5. Fuel Technologies

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (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 as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state 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), the Vehicle Technologies Office 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 VTO Fuel Technologies (FT) subprogram supports research and development (R&D) necessary for industry to develop efficient engines that can utilize renewable fuels, such as advanced biofuels, hydrogen, and e-fuels, to 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. Internal combustion engines will continue to be an important power source for medium- and heavy-duty onroad trucks and off-road vehicles including construction, agriculture and forestry, and rail and marine, during the next several decades. Increasing their efficiency and reducing GHG and criteria emissions will ensure that the clean energy economy benefits all Americans. Optimization of high efficiency engines and emission control systems, integration of hybrid powertrains, and utilization of renewable fuels has the potential to improve heavy-duty engine efficiency.

The subprogram supports cutting-edge research at the national laboratories, in close collaboration with academia and industry, to strengthen the knowledge base of fuels and emission control catalysts.

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 5-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ft098	Propane Engine with Controlled Endgas Autoignition	Daniel Olsen (Colorado State University)	5-3	3.50	3.50	3.33	3.17	**3.44**
ft099	Propane Long-Stroke Engine	Derek Splitter (ORNL)	5-6	3.25	3.25	3.25	3.38	**3.27**
ft100	Co-Optima: Hyundai Multimode Engine	Phillip Zoldak & Shengron Zhu (Hyundai)	5-10	3.38	3.25	3.38	3.25	**3.30**
Overall Average				**3.36**	**3.32**	**3.32**	**3.27**	**3.32**

Presentation Number: ft098
Presentation Title: Propane Engine with Controlled Endgas Autoignition
Principal Investigator: Daniel Olsen (Colorado State University)

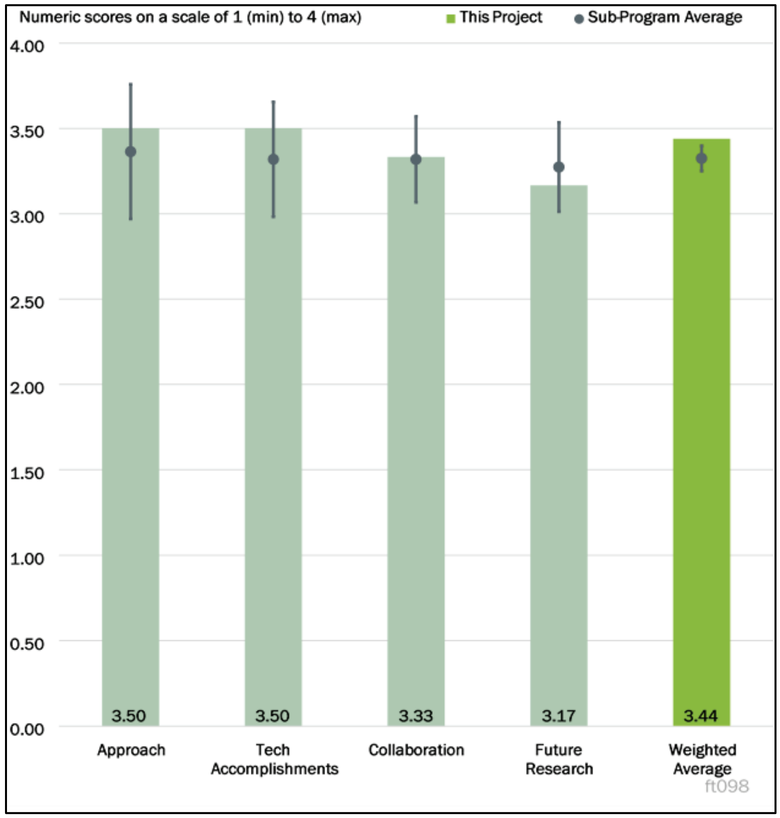

Figure 5-1 - Presentation Number: ft098 Presentation Title: Propane Engine with Controlled Endgas Autoignition Principal Investigator: Daniel Olsen (Colorado State University)

Presenter

Daniel Olsen, Colorado State 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.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated it is a well-designed project to improve liquefied petroleum gas (LPG) engine efficiency by developing a reduced kinetic mechanism for computational fluid dynamics (CFD) modeling, fuel spray visualization and modeling, and experimental investigation using a single-cylinder engine (SCE).

Reviewer 2:

The reviewer commented that a thoughtful approach was planned, including rapid compression machines (RCMs) experiments, kinetic mechanism development, fuel spray characterization, spray model development, CFD, and engine experimentation (Cooperative Fuel Research [CFR] and Cummins X15 engines). The activities to address the barrier of advanced “real-time” combustion control near the knock limit needs further detailed planning.

Reviewer 3:

The reviewer said a combination of RCM experiments, CFD modeling, and SCE experiments are a great strategy to proceed with developing a high-efficiency propane engine. The evaluation of the efficacy of the chemical kinetic mechanism is crucial, which is being pursued by the team. The reviewer said modifications to the injector and the fuel pump are critical for operating with a low-lubricity LPG direct-injection (DI) system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said for a less than 1-year project, technical accomplishments are in line with the schedule. The chemistry mechanism work and CFR engine work in the short period of time are impressive. In addition, the reviewer said setting the spray chamber also seems to be very impressive.

Reviewer 2:

The reviewer stated that the Principal Investigators (PIs) made good progress. The PIs accomplished about 18% of this 3-year project, which started October 2020, and includes RCM testing to support developing the reduced chemical kinetics; LPG DI test rig design; hardware integration; and initial simulation for high-pressure LPG injection.

Reviewer 3:

The reviewer commented the technical accomplishments are substantial, being only 8 months into the project. These accomplishments include chemical kinetic model development and high-performance scientific computing (HPSC) setup, and experimental results linked with CONVERGE CFD results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented collaboration is well planned with clear tasks for each participating partner. All three partners have provided valuable contributions to the project's Phase 1, including chemical kinetic model and RCM testing by Colorado State University, CFD spray results by Argonne National Laboratory (ANL), and hardware design for engine integration by Cummins.

Reviewer 2:

The reviewer observed great collaboration among team members. Team composition is really good as each team member—be it university, national laboratory, or small and large business—bring in their unique expertise.

Reviewer 3:

The reviewer said the project is still at an early stage. Overall, there is a good plan to collaborate across the project team.

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

Reviewer 1:

The reviewer stated that the PI listed the major tasks for each budget period but did not provide details.

Reviewer 2:

The reviewer commented the planned activities are logical next steps. A successful integration of LPG fuel injection with a new cylinder head with DI will be critical.

Reviewer 3:

The reviewer said much of it depends on the functionality and durability of the DI fuel injection system. Work performed by Czero is hence critical in the success of this project. The reviewer said it will be nice to have a plan B if the intended plan fails, which this reviewer has seen with several LPG DI systems. The reviewer said other candidate high-pressure pumps and injectors need to be selected in case the ones selected do not function as planned.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated this work is relevant to the Department of Energy (DOE) objectives to improve understanding and ability to manipulate combustion processes and generating the knowledge and insight necessary for industry to develop the next generation of engines.

Reviewer 2:

The reviewer commented that, yes, this project directly supports DOE's overall mission to "ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions."

Reviewer 3:

The reviewer said LPG DI is something the LPG industry has been interested in for a while, but it is risky for the industry to venture; therefore, DOE funding is required to enable this service. This project aligns well with what the industry is looking for.

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

Reviewer 1:

The reviewer commented sufficient resources are planned. Cummins involvement is a great asset for proper engine design and integration to accomplish project objectives.

Reviewer 2:

Overall, the reviewer noted the team has resources to conduct the relevant research—RCM, HPSC, engine, modeling tools.

Reviewer 3:

Project resources were deemed sufficient by this reviewer.

Presentation Number: ft099
Presentation Title: Propane Long-Stroke Engine
Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

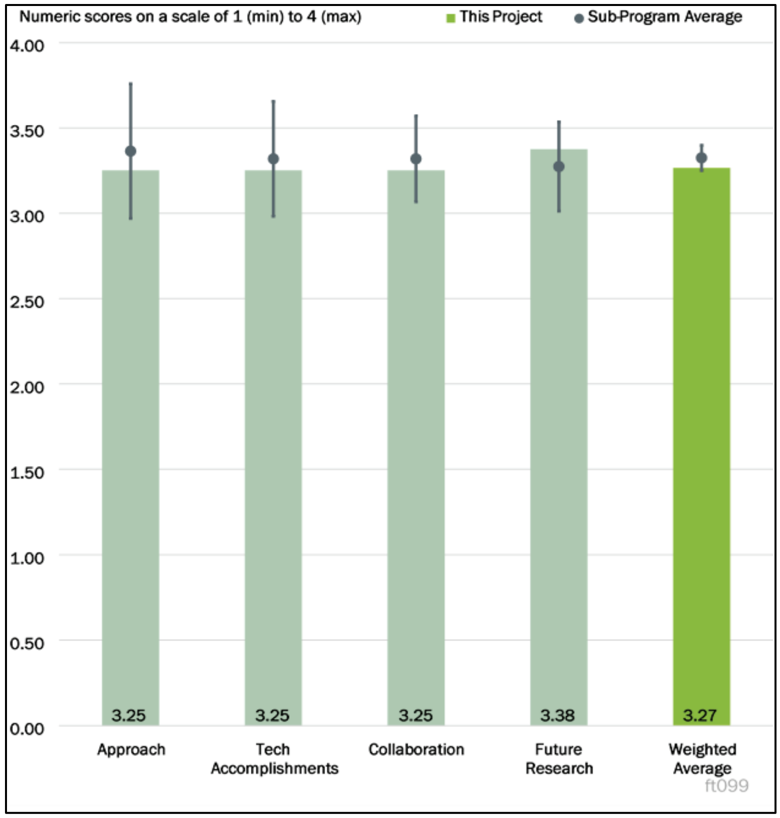

Figure 5-2 - Presentation Number: ft099 Presentation Title: Propane Long-Stroke Engine Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Presenter

Derek Splitter, Oak Ridge 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.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a comprehensive and well-designed project involving fundamental and applied CFD modeling, experiments, and system-level analysis, along with total cost of ownership (TCO) and life-cycle assessment (LCA) analysis.

Reviewer 2:

The reviewer stated that DI, exhaust gas recirculation (EGR)-diluted LPG engines do not exist; hence, learning that LPG is more tolerant to EGR is really useful. Using Katech's DI (and ethanol) experience is critical to delivering a DI solution. The reviewer noted that it is interesting to see how the G-equation model performs for propane under dilute conditions.

Reviewer 3:

The reviewer said the planned approach including fundamental chemical kinetics, CFD, engine design and experimentation, one-dimensional (1-D) system simulation, and LCA analysis is excellent. This approach will lead to a proper understanding of assessing the potential of using propane for medium-duty (MD) engines. The reviewer said the proposed approach will enhance propane engine efficiency and provides contributions toward increasing the engine brake thermal efficiency (BTE) for MD engines. These are important barriers, and the proposed approach is well designed to address them.

The reviewer remarked it could have been even better if the aftertreatment system was also studied along with the existing integrated approach, perhaps via collaboration with other teams if possible.

Reviewer 4:

The reviewer stated it is unclear if the stroke length selected is compatible with engine packaging constraints in the target vehicle. Also, it is not clear how much of this project differs from recent Cummins development programs on their small displacement engine. Although the research is all interesting, it is largely straightforward work given the existing understanding of propane engines.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the PIs made good progress, accomplished about 15% of this 39-month project, which started in October 2020. The PIs performed initial experiments to identify key aspects of engine performance; initial three-dimensional (3-D) CFD using Reynolds-averaged Navier-Stokes (RANS) turbulence and G-equation models; flame simulations; and a literature review of propane mechanisms.

Reviewer 2:

The reviewer said the work progress to date seems fine.

Reviewer 3:

Although the project is at the early stage, the reviewer noted that the team has made very good accomplishments, despite coronavirus disease 2019 (COVID-19) challenges. In particular, the new findings for the chemical response of LPG and study from the literature for chemical mechanisms and effects of fuel types are very helpful. The project is on track building upon prior studies and new simulations. Progress toward measurable metrics for accomplishments will become clearer in the next phases of the project. Referencing the goal of increasing efficiency with no cost premium, the reviewer indicated that aftertreatment system cost needs to be considered because the project mainly focuses on the engine side. For instance, whether the cost of propane oxidation catalyst will increase in the proposed engine (e.g., Generation [Gen] 2) if the same engine covers all engine speed and load conditions and also includes varying thermal conditions.

Reviewer 4:

The reviewer commented that limited progress was achieved since this project was contracted in November 2020. Much of the work presented was from the Gen1 engine.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Although the team is well structured, it was unclear to this reviewer how much of the work is currently shared across the partners.

Reviewer 2:

The reviewer commented the project is still at an early stage. Overall, the team developed a good plan to collaborate across the project team.

Reviewer 3:

The reviewer said there was good collaboration among the partners—a national laboratory (Oak Ridge National Laboratory [ORNL]), Oakland University, Katech, University of Wisconsin, Wisconsin Engine Research Consultants [WERC], and Stellantis—although the role of Stellantis in LPG is unclear apart from donating an engine. Katech's participation can help with General Motors (GM) engine conversions to LPG.

Reviewer 4:

The reviewer commented the project is well coordinated among the two universities, a national lab, an engine design company, and engine research consultants. Tasks are well divided among different team members, and each participant provides meaningful contributions to the project. The reviewer commented no major issue was observed. The project might benefit from collaborating with the project FT098 to utilize their RCM results for chemical kinetic models that are developed in that project.

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

Reviewer 1:

The reviewer said the project plans look good for future work.

Reviewer 2:

The reviewer described future research as well planned.

Reviewer 3:

The reviewer stated planned activities are logical next steps. An on-time Gen 2 prototype engine build will be critical.

Reviewer 4:

The reviewer said the role of direct numerical simulation (DNS) is critical to understanding the fundamental reasons for EGR tolerance. Chemistry mechanism improvements and CFD modeling work are also critical as there is a lack of information on LPG. The reviewer indicated that developing the Gen 2 engine with a belt-driven pump will be interesting to the LPG industry as a potential commercial solution.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated the project support aligned with the current objectives.

Reviewer 2:

The reviewer commented the work is relevant to the DOE objectives to develop and demonstrate an LPG-specific, spark-ignition MD engine that achieves diesel engine efficiency parity and shows pathways for dramatic engine efficiency increases.

Reviewer 3:

The reviewer stated that yes, the project directly supports DOE’s overall mission to “ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions.”

Reviewer 4:

The reviewer indicated that LPG DI engine development with or without EGR is something with which the LPG industry needs help. Hence, public-private partnerships, such as DOE funding is critical in accomplishing the goal.

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

Reviewer 1:

The reviewer commented that, overall, the team has resources to conduct the relevant research—engine and modeling tools.

Reviewer 2:

The reviewer indicated that planned resources are sufficient to meet the project objectives.

Reviewer 3:

The reviewer described the resources as fine.

Reviewer 4:

The reviewer asserted that more funding could be provided for multi-cylinder engine testing as the work will not be picked up by the LPG industry after SCE experiments. The total budget of $1.55 million seems less for this work as this project has tremendous potential for commercialization but needs additional funding from DOE to accomplish it.

Presentation Number: ft100
Presentation Title: Co-Optima: Hyundai Multimode Engine
Principal Investigator: Phillip Zoldak & Shengrong Zhu (Hyundai)

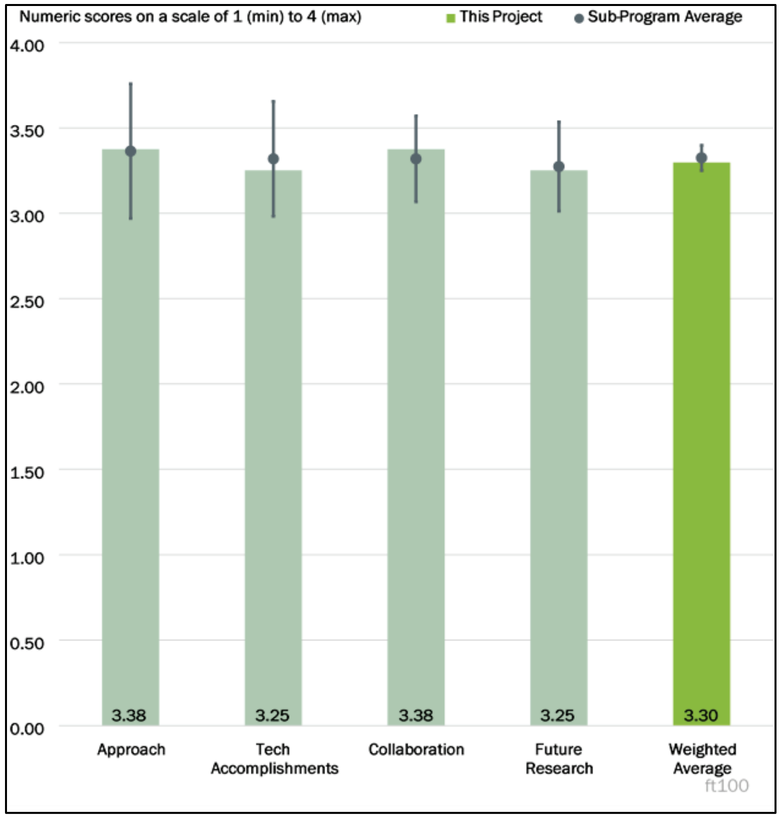

Figure 5-3 - Presentation Number: ft100 Presentation Title: Co-Optima: Hyundai Multimode Engine Principal Investigator: Phillip Zoldak & Shengrong Zhu (Hyundai)

Presenter

Phillip Zoldak & Shengrong Zhu, Hyundai

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.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that combustion mode switching will be very difficult and there is not a clear path to solve the problems, but the researchers are designing the system with production in mind. The project has a good handle on the levers it can use to solve the mode-switching barriers.

Reviewer 2:

The reviewer stated the work covers a fair amount of ground pertaining to gasoline compression ignition (GCI) and low-temperature combustion (LTC) engine performance and operating parameters. However, there was not much here that was truly novel. The reviewer stated most of the work that was done in this presentation was done in other places by Aramco, Delphi, or Argonne. For example, it is unclear why ethylhexyl nitrate (EHN) was explored for ignition enhancement; it is known to have a significant effect on ignition, but it is also known to have a detrimental effect on oxides of nitrogen (NO_x) emissions and EHN is inherently unstable if stored for too long.

Reviewer 3:

The reviewer observed an outstanding approach to the work, particularly identifying the various challenges that must be addressed. In the long term, a minor criticism is the Federal Test Procedure-75 (FTP-75) cycle may not result in use of the complete engine map and thus not show the complete spectrum of challenges the engine will encounter. The reviewer said a more aggressive cycle, such as the US06 or a Real Driving

Emissions (RDE) cycle, would ensure the complete engine map is encountered and thus "exercised" the engine more fully.

Reviewer 4:

The reviewer emphasized that it is terrific to see such a dedicated industry partner/collaborator at work in Co-Optima. Industry partnership always helps focus on practical application issues and that is certainly the case here. The reviewer commented the work appears to be well planned and executed to date; however, there are some inconsistencies in the presentation that must be resolved in the remaining stages of work before the project closeout. There is an indication that spark-assisted LTC (SA-LTC) will be employed to improve lightload performance and mode switching. The reviewer remarked, however, that Slide 7 shows no effect of spark assist. Similarly, one of the challenges recognized early on is that high load burn rate is too slow, but one of the issues in operation is that pressure rise rate is too high. It was not quite clear to the reviewer how these somewhat competing technical issues will lead to a fuel specification that is adequate across the entire operating range and how the currently identified "ideal" fuel specifications, including isobutanol, will play out at high load. Continuously variable valve duration (CVVD) and continuously variable valve technology (CVVT) certainly will be beneficial in all this, which the reviewer described as definitely a clever and valuable machine innovation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that accomplishments included extending the load limit, incorporating cylinder pressure feedback control, and investigating fuel reactivity, fuel injection pressure, and combustion bowl effects—all of which are major accomplishments.

Reviewer 2:

The reviewer commented progress of the work was reasonably good as- there are certainly plenty of results and tests that were accomplished. However, it does not genuinely appear the work has gotten pushed any closer to a production-ready technology as was hoped at the beginning of the project. The reviewer had the distinct impression that all this interesting work will be done, and the project will simply sit on a shelf without moving forward because little attention was paid toward the commercialization aspect.

Reviewer 3:

Overall, the achievements are very good as noted by this reviewer. The reviewer emphasized that the walkup on Slide 15—in which progressively better FTP-75 fuel economy is shown through various technology and fuel changes—was highly misleading. Based on the presenter's responses to reviewer questions, while all configurations could drive the FTP-75 cycle, they would all have different performance (e.g., 0–60 miles per hour [mph] times, grade capability, etc.). Thus, it is very misleading to show these data on such a plot as they can grossly misconstrue the source of the benefits that are obtained. For example, the reviewer explained that downsizing any engine and significantly degrading its performance would likely result in an efficiency improvement, irrespective of anything about the GCI technology that is the focus of this effort. Likewise, hybridizing any engine will result in an efficiency improvement.

Reviewer 4:

The reviewer stated good progress was made to date, as indicated by the results summary across engine operation, combustion chamber design, combustion visualization, and fuel specifications. However, much of the focus has been on light load operation, so it is too soon to tell if high load and low load performance requirements can be reconciled in a single, effective fuel blend. The reviewer stated it might have been better in retrospect to at least have a bit more balance in the engine mapping with engine GCI_01. Some of the final objectives might be ambitious given the time remaining.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated the project team is very well coordinated and, furthermore, this project is an excellent example of collaboration between multiple industries, academia, and (at limited scope) national laboratories.

Reviewer 2:

The reviewer said the extensive list of team members, obvious fuel blending support, and combustion visualization experiments reported from Michigan Technological University (Michigan Tech) certainly give the impression that team collaboration is very good, though it was not addressed explicitly during the review.

Reviewer 3:

The reviewer stated that partners are Phillips 66 and Michigan Tech, along with a variety of suppliers for engine modifications. It was not stated how often they had meetings scheduled. The reviewer asserted that the project's meeting nonreporting could be an area of improvement.

Reviewer 4:

The reviewer commented that collaboration and communication among the team members appear to be quite good. The project has a good mix of contributions from industry, national labs, and universities. The reviewer indicated that, if anything, a bit more attention could have been paid toward the opportunity to move this technology toward the product end of the scale.

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

Reviewer 1:

The reviewer stated future engine improvements, particularly valvetrain improvements, should be very conducive toward pushing the engine operation into a regime of better performance.

Reviewer 2:

Although the project has a good plan, the reviewer was not confident the project can be completed in the time left on the contract. The engine will be installed shortly, but the project team has quite a few tests to run. The reviewer expected that the project will run into some problems with control issues.

Reviewer 3:

The reviewer commented that proposed future research was not explained in great detail in the presentation but appears to be logical and sound. The focus on low load is logical but demonstrating transient capability—especially during mode transients—will be more important.

Reviewer 4:

The reviewer stated this topic was not reviewed in detail (e.g., no detailed project plan or Gantt chart), so one must only go by impressions. Slide 4 and slide 20 do give high-level project plans and expected results. The reviewer stated these plans seem ambitious, but without detailed knowledge of current status and finer-grained elements of work, it is hard to judge. One of the risks is that it might take longer than expected to converge on a fuel blend that adequately satisfies the entire engine operating range. The reviewer stated there is a lot to do to develop and implement an in-cylinder condition estimator into the active engine control system, especially with all the degrees of freedom afforded by CVVD/CVVT and injection pressure. The reviewer expressed great eagerness in seeing the final report.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer highlighted a big opportunity for fuel economy improvements. The project team is designing the system with production in mind; so, it is addressing all the production issues as well.

Reviewer 2:

The reviewer commented that the project addresses the DOE mission of improving engine efficiency and reducing criteria emissions.

Reviewer 3:

The reviewer stated that the project aims to ultimately develop a cleaner and more efficient engine and thus supports DOE's objectives.

Reviewer 4:

The reviewer said Co-Optima's program objective is to identify complementary changes in fuel specifications and engine design to significantly increase engine efficiency, which is exactly what this project is doing. So, yes, it definitely supports DOE objectives.

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

Reviewer 1:

The reviewer said resources allocated appear to be sufficient to achieve the stated goals and milestones.

Reviewer 2:

The reviewer commented that this is a sizable undertaking with an equally sizable and capable team behind it. The resources appear to be sufficient for completion of the planned tasks in a timely fashion.

Reviewer 3:

Based on progress to date and reviewing the individuals who are involved in the project (Slide 21), it certainly appeared to this reviewer that resources are adequate.

Reviewer 4:

The reviewer said resources should be about right but was concerned the project will be unable to complete all tasks in the time allowed. The contract may have to be extended.

Acronyms and Abbreviations

AFC	Alternative Fuel Corridor
1-D	One-dimensional
3-D	Three-dimensional
BTE	Brake thermal efficiency
CFD	Computational fluid dynamics
CFR	Cooperative fuel research engine
COVID-19	Coronavirus disease 2019
CVVD	Continuously variable valve duration
CVVT	Continuous variable valve technology
DI	Direct injection
DNS	Direct numerical simulation
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EGR	Exhaust gas recirculation
EHN	Ethylhexyl nitrate
FT	Fuel and Lubrication Technologies
FTP	Federal Test Procedure
GCI	Gasoline compression ignition
Gen	Generation
GHG	Greenhouse gas
HPSC	High-performance scientific computing
LCA	Life-cycle assessment
LPG	Liquified petroleum gas
LTC	Low-temperature combustion
MD	Medium-duty
Michigan Tech	Michigan Technological University
NO_x	Oxides of nitrogen
ORNL	Oak Ridge National Laboratory
PI	Principal Investigator
R&D	Research and development
RANS	Reynolds-averaged Navier-Stokes

RCM	Rapid compression machine
RDD&D	Research, development, demonstration, and deployment
RDE	Real Driving Emissions test
SA-LTC	Spark-assisted low-temperature combustion
SCE	Single-cylinder engine
TCO	Total cost of ownership
WERC	Wisconsin Engine Research Consultants