewer posed the eventual question of how the demand for low carbon fuels will be met as many engines switch to these fuels.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that the resources for the project appear satisfactory. The reviewer suggested that a larger award might be needed for deployment activities.

Reviewer 2:

The reviewer noted that there was no indication that resources are limiting the proposed work, and the researchers seem to be accomplishing their goals within their budget.

Reviewer 3:

The reviewer commented that it is challenging to provide extensive commentary on project resources when DOE funding for such projects is significantly limited.

Reviewer 4:

The reviewer affirmed that the resources allocated are appropriate for the stated work.

Presentation Number: DORMA023
Presentation Title: Improved Efficiency of Off-Road Material Handling Equipment through Electrification
Principal Investigator: Jeremy Worm (Michigan Technological University)

Presenter

Jeremy Worm, Michigan Technological University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

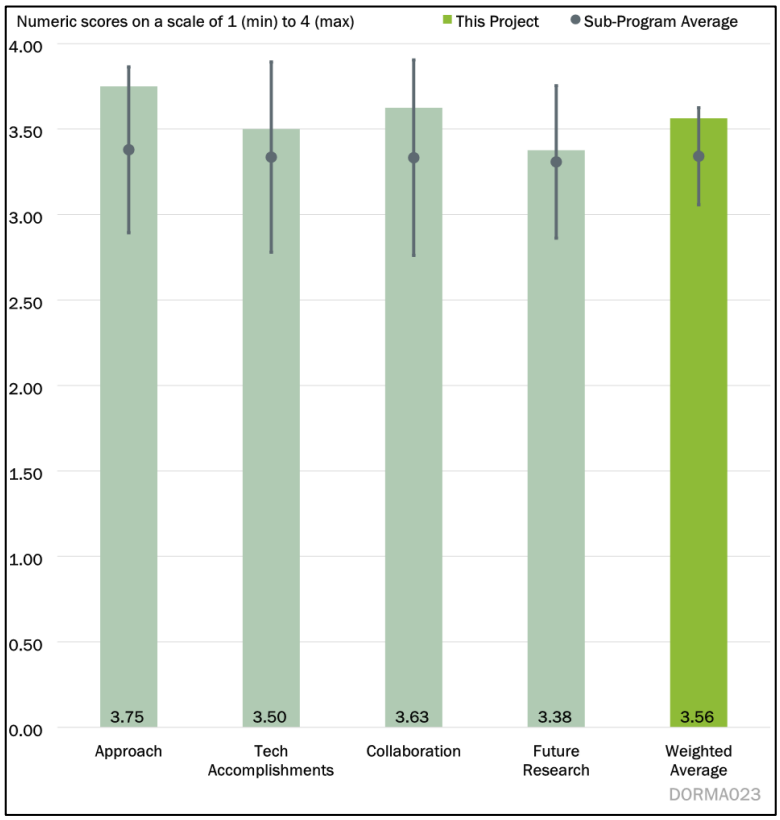

Figure 3-22 - Presentation Number: DORMA023 Presentation Title: Improved Efficiency of Off-Road Material Handling Equipment through Electrification Principal Investigator: Jeremy Worm (Michigan Technological University)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer acknowledged that the project is employing a robust analysis foundation to define the architecture of the material-moving device, aiming for maximum reduction in fuel usage while still meeting full functional mission requirements. They found the analysis of life cycle CO_2 to be very interesting and recommended the publication of that effort. The reviewer pointed out that it is not clear whether renewable, low-carbon fuels were part of the analysis and recommended their inclusion. They considered this project to be an intriguing example of achieving substantial CO_2 reduction without the precondition of decarbonizing the grid.

Reviewer 2:

The reviewer expressed that the work is highly interesting and has the potential to significantly reduce the CO_2 footprint for off-road vehicles not suitable for purely electric vehicle operation. They commended the approach through optimized control of a versatile multi-component powertrain, noting that it appears to have been executed very effectively.

Reviewer 3:

The reviewer stated that the project is well designed, and the timeline is reasonably planned. They expected significantly more progress during the second BP. The balanced approach of identifying the electrified

propulsion and electrified hydraulic architecture that minimizes carbon intensity without sacrificing performance and end-user acceptance was praised. This approach was seen as adaptable to a diverse range of architectures commonly found in the off-road equipment industry. The reviewer believed that even greater CO_2 reduction could be achieved through the electrification of additional components for customers willing to pay the increased cost.

Reviewer 4:

Having selected the vehicle architecture, the reviewer noted that good progress has been demonstrated. Modeling has indicated that the CO_2 reductions should be readily achievable. They mentioned that most supply chain delays have been resolved, though some concerns still linger regarding specific sub-system parts.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer praised the excellent progress in modeling and design, noting a strong focus on the desired outcomes. As noted by the reviewer from the previous year, there remains a lack of specific information regarding the management of the machine's cost, even though cost is identified as a potential barrier.

Reviewer 2:

The reviewer stated that the work is proceeding according to the schedule. They highlighted that the current phase, which they are entering into, is expected to be one of the most challenging. The potential for delays in component delivery, unexpected outcomes during the building and initial testing of the prototype vehicle, and other unforeseen challenges are all possible, although the researchers are mindful of these possibilities.

Reviewer 3:

The reviewer said fantastic progress had been achieved during the second BP of this project, aligning with the overall project plan. The simulation results demonstrating a 46% CO_2 reduction in a commercially viable off-road material handler using the methods identified in this project were described as very encouraging. However, the reviewer suggested that these results should be demonstrated over a broader range of real-world standard operating application duty cycles.

Reviewer 4:

The project has advanced to being over 70% complete and is on track to be finished by Mar. 2024, which the reviewer considered achievable. The reviewer noted that all the expected tasks have been completed, including the major decisions made, such as selecting the vehicle architecture and transitioning to a load-following electrified hydraulic system to enhance hydraulic efficiency. Models have indicated potential fuel consumption reductions of up to 46% compared to conventional vehicles.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the roles and contributions of the diverse team members have been clarified this year.

Reviewer 2:

The reviewer praised the excellent collaboration within the project. They stated that based on the presentation, the comments of the presenter, and the progress that has been made, it appears that all the collaborators are fully engaged.

Reviewer 3:

The reviewer emphasized that the interactions and collaborations within the project team are well-demonstrated. They highlighted that the project has well-defined roles and responsibilities for all the partners, including Michigan Tech (Aps Lab), Pettibone, Parker, EMP, Cascadia Motion, eMatrix, Torsion Control Products, Meritor, Cummins, and Pukall Lumber Company.

Reviewer 4:

The reviewer expressed appreciation for the table showing all the collaborators and how they have contributed. They concluded that with all this collaboration, the project has a good chance of success.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the team is still faced with much to accomplish in order to reach their goals and complete the project. However, they demonstrate a good understanding of the next steps.

Reviewer 2:

The reviewer observed that the future work has been clearly laid out, and the researchers appear to be aware of the challenges and potential pitfalls that lie ahead. They found the potential for this control approach to be applied to other off-road applications very exciting, enhancing the work's potential impact in a significant sector of the mobility arena.

Reviewer 3:

The reviewer stated that the proposed work for the third year has been clearly defined. They appreciated seeing that the physical build has already commenced, and all major hardware design efforts are complete, with major components on order and the remaining design efforts focused on minor components.

Reviewer 4:

The reviewer highlighted that the last part of the project involves completing the demonstration vehicle and verifying the fuel efficiency goals. The schedule appears to be a bit tight, leaving not much time for full vehicle testing.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer observed that the project holds the potential for substantial CO_2 reduction within the off-road sector. It does not necessitate the prerequisites and delays associated with decarbonizing the grid and the challenges of recharging equipment in the field, particularly if the use of renewable liquid fuel is considered.

Reviewer 2:

The reviewer stated that the work is proceeding according to the schedule. They highlighted that the current phase, which they are entering into, is expected to be one of the most challenging. The potential for delays in component delivery, unexpected outcomes during the building and initial testing of the prototype vehicle, and other unforeseen challenges are all possible, although the researchers are mindful of these possibilities.

Reviewer 3:

The reviewer expressed that this project aligns with the broader objectives of the VTO subprogram, particularly focusing on Electrification and Energy Efficient Mobility Systems (EEMS).

Reviewer 4:

The reviewer remarked that the models used in the project have indicated that it could surpass the 20% fuel efficiency goals, potentially achieving over 40%. They noted that it will be intriguing to observe whether the demonstration vehicle can indeed achieve these impressive fuel efficiency values.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that it was not clear whether any team members besides Michigan Technological University would receive DOE funds.

Reviewer 2:

The reviewer remarked that the work is progressing as proposed, which suggests that the resources are sufficient.

Reviewer 3:

The reviewer said that based on what has been completed so far and the work left, the resources should be sufficient to achieve the stated milestones for the project in a timely manner.

Reviewer 4:

The reviewer commented that the project appears to be on budget and has sufficient funding to complete the project.

Presentation Number: DORMA024
Presentation Title: Reduced Cost and Complexity for Off-Highway Aftertreatment
Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Presenter

Ken Rappe, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 33% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

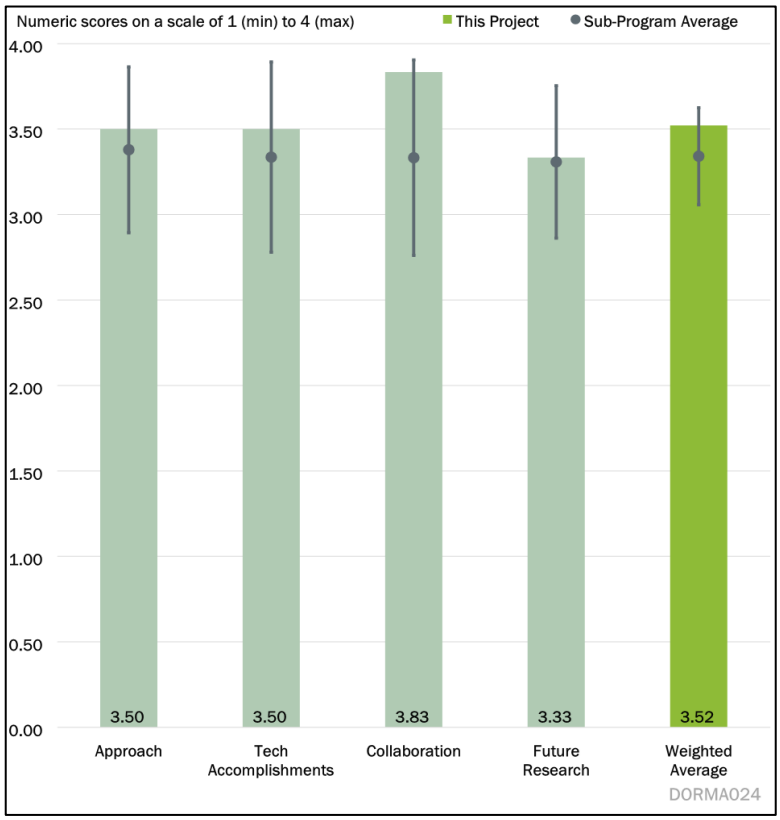

Figure 3-23 - Presentation Number: DORMA024 Presentation Title: Reduced Cost and Complexity for Off-Highway Aftertreatment Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer expressed that this project effectively addresses the high-cost barrier associated with after-treatment systems for diesel engines. They found the project to be well designed with all the necessary components in place for its success. The timeline is well-planned, a judgment substantiated by the information presented and their thirty years of experience in this area.

Reviewer 2:

The reviewer remarked that a strong project team is working on a technically feasible solution involving a diesel oxidation catalyzed filter (DOCF) for integrating aftertreatment. The Michigan Technological University (MTU)/John Deere team has established itself as a leader in this field for nearly thirty years. The project was praised for its adaptability when Carus was unable to deliver on the promised catalyst materials. The reviewer expressed that it's expected John Deere's supplier will offer more implementation-ready solutions. However, more engine testing would be preferable to additional bench tests. They also questioned the absence of clarity regarding transient testing in the project.

Reviewer 3:

The reviewer observed that the project's approach encompasses the use of modeling and detailed laboratory-scale characterization to comprehend, design, and predict the performance of the new multi-functional

component. The reviewer highlighted that the project also involves engine studies to explore performance under practical conditions. The initial emphasis appears to be on fundamental studies at the laboratory scale and model development. The impact of ash and soot management is taken into account. However, there is some lack of clarity regarding the range of designs to be explored, such as washcoat loads, the extent of zone coating, platinum-palladium (Pt-Pd) ratios, operating conditions, and more. Furthermore, it remains unclear how aging of the component is being studied, encompassing hydrothermal and chemical aspects.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that research team has made excellent progress in this project, and this is supported by the information presented in Slides 7 to 14.

Reviewer 2:

The reviewer expressed a desire to see error analysis included on the plots. They found the ash results interesting but questioned how this information will help overcome ash-related issues. They sought clarification on how the new knowledge gained will translate into actionable plans for the device. The reviewer noted that the engine experimental work was particularly well done.

Reviewer 3:

The reviewer noted that a pathway for a 20% platinum group metals (PGMs) reduction has been identified. The DOCF model has been developed, with reaction kinetics calibrated based on available data, and the inclusion of zone coating. The reviewer mentioned that NO_x chemistry has been updated. They noted that the exploration of ash interaction with the catalyst is conducted using advanced characterization tools. The reviewer expressed a need for clear definition of the expected outcome, as similar microstructure-scale work has been done previously, including by the project participants. As it stands, this aspect appears somewhat disconnected. The laboratory reactor measurements were appreciated for providing insights into the DOCF performance at the channel scale and the impact of zone coating, washcoat loading, and other factors.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commented that the team has clearly presented the work conducted by each partner. The reviewer suggested that this project should be rated as a project with very active collaboration among the partners in this team, as demonstrated in Slide 16.

Reviewer 2:

The reviewer noted that all participant roles are clear, and several team members, including Pacific Northwest National Laboratory, John Deere, and Michigan Technological University, have previously collaborated on projects.

Reviewer 3:

The reviewer expressed that all team members are contributing with various strengths, providing hardware, laboratory studies, modeling, and characterization.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer observed that the team had clearly defined the purpose of future work in Slide 18. The reviewer was confident that the future work had a high likelihood of achieving its target, as this was justified by the progress of this project and the reviewer's thirty years of work experience.

Reviewer 2:

The reviewer noted that transient testing was needed and found that plans for it were unclear.

Reviewer 3:

One limitation the reviewer identified in laboratory reactor studies was that the feed gas, which was an approximation of real engine exhaust, might impact the results. The reviewer suggested that the authors explore the sensitivity of any conclusions from this work to the composition of the feed gas. The inclusion of real engine experiments was commendable, as it provided the most practical learning. Given that the model had been developed, the reviewer recommended conducting additional verification with varying zone coating lengths and Pt/Pd distributions to ensure that it captured the chemistry beyond a narrow window. It was imperative for the model to be able to extrapolate to a wide range to assist in optimized catalyst design. The reviewer also emphasized the importance of presenting the results with the impact of hydrothermal and chemical (sulfur, potassium) aging. The reviewer suggested that combining the functionality of a diesel oxidation catalyst (DOC) and diesel particulate filter (DPF) into one component could potentially reduce backpressure. The team should have provided an estimate of the improvement at various soot loadings.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that it was closely relevant to DORMA.

Reviewer 2:

The reviewer affirmed that this project directly supported VTO objectives and exemplified laboratory-university-industry partnering to address real barriers to lower-cost emissions control.

Reviewer 3:

The reviewer emphasized that reducing PGM usage and making components compact for use with upcoming low NO_x systems was an important aspect of emissions reduction from HD equipment.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that they had more than they needed to complete this project, benefiting from the strong support of team partners and the active involvement and participation of each partner.

Reviewer 2:

The reviewer verified that the project funds appeared to be sufficient.

Reviewer 3:

The reviewer observed that the team seemed well-equipped to handle the targets on time and within budget.

Presentation Number: DORMA025
Presentation Title: Fully Electric Powered, Hydraulic Assisted, Compact Track Loader
Principal Investigator: Perry Li (University of Minnesota)

Presenter

Perry Li, University of Minnesota

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

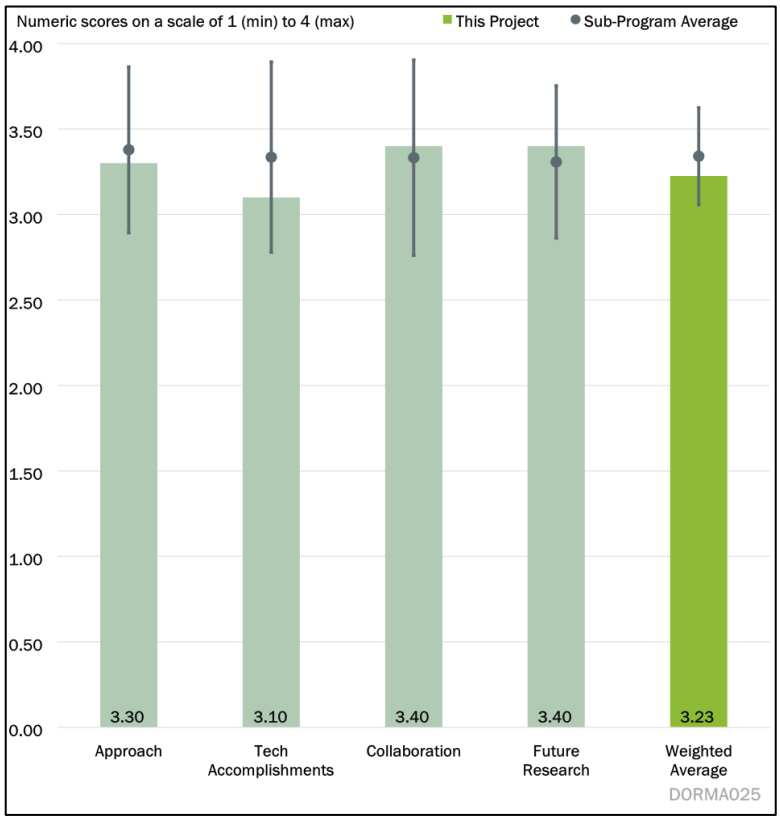

Figure 3-24 - Presentation Number: DORMA025 Presentation Title: Fully Electric Powered, Hydraulic Assisted, Compact Track Loader Principal Investigator: Perry Li (University of Minnesota)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked that the goal is to use an hybrid hydraulic-electric architecture (HHEA) to maintain the high-power density of hydraulics and to improve the overall energy efficiency of the powertrain by not relying on relatively large electric machines. The team is using multiple valve options to charge the various hydraulic rails on the machine, thus the electric motors needed are small compared to what would be needed for electric propulsion or loader arm lift.

Reviewer 2:

The reviewer stated that the project is well designed, technical barriers are addressed, and the timeline is reasonably planned. However, the proposed HHEA with multiple pressure rails may be unnecessarily complex and costly for the compact construction equipment sector, which is very cost-sensitive. It is understandable to use hydraulics for high-power density work functions but not for the propel circuitry. The reviewer affirmed that a costed bill of materials comparison between the baseline and proposed architecture will be helpful.

Reviewer 3:

The reviewer expressed that the approach is very good, a combination of simulations and hardware-in-the-loop laboratory work. There are still a lot of technical barriers, but the team has good ideas on how to tackle them. The timeline seems to be reasonable. The reviewer raised a question, asking, “I believe there is a mistake on Slide 19 (BP 3 is probably July 2024 to June 2025)? My concern is related to the ability to smoothly switch without having an impact on machine controllability and finding components that will be suitable for that.”

Reviewer 4:

The reviewer exulted that an interesting concept is developing a fully electric hydraulic-assisted vehicle. The main barrier is overcoming the low efficiency of the existing throttled control hydraulic pump for transferring the engine's energy to the hydraulic system. This is overcome by using a high-efficiency Danfoss digital displacement pump and using three to four different pressure rails and fast switching valves to control the necessary flow rates. The reviewer praised this approach, stating that the system is more cost-effective than a fully electric version and should be able to use mostly off-the-shelf parts. The reviewer verified that the project should have a high probability of success.

Reviewer 5:

The reviewer commented that the approach section and overall work could be enhanced with a more descriptive overview of the HHEA. On Slide 4, the HHEA schematic shows two pressure sources plus a tank as modulating hydraulic forces to control the actuator piston. The electrical side is represented as a pump drive, with no distinguishing sequence for how pressure regulation is done on the mid and high-pressure lines. The reviewer questioned the reason for the "optional" pressure augmentation on one side of the piston arrangement and noted that the reference to a previous study is accompanied by a picture that gives no information to substantiate the savings or downsizing claims reported. On the proposed electric powered compact track loader (CTL) with HHEA (Slide 5), the reviewer asked what the authors are trying to convey here and whether there are any unique features on the Danfoss E96 pump worthy of note. The reviewer clarified that the approach could be strengthened with a clear energy audit of the baseline product, the hydraulic-electric, and electric variants. Additionally, the reviewer observed that the project appears vague, as noted by the need to differentiate HHEA from "alternative" schemes, providing measurable targets for "fast" pressure switching. The reviewer sought to verify if it is possible to provide more details on the baseline - current product. The reviewer concluded by observing that the six-tier approach is clear, with Step 1 providing a baseline of the technology readiness level and suggested that it may be helpful to understand to what next level the work aims.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer acknowledged that the team was somewhat fortunate that the propel circuit efficiency is estimated to be as good as it is. The reviewer noted that it's positive that the work circuit is very efficient, and thus the overall improvement aligns with the project target. The reviewer commented that the combined donut-pie chart on Slide 18 is quite confusing and does not effectively communicate the results. The reviewer suggested that a Sankey diagram or a similar visualization would be more useful for illustrating the smaller input power and smaller losses of the electric HHEA powertrain.

Reviewer 2:

The reviewer praised the proposed concept as innovative and acknowledged the very good technical progress made compared to the project plan. However, the reviewer pointed out that there are some technical challenges that need to be addressed, specifically concerning the controllability of the pressure rail switching valve system. The reviewer noted that the valves will need to be operated at very high speeds to minimize throttling losses.

Reviewer 3:

The reviewer expressed satisfaction with the fact that the principal investigator acted on their suggestion from last year related to the assumptions about the energy used by the propel circuit vs. implement circuit. The reviewer also commended the progress in defining a solution for feeding multi-pressure rails with one pump, particularly the use of a digital pump. The reviewer indicated curiosity about the pump size needed to provide

flow to different pressure rails. The reviewer also expressed contentment with the principal investigator's examination of different operating cycles to understand the potential for energy savings. The reviewer did, however, point out that packaging and integration of all components may become a challenge, and that cost and controllability still need to be demonstrated.

Reviewer 4:

The reviewer stated that the project appears to be on schedule and meeting the various milestones. For BP 1, the reviewer noted that the five milestones were met, with the most important one showing over 40% electricity savings (approximately around 43%).

Reviewer 5:

On Slide 8, the reviewer suggested that the author could elaborate on the relationship between the five representative cycles and the energy distribution regarding whether the ranges reflect the cycles and how the efficiencies are measured. On Slide 9, concerning the models of HHEA, the reviewer commented that it is not clear whether the work was able to firm up and provide, "optimum" configurations for the parameters studied. The reviewer found the report to be overly generic and suggested providing a representation of the number of pressure rails, hydraulic motor size (i.e., variable displacement?), gear ratios for electrical assist, and so on. On Slide 10, the reviewer noted that the presentation is a bit unclear when tables are given in HHEA percent efficiency and percent savings vs. electrical. The reviewer suggested that it might be best to provide a table of efficiencies for stock, HHEA, and electrical across all five duty cycles. On Slide 11, regarding the losses pi-charts, the reviewer found them hard to follow. The reviewer also questioned the statement "If diesel-downsized engine is retained" and asked whether the savings are further vs. the baseline and if there would be any compromises. On Slide 13, the reviewer found the schematic rather poor in quality and saw an opportunity to show the system layout and overlay or compare it with the actual hardware shown on the same slide, such as indicating the four drive motors, arm motors, control valves, etc. On Slide 15, the reviewer expressed difficulty in understanding the "soft-switch" concept and its loss reduction and suggested it would be easy to describe this technically with time traces of the pressure and motion control.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer affirmed that it appears the project team members are appropriately contributing to the overall effort and results on the project.

Reviewer 2:

The reviewer commended that the responsibilities as well as contributions from collaboration partners in academia (University of Minnesota and The University of Wisconsin-Madison) and industry (CNH Industrial, Danfoss, and Parker) are clearly defined, stating, "Well done!"

Reviewer 3:

The reviewer noted that there is no real insight provided on collaboration, but the reviewer found it reassuring to see that the analysis of the base machine cycles was completed, indicating that the OEM provided the necessary data to conduct the analysis. The reviewer expressed confidence in the project's partners' capabilities and stated that the confidence to deliver on the project objective is satisfactory.

Reviewer 4:

The reviewer recognized that the project has the appropriate partnerships with two universities (University of Minnesota, University of Wisconsin), Danfoss, Parker, and the most important one, New Holland. The

reviewer noted that the project is making good progress on the modeling (from the universities) and also on the hardware (loader frame, pumps, rails, and inverters). The reviewer observed that all team members appear to be contributing and making good progress.

Reviewer 5:

The reviewer commented that the project assembles a strong team and encouraged the team to provide more information to see or understand their specific contributions to the project, particularly on the technical side.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer noted that the team is revising their plan for the propel circuit dynamometer to accommodate long lead times. The original dynamometer was a regenerating electric dynamometer, but the team will now use an electro-hydraulic dynamometer to absorb the propel circuit power. The reviewer suggested that given the questions that have come up on this project, a techno-economic analysis would be useful to help evaluate the HHEA system versus other options.

Reviewer 2:

The reviewer affirmed that the proposed future research scope and purpose are clearly defined. Based on the progress and simulation results from the work completed to date, the reviewer expressed confidence that the future work will likely achieve its targets.

Reviewer 3:

The reviewer commented that the proposed future research is focused on a combination of controls development and simulation while starting to utilize the laboratory and parts of the machine for validation of their approach. The reviewer noted that this second phase will determine if real challenges related to the soft pressure switching and the valve concept will be overcome. The reviewer raised a concern about the statement that a 10–20 ms valve response time is pretty demanding for typical off-highway equipment valves. The reviewer recommended studying component packaging and conducting a rough machine cost calculation to compare with the baseline. The reviewer also mentioned that another challenge will be the integration of electro-hydrostatic actuation or e-motor driven pump in line with the switching valve.

Reviewer 4:

The reviewer stated that the tasks for BP 2 and 3 are right on target and that the team should be able to demonstrate the vehicle near the end of the project.

Reviewer 5:

The reviewer appreciated that the steps for upcoming BPs are well described, providing a clear path to the final testing and evaluation.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that the team is actively seeking to reduce energy use, thereby minimizing GHG emissions from a compact track loader and similar small non-road machines.

Reviewer 2:

According to the reviewer, the project aligns with and supports the overarching objectives of the VTO subprogram in Analysis, Electrification, and EEMS.

Reviewer 3:

The reviewer found the approach to be highly relevant. The project's objectives strongly bolster efficiency improvements in off-highway machines, consequently contributing to decarbonization goals by leveraging the strengths of both hydraulic and electrical systems.

Reviewer 4:

The reviewer stated that the off-road sector poses unique challenges in terms of electrification, and the HHEA concept significantly enhances overall vehicle efficiency when compared to traditional engine-powered vehicles. The incorporation of pressure rails should reduce the need for larger electric motors, thereby reducing overall costs. The reviewer expressed confidence that this architecture holds real promise for success.

Reviewer 5:

Off-road vehicles heavily rely on electro-hydraulics to deliver high power. Electrification is recognized as a pathway to enhance efficiency. Nevertheless, the reviewer acknowledged that the cost of high-power/torque electric machines remains a challenge. The proposed architecture integrates hydraulic and electric actuations, aiming to achieve improved efficiency, enhanced control performance, and a cost-competitive approach to high-power electric machines.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer confirmed that the resources appear sufficient to complete the project as planned.

Reviewer 2:

The reviewer, based on the spending rate to date and the proposed future research work, expressed confidence that the resources of the project should be sufficient.

Reviewer 3:

The reviewer noted that it appears the project has committed resources and strong contributors to ensure timely progress.

Reviewer 4:

The reviewer found that the resources seem appropriate, and the project team is making satisfactory progress.

Reviewer 5:

The reviewer affirmed that the resources appear sufficient for the scope of work.

Presentation Number: DORMA026
Presentation Title: Articulated Dump Truck (ADT) Electrification - Greenhouse Gas Reductions and Commercialization of New Technology
Principal Investigator: Brij Singh (John Deere)

Presenter

Brij Singh, John Deere

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

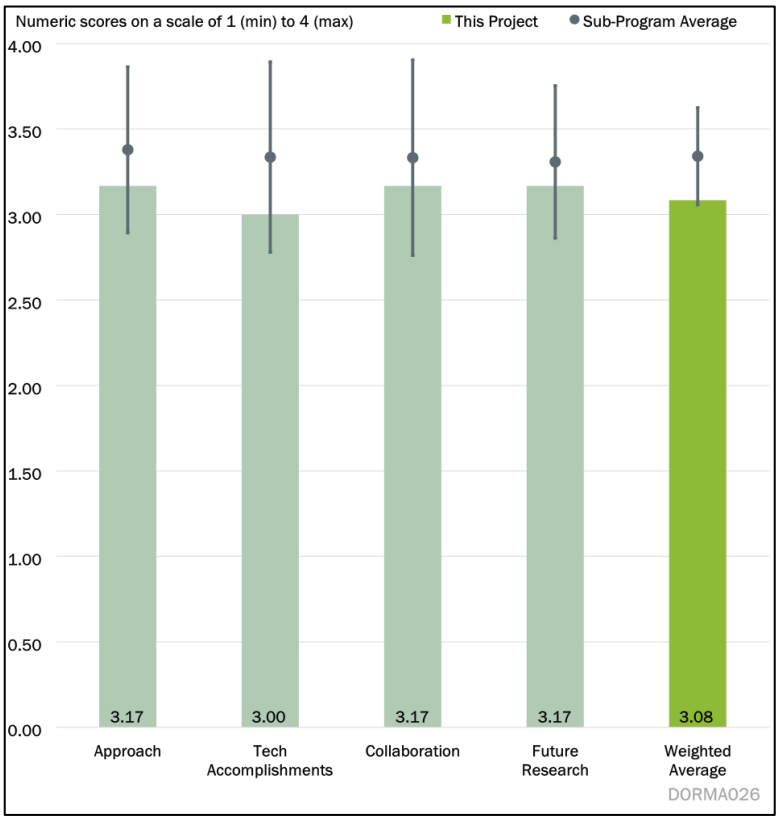

Figure 3-25 - Presentation Number: DORMA026 Presentation Title: Articulated Dump Truck (ADT) Electrification - Greenhouse Gas Reductions and Commercialization of New Technology Principal Investigator: Brij Singh (John Deere)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer pointed out that there is a significant amount of technical risk associated with the new technology being explored for the high-power DC/DC converters. However, the reviewer noted that the rest of the hybrid electric vehicle (HEV) powertrain work appears to build on existing components or systems for integration into a new application, the ADT. The reviewer recommended that the team also evaluate the thermal management system for the HEV architecture since there will be at least two coolant loops (high temperature for the internal combustion engine and low temperature for the battery pack and power electronics) on the ADT.

Reviewer 2:

The reviewer stated that during BP 1, the project approach was to design the components of the diesel-electric-hybrid powertrain. This was achieved through simulations to determine the sizing.

Reviewer 3:

The reviewer identified two main technical barriers. The first is the need to develop a reliable diesel-electric hybrid powertrain for the off-road market, and the second barrier is the SiC DC/DC converters needed. The project plan addresses the hybrid powertrain, and the reviewer expressed confidence that a reliable system should be able to be developed. The reviewer further noted that the auxiliary resonant commutated pole SiC

inverter has the potential for significant energy savings, which will need to be verified. The overall project aims to develop an articulated dump truck that achieves over 20% fuel savings. The reviewer observed that since John Deere is leading the project, many of the technical barriers required to put a vehicle into production are being addressed, including the need for a 15,000-hour vehicle.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer raised a concern that at 15%, the progress seems relatively low, especially considering it is most of the way through BP 1. The reviewer questioned whether BP 1 was extended due to contracting-related delays. The goal for BP 1 is sizing components for the diesel-electric HEV powertrain, and the reviewer acknowledged that the team appears to be well on their way to achieving that goal. However, the reviewer recommended revisiting the battery pack sizing work to ensure that an appropriate pack is used in this application. While 35 kWh is deemed acceptable, the reviewer suggested that a more rigorous decision-making process would be beneficial.

Reviewer 2:

The reviewer commended the first-year accomplishments, which include system modeling, optimization, and prototype data collection, stating that they have made significant progress in getting the project off the ground.

Reviewer 3:

The reviewer noted that a table of milestones was provided, and while the milestones are considered pertinent, there is uncertainty regarding how many of them have been accomplished. The reviewer expressed concern that the project is reported as being 15% complete, which seems low for this stage, as it should ideally be around 30% complete. The reviewer emphasized that, based on the presentation, there appears to be progress on all the accomplishments, but many of them are not yet complete.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer acknowledged that the project team includes John Deere and two universities. The reviewer observed that it seems several divisions within John Deere are involved, and the reviewer appreciated that this could create a feeling of having multiple industrial partners on the project.

Reviewer 2:

The reviewer found that coordination between team members was difficult to assess, particularly between the various branches within John Deere. The reviewer recommended that for future presentations, it would be beneficial to identify which collaborators contributed to each of the technical accomplishments to make this assessment more straightforward. The reviewer noted that for the current presentation, the assumption was that this information is shown in the boxes on Slide 19.

Reviewer 3:

The reviewer pointed out that the project is being led by John Deere, and there are five different groups within John Deere that are assisting with the project, which is required because different groups are needed for different system components. The two universities are providing assistance with power converters and prototyping and testing. The reviewer concluded that overall, it appears to be a good collaboration.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer understood that continuing supply chain issues have significantly increased lead times for components, particularly for HEV powertrains. The reviewer also acknowledged that there is a significant risk associated with inventing the soft-switched silicon carbide (SiC) inverter, especially for the 250 kW power levels required for the electrified ADT.

Reviewer 2:

The reviewer recommended providing more detailed context for the future work next year. For instance, the reviewer pointed out that a statement like "Additional testing of early prototype of 310E electrified ADT" does not clearly convey the specific goals of the testing.

Reviewer 3:

The reviewer commented that the proposed future research tasks are presented in a relatively high-level format. The reviewer expressed a desire to see more details on how these tasks will be met in the future.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that this project supports vehicle electrification and DORMA goals to reduce energy use and GHG emissions.

Reviewer 2:

The reviewer affirmed that the electrification of a diesel-electric-hybrid powertrain of this scale in an off-road vehicle demonstrates a reduction in GHG emissions and effectively meets the objectives.

Reviewer 3:

The reviewer highlighted the project's goal, which is to provide fuel savings for hard-to-electrify off-road vehicles, and expressed confidence that this project is on track to meet the goal of providing over a 20% reduction in fuel consumption.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer assessed that it looks like the John Deere-led team should have sufficient resources to complete the work on time.

Reviewer 2:

The reviewer considered it early in the project to make a final judgment but found the resources allocated to be appropriate at this stage.

Reviewer 3:

The reviewer stated that the overall budget appears to be about right.

Presentation Number: DORMA027
Presentation Title: LLCF Effects on Emissions Control Catalyst Performance and Durability
Principal Investigator: Sreshtha Sinha Majumdar (Oak Ridge National Laboratory)

Presenter

Sreshtha Sinha Majumdar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

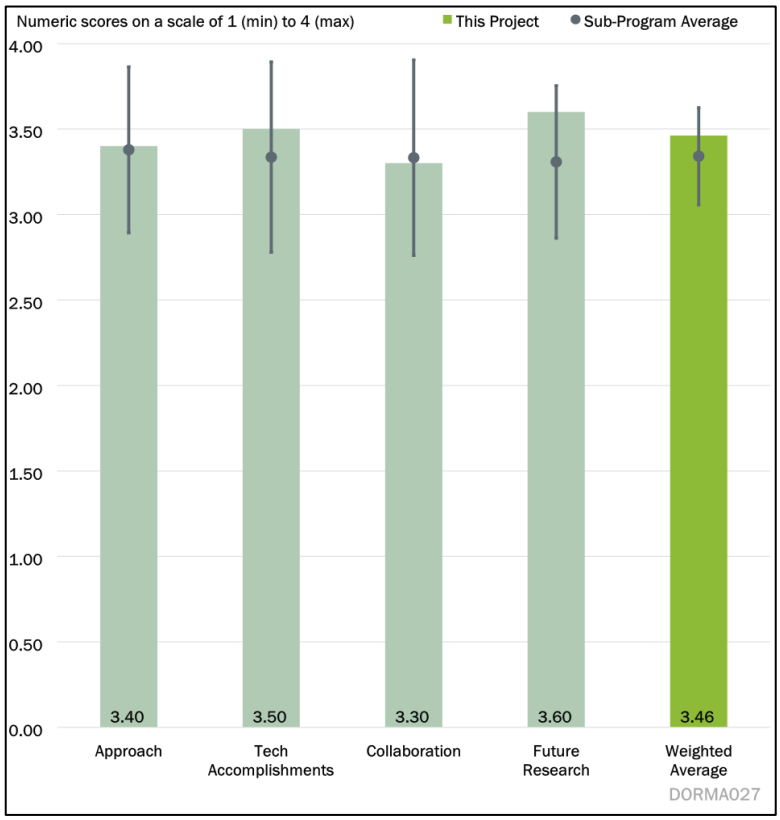

Figure 3-26 - Presentation Number: DORMA027 Presentation Title: LLCF Effects on Emissions Control Catalyst Performance and Durability Principal Investigator: Sreshtha Sinha Majumdar (Oak Ridge National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer found that this project is, to some extent, well designed but could benefit from improvement. The reviewer concurred with the team's assessment that electrifying the rail, marine, and off-road sectors is a challenging task. However, the reviewer raised concerns about the use of high-power engines to burn ethanol and methanol fuel, noting that aldehyde emissions from alcohol have been a topic of discussion for over twenty years. The reviewer emphasized that aldehyde emissions from engines, including car and truck engines, should have been well-documented. The reviewer argued that the industry is aware of the challenges and that the key question should be about finding new DOC technology instead of characterizing light-off temperatures using the current DOC.

Reviewer 2:

The general approach taken in these studies is seen as broadly based, aimed at understanding the issues surrounding low-lifecycle-carbon fuels (LLCFs), including methanol, ethanol, and isobutanol, as replacements for other alternative fuels. These fuels were tested over a commercial palladium and platinum diesel oxidation catalyst (Pd-Pt DOC), and in the case of the two lighter alcohols, over a platinum only diesel oxidation catalyst (Pt DOC). The reviewer noted that a substantial amount of data was collected, including information on the impact of CO and the resultant NO chemistry. The reviewer also recognized that there were additional measurements that could not be discussed due to time constraints.

Reviewer 3:

The work is targeted at addressing the de-fossilization of the so-called "hard to electrify" sectors of rail, marine, and off-road vehicles by operating these vehicles on low-carbon fuels while maintaining emissions compliance.

Reviewer 4:

The reviewer noted that the project addresses the need for a better understanding of emissions when using various alcohol fuels, which can contribute to GHG reductions in the non-road sector. The utilization of two different catalyst formulations helps in understanding the impact of Pt/Pd. The project is well planned, employing established laboratory methodologies and commercial DOCs. The reviewer did acknowledge that there are always some limitations when conducting laboratory studies and translating them to real-world applications. To address this, the reviewer suggested that it might be useful to scale these experiments to engine experiments with real exhaust.

Reviewer 5:

The reviewer concluded that the work is well-documented for alcohol-containing fuels' reactions over DOCs, the intermediate species generated, and the associated challenges. The reviewer also highlighted the importance of the next steps, such as examining other low-carbon fuels (bio-diesel, renewable diesel, dimethyl ether) and exploring alternate formulations to address intermediate species.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

Based on the milestones presented in Slide 6 and the research results presented, the reviewer determined that the team has made significant progress in this project.

Reviewer 2:

The reviewer recognized that a wealth of valuable knowledge has been obtained. Specifically, the quantification of alcohol light-offs occurring at lower temperatures than model commercial diesel fuels and the documentation of aldehydes produced were noted. The reviewer found the small amount of N_2O produced with alcohols to be very interesting. However, the reviewer pointed out that one item not discussed in the presentation was the fact that for the Pd-Pt DOC, isobutanol reacted more fully at lower temperatures than ethanol and appeared to produce much less acetaldehyde. The reviewer suggested that this could be a topic for subsequent studies, especially when considering that methanol consistently formed the smallest amount of aldehyde among the alcohols studied. From a commercial standpoint, there might be a preference for using a fuel like isobutanol over methanol, with the Pd-Pt DOC likely being favored over a Pt-only DOC.

Reviewer 3:

The reviewer noted that this project has an aggressive timeline and commended the team's work on developing a delivery system for the formaldehyde reactant to the bench reactor. The reviewer considered this particularly impressive as it has been a challenge in many research laboratories. The solution devised by this team and its successful implementation is stable and capable of reaching high concentrations. The reviewer found the results to be interesting, as they showed that the PGM content did not impact the reactivity trends of the alcohols or aldehydes. Additionally, the study revealed that methanol oxidation resulted in unfortunate byproducts in the form of formaldehyde, and ethanol formed acetaldehyde. These aldehydes were found to be less reactive than the alcohols, making remediation more challenging. The reviewer acknowledged that there are still barriers to overcome, which will be addressed in future work.

Reviewer 4:

The reviewer commended the project for providing a good fundamental understanding of intermediate aldehyde species' formation and their reactivity on commercial catalysts. The choice of two commercial catalysts, Pd/Pt and Pt-only, was noted as providing a valuable directional understanding.

Reviewer 5:

The reviewer stated that the work on alcohol-containing fuels is well executed and suggested that a similar process should be followed for other LLCFs.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that the research work has been carried out at Oak Ridge National Laboratory. Caterpillar's contribution to this project is primarily in-kind support and industry input related to test cycles, industry opinions about ethanol/methanol fuel, and supplying DOCs, among other aspects. However, the reviewer found that there appears to be no significant technical contribution from Caterpillar. The reviewer suggested that the principal investigator may want to provide more detailed information about the technical contribution from Caterpillar.

Reviewer 2:

As mentioned in the Response to Comments from Reviewers, the reviewer pointed out that the inclusion of a catalyst supplier could be beneficial. Specifically, obtaining DOC catalysts from a catalyst supplier could enhance the project. Informal discussions with such a supplier could offer valuable insights. The reviewer also suggested that other researchers at universities and national laboratories who are working on aldehyde reactions might be potential collaborators, either at some level or more directly, particularly when transitioning from alcohols to CO_2 and H_2O.

Reviewer 3:

The reviewer found that clear roles for the partners have been established, with Caterpillar actively providing input and guidance.

Reviewer 4:

The reviewer commended Caterpillar for its industry guidance on aging conditions and for providing catalysts.

Reviewer 5:

The reviewer raised the question of whether having a catalyst formulation supplier as part of the project team would be useful.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer considered the proposed future work to identify and evaluate alternate catalyst formulations to be excellent, especially given the challenging nature of the task. The reviewer suggested that the team should focus on this topic in their future work.

Reviewer 2:

The reviewer emphasized that the future research topics are essential, particularly in the context of finding better catalysts for converting aldehydes at low temperatures and exploring other alternative LLCFs. The reviewer also raised the possibility of considering an additive to a Pd-Pt DOC that could potentially lead to a

fuller oxidation of the reaction, inhibiting aldehyde formation. The reviewer noted that this option was not mentioned among the choices presented. The reviewer inquired about the impact of NO in the area, as it was mentioned that carbon monoxide (CO) reaction could slow alcohol reaction, but the reviewer did not recall a study of the impact of NO.

Reviewer 3:

The reviewer recognized that as part of this year's technical accomplishments, it has been identified that alcohol fuels, both methanol and ethanol, lead to aldehyde products of combustion, which are challenging to remediate. The planned future work addresses the key barrier of low-temperature aldehyde oxidation. Additionally, the future work extends the fuel matrix to include additional renewable fuels.

Reviewer 4:

The reviewer suggested discussing the results of the NO–NO_2 reactivity study, which were not shown, in the next meeting. The reviewer also recommended including an examination of the impact of sulfur and other chemical aging. Finally, the reviewer suggested including some real engine work with full-size catalysts.

Reviewer 5:

The reviewer concluded that looking at other LLCFs and exploring different DOC formulations to address intermediate species are the right next steps.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer found that this project is closely relevant to future off-road engines, which support the overall VTO subprogram objectives.

Reviewer 2:

The reviewer observed that the research on LLCFs that this project conducts clearly meets the needs of our society to cost-effectively meet emission standards and lower GHG emissions at the same time, which is a core principle in the DORMA area.

Reviewer 3:

The reviewer stated that this project is extremely relevant to DOE VTO program objectives.

Reviewer 4:

The reviewer pointed out that oxygenated fuels are promising candidates for GHG reductions, and it is crucial to understand the side emission issues associated with them.

Reviewer 5:

The reviewer considered this to be a very timely topic and encouraged the project to continue.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that ORNL has sufficient facility and resources to achieve the milestones in a timely fashion.

Reviewer 2:

The reviewer found that the experimental tool resources needed and available are well-covered for this project at ORNL.

Reviewer 3:

The reviewer suggested that while $400,000 per year seems sufficient, it may be just barely enough for this work. The reviewer encouraged considering additional funding if possible.

Reviewer 4:

The reviewer acknowledged that the resource allocation is currently good but emphasized that it will benefit from engine testing.

Reviewer 5:

As mentioned in previous comments, the reviewer reiterated the idea that perhaps the inclusion of a catalyst formulation supplier would be useful.

Presentation Number: DORMA028
Presentation Title: Comprehensive Integrated Simulation Methodology for Enabling Near-Zero Emission Heavy-Duty Vehicles
Principal Investigator: Andrea Strzelec (University of Wisconsin-Madison)

Presenter

Andrea Strzelec, University of Wisconsin-Madison

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

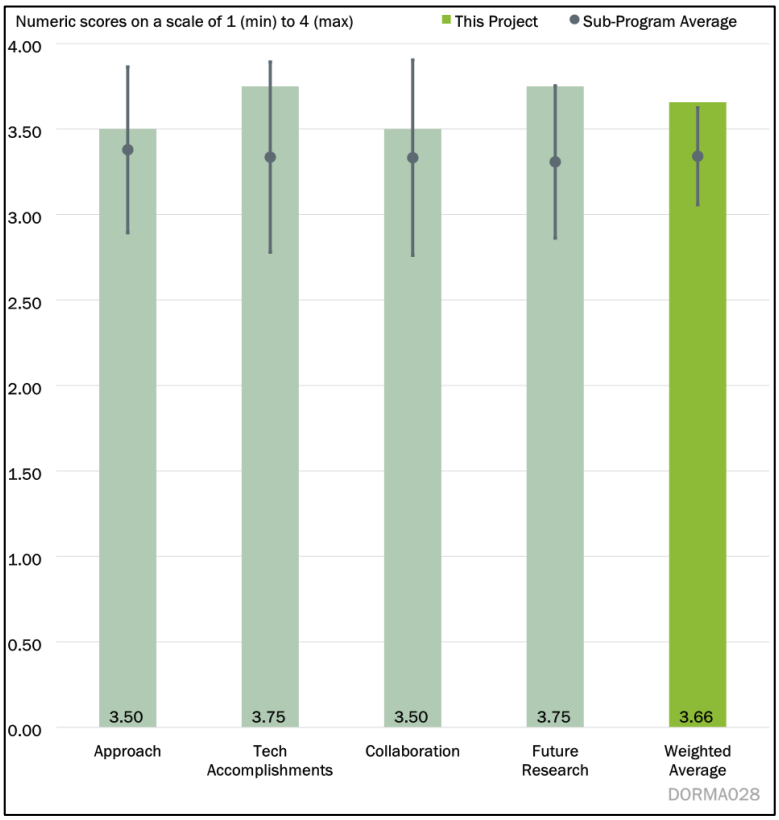

Figure 3-27 - Presentation Number: DORMA028 Presentation Title: Comprehensive Integrated Simulation Methodology for Enabling Near-Zero Emission Heavy-Duty Vehicles Principal Investigator: Andrea Strzelec (University of Wisconsin-Madison)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The project is well-designed to develop an integrated simulation platform for designing exhaust system architectures and control strategies to meet future ultra-low NO_x emissions standards throughout a vehicle's full useful life. The reviewer recognized that this model could potentially assist OEMs in reducing the time and costs associated with deploying new emission reduction technologies.

Reviewer 2:

The reviewer found that the overall project is well laid out, and everything appears to be on schedule. The reviewer also noted that all collaborators are actively contributing.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that the project has made significant progress, having accomplished approximately 40% of this 3-year project. The GT-SUITE stochastic reactor model (GT-SRM), GT engine, and GT-multi-cylinder SRM models have been developed and validated. Additionally, the aftertreatment components have been calibrated for both steady and transient conditions, which are crucial for cycle and cold-start simulations.

Reviewer 2:

The reviewer noted that the overall project is making good progress and encouraged the team to continue their good work.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer expressed appreciation for the strong collaboration involving a national laboratory, a university, automotive transmission companies, an automotive consulting company, and an oil company. The collaborative efforts seem well-structured and diversified, bringing together expertise from various sectors. Furthermore, the reviewer acknowledged the principal investigator's efforts to work with the Coordinating Research Council (CRC) to expand the project's scope to cover fuel effects on aftertreatment systems.

Reviewer 2:

The reviewer commended the project for its well-balanced mix of collaborators, including an engine OEM, a catalyst supplier, government laboratory utilization, two universities, FEV Test Systems for testing, a fuel company, and the CRC. This diverse set of collaborators is expected to provide the project with valuable resources and expertise to overcome potential challenges. The reviewer also expressed appreciation for the CRC's offer to provide additional fuels for testing.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the future research is well planned.

Reviewer 2:

The reviewer highlighted the significance of investigating SCR catalyst aging, emphasizing its importance and the need for validation. However, the reviewer noted a potential gap in the project's plans, as there does not seem to be any specific provisions for modeling NH_3 storage or addressing the potential for urea deposits. The reviewer raised a question about whether these aspects would be addressed in the future work.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer expressed that this work is absolutely relevant to DOE objectives, particularly in the context of reducing criteria emissions, which are crucial for achieving clean and sustainable transportation in the future.

Reviewer 2:

The reviewer affirmed that the improved models resulting from this project will provide valuable assistance to engine OEMs in optimizing their systems for improved fuel economy. The reviewer also noted that these models are expected to eventually be incorporated into GT-POWER simulation model, making them accessible for all users. The reviewer praised the involvement of the CRC in the project and highlighted its potential to encourage testing with renewable diesel fuel and possibly other low net carbon fuels. The reviewer recognized that this aligns with the VTO objectives.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that overall, the team has the most resources to conduct the relevant research.

Reviewer 2:

The reviewer expressed that it appears good progress is being made with the resources provided.

Presentation Number: DORMA029
Presentation Title: Fast Simulation of Real Driving Emissions from Heavy-duty Diesel Vehicle Integrated with Advanced Aftertreatment System
Principal Investigator: Hailin Li (West Virginia University)

Presenter

Hailin Li, West Virginia University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

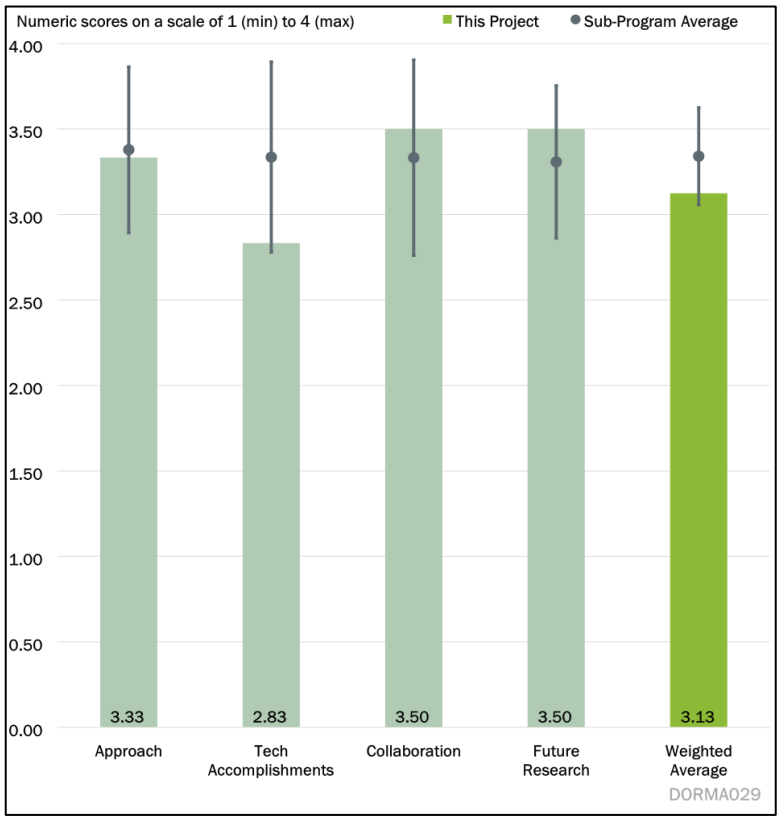

Figure 3-28 - Presentation Number: DORMA029 Presentation Title: Fast Simulation of Real Driving Emissions from Heavy-duty Diesel Vehicle Integrated with Advanced Aftertreatment System Principal Investigator: Hailin Li (West Virginia University)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer praised the outstanding approach taken in this project, which encompasses a wide range of simulation tools, from 1D to 3D, detailed and map-based engine models, to complete vehicle models. The fact that all these models will be validated against experimental data was seen as a substantial enhancement to model fidelity.

Reviewer 2:

The reviewer found the project to be well-designed, focusing on developing and validating simulation tools that enable the virtual coupling of engine combustion with aftertreatment systems. The reviewer acknowledged the potential significance of these simulation tools for both OEMs and the research community. These tools can be used to simulate real driving emissions from HD diesel trucks, optimize HD diesel engines and aftertreatment systems for near-zero emissions, develop pathways to achieve super-low NO_x emissions, and explore technologies to minimize CO_2 emissions.

Reviewer 3:

The reviewer mentioned some challenges in the project, particularly related to the contract's duration and delays due to issues with the West Virginia University (WVU) engine laboratory. While the reviewer appreciated the efforts to find an alternative test laboratory and WVU's additional funding to cover increased test costs, they anticipated that testing at a third party could be more challenging to manage, potentially

extending the timeline for data collection. The reviewer raised a concern about the absence of plans to model urea storage in the SCR catalyst, highlighting its importance for achieving faster NO_x conversion at low temperatures. Additionally, the reviewer pointed out that urea deposits can occur over time and suggested that it might be beneficial to discuss or consider modeling urea deposits, even if a good model is not available at present.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted significant progress on the modeling side, with advancements in 1D, 3D, and aftertreatment models. However, the lack of progress on engine testing was a concern for the reviewer, as it could noticeably impact the overall project progress.

Reviewer 2:

The reviewer reported that the project had progressed well, accomplishing about 70% of the year-one project. Key accomplishments included the validation of CFD and 1D models for combustion simulation, the development and integration of aftertreatment components models with GT, and the development of a 1D urea model. The delay in engine experimental research was attributed to the temporary closure of the WVU engine laboratory. A remedy plan was in place to catch up, and a 12-month no-cost extension had been approved by DOE, which was expected to help keep the project on schedule.

Reviewer 3:

The reviewer recognized that the project had experienced delays in obtaining a signed contract and faced issues with the WVU engine laboratory, resulting in a delay in engine testing. While model development seemed to be on track, the reviewer stressed the importance of generating engine data for validation. Additionally, there was a concern about obtaining the necessary information on the SCR catalyst to properly tune the model.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer expressed that it seems that all key partners are contributing to the progress of the project.

Reviewer 2:

The reviewer noted strong collaboration with national laboratories, research institutes, automotive consulting companies, and energy companies.

Reviewer 3:

The reviewer mentioned that while all the correct partners have been identified, it is challenging to judge the extent of their contributions, particularly since the project is behind schedule.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the future research is very well defined and expressed eagerness to see more progress on machine learning in the following year.

Reviewer 2:

The reviewer commended the team’s plan to catch up on experimental work and acknowledged the well-planned aspects of the project. This included CFD, algorithm development, criteria for achieving adaptive

aftertreatment system simulation under transient operation, simulating real-world driving emissions, and using machine learning for aftertreatment system simulation and emissions research.

Reviewer 3:

The reviewer found the future work related to developing adaptive aftertreatment system simulation over transient operation to be interesting. They also recognized the value of exploring a Machine Learning-based framework for adaptive system simulation in enhancing the existing knowledge base for engine modeling.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer stated that with a range of simulation tools from 1D to 3D, covering everything from the engine to the vehicle, the project should support the overall VTO program objectives.

Reviewer 2:

The reviewer noted that the project is aligned with overall DOE objectives for clean, efficient, and sustainable transportation.

Reviewer 3:

The reviewer also recognized that improving the complete engine/aftertreatment system to meet future emission regulations with reduced fuel consumption and lower precious metal costs aligns with the VTO goals.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer expressed confidence that the project should have enough funding to complete the project.

Reviewer 2:

The reviewer found the resources to be adequate for the proposed research and expressed hope that WVU could reopen the engine laboratory to facilitate the accomplishment of the project.

Reviewer 3:

The reviewer believed that funding should be sufficient, especially given that WVU is covering the additional engine test cell costs for performing the engine tests at an outside laboratory.

Presentation Number: DORMA030
Presentation Title: Opposed-Piston 2-Stroke Hybrid Commercial Vehicle System
Principal Investigator: Fabien Redon (Achates Power)

Presenter

Ming Huo, Achates Power

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 33% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

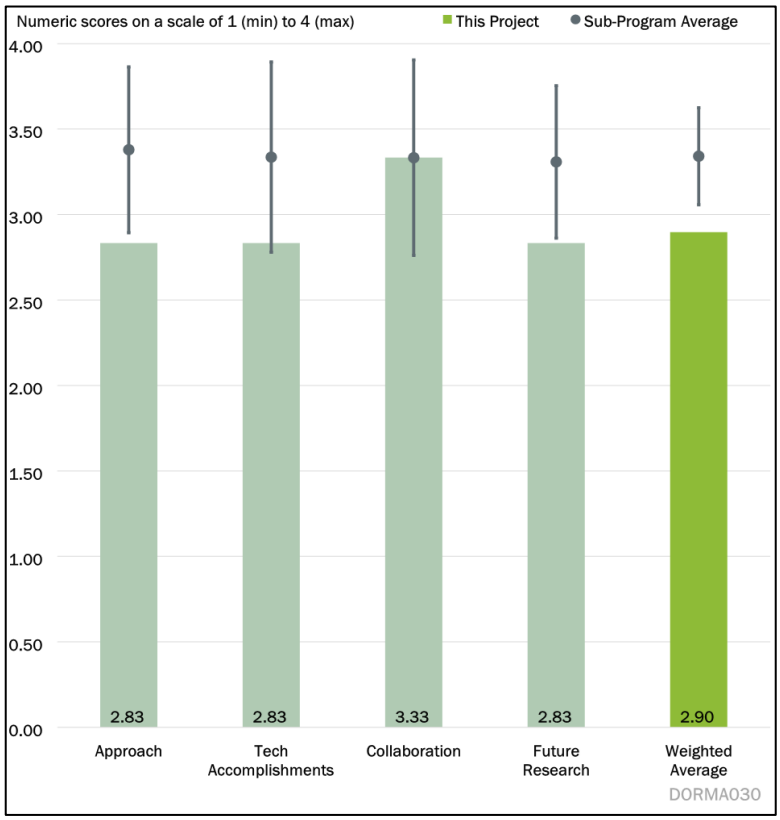

Figure 3-29 - Presentation Number: DORMA030 Presentation Title: Opposed-Piston 2-Stroke Hybrid Commercial Vehicle System Principal Investigator: Fabien Redon (Achates Power)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that while the adaption and implementation of a hybrid system in medium- and HD vehicles is generally interesting, it is not clear whether there is a compelling need for the opposed piston, two stroke (OP2S) architecture. They pointed out that ultra-low emissions require aftertreatment in any case and have been demonstrated with conventional configurations. The reviewer also raised concerns about the use of H_2 combustion and cited past experiences with two-stroke commercial methanol engines.

Reviewer 2:

The reviewer acknowledged that the project combines simulations and experiments to optimize engine/emission performance and sees the potential for finding synergistic benefits in combining opposed piston and hybridization. They also appreciated the inclusion of H_2 as a new fuel, given industry efforts to evaluate H_2 combustion. However, the reviewer cautioned that the current approach appears to aim for too many objectives simultaneously, including achieving low NO_x, improving efficiency through hybridization, and evaluating H_2, potentially stretching the project's focus.

Reviewer 3:

The reviewer raised questions about the approach for the dual ignition mode combustion strategy and the machine learning approach, seeking more clarity on how these approaches will help achieve the project's overall goals.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that while there is evidence of progress in modeling and seeking improvements in diesel combustion, the report lacks clarity on any new discoveries that have emerged. They mentioned that the development of hybrid configuration models is interesting but should be compared to prior work. The reviewer also suggested that the advantages of the OP2S architecture are not distinct at this stage. However, they expressed interest in the upcoming H_2 testing.

Reviewer 2:

The reviewer stated that data collected from opposed piston engines has been used for model calibration and supports the engine's ability to meet ultra-low NO_x requirements with a conventional aftertreatment. This represents a significant change compared to conventional diesel engines, which usually require additional close-coupled SCR. The simulations demonstrated the potential for improvements through hybridization and combustion enhancements, as well as the feasibility of H_2 combustion. However, the reviewer wished there was more experimental data available to support the claims already made.

Reviewer 3:

The reviewer found the progress toward the project plan to be good regarding the modeling and calibration of the engine but noted that the report lacked details on the status of testing with H_2.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commented that the team members are highly qualified and have collaborative roles.

Reviewer 2:

The reviewer noted that there appears to be good collaboration with academia, national laboratories, and another OEM. However, it was unclear how much or what work is being done by Isuzu.

Reviewer 3:

The reviewer mentioned good coordination across the teams but found it unclear what role Argonne National Laboratory has in the project. While Argonne is not listed as a partner, testing at Argonne was noted on Slide 16.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed an interest in seeing evidence that the OP2S engine would have a higher thermal efficiency of 20% or more and inherently lower NO_x emissions compared to reciprocating engines.

Reviewer 2:

The reviewer appreciated the shift in focus from simulations to engine testing. However, the reviewer mentioned that it might have been better to concentrate on either hybridization or H_2 instead of pursuing both simultaneously.

Reviewer 3:

The reviewer noted that while the future research plan includes clear deliverables, the connection between these plans, specific targets, and the ultimate project goals is not clearly presented.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer expressed concerns about the relevance of the project, suggesting that the benefits are not conspicuous and likely not significant. The reviewer highlighted that the assessment of hybrid electric vehicles is the most relevant area.

Reviewer 2:

The reviewer noted that meeting low NO_x and GHG reductions simultaneously for HD trucks is a critical focus in the coming years.

Reviewer 3:

The reviewer mentioned that the project does support the overall VTO subprogram objectives but noted the absence of specific references to the relevance of the project to the decarbonization blueprint or specific VTO goals. Instead, the relevance is primarily focused on market barriers.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commended Achates for its success in leveraging funds and finding cost-sharing opportunities.

Reviewer 2:

The reviewer expressed concerns about the sufficiency of resources based on the project's scope, which includes improving engine efficiency, considering hybridization, and H_2 internal combustion engines.

Reviewer 3:

The reviewer believed that the resources appear to be sufficient for the proposed work.

Presentation Number: DORMA031
Presentation Title: Dynamic Skip Fire (DSF) on a Heavy-Duty Natural Gas Engine
Principal Investigator: Jay Shah (Cummins)

Presenter

Jay Shah, Cummins

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

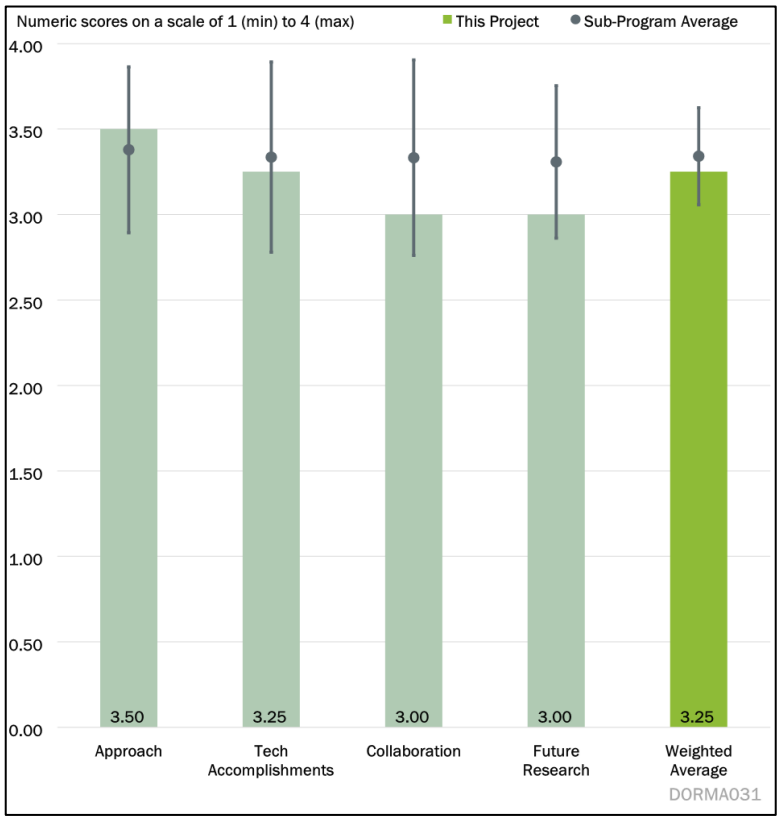

Figure 3-30 - Presentation Number: DORMA031 Presentation Title: Dynamic Skip Fire (DSF) on a Heavy-Duty Natural Gas Engine Principal Investigator: Jay Shah (Cummins)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that dynamic skip fire (DSF) is an effective approach to improving part-load efficiency, which is crucial for achieving near-diesel efficiency in natural gas (NG) engines. They also noted that the project is addressing the challenges related to developing a fully functioning DSF system with suitable emission controls and noise, vibration, and harshness considerations.

Reviewer 2:

The reviewer praised the project's organization and the distinct roles of each team member. The project involves applying a proven valve deactivation strategy used in smaller engines to a HD NG engine at Cummins. This adaptation requires hardware development, system modeling, integration, and calibration.

Reviewer 3:

The reviewer mentioned that many technical barriers related to implementing DSF have been addressed by developing an advanced NG engine platform with a different valve train design, making it more suitable for DSF implementation.

Reviewer 4:

At a high level, the approach is considered appropriately defined. The reviewer appreciated the incorporation of a workplan in the report. However, the reviewer expressed concerns about the project's timing, noting that it has already been extended by seven months since its initiation. The timeline and workplan appear to be behind schedule. The material required date for engine parts is expected in August 2023, which implies that

completing the engine build and rig testing by the end of Q3 2023 could be challenging. The reviewer recommended developing detailed plans to ensure alignment between engine dynamometer calibration and vehicle integration activities. Using start carts/rigs and hardware-in-the-loop testing to develop and validate DSF controls before engine dynamometer testing was also suggested.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer expressed that progress is evident in system simulation and the design and start of component build.

Reviewer 2:

The completion of all project milestones for budget period 1 was considered a success, and the involvement of Jacobs Vehicle Systems to help with CDA hardware design was noted as beneficial.

Reviewer 3:

The project was commended for addressing critical barriers related to transient air-fuel ratio control and oil consumption through design changes and improved control strategies. The reviewer was particularly impressed that the risk of oil consumption was mitigated by changes in piston ring design and recharge strategy. However, the results shared in the presentation did not provide substantial information about engine vibration characteristics. The reviewer expressed hope that future updates would shed more light on this aspect.

Reviewer 4:

The reviewer noted that, relative to 2022, progress in the project seems limited. They observed that several slides and results appeared to be a carryover from the previous year, which might contribute to the impression of slow progress. The reviewer suggested that including additional details from CDA hardware design, control development, and DSF simulations in future updates would aid in assessing project accomplishments.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer mentioned that the project team consists of pioneers and leaders in DSF and CDA, with complementary roles.

Reviewer 2:

The reviewer considered this to be a good teaming arrangement to achieve the project's technical goals. However, the reviewer expressed concerns about the absence of national laboratory and academic partners. They suggested that the lack of academic partners might limit the amount of information that the project could release to the public through journal publications and missed an opportunity to help develop the next generation of scientists and engineers in the field.

Reviewer 3:

The project's collaboration with Cummins was noted as excellent by the reviewer.

Reviewer 4:

The reviewer pointed out some concerns about the roles and contributions of specific project partners. For example, they mentioned that Tula Technology, responsible for DSF controls integration, and Jacobs Vehicle Systems, responsible for CDA and engine brake hardware design, lacked clear definitions of their current and future contributions. The reviewer suggested that, in future reviews, it might be beneficial to define the roles and responsibilities of all project partners in greater detail.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The project's plan to proceed through full engine tests and potentially chassis/vehicle tests was considered solid by the reviewer. However, there was some uncertainty during the presentation about the commercialization of DSF for NG engines. The reviewer hoped that the system could be proven to be robust and cost-effective for commercial NG engines, helping to close the efficiency gap with diesel engines.

Reviewer 2:

The research plan for the project was considered good and appeared to be sufficient to achieve the project's objectives. However, the reviewer expressed disappointment that there was not a production feasibility analysis included in the project to understand the additional cost of producing an engine with the Tula controlled dynamic CDA technology compared to the fuel economy benefit.

Reviewer 3:

The reviewer expressed interest in future results related to tailpipe-out NO_x during transient operation, pumping loss characteristics, and associated CO_2 benefits.

Reviewer 4:

The reviewer noted that while the next steps for the next year were clearly defined, the description of the tasks was somewhat limited. In particular, they suggested that the tasks for emissions calibration and validation could be better defined.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized that natural gas, especially in conjunction with renewable natural gas (RNG), serves as an effective CO_2 reduction pathway already widely implemented. Furthermore, they pointed out that improved engine efficiency achieved through this project offers the potential for additional carbon reduction and the expansion of RNG supply.

Reviewer 2:

In the reviewer's assessment, the project's primary objective is to enhance engine efficiency by utilizing natural gas as a lower-carbon alternative to traditional diesel fuel.

Reviewer 3:

The reviewer believed this approach aligns with DOE's objectives, which include reducing CO_2 emissions and promoting the use of domestic fuels for transportation.

Reviewer 4:

The reviewer also observed that the project is in harmony with DOE's overarching goal of enhancing vehicle efficiency and reducing GHG emissions through advancements in engine efficiency and the adoption of alternative and low-carbon fuels.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, the progress suggested that the resources are adequate so far.

Reviewer 2:

The reviewer said that the project resources appeared to be sufficient to achieve the objectives of the project.

Reviewer 3:

The reviewer believed that the funding is sufficient for the proposed work.

Presentation Number: DORMA032
Presentation Title: High Efficiency, Ultra Low Emissions Heavy-Duty 10L Natural Gas Engine Project
Principal Investigator: Tim Lutz (Cummins)

Presenter

Tim Lutz, Cummins

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

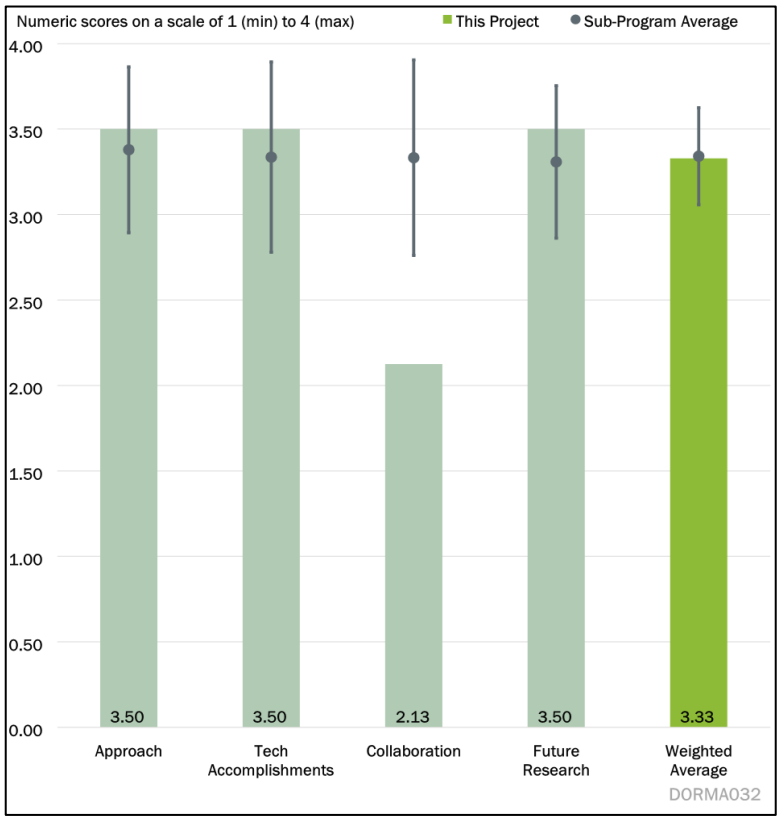

Figure 3-31 - Presentation Number: DORMA032 Presentation Title: High Efficiency, Ultra Low Emissions Heavy-Duty 10L Natural Gas Engine Project Principal Investigator: Tim Lutz (Cummins)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer found that the project was well-focused on improving engine efficiency, recognizing it as one of the key hindrances for expanded use of natural gas (NG) in freight trucks. The path to high efficiency appeared to be very solid, characterized by good engineering with moderate risk. Higher-risk technology breakthroughs or more stretching innovations, such as the advanced materials mentioned in the slides, were noted but lacked sufficient detail.

Reviewer 2:

The reviewer assessed the approach as sound and appropriate for development. The use of CFD and modeling as the initial step was acknowledged as an industry standard and a commendable approach before proceeding to test a metal engine.

Reviewer 3:

The reviewer observed that the project was well-organized and aimed at developing and implementing next-generation technologies for natural gas in large engines. The approach involved analyzing various known available technologies demonstrated to increase efficiency and reduce emissions in other applications. The reviewer also noted the use of a modeling approach to determine an experimental platform for testing. The main criticism highlighted was related to the analysis, which indicated that EGR might not be necessary to meet efficiency targets, but there was a significant amount of uncertainty regarding the modeling results, particularly in exhaust temperature predictions and knock prediction. The reviewer understood the hesitation

towards EGR due to its potential design compromises in terms of durability, transients, and air handling. However, the reviewer expressed the view that ruling out EGR based on modeling results appeared to be a missed opportunity. At the very least, having the option to use EGR in the first generation of hardware could have helped reduce uncertainty and enhance design tools for future applications. The reviewer also suggested that providing a more detailed description of the baseline technology in terms of efficiency and compression ratio relative to the engine being developed would have been beneficial.

Reviewer 4:

The reviewer pointed out one of the primary issues with stoichiometric NG engines, which is maintaining flame speed at low loads and managing exhaust temperatures at high loads. The proposed approach of using a pent-roof head for tumble while minimizing swirl was seen as a potential solution to improve NG combustion speed and mitigate knock. The switchable Miller late intake valve closing approach was expected to aid in increasing temperatures at low load, thus enhancing the effectiveness of the three-way catalyst under low load conditions. The reviewer acknowledged some uncertainty in the model predictions, particularly in temperature and the necessity of EGR and manifold cooling. Additionally, there was some uncertainty regarding knock prediction.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the project, in its relatively early stage, is on a solid path, utilizing modeling and simulation to guide engine improvements and transition towards hardware development. The reviewer expressed a need for more detailed information regarding the contributions of materials to the project's advancements. Furthermore, the reviewer observed a lack of comparison and benchmarking against existing technology and efficiency in the presentation, suggesting that incorporating public data from previous Cummins engines and competitor data would provide a clearer assessment of progress.

Reviewer 2:

In the reviewer's evaluation, the project was found to be on track. The principal investigator acknowledged the challenge of predicting knock, and the reviewer recommended additional work to refine exhaust temperatures before proceeding to engine testing.

Reviewer 3:

The reviewer commended the good progress achieved at this early stage of the project. The modeling results had effectively guided design decisions for the first generation of hardware.

Reviewer 4:

The reviewer, considering the project's first year, found the progress to be promising. The reviewer noted that the project had established the design landscape and defined the overall approach, with simulation work completed and predictions aligning with the project's target goals.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The absence of formal partners within the team was noted by the reviewer.

Reviewer 2:

In the reviewer's assessment, all project work is conducted exclusively within Cummins, making it appropriate to include a "N/A" option for this section due to the singular entity involved. The reviewer emphasized that the

internal teams within Cummins appear to be collaborating effectively and expressed a reluctance to assign a low rating solely due to the lack of external partners.

Reviewer 3:

The reviewer observed a lack of collaboration within the project, as Cummins stands as the sole participant. While recognizing that Cummins may possess the technical capabilities required to achieve the project goals independently, the reviewer stressed the potential benefits of including academic partners or national laboratories. Such partnerships would enhance the likelihood of disseminating technology development through journal or conference papers, thereby contributing to the public domain. Additionally, partnering with universities could provide funding for training the next generation of scientists and engineers in the field.

Reviewer 4:

The reviewer acknowledged the challenge of rating this criterion, given the absence of external partners in the project. Cummins remains the sole participant. The reviewer suggested that coordinating work with a university and/or a national laboratory, or even involving a supplier, could have been beneficial. This, in the reviewer's opinion, might have provided Cummins with an opportunity to leverage their ongoing collaborations with universities and national laboratories to investigate fundamental issues related to NG engine knock, thereby helping validate simulation models.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the description of the path to project completion and success is clear and comprehensive, with an understanding of the associated uncertainties and challenges.

Reviewer 2:

The reviewer acknowledged that the project had correctly identified the engine testing requirements. However, the reviewer suggested that including additional work on the total cost of ownership and conducting a life-cycle analysis would be a valuable addition.

Reviewer 3:

The proposed future work aligns with the well-organized approach outlined in the project, including a demonstration of the first engine's performance. The reviewer viewed the absence of cooled EGR capabilities in the engine's design as a missed opportunity, given the significant uncertainties in exhaust temperature and knock modeling. The reviewer noted that incorporating cooled EGR into the engine's design could have provided valuable performance metrics and informed modeling approaches to reduce modeling uncertainty.

Reviewer 4:

The reviewer commended the decision to build and test an engine as a means of validating the extensive simulation work conducted thus far. However, a slight drawback mentioned by the reviewer was the inability to modify Engine #1 for EGR if it were to become necessary. The reviewer highlighted the potential issue of being unable to rectify any errors if the initial prediction that "no EGR is needed" turns out to be incorrect until the construction of Engine #2.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer said that the utilization of NG, particularly RNG, represents a clear and feasible approach to reducing CO_2 emissions in this sector. The reviewer remarked that these fuels are cost-competitive but could benefit from enhanced engine efficiency, a fact well-documented by DOE and the industry. According to the

reviewer, the project's path is highly relevant to national energy security and promoting affordable freight movement.

Reviewer 2:

The reviewer expressed the view that diesel engines are expected to remain in use for the foreseeable future, making it imperative to focus on decarbonizing them rather than neglecting the issue.

Reviewer 3:

The reviewer affirmed that the project aligns with program goals, particularly the objective of increasing engine efficiency and transitioning towards lower carbon fuels while maintaining or improving emissions performance.

Reviewer 4:

The reviewer observed that this project supports DORMA by offering a pathway to enhance the efficiency and emissions performance of NG HD engines. The reviewer articulated that in sectors where electrification is challenging, NG engines are seen as a viable means for decarbonization and improving air quality. Additionally, the reviewer pointed out that if RNG becomes more readily available at scale, there could be added benefits to this approach.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the project funding appears adequate and is a suitable investment by DOE and Cummins cost-share.

Reviewer 2:

The reviewer pointed out that DOE should allocate more resources to the hard-to-decarbonize sectors and ICE technology. The reviewer expressed the belief that the idea of electrifying everything is not entirely true, and the timeline for such a transition is too distant. The reviewer stressed the continued need for ICE technology. In the reviewer's opinion, it is better to focus on projects like this one that seek ways to lower the GHG emissions of ICE technology rather than ignoring it and relying solely on electrification for all applications.

Reviewer 3:

The reviewer remarked that the resources for the project appear to be sufficient, as most of the project milestones are on track.

Reviewer 4:

The reviewer also stated that the resources seem adequate to achieve the goals of this project. The reviewer acknowledged that Cummins already possesses an internal infrastructure for designing and building NG engines. According to the reviewer, this project pushes Cummins out of its comfort zone somewhat, particularly with elements like the pent roof head and switchable Miller late intake valve closing. The reviewer noted that resources would be allocated to these innovative aspects. Overall, the reviewer saw this as a beneficial combination of exploring new ideas while building upon existing experience and capacity.

Presentation Number: DORMA033
Presentation Title: High Pressure Fast Response Direct Injection System for Liquified Gas Fuels Use in Light-Duty Engines
Principal Investigator: William de Ojeda (WM International Engineering)

Presenter

William de Ojeda, WM International Engineering

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

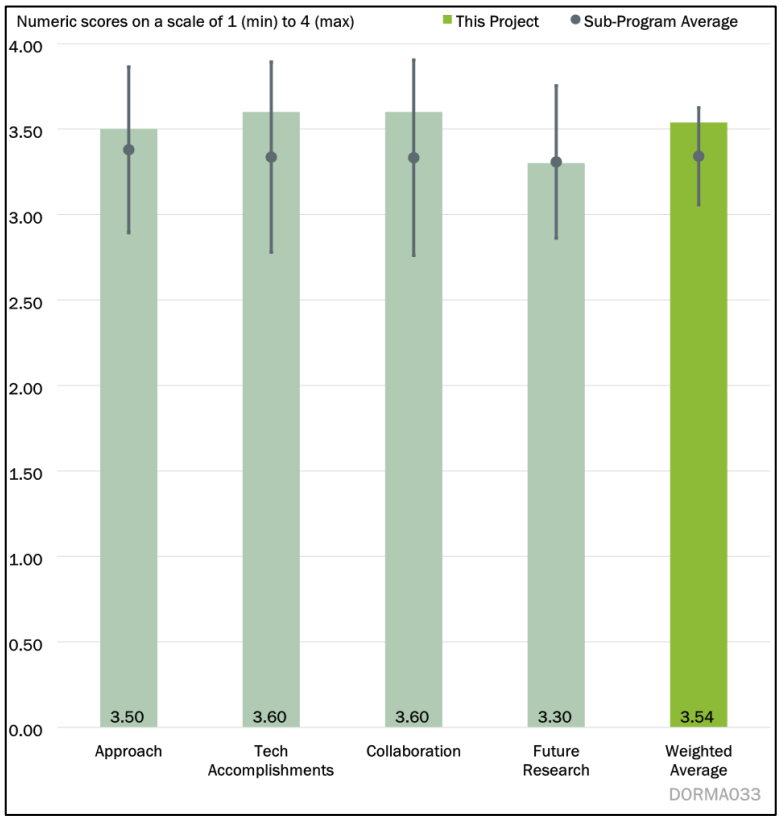

Figure 3-32 - Presentation Number: DORMA033 Presentation Title: High Pressure Fast Response Direct Injection System for Liquified Gas Fuels Use in Light-Duty Engines Principal Investigator: William de Ojeda (WM International Engineering)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer noted that the project's targets are very specific and clear. Detailed barriers are presented, and the overall approach is considered sound. However, the reviewer questioned the overall impact of this fuel strategy in achieving lower CO_2 emissions in light-duty vehicles (LDVs). Since this is the first year of review for the project, the reviewer recommended providing some background and explanation of the overall strategy for CO_2 reduction. The reviewer suggested discussing whether this strategy is relevant for the U.S. market or the European Union, where compression ignition LDVs are more prevalent. The reviewer also pointed out the existence of prior literature on this approach and recommended that the presentation at least mention some of those efforts.

Reviewer 2:

The reviewer assessed the approach being taken to address the challenges with a liquefied gaseous fuel, noting its strengths and weaknesses. The reviewer considered the fuel system design as the strongest element of the approach, with the team making excellent progress in the areas of pumping, fuel injection, and control systems. However, the reviewer expressed some skepticism about the approach of mixing propane and DME, as these fuels have distinct ignition characteristics. The reviewer found the motivation behind this strategy to be lacking clarity and suggested a more comprehensive explanation of the rationale for this choice.

Reviewer 3:

The reviewer found that the project is well-designed to address key barriers related to injector wear, performance comparison to diesel injectors, and unstable combustion. The development of the injector test rig was identified as an important project update for the first budget period.

Reviewer 4:

The reviewer noted that the technical approach for the project is well defined and meticulously tracked. The reviewer appreciated the clear identification of technical barriers and the well-defined project tasks to address these barriers. The reviewer highlighted the clarity of the description of the overall approach, indicating that the project team has a good understanding of system-level interactions between different components and sub-systems, including the fuel system, combustion strategies, control requirements, and engine/vehicle functional objectives. The reviewer acknowledged that tasks have been designed to address relevant technical challenges, and the responsibilities of the project partners are clearly defined for both testing and modeling efforts.

Reviewer 5:

The reviewer commended the project team for thoroughly exploring both the combustion process and fuel injection system behavior in liquefied gas engines. The approach was seen as sound, given the interrelated nature of these aspects. The reviewer also noted that the project was well presented, and the challenges and barriers were very well explained.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The project has made good progress on developing models and the build-up of the experimental system, including the fuel pump, among other components.

Reviewer 2:

The reviewer noted that the project is making good progress in developing a pumping and fuel delivery system compatible with liquefied gases, specifically propane and DME. The project team has successfully identified and addressed several key barriers, including maintaining the fuel in a liquid form during the pumping process. They have also identified additional barriers related to controlling the rail pressure with a compressible fuel.

Reviewer 3:

During budget period 1, the project accomplished a significant number of activities. The simulations developed appear to align well with test data, defining the engine requirements for developing an injector system and high-pressure fuel pump. The reviewer raised two questions for the authors: (1) Could they comment on how they plan to address the fuel lubricity issue related to propane-DME? (2) Will future work focus on any injector seat deterioration, which could lead to incomplete sealing of the injector tip after injection stops?

Reviewer 4:

The project team has simultaneously completed multiple workstreams, including fuel system modeling, fuel bench commissioning, fuel injector and fuel pump design and testing, spray testing, and vehicle drive cycle simulations to estimate CO_2 emissions. The reviewer commended the impressive progress made by the project team and expressed confidence that the project appears to be on track. The reviewer encouraged the project team to distinguish between the benefits derived from improved engine efficiency and fuel composition when presenting drive cycle fuel economy/GHG results. Additionally, the reviewer raised questions regarding the substantial (about 3%) brake thermal efficiency (BTE) benefit observed when using a DME and propane fuel mixture relative to diesel. The reviewer sought additional data to support these BTE improvement projections.

Reviewer 5:

The reviewer highlighted important observations made in the application challenges of lubricity agents and design requirements for the fuel injection system. The observation that relying on inlet metering can help with temperature control in liquefied gas fuel was considered an essential insight.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer noted that team member contributions are clearly explained and establish all the key disciplines.

Reviewer 2:

The reviewer said that the project team appears to be well-organized, with each member having a well-defined role. The team includes participants from a national laboratory, academia, and two industrial partners. However, the reviewer mentioned that the industrial partners do not include a large OEM capable of credibly commercializing this technology. Consequently, the commercialization path seems to involve developing and demonstrating the technology, with the intent to seek a commercialization partner in the future.

Reviewer 3:

The reviewer noted that the project, in collaboration with a university and a national laboratory, has demonstrated very effective collaborative research work. The resources from the various partners have been utilized successfully.

Reviewer 4:

The reviewer observed that the roles and deliverables of the multiple project partners (WM International, Argonne National Laboratory, Illinois Tech, Diversified CPC International, OEM) are clearly defined. The timely completion of all BP 1 tasks indicates very good collaboration across the project team.

Reviewer 5:

The reviewer highlighted that the partnership is broad and comprehensive, providing the necessary skills and connections to increase the likelihood of an overall successful outcome.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The project plan was acknowledged by the reviewer as covering the necessary steps to validate a method and hardware for a propane-DME compression ignition experimental engine.

Reviewer 2:

The proposed future work was described as well-organized and clear. The reviewer expressed interest in seeing the results of future engine tests.

Reviewer 3:

The reviewer expressed curiosity about the potential translation of the impressive injector spray work to in-cylinder combustion and suggested that engine test data from future work would be interesting to observe.

Reviewer 4:

The reviewer found that the next steps, particularly for the next year, are clearly defined. The tasks for BP 2 were considered well-defined and planned. Given that one of the project's deliverables is to improve emissions capability from ultra-low emissions vehicle (ULEV) 50 to ULEV 30, the reviewer encouraged the project team to clearly define the calibration and validation plan for emissions compliance.

Reviewer 5:

The reviewer concluded that the plans for BP 2 are appropriate and are expected to yield valuable outcomes. The plan was commended for its clear explanation and presentation.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer expressed the need for further explanation of the project's relevance to the VTO mainstream objectives, which include reducing CO_2 emissions and improving mobility. The reviewer suggested providing benchmarks against other fuels and inquired if the applicability to medium- and HD vehicles might be greater.

Reviewer 2:

The reviewer acknowledged that the project could be viewed as relevant but also considered an alternative viewpoint. The reviewer highlighted the relevance of developing new fuel system technologies for liquefied gaseous fuels while expressing reservations about the mixing of propane and DME and the lifecycle analysis portion of the work. The reviewer questioned the use of renewable fuels to offset CO_2 emissions, emphasizing that U.S. CO_2 emission targets are measured at the tailpipe. The reviewer suggested a more straightforward approach to evaluating tailpipe CO_2 emissions against targets.

Reviewer 3:

The reviewer found the project highly relevant to improving the state of the art in propane-fueled engines. The development of high-pressure direct fuel injection was seen as the next step to maximize the benefits of propane as an automotive fuel, particularly for certain applications.

Reviewer 4:

The reviewer stated that the project was viewed as aligned with DOE's goal of enhancing engine efficiency and utilizing alternative/low carbon fuels to improve vehicle efficiency and reduce GHG emissions.

Reviewer 5:

The reviewer noted that liquefied gaseous fuels have significant potential to provide low GHG emissions. The work was deemed valuable in advancing the field and the technologies available to consumers.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources appear adequate for objectives. It is recommended to indicate which of team are receiving DOE funding.

Reviewer 2:

The reviewer noted that the project resources seem sufficient.

Reviewer 3:

The reviewer said the funding is sufficient for the proposed work.

Reviewer 4:

The reviewer stated that the resources are appropriate for a project with this technical scope.

Presentation Number: DORMA034
Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications
Principal Investigator: Qigui Wang (General Motors)

Presenter

Qigui Wang, General Motors

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

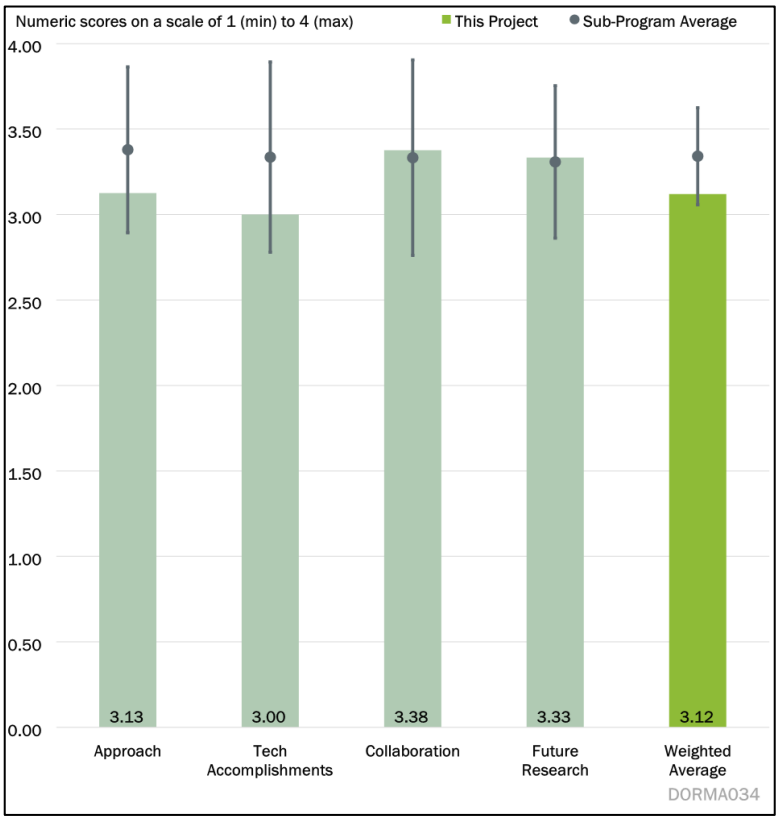

Figure 3-33 - Presentation Number: DORMA034 Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications Principal Investigator: Qigui Wang (General Motors)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer remarked that upon reviewing the response to the reviewer comments from the previous year, it is evident that the comments made this year closely mirror those of the past. The actual fuel economy gains, as seen on Slide 8, are notably less than the originally predicted figures, and achieving successful project completion appears even more challenging at this stage.

Reviewer 2:

The reviewer expressed that the approach employed in the project is technically solid but leans towards the conservative side. The reviewer suggested that more attention could be directed towards exploring the air handling system with variable breathing in greater depth.

Reviewer 3:

The reviewer observed a logical and comprehensive approach presented in the project.

Reviewer 4:

The reviewer affirmed that, in their opinion, the overall approach is commendable. It commenced with simulations, progressed to engine development and testing, and is now entering the phase of fabrication and performance verification. However, the reviewer proposed that the project would benefit from concluding with vehicle testing.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer stated that given the state of project completeness, with an anticipated end date in March 2024 and approximately 9 months remaining, the accomplishments are considered fair. While some improvements have been achieved, the actual outcomes fall significantly short of the initial goals, and the principal investigators convey a sense of contentment with the current state.

Reviewer 2:

The reviewer observed that it is evident that a substantial gap still exists between the simulations and the testing results, as illustrated in Slide 8.

Reviewer 3:

The reviewer praised the technical accomplishments, highlighting that the only concern in the materials segment of the project, as indicated in the question and answer, is the variability in additive manufacturing.

Reviewer 4:

The reviewer commented that the project has incorporated various advanced combustion technologies, including higher compression ratios, increased EGR, and full CDA, among others. The project outlines a clear pathway toward achieving an overall engine mass reduction of more than 15%, with some of the reductions achieved through material changes such as transitioning from cast iron to aluminum. Notably, the inclusion of additively manufactured pistons is a valuable contribution. The reviewer affirmed that the quantification of actual fuel economy benefits and the comparison with simulations, which are not always provided, is appreciated. This comparison is deemed essential for identifying further opportunities for improvement, both on the hardware and simulation fronts.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer affirmed the presence of clearly defined roles for all collaborators.

Reviewer 2:

The reviewer remarked that it appears that all partners are actively engaged and fulfill their designated roles in the project.

Reviewer 3:

The reviewer commented that while the roles of the collaborators were well described on Slide 16, it would be beneficial if individual contributions were prominently highlighted on the technical accomplishment slides as well. The reviewer noted that the proposed future work effectively outlines this aspect.

Reviewer 4:

The reviewer observed that collaboration across partners seems to be functioning effectively, although assessing the exact level of contributions from other partners proves challenging.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed that, at this point, the project has all but ended. There were no plans presented to get this project back on track to deliver at the promised levels of light-weighting and efficiency.

Reviewer 2:

The reviewer noted that the future research includes detailed steps to achieve the project goals.

Reviewer 3:

The reviewer articulated that the layout is nicely done and provides good detail about the contributors involved.

Reviewer 4:

The reviewer suggested that, apart from completing the fuel economy assessment, it would be beneficial to quantify the emissions from the engine. Additionally, it might be useful to revisit and investigate the discrepancy between simulations and measured fuel economy improvements. Regarding CDA, the reviewer proposed that it would be valuable to showcase the improvements at various operating conditions, such as higher improvements at low loads.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer affirmed that the goal of the project is relevant to VTO goals.

Reviewer 2:

The reviewer observed that reducing both fuel consumption and weight would unquestionably support the overarching VTO program objectives.

Reviewer 3:

The reviewer commented that the project's objectives of reducing energy usage, CO_2 emissions, and increasing energy security align well with the program's overarching objectives.

Reviewer 4:

The reviewer emphasized that the project's aim to reduce fuel consumption is a pivotal focus of the contemporary transport industry.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer expressed that the amount of money spent on this project is substantial, given the relatively modest results achieved. This project unfavorably compares to the Ford project with similar objectives.

Reviewer 2:

The reviewer remarked that it appears the project is adequately funded to achieve its stated goals.

Reviewer 3:

The reviewer commented that, as one of the larger projects, the level of funding allocated seems appropriate, considering the project's expansive scope and ambitious goals.

Reviewer 4:

The reviewer observed that the project is progressing on track for completion with its existing resources, indicating that the resources are sufficient.

Presentation Number: DORMA035
Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development
Principal Investigator: Michael Shelby (Ford)

Presenter

Michael Shelby, Ford

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

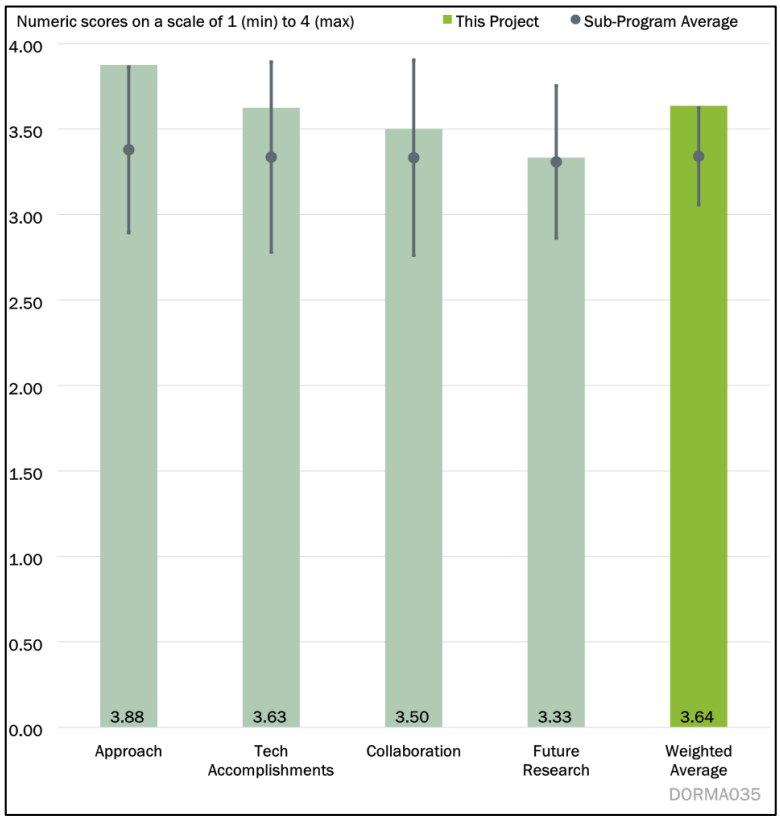

Figure 3-34 - Presentation Number: DORMA035 Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development Principal Investigator: Michael Shelby (Ford)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer praised the project for its intelligent and well-integrated approach, utilizing advanced analytical tools and conducting dynamometer testing on both single-cylinder and multi-cylinder engines and models. This approach aims to design and construct a lightweight engine with improved fuel economy to reduce the CO_2 emissions of the largest volume engine in the Ford fleet.

Reviewer 2:

The reviewer commented that the approach taken is comprehensive, which should significantly contribute to the project's ability to achieve its goals.

Reviewer 3:

The reviewer affirmed that this project is thoughtfully designed and explores a broad spectrum of reasonably known technologies available for enhancing efficiency and reducing weight.

Reviewer 4:

The reviewer observed that the project is nearing completion and has been executed effectively. All barriers were identified, and work was carried out at various levels, encompassing modeling, single-cylinder and multi-cylinder engine testing, and dynamometer studies.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that technical accomplishments to date are substantial. Single-cylinder and multi-cylinder engines, along with their support systems, have been successfully designed and tested. Moreover, the majority of final vehicle testing has been completed.

Reviewer 2:

The reviewer acknowledged that the project has made remarkable progress in both fuel consumption and weight reduction. Nevertheless, the delay in the final engine delivery is concerning in terms of the overall project timeline.

Reviewer 3:

The reviewer emphasized that the project has effectively met or exceeded all of its goals, with only minor tradeoffs.

Reviewer 4:

The reviewer stated that the two multi-cylinder engines have been constructed, implementing a range of engine enhancements, such as increased compression ratio, pre-chamber ignition, higher EGR, and continuously variable valve timing, among others. Substantial weight reduction efforts have been undertaken for various engine components. The project has outlined a feasible pathway to achieving a 15% reduction in engine weight. Although the improvements in fuel economy have been targeted, they are yet to be quantified in the final demonstration. The reviewer commended the inclusion of criteria pollutant emissions reduction and the expectation of early three-way catalyst light-off.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer articulated that the response to previous review comments effectively clarified participant roles and collaborative efforts.

Reviewer 2:

The reviewer observed that it appears that all partners actively fulfill their designated roles in supporting the project.

Reviewer 3:

The reviewer noted that while there are not many partners, notably, this team lacks a university partner.

Reviewer 4:

The reviewer praised the effective collaboration with various project partners in ensuring that the project proceeded mostly on time, albeit with some delays. The principal investigator made a comment that underscored the substantial contributions of all partners leveraging their respective strengths.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer stated that the project is scheduled to conclude in the third quarter of this year, with only the end-of-project work remaining.

Reviewer 2:

The reviewer commented that the future research plans encompass all the essential steps required to attain the final project goals.

Reviewer 3:

The reviewer noted that future work has been identified to progress towards the project's conclusion later this year.

Reviewer 4:

The reviewer mentioned that as the project is nearing completion, there is not much left to address in terms of future work. However, it could have been advantageous to consider hybridization as part of the project's scope.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer expressed that the project clearly supports the development of energy-efficient mobility systems.

Reviewer 2:

The reviewer remarked that reducing both fuel consumption and weight would undeniably contribute to the overarching goals of the VTO program.

Reviewer 3:

The reviewer commented that the efforts to improve efficiency and reduce vehicle weight align well with the objectives of DOE VTO.

Reviewer 4:

The reviewer emphasized that reducing fuel consumption is a pivotal requirement for addressing transportation costs and reducing GHG emissions.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the project is nearly complete and has remained on budget.

Reviewer 2:

The reviewer expressed confidence that the project should possess adequate funding to achieve its project goals, particularly with the additional 9-month extension.

Reviewer 3:

The reviewer affirmed that the significant DOE funding and the scale of the project are justified by the challenging and ambitious objectives set. The funding level is regarded as appropriate given the complexity of the project.

Reviewer 4:

The reviewer observed that it appears the resources allocated to the project have been sufficient, allowing the work to progress nearly on schedule.

Presentation Number: DORMA036
Presentation Title: SuperTruck 2 – PACCAR
Principal Investigator: Maarten Meijer (PACCAR)

Presenter

Maarten Meijer, PACCAR

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

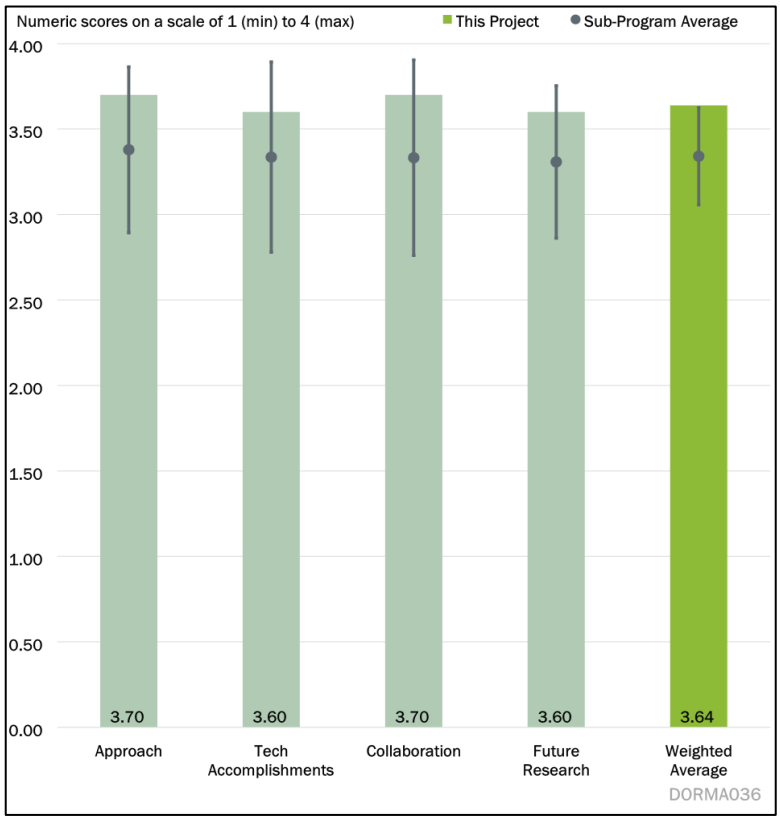

Figure 3-35 - Presentation Number: DORMA036 Presentation Title: SuperTruck 2 – PACCAR Principal Investigator: Maarten Meijer (PACCAR)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer stated that the project is nearly complete and has successfully achieved the expected targets, resulting in substantial learning and knowledge that will benefit freight efficiency. For future endeavors with similar objectives, it is recommended that low-carbon fuels be considered as part of the solution for freight CO_2 reduction targets.

Reviewer 2:

The reviewer pointed out that the goals of this project are highly ambitious, with a target of achieving a 120% improvement in efficiency compared to a 2009 baseline. This improvement is to be achieved while maintaining a BTE of better than 55% and using technology with a 3-year payback period. The approach to achieve these objectives encompasses a blend of engine, hybrid, lightweighting, and aerodynamic technologies, leaving no stone unturned in the quest to reach this goal.

Reviewer 3:

The reviewer commended the comprehensive approach taken, which represents the state of the art in all advanced technology domains. However, the reviewer noted a drawback related to the use of Cummins' waste heat recovery (WHR) technology, which could potentially create conflicts of interest and be considered unfair to its competitors.

Reviewer 4:

The reviewer highlighted that the project has successfully addressed barriers in order to meet its objectives, demonstrating a successful approach.

Reviewer 5:

The reviewer noted that the project team has systematically and holistically explored numerous avenues for improving engine and vehicle-level efficiencies. This exploration included testing several new or advanced components related to engine and powertrain, weight reduction, drag reduction, trailer architecture, aerodynamics, and more.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the WHR technology used in the project was somewhat borrowed from Cummins. However, it was constructive to conclude that this specific form of WHR is not cost/weight competitive for the efficiency benefits it offers.

Reviewer 2:

The reviewer observed that the major tasks of completing the truck build and executing the demonstration are yet to be completed.

Reviewer 3:

The reviewer suggested that the project's accomplishments could have been outstanding if it had not used a competitor's WHR technology, as this could create an unfair playing field in the market. Many of PACCAR's competitors have invested significant resources in developing their own WHR systems, making it essential to uphold fairness and competitiveness.

Reviewer 4:

The reviewer highlighted that the final truck build and the payback demonstration are the only remaining tasks, describing the project as great.

Reviewer 5:

The reviewer detailed the project's investigation of various key aspects of engine and vehicle technologies to achieve BTE and freight efficiency goals. These aspects included engine efficiency improvements to meet the project target, the development and implementation of new technologies like long stroke engines, two-stage charging, and a 48V EGR pump. The project also involved testing a WHR system, 48V hybridization, achieving ultra-low NO_x compliance with close-coupled SCR, a gasoline compression ignition engine, weight reduction by 30% in chassis and suspension, and the use of low rolling resistance tires, among other measures. The overall improvements in powertrain efficiency, weight reduction, and aerodynamic drag reduction were deemed very impressive, with an overall freight efficiency improvement of approximately 150%.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commended the team for its excellent performance and collaboration.

Reviewer 2:

The reviewer acknowledged the strength of the team but noted that partner roles are not obvious or clearly defined.

Reviewer 3:

The reviewer observed that the team fully utilizes the strengths of all partners.

Reviewer 4:

The reviewer pointed out that Slide 20 provides a clear and helpful summary of the partners and their roles. In future projects, it would be beneficial to identify the collaborators' contributions on the technical accomplishment slides as well.

Reviewer 5:

The reviewer concluded that the overall collaboration is excellent, with advanced components provided by partners on the team.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer mentioned that the project is nearly finished, with clear plans for on-road vehicle studies.

Reviewer 2:

The reviewer noted that there is a clear pathway to successfully complete the project ahead.

Reviewer 3:

The reviewer expressed that the future work is well-defined and aligns with the direction needed to achieve all the project goals.

Reviewer 4:

The reviewer emphasized that the project is in the final stages of completion at the end of the calendar year, and the proposed future work is instrumental in helping the team cross the finish line.

Reviewer 5:

The reviewer pointed out that a few remaining tasks have been identified, which are in line with what is typically expected in the final months of the project. These tasks include completing the vehicle build and demonstrating its performance on the road. Additionally, it is important to present the payback period calculations.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that many findings and developments from the project are expected to have a significant impact on improving freight movement.

Reviewer 2:

The reviewer affirmed that the SuperTruck projects are directly relevant to the objectives of the VTO.

Reviewer 3:

The reviewer stated that the achievement of the engine and vehicle performance goals effectively supports the overall objectives of the DOE program.

Reviewer 4:

The reviewer emphasized that the project's major objectives are well-aligned with the DOE VTO objectives. These objectives include a 120% improvement in freight efficiency relative to a 2009 baseline, achieving a BTE of at least 55%, and ensuring a 3-year payback period on developed technologies.

Reviewer 5:

The reviewer highlighted that reducing fuel consumption is a critical need in the transportation sector, and this project effectively addresses that need.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that the project appears capable of reaching completion within the planned budget.

Reviewer 2:

The reviewer noted that the resources appear to be sufficient for the project's needs.

Reviewer 3:

The reviewer expressed confidence that the remaining funding should be adequate to successfully complete the project.

Reviewer 4:

The reviewer commented that the funding levels for the SuperTruck project are notably high, but the extensive work required for technology integration and building demonstrator trucks justifies the higher costs.

Reviewer 5:

The reviewer concluded that the project is nearing successful completion, indicating that the resources allocated were indeed sufficient.

Presentation Number: DORMA037
Presentation Title: SAF Specifications and Testing Protocols
Principal Investigator: Gina Fioroni (National Renewable Energy Laboratory)

Presenter

Gina Fioroni, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

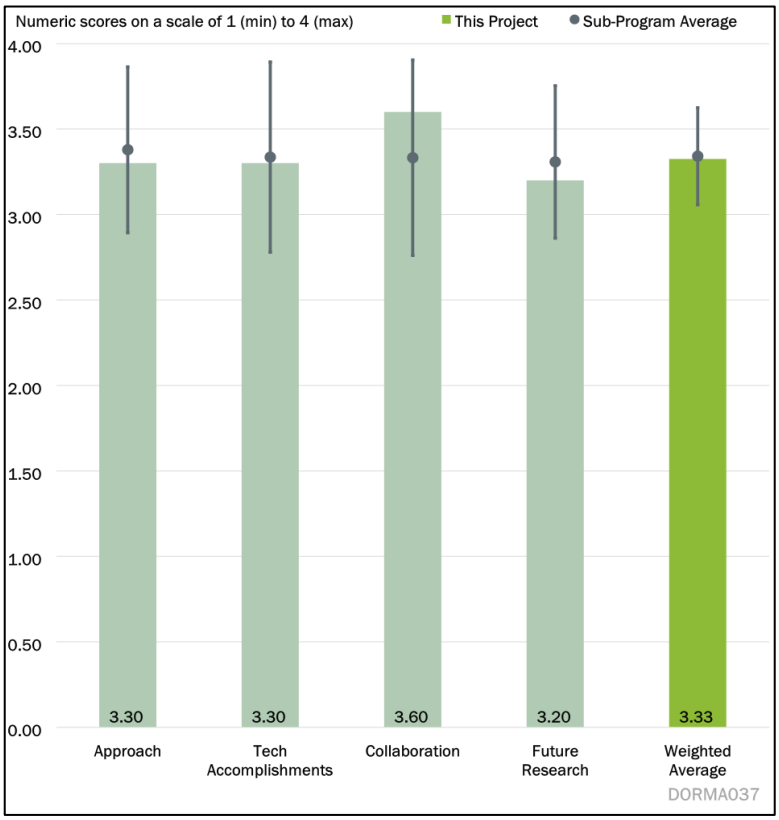

Figure 3-36 - Presentation Number: DORMA037 Presentation Title: SAF Specifications and Testing Protocols Principal Investigator: Gina Fioroni (National Renewable Energy Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The reviewer suggested that as the team makes progress in their NASA and OEM geometry validations, they should work closely with the industry to refine industry-scale codes and design tools, allowing for further model improvements and optimization.

Reviewer 2:

The reviewer recommended that the project, while studying the properties of liquid fuels over a wide range of temperature and pressure conditions, should focus on specific properties and/or conditions that have a significant impact on combustor operability or emissions.

Reviewer 3:

The reviewer acknowledged that the project had many aspects, leading to the identification of numerous barriers that will evolve as the work progresses. Despite this complexity, the reviewer recognized the team's excellent work in resolving expected barriers. They noted the project's emphasis on improved test methods for measuring fuel properties, pathways for utilizing 100% SAF in aircraft, examination of new fuels and components, and new fuel property measurements at extreme conditions. The reviewer also indicated that the future work section should provide additional insights into how identified barriers may be refined and focused.

Reviewer 4:

The reviewer described the focus of efforts in the NREL program, emphasizing measurements of SAF properties and exascale calculations of SAF sprays and combustion processes at relevant conditions.

Reviewer 5:

The reviewer provided an overview of the project's goals, which involve developing a SAF with the aim of achieving a 100% substitution for Jet A. They mentioned the focus on building a database of properties for Jet A and "emerging" SAFs, as well as experiments on combustors with varying complexities for comparison. The reviewer noted the challenge in connecting the results from basic burners to turbine performance metrics and recommended clarification in this regard. Additional comments included the importance of sharing results with the ASTM Committee D02, Subcommittee D02.J0.06 on Synthetic Aviation Turbine Fuels (SATF). The reviewer expressed some confusion about which SAF is being considered as a 100% replacement for Jet A and requested clarification on SAF types mentioned. The reviewer also suggested discussing the expectations of SAF costs, as high costs could impact airline ticket prices and the global economy.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer noted that the team has established good fuel characterization capabilities and identified reference validation cases of technical relevance.

Reviewer 2:

The reviewer pointed out that while properties beyond viscosity may have been measured over a wide range of temperatures, the project is purchasing new equipment for large temperature-pressure ranges for density, viscosity, and surface tension, as well as a thermal stability rig. The reviewer recommended checking for similar or complementary thermal stability measurements at Air Force Research Laboratory or University of Dayton Research Institute.

Reviewer 3:

The reviewer acknowledged that the project team has identified new experimental facilities that can expand the range of known property data for fuels. This expansion was illustrated through viscosity data, while new datasets for density and surface tension were mentioned. The reviewer suggested that in future works, uncertainties in the new datasets should be included or referenced. The project also examined new fuel components, such as dimethyl-cyclooctane, and produced new property data that showcased positive attributes compared to conventional jet fuel. The project engaged in new simulations using PeleLM, enabled by exascale computing, on a lean direct injector (LDI) design combustor, which was not considered under the National Jet Fuel Combustion Program. The reviewer recognized the importance of addressing different combustor designs and operating conditions, considering that different engine configurations and conditions may exhibit varying sensitivities to fuel properties. The reviewer concluded that, based on the progress to date, it is reasonable to expect the completion of the FY 2023 Q4 milestones as stated in the presentation.

Reviewer 4:

The reviewer acknowledged the good progress made by the National Renewable Energy Laboratory team in both measuring SAF properties and advancing exascale simulation efforts. The reviewer emphasized the importance of measurements on SAF properties, particularly for low-temperature surface tension and density data and viscosity data for SAF/conventional fuel blends. The reviewer also raised questions about the volume and yield of synthesized SAFs, cost estimates, and purity levels. Additionally, the reviewer inquired about the focus of spray studies and the differences from ground transportation systems.

Reviewer 5:

The reviewer noted some uncertainties and aspects requiring clarification, such as the specific SAF or SAF blend being simulated in temperature-pressure variations, the quantitative connection between surface tension and engine efficiency, the accuracy of surface tension measurements at elevated temperatures, the use of surrogates for SAFs, the lack of effort in determining gas phase property data, and the need for developing new data at extreme conditions for accurate simulations. The reviewer highlighted that the work plan should address these considerations more explicitly.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer commended the team for being well-coordinated and establishing excellent collaboration across multiple research entities.

Reviewer 2:

The reviewer noted that the collaboration efforts are directly contributing to the project's goals. Collaborations include testing of combustors with various fuels at GE or Georgia Tech (under Federal Aviation Administration (FAA) Aviation Sustainability Center and NASA University Leadership Initiative, utilization of existing data from NASA Glenn, provision of kinetics and property routines for high-fidelity simulations by Lawrence Livermore National Laboratory and Argonne National Laboratory, and property measurements collaboration with the Bioenergy Technologies Office. New fuels are provided by the Navy, and there is a collaboration with Washington State University for ignition delay, though the exact nature of that collaboration was not entirely clear.

Reviewer 3:

The reviewer acknowledged the superb composition of the broader team, which covers a wide range of expertise and talent needed to address the project's requirements. Collaboration was highlighted as key to the project's success, given the diverse sources of funding from the FAA, NASA, Navy, and various DOE laboratories, involving government entities, universities, and an engine OEM. The coordination and interaction between Georgia Tech/GE and DOE were identified as critical for the project, as modelers require precise hardware and operational details, test methods, diagnostic sensitivity, and data interpretation. The reviewer pointed out that while experimental work was not yet complete, modeling results had already been generated, providing pre-test predictions in advance of the experiments. The reviewer expected that very useful data would be obtained to validate the computational model.

Reviewer 4:

The reviewer commended the team for its excellent efforts in establishing relevant external collaborations.

Reviewer 5:

The reviewer assessed the project team as excellent, encompassing groups with expertise in various elements, including single burning studies, kinetic modeling, SAF property determination, ignition delay studies, and fuel properties. However, there were concerns about how these components were coordinated within the project.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer raised questions and provided recommendations regarding the project's vision for validating the chosen geometries, particularly regarding the challenge of ensuring that the modeling effort remains agnostic to any specific OEM geometry. The reviewer emphasized the importance of developing models and data that are broadly applicable and valuable for the community at large.

Reviewer 2:

The reviewer noted that the work started in FY 2022, and the presentation only covered future work up to FY 2024 without a detailed timeline. The reviewer acknowledged that the proposed FY 2024 work directly addresses the barriers identified.

Reviewer 3:

The reviewer highlighted the need for close coordination and discussions with key groups, including ASTM committees, FAA, Commercial Aviation Alternative Fuels Initiative, European Union partners, and other entities with similar objectives. This collaboration was seen as critical for maximizing the impact of DOE's efforts. The reviewer recommended developing a deep understanding of the accuracies and uncertainties required for different properties as a function of temperature. This understanding should take into account both the sensitivity of combustor parameters to fuel properties and the sensitivity of numerical predictions to combustor performance. The reviewer suggested assessing existing accuracies and uncertainties in existing measurements to compare with what is possible and what is needed. The reviewer also recommended using reaction-observation models for early sensitivity analyses, discussing with OEMs to collect critical information, and identifying additional barriers and research priorities through discussions with OEMs and ASTM members. The reviewer recommended that future work include modeling and testing of alternative combustor configurations and different operating conditions, as sensitivities to fuel properties may vary. The work on a specific operating condition for the LDI burner should be viewed as a starting point. The reviewer also urged the team to consider the interdependence of fuel properties in subsequent studies and work on refining theory/models for predicting the properties of fuel blends, particularly for large molecule hydrocarbon components. The reviewer raised a minor issue regarding the relative benefits of the new ignition testing device and its accuracy in determining cetane number and/or derived cetane number. The reviewer suggested increased coordination and collaboration with the 038 project team, led by Dasgupta, especially in the modeling area.

Reviewer 4:

The reviewer noted that the proposed future work was well thought out in terms of SAF property measurements but lacked details regarding exascale simulations.

Reviewer 5:

The reviewer found the plan to develop new equipment and expand the range of property data to be obtained suitable. However, the plan to "probe kinetics" was unclear, and the presentation lacked specificity regarding the structure/property relations and validation. The reviewer emphasized the importance of addressing the development of surrogates for validation purposes.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer noted that the project has the potential to serve as a blueprint for best practices in coordinating industry and federal laboratory efforts to address SAF challenges in the aviation sector.

Reviewer 2:

The reviewer emphasized the importance of the project in enhancing the understanding of the impacts of using SAFs in aircraft engines. It was noted that while a substantial amount of experimental data on synthetic hydrocarbon fuels has been collected over the past two decades, there is still a need for a comprehensive understanding of SAF behavior across the entire range of operating conditions, especially for current and next-generation gas turbine engines.

Reviewer 3:

The reviewer raised concerns about the outdated link in question 9, which did not include updated objectives of the VTO. However, based on separate sources, the main VTO objective deduced was to "Enable the use of drop-in unblended SAF and SAF blends up to 100%." The reviewer affirmed that the project's work aligns with and supports this objective. The project addresses various aspects, including accurate property measurements, the development of new simulation tools, the synthesis and assessment of new fuel components, and coordination with other groups and teams both within and outside DOE who share common goals.

Reviewer 4:

The reviewer acknowledged the project's relevance to the DORMA subprogram.

Reviewer 5:

The reviewer approved of the project's broader relevance in the context of combustion technologies using SAFs.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found that computational resources appear to be adequate and readily available. Experimental capabilities and fuel availability also appear to be adequate.

Reviewer 2:

The reviewer stated that budgets for FY 2021 and FY 2022 look appropriate for the scope of work. The reviewer noted that no details are provided on the split between people and procurements, so it is difficult to make a detailed assessment.

Reviewer 3:

The reviewer scored the funding as insufficient, noting that in reality, there are a great number of additional efforts that could be pursued. Many of these are highlighted in the future work section. Of course, this is a management decision, balancing many conflicting priorities. While there are several other organizations that might be contributing to the key goals of this effort, the reviewer suspected many will be taking engineering solutions as opposed to enhancing the science base for making decisions. The latter is generally more of DOE focus and ownership of capability; hence the reviewer attributed more responsibility to the DOE budget to enhance such capabilities.

Reviewer 4:

The reviewer commented the resources appear to be sufficient.

Reviewer 5:

While resources were generally considered adequate, the reviewer emphasized that without detailed information, it would be challenging to make a comprehensive judgment. A more thorough assessment would

require a cost/benefit analysis based on DOE's investment relative to the potential commercialization of the SAFs or synthetic aviation turbine fuels being studied.

Presentation Number: DORMA038
Presentation Title: Towards accurate reacting flow simulations of SAFs
Principal Investigator: Debolina Dasgupta (Argonne National Laboratory)

Presenter

Debolina Dasgupta, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 40% of reviewers felt that the resources were sufficient, 60% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

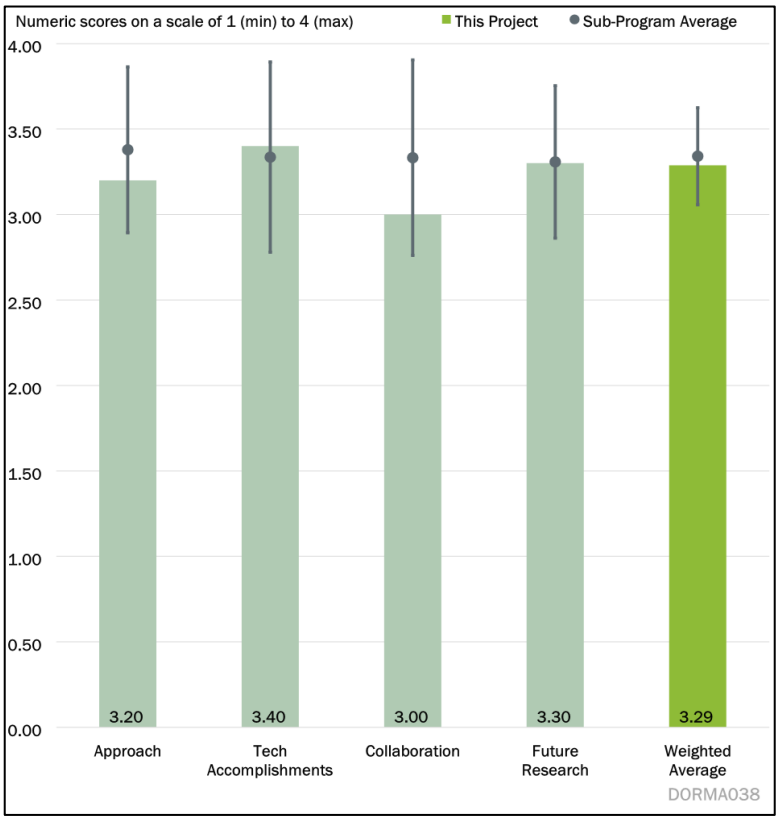

Figure 3-37 - Presentation Number: DORMA038 Presentation Title: Towards accurate reacting flow simulations of SAFs Principal Investigator: Debolina Dasgupta (Argonne National Laboratory)

Question 1: Please comment on the degree to which technical barriers are addressed. Is the project well designed, and is the timeline reasonably planned?

Reviewer 1:

The approach to the work plan was commended as solid, particularly the utilization of the CFD development rooted in a previous project, the National Jet Fuel Combustion Program (NJFCP). The reviewer appreciated the small "deltas" to fuel properties leveraged from existing work. However, a caution was raised regarding the importance and challenges of spray modeling, given its sensitivity to various fuel properties.

Reviewer 2:

The reviewer expressed the need for the team to identify and develop models that are agnostic to geometry, covering various combustion scenarios from rich burn to lean or lean premixed and prevaporized combustion. The reviewer emphasized the importance of considering commonalities with the aero-engine sector and prioritizing computational simulation activities.

Reviewer 3:

The exploration of fuel property impacts within the limits of ASTM specifications using high and medium fidelity simulations was seen as beneficial. The reviewer highlighted the use of two codes, Nek5000 and CONVERGE, and two experiments, Army Research Combustor-Midsize (ARC-M1) and NJFCP Referee Rig, focusing on single-cup rich-burn combustor designs. The project's goals to assess fuel property impacts on lean blowout, cold start, and high-altitude relight were noted as directly addressing technical barriers.

Reviewer 4:

The reviewer identified the three main barriers identified by the project team: assessment of fuels, heat transfer for durability examination, and tools for predicting combustor instability and ground-level noise. The reviewer acknowledged the significance of addressing these barriers but stressed the need for further work on demonstrating and validating the simulation tools, especially concerning combustor instability and noise prediction.

Reviewer 5:

According to the reviewer, the research team's use of state-of-the-art computational tools for modeling the ARC-M1 and the NJFCP Referee Rig was noted in the feedback.

Question 2: Please comment on the technical progress that has been made compared to the project plan.

Reviewer 1:

The reviewer found this area to receive the highest mark and was most impressed with how the completed work had progressed and approached technical barriers. It was clear that the simulation framework had been established, and an approach for the "deltas" to the fuel properties had been set up. In the reviewer's opinion, many of the technical challenges had been completed, and it was now just a matter of working through the simulations test plan.

Reviewer 2:

The reviewer encouraged the team to identify current modeling gaps in the OEM community so that their efforts aligned with industry needs. Moreover, the reviewer requested that the team closely work with industry and federal laboratory experts in this area for results interpretation. Validation of the simulations needed to be performed to assess model accuracy. The reviewer also noted the importance of identifying metrics for quantitative comparisons.

Reviewer 3:

Non-reacting simulations with Nek5000 were completed for ARC-M1, which was considered a formidable undertaking by the reviewer. Reacting simulations at stable flame conditions were completed with CONVERGE for the Referee Rig, examining variations in Jet A density, viscosity, and heat of combustion. The reviewer acknowledged that a large amount of effort would likely be required to achieve reacting spray simulations of ARC-M1 with Nek5000 and simulations of ignition (cold start and high-altitude relight) with CONVERGE for the Referee Rig.

Reviewer 4:

The reviewer recognized this as a relatively new project with limited resources, and thus, accomplishments were expected to be limited. The relatively high score, according to the reviewer, took this limitation into account. The project team, in the reviewer's assessment, successfully demonstrated simulations of the (non-reacting) flow field in the ARC-M1 combustor, using Nek5000 and applying high-fidelity wall-resolved modeling. This was seen as the first such simulation the reviewer had encountered (of this burner), although they acknowledged the possibility of other similar simulations. The reviewer considered this a significant step toward reacting flow simulations with vaporizing sprays. Of particular interest to the reviewer was the team's performance of reacting flow simulations of the NJFCP Referee rig with A-2 fuel, wherein they varied independently, and jointly, three fuel properties (viscosity, density, and heat of combustion) to observe the impact on the flame structure. The reviewer found these results very interesting and noted that if they could be validated, this capability could be highly useful in subsequent assessments of SAF being examined for 100% utilization. While not critical to the main message of the slides, the reviewer suggested it would be useful to include the specific conditions under which the simulations were performed, and perhaps useful to provide

comparisons to simulations using CONVERGE or other CFD modeling tools, so that potential benefits of the Nek5000 work could be assessed readily. The reviewer acknowledged that the latter might increase project costs.

Reviewer 5:

The reviewer emphasized that simulation of these reacting flows with sprays was very challenging, and the simulation results did provide valuable insight into the flame structure in these experiments.

Question 3: Please comment on the collaboration within the project team. Are there specific contributions made by industry, national laboratories, or other external entities? Are there areas where more collaboration is needed?

Reviewer 1:

The reviewer remarked that the presentation identified several collaborators, primarily working in conjunction with the NJFCP. The reviewer believed that the identified partners are appropriate and will help establish a strong team. However, the reviewer recommended considering a partner who can contribute to spray modeling and provide insights from their involvement with the NJFCP.

Reviewer 2:

The reviewer stated that the team is requested to closely collaborate with industry and federal laboratory experts in this area for results interpretation, identification of modeling gaps, and validation needs.

Reviewer 3:

The reviewer commented that this work makes good use of existing experiments, such as the ARC-M1 and NJFCP Referee Rig, as a platform for code validation and exploring the impacts of fuel property variations. The reviewer suggested exploring potential collaboration with DORMA037, which also involves simulations with fuel property variations using different codes and different experiments.

Reviewer 4:

The reviewer affirmed that coordination with the team is very effective. In particular, the sharing of information on priorities from the NJFCP industry partners is clear. Furthermore, the University of Illinois Urbana-Champaign (UIUC) is providing detailed information on their burner, and the U.S. Army Research Laboratory is granting approval for sharing such information. The reviewer expected substantial sharing of experimental results and observations of fuel-property effects during interactions in the coming year. The reviewer also anticipated results from Convergence Science or their software during the coming year. Such coordination efforts may need to be expanded. The team will require validation datasets, and the old NJFCP datasets and new UIUC data could be useful. Additionally, there is new data developing from the collaboration between the Georgia Institute of Technology, the Federal Aviation Administration, and General Electric interactions. The reviewer also encouraged coordination with the DOE team in Colorado, who share similar interests, even though that might already be occurring but is not cited. Coordination with other strong CFD groups, such as Stanford, Princeton, and commercial groups like Fluent/Ansys, could be fruitful and help demonstrate the advantages of DOE simulation capabilities.

Reviewer 5:

The reviewer verified that the principal investigator has successfully established the necessary collaborations to obtain the required boundary conditions for the simulations and the data needed for comparison with the calculated results.

Question 4: Please comment on the proposed future research. Has the project clearly defined a purpose for future work? To what extent will future work likely achieve its targets?

Reviewer 1:

The reviewer expressed their opinion that the proposed future work aligns with the right path, and they are pleased to see it presented in the review. They noted that the small "deltas" to the fuel properties will provide valuable insight and intuition, directly impacting accelerated fuels certification/acceptance. However, the reviewer raised concerns about the readiness of solid mechanisms and spray models to translate these deltas into simulations.

Reviewer 2:

The reviewer inquired about the team's approach to validation needs for various combustion regime operations encountered in a realistic engine. Furthermore, they sought information on how the models would be assessed and validated for changing combustion modes.

Reviewer 3:

The reviewer praised the goals of the future research as excellent but expressed concerns regarding the availability of resources to achieve the ambitious goals, especially in simulating ignition events (cold start and high-altitude relight) and capturing fuel property impacts.

Reviewer 4:

The reviewer discussed the future plans, which include examination and interpretation of data sets from the Referee Rig (NJFCP), the ARC-M1 rig, and an unspecified swirl-stabilized flame. They highlighted the challenge of using these data sets for the validation of CFD codes and suggested encouraging those collecting experimental data to test fuels and conditions beyond their current scope. The reviewer also suggested engaging Stanford and/or NASA to develop experimental data sets and model development for chemical kinetic models suitable for new fuels. Additionally, they recommended comparisons to simulations using codes from other CFD groups for confirmation of capability. The reviewer noted that while there is likely coordination with the 037 project team (Fioroni), it was not explicitly mentioned, and they suggested increased coordination and collaboration between the teams.

Reviewer 5:

The reviewer considered the proposed future research efforts to be good and logical, particularly the extension of the current nonreacting flow modeling of the ARC-M1 to modeling of reacting flow. However, they expressed uncertainty about the feasibility of the proposed DNS of swirl-stabilized flame and inquired about the specifics of DNS of the spray.

Question 5: Please comment on the relevance of the project. Does the project support the overall VTO subprogram objectives?

Reviewer 1:

The reviewer emphasized the high relevance of this work, highlighting its critical role in fast-tracking fuels certification/acceptance. They noted that understanding the effects of different fuel properties on performance metrics is essential, and this work directly addresses that need.

Reviewer 2:

The reviewer underlined the necessity of this project in overcoming current modeling gaps within the OEM community.

Reviewer 3:

The reviewer pointed out that this work significantly advances the understanding of fuel's impact on combustor operability. They emphasized that this advancement is essential for the development and utilization

of sustainable aviation fuels, which is a key approach for the aviation industry to achieve its net-zero carbon emissions goals by 2050.

Reviewer 4:

The reviewer expressed concerns about the outdated link provided in question 9 and suggested that they had deduced the main objective pertinent to the project through separate sources. They clarified that the main relevant objective from the VTO is to "Enable the use of drop-in unblended SAF and SAF blends up to 100%" and they affirmed that the project work aligns well with this objective. They further elaborated on the aspects covered by the project team, such as assessing fuel performance, modeling heat transfer for predicting its impact on engine component durability, and developing tools for predicting combustion instability and ground noise. The reviewer emphasized that these efforts, primarily through advancements in CFD simulation capabilities, are expected to confirm that minimal or no changes are anticipated in key operational metrics due to fuel property variations, as sought by the OEMs.

Reviewer 5:

The reviewer also pointed out the relevance of the research to the DORMA subprogram.

Question 6: Please provide comments on the resources of the project. Are the resources sufficient for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer raised concerns about the budget presented in the presentation, which indicates a budget of $200,000 for a 4-year project. They mentioned that, in their opinion, this budget appears to be extremely thin, unless it was intended as a yearly budget. The reviewer suggested that if significant funding is going out to collaborators, such as for kinetics, spray models, and the Air Force Research Laboratory, then the budget may be inadequate.

Reviewer 2:

The reviewer noted that the project seems to have adequate computational resources.

Reviewer 3:

The reviewer expressed uncertainty about whether the $200,000 listed in the presentation was an annual budget or the total budget for FY 2022–2023, starting in Q2 of FY 2022. They assumed there was no cost for using the CFD codes or performing simulations on DOE computing clusters. The reviewer pointed out that a budget of $100,000 or $200,000 per year for the goals outlined for FY 2024 appears insufficient, given the challenges of performing ignition simulations (cold start and high-altitude relight), capturing fuel property impacts, conducting lean blowout simulations, reacting spray simulations for ARC-M1, and performing DNS of a swirl-stabilized flame.

Reviewer 4:

The reviewer expressed the opinion that it seems the project team is operating with limited resources and may require additional funding. They acknowledged the project's powerful objectives, potential scientific contributions, and significant impact as reasons for the need for additional resources.

Reviewer 5:

The reviewer deemed the resources for the project to be sufficient.

Acronyms and Abbreviations – DORMA

Abbreviation	Definition
0D	Zero-dimensional
1D	One-dimensional
2-EHN	2-ethylhexyl nitrate
3D	Three-dimensional
ADT	Articulated dump truck
AEC	Advanced Engine Combustion
ANL	Argonne National Laboratory
APS	Advanced Photon Source
APU	Auxiliary power unit
ARC-M1	Army Research Combustor Midsize (ARC-M1)
ASTM	ASTM International, formerly known as American Society for Testing and Materials
BAs	Boron arsenide
BASF	BASF Corporation
BES	Basic Energy Sciences
BP	Budget period
BTE	Brake thermal efficiency
CDA	Cylinder deactivation
CFD	Computational fluid dynamics
CGM	Carbon-growth-on-metal
CI	Compression-ignition
CO	Carbon monoxide
CO_2	Carbon dioxide
COVID	Coronavirus disease (COVID-19), infectious disease caused by the SARS-CoV-2 virus
CRADA	Cooperative research and development agreement
CRC	Coordinating Research Council
CTL	Compact track loader
Cu	Copper
DC	Direct current
DEI	Diversity, Equity, and Inclusion

Abbreviation	Definition
DFI	Ducted fuel injection
DFT	Density functional theory
DI	Direct injection
DME	Dimethyl ether
DNS	Direct numerical simulation
DOC	Diesel oxidation catalyst
DOCF	Diesel oxidation catalyzed filter
DOE	U.S. Department of Energy
DORMA	VTO Decarbonization of Off-Road, Rail, Marine, and Aviation subprogram
DPF	Diesel particulate filter
DSF	Dynamic skip fire
ECN	Engine Combustion Network
EERE	Office of Energy Efficiency and Renewable Energy
EGR	Exhaust gas recirculation
EV	Electric vehicle
FAA	Federal Aviation Administration
Fe-zeolite	Iron zeolite
FN	Foreign national
FTP	Federal Test Procedure
FY	Fiscal Year
GE	General Electric, Inc.
GHG	Greenhouse gas
GM	General Motors
H_2	Hydrogen
H_2O	Water
HD	Heavy-duty
HEV	Hybrid electric vehicle
HHEA	Hybrid hydraulic-electric architecture
HIL	Hardware-in-the-loop
HPDI	High-pressure direct injection

Abbreviation	Definition
ICE	Internal combustion engine
ID	Identification
ID	Ignition delay
LDI	Lean direct injection (LDI)
LES	Large eddy simulation
LLCF	Low-lifecycle-carbon-fuels
LLNL	Lawrence Livermore National Laboratory
MAN	MAN Energy Solutions
MCCI	Mixing-controlled compression ignition
MD	Medium-duty
MeOH	Methanol
N_2O	Nitrous oxide
NASA	National Aeronautics and Space Administration
NG	Natural gas
NH_3	Ammonia
NH_4NO_3	Ammonium nitrate
NJFCP	National Jet Fuel Combustion Program
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
O_3	Ozone
OEM	Original equipment manufacturer
OP2S	Opposed piston, two stroke
ORNL	Oak Ridge National Laboratory
Pd	Palladium
PGM	Platinum group metals
PIV	Particle image velocimetry
PNA	Polynuclear aromatics
PNNL	Pacific Northwest National Laboratory

Abbreviation	Definition
Pt	Platinum
R&D	Research and development
RDD&D	Research, development, deployment, and demonstration
Rh	Rhodium
RNG	Renewable natural gas
RQL	Rich-quench-lean (RQL) combustor
Ru	Ruthenium
RuO_2	Ruthenium oxide
SAE	SAE International, formerly known as the Society of Automotive Engineers
SAF	Sustainable aviation fuel
SATF	Synthetic aviation turbine fuel
SCE	Combination of simulation and experiments
SCR	Selective catalytic reduction
SCRE	Single-cylinder research engine
SHA	Single-hole atomizer
Si/Al	Silicon/aluminum
SiC	Silicon carbide
SNL	Sandia National Laboratories
SRM	Stochastic Reactor Model
SULEV30	Super-ultra-low emissions vehicle 30 standard
SwRI	Southwest Research Institute
TWC	Three-way catalyst
UIUC	The University of Illinois Urbana-Champaign
ULEV	Ultra-low emissions vehicle
USA	United States of America
VTO	Vehicle Technologies Office
WHR	Waste heat recovery
WVU	West Virginia University

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