

Co-Optima Stakeholder Listening Day Summary Report

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the Bioenergy Technologies Office

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Abbreviations and Acronyms

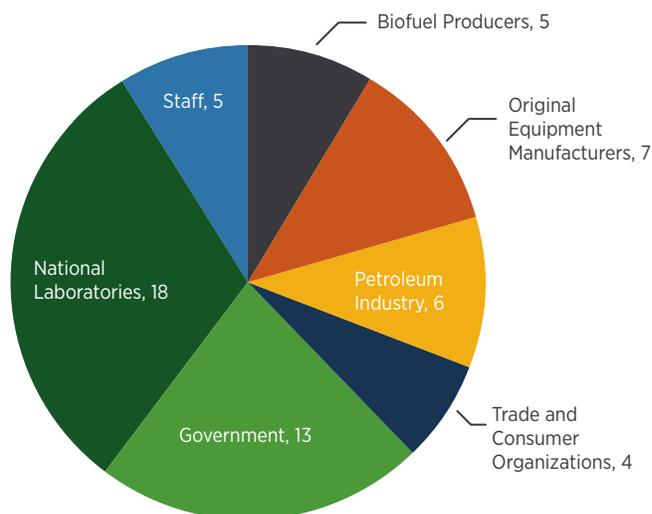
ACI	advanced compression ignition
DOE	U.S. Department of Energy
GHG	greenhouse gas
SI	spark ignition
OEM	original equipment manufacturer
R&D	research and development
RON	research octane number

Executive Summary

On June 16–17, 2015, the U.S. Department of Energy (DOE) convened the Optima Stakeholder Listening Day to share information on an emerging effort to concurrently investigate the optimization of fuels and vehicles. At the time of the stakeholder listening day, this effort was referred to as “Optima.” The revised name of the effort is Co-Optimization of Fuels & Engines (Co-Optima). The effort and the listening day will use the term “Co-Optima” hereafter in this report.

Co-Optima officially began in FY 2016 and is a collaboration of the DOE Vehicle Technologies Office, Bioenergy Technologies Office, and the DOE national laboratories. In FY 2015, DOE invited industry stakeholders to the listening day to obtain critical input on the opportunities and challenges of this effort. The meeting was held in Golden, Colorado, and hosted by the National Renewable Energy Laboratory.

In total, 22 participants attended the listening day in person, and another 4 participated via webinar. The participants represented six key stakeholder groups, including (1) automotive and truck manufacturers, (2) the petroleum and refining industry, (3) biofuels and bioproducts companies, (4) federal and state government agencies, (5) industry and trade associations, and (6) consumer advocacy organizations. In addition, there were about 30 DOE and national laboratory representatives in attendance. The two-day workshop included an overview session that introduced the stakeholders to Co-Optima and some of the key personnel involved in the projects.



Workshop participation by sector

Trained facilitators guided participants through a series of brainstorming and idea categorizing and topical voting exercises during four working sessions that used an innovative, Web-based, collaboration software called ThinkTank. This interactive process enabled the gathering and refining of information in a quick and effective manner.

Introducing Stakeholders to Co-Optimization of Fuels & Engines

At the start of the Co-Optima Stakeholder Listening Day, participants were offered a detailed overview of Co-Optima goals and activities. The fiscal year 2015 budget appropriations language for both the Vehicle Technologies Office and the Bioenergy Technologies Office encouraged collaboration in several technical areas that pertain to the marketplace deployment of new fuels. Co-Optima builds on that collaboration by developing new fuels and engine architectures that are co-optimized—designed in tandem to maximize performance and carbon efficiency.

These DOE offices and the national laboratories are well positioned to lead the research needed to improve the thermal efficiency and vehicle fuel economy potential of spark ignition (SI) engines and to map the Co-Optimal fuel and hardware options for advanced compression ignition (ACI) engines that maximize fuel efficiency with very low emissions. These activities serve as the foundation of Co-Optima.

Co-Optima aims to provide DOE and stakeholders with the research and development (R&D) and analysis to enable (1) a definitive technical assessment of biofuel options that enable advanced SI engines, (2) new “market-pull” drivers that convey the value of advanced biofuels to consumers, (3) fuels that have lower greenhouse gas (GHG) emissions and expand the stable operating conditions for ACI drive cycles, and (4) a reduction of the technical barriers required for ACI vehicle market penetration. Co-Optima will also help enable the United States to meet 2013 Climate Action Plan goals on an accelerated time frame, serve as a catalyst to reinvigorate U.S. technology competitiveness, encourage job creation, provide lasting environmental benefits, and increase energy security.

The effort includes two thrusts:

Thrust 1—Improve near-term conventional SI engine efficiency. High research octane number (RON) fuels enable more efficient, higher-performance operation via engine downsizing and boosting. Many biofuel

blending components exhibit high RON and can be introduced into the market in the near to medium term for engines optimized to operate on those fuels. Fuel properties beyond RON, such as heat of vaporization, burn rate, viscosity, volatility, and energy density will also be characterized, and the complexity of their interactions mapped to evaluate the full value opportunity. This thrust has lower risk relative to Thrust II because SI engines are in use today—although not tuned to take advantage of the potential new fuels.

Thrust II—Enable full operability ACI engines. Thrust II will provide the science and technology underpinnings needed to make new fuels compatible with commercially viable new ACI engine technologies. This engine platform, which includes kinetically- controlled and low-temperature combustion approaches, offers the promise of significantly greater thermal efficiencies with lower criteria-pollutant emissions, and presents attractive options for both light- and heavy-duty vehicles. Fuel research will focus on low-GHG, advanced biofuel/petroleum blends. In addition, already-efficient, conventional compression ignition (CI) engines can realize fuel economy increases enabled by improved, low GHG-intensity fuels. Thrust II, to be conducted in parallel with Thrust I, presents a more complex technical challenge with higher potential risk and reward.

The research cycle for each thrust will include identifying fuel candidates, understanding their fuel characteristics and combustion performance, and determining market transformation requirements such as cost, GHG reduction, feedstock requirements, scalability, and infrastructure compatibility.

Gathering Opinions from Stakeholders

Following the Co-Optima overview, participants progressed through a series of four working sessions that included brief presentations to establish the context for each topic, and a 90-minute facilitated process in which participants responded to questions via brainstorming, topical binning, and vote prioritization exercises. Each pair of session co-leads included a representative from a DOE national laboratory.

Following the topical presentations, participants were encouraged to enter responses to the working session questions into the ThinkTank tool to facilitate discussion with the other participants. The use of ThinkTank provided users with additional opportunities to comment on ideas submitted by their peers and added to the robust nature of the discussions. After the brainstorming and commenting periods were closed, the session co-leads, meeting facilitators, ThinkTank

session manager, and participants worked together to prioritize and bin the information into topical categories.

Results from the Facilitated Working Sessions

The collaborative process and tools used to gather input during the Co-Optima Stakeholder Listening Day working sessions made it possible to capture substantive and meaningful information from a broad cross-section of stakeholders. Some of this information is already being applied to fine-tune plans for Co-Optima, and the DOE offices and national laboratories will continue to use this information in formulating strategies that address key technical and analytical issues. The following are key points from the working sessions:

1. Clearly Defining Project Scope

Participants remarked on the nascency of Co-Optima and the importance of consistent and comprehensive messaging. They recognized a need to “draw a box around the issues/problems that Co-Optima seeks to resolve” and communicate how these activities relate to broader issues. They communicated how imperative it will be for the Co-Optima Team (which includes representatives from the DOE Vehicle and Bioenergy Technologies Offices and the DOE national laboratories) to better understand issues like infrastructure (rail, pipeline, and retail) in devising strategies to move product from point of production to the fuel pump. They also asked that the team consider what role, if any, might exist for biolubricants and bioplastics in automotive applications, realizing that these higher-value products could make fuels more cost-effective. Participants also expressed interest in more background on some of the issues, more information/data on the potential impact of co-optimization on GHG reductions, and a clearly defined set of acronyms. Several recommended communicating Co-Optima goals in more concrete metrics, such as “We need X gallons of molecule Y by date Z,” or by translating engine efficiency targets into the barrels of oil avoided or U.S. dollars saved nationwide or per capita.

2. Expanding External Communications and Reach

Participants noted a need for stronger interagency coordination with the U.S. Department of Transportation, the U.S. Environmental Protection Agency, the U.S. Department of Commerce’s National Institute on Standards and Technology, and other federal agencies. Participants suggested that national and state government collaboration could be achieved by working with the National Governor’s Association,

or the National Association of State Energy Officials. Communications could be expanded to include allied industries, as well as additional consumer groups, major trade associations, and codes and standards development organizations. Additional efforts could also include holding outreach and educational sessions to inform policy- and decision-makers of the benefits of biofuels to create a national sense of urgency—spurring investment and securing buy in from key players.

3. Defining the Value Proposition

Participants observed a need for the Co-Optima Team to better define the value proposition for a wide range of stakeholders, noting that increasing performance will provide a purchasing incentive for some but not all consumers. While much has been written about the purchasing power of the Millennial Generation, workshop participants said that the target market for this new fuel/vehicle combination has completely different buying habits/desires than those of today’s customers. Participants debated the value of including social responsibility considerations, acknowledging that environmental interests need to be weighed against financial considerations.

4. Establishing and Maintaining Coordination and Collaboration

Participants emphasized the need for collaboration and dialogue on Co-Optima, noting that the efforts initiated during the Co-Optima Stakeholder Listening Day were a good start, but that continued activities are needed to sustain effective collaborations. The participants agreed that DOE has an important role to play in bringing together the original equipment manufacturers (OEMs), fuel providers, allied industries, and other stakeholders to talk and coordinate efforts. Many participants expressed an interest in discussing Co-Optima activities with their colleagues and in group sessions upon their return to their respective offices. Participants supported the establishment of appropriate mechanisms to enable collaborative participation in technology teams or advisory groups to further engage industry and lab participants in solving problems with system-wide implications.

Next Steps

The Co-Optima Team has several initiatives planned coming out of the Co-Optima Stakeholder Listening Day. The first includes incorporating feedback from the Listening Day into the Co-Optima multi-year R&D plan. Secondly, the team will refine the stakeholder engagement strategy based on the following tenants: (a) developing consistent and comprehensive messaging, (b) establishing a mechanism for technical

meetings with stakeholders, and (c) expanding stakeholder activities to more deeply engage various groups. Thirdly, the team will plan another Co-Optima stakeholder listening day as a follow-on to this workshop. Finally, now that the stakeholder community has had a chance to provide input, the team will work to create mechanisms for public input such as issuing a request for information.

Summary of Working Sessions

The Co-Optima Stakeholder Listening Day’s four sessions gave delegates the opportunity to provide input and feedback in response to discussion points, surveys, and exercises. An overview of output from the ThinkTank exercise is summarized below. Note that this summary is synthesized from the participant input and does not necessarily reflect the views of the

Working Session Topics

1	Scoping New horizons for Fuels and Vehicles
2A	Fuel and Vehicle Interactions - Thrust I
2B	Fuel and Vehicle Interactions - Thrust II
3	Barriers to Deployment
4	Stakeholders Engagement Issues

Co-Optima Team, DOE, or the national laboratories. The listening day workshop was organized into four (4) distinct sessions based on the primary topical areas decided by meeting organizers. The working sessions topics and summarized feedback are presented below.

Session 1: Scoping New Horizons for Fuels and Vehicles

Session 1 examined issues that will need to be considered to successfully implement Co-Optima, including the following key discussion points:

Improving Engine Efficiency: Breakthrough technologies capable of dramatically improving engine efficiency will necessitate a clear definition of technical and deployment requirements. Engines developed for Co-Optima may need to operate over a broader range of fuel properties than those that are found with

engines at the present time. Improvements in vehicle efficiency can be good for the oil industry, so long as they are marketable and make economic sense.

Improving Engine Performance: Technical challenges for engines include meeting emissions standards while ensuring that improvements designed to boost engine efficiency and reduce GHGs do not negatively impact criteria emissions and useful life durability. After a technology demonstration meets these efficiency and emission targets in the research stage, new engine quality, reliability, durability, safety, and cost will need to be addressed.

Producing Future Fuels: Introduction of low-GHG fuels is limited by the time frame and cost of building production-scale facilities; therefore, R&D efforts in this area need to focus on long-term outcomes. Simultaneous market readiness of all stakeholders, an established process for agreements with fuel producers, and a breakthrough in large-scale and broad supplies of new low-GHG fuels that can be used with the existing fleet are all viewed as positive factors capable of accelerating deployment of new fuel and engine technologies. Refineries can contribute to some of these advancements by moving toward renewable feedstocks. The role of other players could evolve over time, with some making contributions on unexpected fronts. For example, the auto industry has improved engine efficiency over the past several decades during which fuel ignition quality (e.g., octane and cetane numbers) have remained constant.

Future Fuel Dispensing: Co-Optima needs to consider how dispensing infrastructure will be affected by fuel changes. New fuels will need to be drop-in compatible with existing distribution equipment and vehicles, or new infrastructure and automotive technologies will need to be developed. Fuel that is compatible with existing infrastructure can be brought to market sooner. Large infrastructure changes will require an extended timeline and significant monetary investments.

Cultivating Market Acceptance: Co-Optima will need to secure consumer and fleet operator buy-in by accurately identifying and meaningfully addressing value propositions and pain points. Although market acceptance will benefit from the consumer appeal of options that are more sustainable, it will be challenging to convince customers (particularly fleet operators) to trade tried-and-true solutions for these new fuel/engine technologies, especially given the expected cost differential. Integration of the new fuel or fuel specification with existing fuel can help smooth the

path to market acceptance, as was the case with phase-in of unleaded gasoline and ethanol blends.

Messaging is Important: There should be a push to help consumers recognize the value and benefits of the new fuel/technology. This push should balance the negative response to upfront cost increases and will be key to successful market adoption. Co-Optima will also need to establish how it fits in with competing technologies (e.g., electrification, hydrogen). Demographic research will identify target markets that have the greatest likelihood of embracing this new fuel/technology, such as consumers who already own hybrids and electric vehicles. Participants discussed the following other components of messaging and public acceptance:

- Fleet operators will need to be sold on the business case for adopting the fuel/technology, factoring in both cost and reliability. Fleet demonstrations staged by government stakeholders and early adopters can help showcase benefits to this audience.
- Financial incentives could encourage more widespread and rapid adoption. Ultimately, technologies that make economic sense get to market fairly quickly, and developers and manufacturers want to reap rewards from investments. A carbon-based marketplace could foster the economic justification for these fuels. States and national governments could use customer rebates/tax incentives to promote early adoption.
- Messaging also needs to be developed that can be used when reaching out to industry stakeholders responsible for production and deployment, such as those found within the agriculture/biofuel production industry. The ethanol industry needs to coordinate messaging to clearly identify what fuels are being brought to market.
- Other strategies that enable substantial fuel savings could pose barriers to market acceptance of new fuels or engines. For example, widespread deployment of connected and autonomous vehicles could significantly improve efficiency and reduce GHGs, diminishing the perceived need for deployment of other technologies.

Conducting Life-Cycle Analyses: Life-cycle and techno-economic analyses will be crucial in identifying strategies that increase the odds for every part of the supply chain to achieve profitability.

Formulating Policy: Key policy components include establishment of consistent government policy and regulatory guidelines, as well as coordination among stakeholders and policymakers to develop unified time horizons and standards. Additionally, comprehensive feedstock-to-end use carbon pricing, loan guarantees from DOE, and R&D funding to accelerate technology development should be considered. Time horizons need to align stakeholder payoff with long-term policy objectives.

The uncertainty of energy and climate policy in the United States could pose barriers to achieving this vision. Challenges often arise due to changes in R&D priorities as administrations and legislatures turn over, which breeds uncertainty among stakeholders. It is likely that Co-Optima will need to work within the confines of existing legislation.

Engaging Stakeholders: The value of Co-Optima needs to be defined for the petroleum industry and other stakeholders. It will be a challenge to get the majority of stakeholders on the same page to align priorities and timelines and collaborate, especially considering the competitive nature of some stakeholder relationships. Increasingly globalized markets could translate into an additional body of international stakeholders, which will introduce a new set of opportunities and challenges. Coordination with established initiatives (i.e., 21st Century Truck Partnership, U.S. DRIVE, etc.) could help bring together important stakeholders who are already receptive to a collaborative dynamic. In addition to the messaging and outreach efforts mentioned earlier in this document, creative approaches, such as a fuel development contest modeled after the “X Prize,” could spur interest from less traditional stakeholders.

Determining Economic Viability: Cost remains the bottom line for industry, and it is unclear how low-carbon fuels can compete without a mechanism to value carbon. Compelling value propositions need to be identified for the refining industry and other commercial partners if major changes are required to their product mix or if market share needs to be sacrificed. To make the Co-Optima partnership more attractive to the conventional refining industry, it would be helpful to determine how these potential stakeholders can derive greater value from new fuels than from incumbent fuels. Medium- and heavy-duty customers will require a short-term return on investment to consider it of value.

Session 2A: Fuel and Vehicle Interactions – Thrust I: Spark Ignition Applications

Session Topics 2A and 2B fostered discussion about the interplay between fuels and vehicles, including the following key discussion points:

Addressing Gaps in Technology: Participants identified technology gaps in multiple areas. An 80% GHG reduction will require identification of a high-volume, low-cost/cost-competitive production route. Options other than octane and compression ratios and low-temperature clean combustion need to be uncovered. Development of engines and engine management systems capable of detecting fuel properties, as well as online engine optimization, would make it possible to best utilize a range of new fuels. There is also room for improvement in fuel testing. It will need to be determined how new vehicle technologies and fuels would affect the current dispensing infrastructure, but it is most likely that new infrastructure would need to be developed. A mechanism will be needed to prove new technology concepts, and techno-economic analysis methods will need to be established to prove commercial and manufacturing readiness.

Identifying Candidate Fuels: Cost is one of the most important factors in terms of new fuel adoption, and it needs to be strongly considered when weighing options for viable, affordable, low-carbon fuels. Natural gas/liquid propane gas may present unique opportunities, and plans for its inclusion in Co-Optima need to be clarified. Isobutanol is an important fuel to consider due to its compatibility with current infrastructure, but its importance as a building block for chemicals and higher-value products may diminish the case for its use as a fuel. There was considerable debate about how easy a move to higher ethanol blends and associated higher octane might be. Clarification is needed on the octane levels Co-Optima plans to target.

Concurrent Availability of Fuels and Engines: Constant octane levels have prompted engine designers to be more creative; now it is time for octane to play a bigger role in efficiency improvements. Co-optimization requires changes coordinated between engine and fuel producers, which will rely upon market certainty as well as industry cooperation. When it comes to research octane number (RON), it will be necessary to consider factors including whether 100 RON is E10, E20, or E30; which fuel is right; and which fuel properties have the correct specifications. Some participants said that if 100 RON was available today, manufacture of compatible engines would be a given.

Involving Government: Co-Optima success will rely on industry working constructively with the government as well as with other stakeholders. The role of government might include conducting early-stage, high-risk R&D at the national laboratories; coordinating the exchange of concepts among stakeholders; establishing guidelines; and providing cost-shared funding for advanced industrial RD&D. Government research can help reduce industry risk and expense by handing off technologies to commercial partners at higher technology readiness levels, and by following a consistent, long-term vision. The government can also foster collaboration through leadership and funding, can provide incentives and penalties to encourage regulatory compliance (CAFE, Tier 3 and the Renewable Fuel Standard), and can establish fuel and vehicle testing standards.

Establishing Market Drivers and Incentives: Market drivers for technologies and fuels developed in Co-Optima include customer value propositions and the social responsibility appeal of reducing environmental impact. Price is a major factor for consumer acceptance, as is so clearly demonstrated by drivers' resistance to using premium gasoline, even if it is specified by the auto manufacturer. Premium fuels are likely to be less expensive in the future, making it all the more crucial for new fuels to be cost-competitive with conventional gasoline and diesel. Education is key to getting consumers to consider factors beyond cost. Regulations imposed on consumers can also have dramatic effects on purchasing patterns, such as the case of the mandated switch to unleaded gasoline in 1975. Confusion at the pump can pose additional barriers, and technology that helps prevent misfueling will be important during any transition to new fuels.

Engaging Stakeholders: Stakeholders will need to work together to define future fuel specifications and identify ways to accelerate the selections of fuels. Open and honest assessment of options by the full range of stakeholders will be necessary for Co-Optima to succeed.

Session 2B: Fuel and Vehicle Interactions – Thrust II: Advanced Combustion Applications

Addressing Technology Gaps: Gaps can be found in the overall knowledge base, as well as in methodologies, tools, and technology. Information on the cost/GHG profile of octane-on-demand can be sparse, particularly compared to cost of higher-octane fuel. There are still fundamental knowledge gaps that

lead to failures for heavy-duty engines (i.e., emissions control/aftertreatment that works for low-temperature combustion and traditional combustion modes). Customers having to carry two fuels for high pressure direct injection systems is a big concern. For fuels that could replace current volumes of U.S. consumption, there is no commercially available fuel substitute, and there are not many scalable fuel options that meet low-GHG targets. The ability for engines to self-optimize based on data from the fuel read in-station or in the vehicle could advance Co-Optima, building on existing capabilities to sense the knock quality of a fuel and adjust operation in real time. Better tools also may be needed to predict benefit/cost trade-offs.

Identifying Combustion Mode and Fuel Candidates: The goal of Co-Optima is to design the fuel and vehicle together to improve energy efficiency and reduce GHG emissions. A key function of Co-Optima will be to downselect technologies and fuel options, identifying the most promising scheme and associated fuel. Participants also discussed the following:

- When new fuels are introduced to the market, the incumbent fuel is typically favored, due to engine changes required by new fuels. This may provide a convincing argument for using the same new fuel for Co-Optima's Thrust I and Thrust II.
- An optimized system of fuels/engines might prove more tractable by blending fuels. Using two highly refined fuels (e.g., diesel and gasoline) can result in a less-refined fuel. However, the use of straight run gasoline and/or natural gasoline in advanced compression ignition engines may benefit refiners, and this fuel could be blended with ethanol to produce a high-octane fuel that also meets the needs of advanced SI engines. E0 is 50/50 regular/premium, but it is unclear if E0 meets drivability requirements.
- Ethanol has the distinct advantages of being present in the fuel supply now (comprising 10% of gasoline) and being rapidly scalable. The fuel property requirements of naphtha with additives would depend on the specific Thrust II technology. There is a diesel engine Thrust II technology that is insensitive to fuel properties. Octane is controlled in the manufacturing process.
- If there is a very tight fuel specification, then the engines can be optimized for it. For example, more stringent diesel and biodiesel standards could improve heavy-duty engine fuel

consumption and emissions. However, tighter specifications come at a well-to-tank CO₂ and financial cost.

- All of the fuel streams need to optimize carbon reduction. Cultivation of different feedstocks produces different carbon footprints, but the fuels derived from these feedstocks are not significantly different.
- From the international standpoint, optimizing one engine in the United States would put pressure on other countries to adopt similar technology.

Making Fuels and Engines Available Concurrently:

Fuel availability will be enhanced by getting both feed value and ethanol out of a field of corn. Further improvements to cellulosic and corn-based fuel processes should help reduce the GHG emissions associated with ethanol production. The ethanol industry also provides a strong example of how dramatic expansion is possible when the right incentives are in place.

Other fuel options include using a blend stock at the pump, such as an after-market add-on that offers a dual-fuel capability. Other prospective additives include low-cost modifiers such as cetane enhancers. Although extracting sugars from cellulosic biomass presents challenges, once the sugars are obtained, there are opportunities for quicker development into other fuels. It was unclear whether the combination of engines/fuel specs presents additionality.

On the engine side, engine makers need detailed fuel properties of a candidate fuel six to eight years in advance of a product launch, as well as assurances that the investment will be made to produce the candidate fuel at scale. For a path forward, it will be important to establish an understanding of what is needed at each juncture from each of the Co-Optima stakeholders in both the fuel and engine sectors.

Involving Government: Currently, most government involvement in Co-Optima falls in the R&D arena. Unless the government can offer policy changes, rulemakings, etc., Co-Optima will consist simply of research and technical work designed to provide knowledge to industry. Guidance and direction from the government would be useful to all stakeholders in mapping out a strategic plan for a transition that is seamless, safe, and understandable to consumers. The government's role also can include tracking the status and trajectory of development to define performance needs.

Establishing Market Drivers and Incentives:

Considering the anticipated value proposition, there is some debate about whether the benefits will justify the cost to the consumer. It is important to recognize the varying opportunities and challenges associated with different fuels and pathways from the consumer perspective. Consumer preferences for new fuel functionality will vary based on a comparison with current fuels. Dual fuel approaches requiring dispensing of multiple fuels will be a hard sell for many customers. Fuel economy benefits in the range of ~10% could encourage customer adoption. Co-Optima research should include a study of end-user/consumer concerns and recommendations on how to address issues, examining the real and perceived impacts of incentives, cost, and non-tangible factors.

Session 3: Barriers to Deployment

Session 3 covered the technical, social, and political challenges to deploying Co-Optima:

Setting Policy: The best approach to overcoming barriers is an all-of-the-above approach combining policy/regulation with successful technology implementation, incentives, consumer outreach, and infrastructure compatibility planning. Additionally, although OEMs can be expected to conform to new policy, coordinating new fuel and new engine/vehicle technology rollouts could be difficult under a "market pull only" scenario, especially given time urgency. An integrated approach will speed the process and avoid the complication of fuel producers and OEMs trying to meet separate regulations with sometimes conflicting incentives.

Flexibility is needed when identifying barriers to adoption, as preferences and demand can vary due to a number of externalities. By socializing the concept early we can better grasp what those variables might be and put items in place to attempt to address them. Additionally, regional deployments may allow a managed, gradual transition to better deal with some barriers. A regulatory approach to overcoming barriers in promoting new fuels is inherently compatible with a market pull approach. Government makes rules based on weighing costs and benefits using data derived from industry to create new, uniform market conditions. At a minimum, adopters should not be harmed by policy changes (e.g., transition to unleaded fuel), but analysis is needed to determine any burden on non-adopters.

Shaping Public Perception: Barriers to adoption can vary based on a wide range of preference and demand factors. Socializing the Co-Optima concept at its

early stage will make it possible to better identify and address variables.

Consumers are often focused on cost factors and can be persistent in maintaining the status quo, but when they are given incentives, or are exposed to social benefits of a certain purchase, they can be moved to make that purchase in spite of a price differential. The key is educating the consumer, quantifying the benefits, and getting consumer groups involved. DOE's Clean Cities was referenced as a group that could foster consumer involvement. Outreach will also need to demonstrate benefits to fleet operators.

Concurrent availability of older, cheaper fuels make the consumer's decision to opt for new fuels even tougher, especially when crude prices are low. Lower taxes for higher-octane fuels could solve this dilemma. An alternative solution invisible to the consumer might be blending in of a low-carbon-intensity fuel that does not have negative performance impacts. As a fallback, if policy and outreach do not lead customers to migrate to the new fuels, an alternative would be to have blender pumps capable of supplying both current and new fuels.

While most fuel providers and engine and vehicle manufacturers want to be part of the solution, Co-Optima will need to include all stakeholders for strongest advocacy. Their input will be crucial in determining the impact of new technologies on vehicle cost structure and how this can be effectively conveyed to the consumer. Environmental groups are not always on board with biofuel initiatives, especially in the case of first generation biofuels, but they need to be included as stakeholders in this effort.

Other perception barriers include the following:

- The life of current fleet and the warranty limitations on E10, etc., while transitioning.
- Multiple nozzle configurations.
- Previous issues with dramatic decrease in aromatic levels.
- Previous flammability issues with low sulfur diesel.
- Potential liability connected to the fuel dispenser, end user, fuel producer, OEM, or all the above

Regional deployment may provide a managed, gradual transition to incrementally deal with some barriers.

Addressing Regulatory Issues: Regulations tend to set performance standards (based on hard economic or

technical information) and not technology specifications. As demonstrated by some areas that have been stymied by legacy issues, fuel standards can be a bit more complicated and can have greater impacts on fuel, vehicle, or industry development. Foundational R&D is often used to establish a regulatory regime, but regulations can be divisive and slow to implement, can be difficult to change, and can inhibit or unduly influence research directions. Achieving the correct level of regulatory specificity is important in fostering new, innovative R&D solutions. For example, specifying preferred octane levels might run counter to future developments identifying low-octane fuels with different combustion modes. Also, regulations should not be introduced too early because of the potential impacts on developments and directions. However, regulations also can provide some certainty to the marketplace (e.g., for the development of compatible technologies, or determining infrastructure investments). Mandates are not an efficient way to achieve a policy objective; taxes or other mechanisms that use a market-based effect are better.

Specific regulatory issues related to Co-Optima include the following:

- Material evaluations for new fuels take too long.
- Fuel C is not a real-world fuel test. Fuel C is intended as a represented test fuel, comparable to Indoline, but it may be overly conservative.
- The "One-Pound Waiver" is an issue for future fuel blends. Currently E15 is not included for blending with standard stock gasoline, although the industry could choose to change the blend-stocks depending on the additional costs for that transition.
- Changing nozzle designs is a good method for reducing misfueling, but persistent consumers have found a way around it in the past. A higher-tech approach (like confirmation via radio-frequency identification) might be needed.

Ensuring Infrastructure Compatibility: Co-Optima needs to consider market-pull mechanisms to encourage turnover of technology if, for example, co-optimization is advanced. Some technologies, such as shorter-lived small engines, will have quicker and easier transition timelines. Aftermarket providers are not necessarily a barrier, but impacts on them should be considered. Refueling infrastructure compatibility is a major area for consideration, including the coexistence of nozzles for refueling new and old vehicles during the transition period to ensure the existing fleet is not

rendered obsolete or warranties voided; sufficient underground storage is available for fuels; and the materials in the dispensers and vehicle systems are compatible. The RFID approach to prevent misfueling appears to be cheap, practical, scalable, and a simple retrofit to legacy cars. Smaller markets, like classic cars with components that will not be upgraded to meet new fuel properties, might need special considerations or might not be accommodated and will have to find a market-only solution.

Supplying Adequate Feedstock: Availability of corn supply, especially with second-generation fuels, is not a barrier after corn stover feedstock is factored in. Ethanol from corn could easily yield more than 15 billion gallons, and even as much as 22 billion gallons without increasing acreage. A potential 1.8 billion gallon year-over-year increase is expected for cellulosic ethanol. About a billion tons of other feedstocks are also available, including residues, woody, energy crops, and municipal solid waste.

Beyond the need for simply producing enough of the major biofuels and biofuel blends (e.g., ethanol and biodiesel), Co-Optima needs to consider the volumetric considerations (constituents, etc.) for other applications (i.e., small engines and marine), and other available fuels. Since biofuels companies are providing ~10% of the fuel supply, it is clear that a broad consensus is needed among biofuels and oil producers and OEMs. It will be important for biomass producers to collaborate with biofuel producers to enable low net GHG fuels from second-generation feedstocks.

Session 4: Stakeholder Engagement Issues

Session 4 explored opportunities for collaboration with stakeholder groups:

Ensuring Strong Industry-Government

Collaboration: Attendees said they felt the workshop should be part of an ongoing dialogue. The Co-Optima Team will leverage existing public/private partnerships on the state, regional, and national levels to facilitate further discussion. For instance, the truck partnership meets regularly and could make Co-Optima a regular agenda item. Similarly, an alliance with government support between the petroleum and biofuels producers would be a powerful means for introduction of new fuels and blends. DOE needs to play a mediating role to help participants set aside preconceived solutions. It is useful to have discussions that focus on priorities from each stakeholder's perspective. From the government research side, Co-Optima could build upon related projects, which include involving stakeholders

in these existing projects. Finally, outcomes of working meetings should be conveyed to top executives and decision-makers.

Engaging Stakeholders: Attendees identified key stakeholder demographics that are critical to moving forward with Co-Optima; these included government agencies, industry, consumer groups, environmental organizations, and technical, industry, and marketing associations. Participants said that future efforts should seek to engage stakeholders representing infrastructure perspectives (pipelines, retail, etc.). Additionally, they suggested that representation from consumer groups should be expanded. Options for additional consumer perspectives include the National Association of Convenience Stores, grassroots groups, consumer unions, petroleum marketing associations, the National Association of Auto Dealers, the American Lung Association, Consumer Reports, and fleet stakeholders such as American Trucking Associations and the Owner-Operator Independent Drivers Association. Past examples of strong industry/government collaboration include U.S. Drive, Electric Power Research Institute, SEMATECH, and the 21st Century Truck Partnership.

Stakeholders should be kept apprised of Co-Optima updates via briefings to inform them of economic, performance, and environmental benefits and to help spread the message to constituents. Big data can also play a role in relaying information to stakeholders. Information on the benefits of this new fuel/engine system should be made available on the DOE and U.S. Environmental Protection Agency websites.

Winning Hearts and Minds: Companies would benefit from establishment of clear and quantitative Co-Optima objectives along the lines of, "X gallons of molecule Y by date Z." Targets should include GHG reductions, engine efficiency improvements, foreign oil imports avoided, and dollars saved nationally and per capita.

Conclusion

The Co-Optima Listening Day has yielded new information and insights that will help shape Co-Optima going forward. The Co-Optima Team is using this stakeholder input to inform the multi-year R&D plan and refine the stakeholder engagement strategy. In addition, the Co-Optima Team plans to hold future listening day workshops and implement other stakeholder engagement activities to continue to collect important feedback. This will be an iterative process, with the stakeholder community playing a vital role in the success of Co-Optima.

Appendix A: Agenda

June 16–17, 2015

Energy Systems Integration Facility National Renewable Energy Laboratory (Golden, Colorado)

Day 1

12:00 Introduction and Welcome

12:20 Overview of the Co-Optima Initiative

13:00 Stakeholder Questions on Co-Optima

13:45 Break

14:15 Working Session 1: Scoping New Horizons for Fuels and Vehicles

15:45 Break

16:15 Working Session 2: Fuel and Vehicle Interactions – Thrust I

17:45 Close

Day 2

08:00 Feedback from Day 1

08:30 Working Session 2 (continued): Fuel and Vehicle Interactions – Thrust II

09:45 Break

10:15 Working Session 3: Barriers to Deployment

11:30 Working Session 4: Stakeholder Engagement Issues

12:15 Closing Comments and Feedback

Appendix B: Attendees

Teresa Alleman, National Renewable Energy Laboratory

Jim Anderson, Ford

Andrea Bailey, BCS, Incorporated

Ewa Bardasz, Energetics

Max Broad, BCS, Incorporated

Eric Bunnelle, ExxonMobil

Allan Chute, Lean Six Sigma

Nathan Danielson, DuPont

Mark DeVries, POET

Todd Dooley, California Air Resources Board

Jennifer Dunn, Argonne National Laboratory

John Farrell, National Renewable Energy Laboratory

Chris Gehrke, Caterpillar

Anthe George, Sandia National Laboratories

Stephen Goguen, DOE Vehicle Technologies Office

Jason Hansen, Idaho National Laboratory

Ting He, Idaho National Laboratory

Annette Hebert, California Air Resources Board

Richard Hess, Idaho National Laboratory

John Holladay, Pacific Northwest National Laboratory

Robert Hwang, Sandia National Laboratories

George Kervitsky, BCS, Incorporated

Michael Laughlin, Energetics

Alicia Lindauer, DOE Bioenergy Technologies Office

Doug Longman, Argonne National Laboratory

Jorge Lozada, PACCAR

Paul Machiele, U.S. Environmental Protection Agency

Jonathan Male, DOE Bioenergy Technologies Office

Amir Maria, Chevron

Babs Marrone, Los Alamos National Laboratory

Robert McCormick, National Renewable Energy Laboratory

Sam McLaughlin, Volvo

Matt McNenly, Lawrence Livermore National Laboratory

Paul Miles, Sandia National Laboratories

Paul Miller, Cummins

Reginald Modlin, Chrysler

Adewale Oshinuga, South Coast Air Quality Management District

William Pitz, Lawrence Livermore National Laboratory

Art Pontau, Sandia National Laboratories

Derek Regal, Tesoro

Reuben Sarkar, DOE Office of Energy Efficiency and Renewable Energy

Sam Saxena, Lawrence Berkeley National Laboratory

Arun Solomon, GM

Jim Spaeth, DOE Bioenergy Technologies Office

Christopher Standlee, Abengoa

Kevin Stork, DOE Vehicle Technologies Office

Tim Theiss, Oak Ridge National Laboratory

Steve Vander Griend, ICM

Sam Wade, California Air Resources Board

Robert Wagner, Oak Ridge National Laboratory

Todd Werpy, U.S. Department of Agriculture

Brian West, Oak Ridge National Laboratory

Robert Wilson, SRI

Raymond Wissinger, Honeywell

Donovan Woods, Fuels Institute

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