Request for Information (RFI) DE-FOA-0001460: Co-Optimization of Fuels and Engines

DATE: December 16, 2015
SUBJECT: Request for Information (RFI)

Description

The U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy's (EERE) Bioenergy Technologies Office (BETO) and Vehicle Technologies Office (VTO) are seeking stakeholder input on its Optima initiative, a DOE-sponsored program focused on the development of new fuels and engine architectures that are co-optimized—designed in tandem to maximize performance and carbon efficiency. DOE is specifically interested in stakeholder input on (1) perspectives and interest in co-optimization of fuels and engines, (2) technical aspects of fuel and advanced compression ignition (ACI) engine interactions, and (3) barriers to market acceptance and deployment of co-optimized fuels and engines.

Background

BETO and VTO are two of ten technology development offices within EERE. BETO and VTO support EERE's efforts to expand the adoption of sustainable, domestically powered transportation alternatives and to stimulate the growth of a thriving domestic clean energy manufacturing industry.

BETO's mission is to develop and transform renewable biomass resources into commercially viable, high-performance biofuels, bioproducts, and biopower through targeted research, development, and demonstration supported through public and private partnerships. BETO is working to enable sustainable, nationwide production of biofuels that (1) are compatible with today's transportation infrastructure, (2) reduce greenhouse gas emissions relative to petroleum-derived fuels, and (3) can displace a share of petroleum-derived fuels to reduce U.S. dependence on foreign oil.

VTO supports research, development, and deployment (RD&D) of efficient and sustainable highway transportation technologies to improve vehicles' fuel economy and minimize petroleum use. These technologies, which include plug-in electric vehicles (also known as electric vehicles (EVs) or electric cars), batteries, electric drive technologies, advanced combustion engines, lightweight materials, and alternative fuels, will increase Americans' energy security, lower costs, and reduce environmental impacts.

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Optima is a key collaborative initiative being pursued by EERE, VTO, and BETO. The Optima initiative is focused on the development of new fuels and engine architectures that are co-optimized—designed in tandem to maximize performance and carbon efficiency. Internal combustion engines (ICEs) are expected to continue to dominate the vehicle fleet for the next several decades—as either prime movers or range extenders for the increasing number of EV and hybrid drive systems. Co-optimization of fuels and engines offer the opportunity to build on decades of remarkable advances in both fuels and engines. Ground-breaking research in the last ten years has identified combustion engine strategies that—especially if optimized to run on new fuels—would offer significantly higher efficiency and produce less engine-out pollutants than current engines. The initiative intends to accelerate the widespread deployment of significantly improved fuels and vehicles (passenger to light truck to heavy duty commercial vehicles) by 2030. Specifically, Optima is targeting a reduction in per-vehicle petroleum consumption by 30% versus the 2030 business as usual. This goal reflects contributions from both improved engines (7%–14% reduction in fuel consumption) and improved fuels (including 15 billion gallons/year of advanced biofuels). At a fleet level, Optima will result in an additional 9%–14% fleet greenhouse gas (GHG) reduction by 2040.

In fiscal year 2016 (beginning October 1, 2015), BETO and VTO jointly funded a consortium of nine DOE national laboratories to begin an initial three-year effort focused on Optima. Activities funded under this initiative cover six major technology areas that leverage existing, foundational fuels and engines R&D along with initial stakeholder engagement. The Optima project will provide DOE and stakeholders with (1) a definitive technical assessment of biofuel options that enable advanced spark ignition (SI) engines, (2) new "market-pull" drivers that convey the value of advanced biofuels to consumers, (3) fuels that emit less GHGs and expand the stable operating conditions for advanced compression ignition (ACI) engines, and (4) a mitigation of the technical barriers required for ACI fuel and vehicle market penetration.

The Optima initiative includes research thrusts:

Thrust I – Improvement of near-term conventional SI engine efficiency. High-research octane number (RON) fuels are known to enable more efficient, higher-performance SI 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—but will benefit from additional optimization to take advantage of 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

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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 characteristics and combustion performance, and determining market transformation requirements such as cost, GHG reduction, feedstock requirements, scalability, and infrastructure compatibility, while providing feedback to stakeholders and future collaborators.

The current DOE national laboratory effort focuses on six major, interrelated areas:

1) **Low Greenhouse Gas Fuels that Enable Increased Efficiency and Higher Performance.** Tasks include:
    a. Developing selection criteria for ACI engines with interties to the SI fuels activities and analysis groups
    b. Correlating fuel properties to biofuel conversion process outputs
    c. Investigating biofuel blends and additives for both SI and ACI engines that meet minimum performance requirements at lowest cost (small-scale, single cylinder testing)
    d. Providing real and synthetic fuels (liter scale, multi-cylinder testing) for further property and performance testing
    e. Developing affordable, sustainable, and scalable biomass conversion pathways to produce targeted biofuels and blendstocks

2) **Fuel Properties Characterization.** Tasks include:
    a. Investigating fuel composition and performance based metrics to describe how the fuels may perform in future engines; development of a fuels properties database for conventional and bio-derived individual components and blending streams
    b. Developing the information to predict fuel properties of blends; kinetic models, small sample size (mL scale) auto-ignition testing apparatus to inform early stage feedback
    c. Investigating the effects of Heat of Vaporization (HoV) on engine knock and Research Octane Number (RON) and how to reliably characterize HoV for various fuels
3) **Advanced Engine Development.** Tasks include:

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a. Enabling optimal engine design by exploring and quantifying fuel-engine interactions in advanced SI engines
b. Developing a better understanding of how fuel properties impact auto-ignition under conventional SI combustion conditions, multimode combustion strategies, and fully stratified lean operation
c. Developing and quantifying fuel effects on ACI combustion systems using advanced SI fuels, increasing efficiency while maintaining synergies with co-optimized SI fuels and market transformation elements
d. Developing ACI combustion systems that operate on diesel-like fuels to increase efficiency and lower emissions

4) **Analysis of Sustainability, Scale, Economics, Risk, and Trade.** Tasks include:
   a. Applying techno-economic analyses (TEA) and life-cycle analysis (LCA) to estimate energy and environmental impacts and costs of candidate molecules and blendstocks
   b. Estimating the benefits of Optima in terms of economy-wide energy savings, GHG reduction, cost savings, and job creation
   c. Developing selection criteria, metrics and methodologies in collaboration with other project teams and technical areas
   d. Analyzing the feedstock supply system to investigate viable routes to feedstock production at scale. Analysis will examine regional trade envelopes of feedstock intermediates and identify and characterize competing co-product markets
5) **Market Transformation and Deployment.** Tasks include:
   a. Developing guidance documentation on fuel-vehicle introductions, distribution, infrastructure barriers, laws and regulations, and the evolution of biomass feedstock markets alongside the petroleum market in order to meet current biofuels demands
   b. Working with the Society of Automotive Engineers (SAE) on standards development focused on market acceptance and misfueling issues
   c. Engaging with key stakeholders and initiating work with key industry stakeholders on identifying and infrastructure compatibility barriers and associated mitigation measures

6) **Simulation Toolkit Development.** Tasks include:
   a. Coordinating and performing detailed analyses to help the Optima team evaluate engine and fuel combinations faster and with more confidence
   b. Applying existing simulation models to quantify effects of blendstocks on vehicle efficiencies
   c. Conducting sensitivity and uncertainty analyses to improve confidence and guide experiments

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d. Modeling support for small volume fuel testing, combustion kinetics, SI auto-ignition behavior and limits
e. Accelerating workflow bottlenecks simulating new fuels and engines

Coordination of the foregoing activities are guided by six integrated teams at the national laboratories with guidance from DOE. Significant external stakeholder engagement is planned through additional strategy workshops, a project advisory board, and other formal and informal interactions.

Additional Optima information can be found at the following website:
http://www.energy.gov/eere/bioenergy/downloads/optima-program-overview

Purpose

The purpose of this RFI is to solicit feedback from industry, academia, research laboratories, government agencies, and other stakeholders on issues related to the Optima initiative. EERE is specifically interested in information regarding additional areas of research that universities and others are interested in contributing to and collaborating on. This RFI will help BETO and VTO understand the additional areas of research, capabilities, and yet to be addressed barriers and opportunities for stakeholder engagement relative to the co-optimization of engines and fuels. This is solely a request for information and not a Funding Opportunity Announcement (FOA). EERE is not accepting applications.

Disclaimer and Important Notes

This RFI is not a Funding Opportunity Announcement (FOA); therefore, EERE is not accepting applications at this time. EERE may issue a FOA in the future based on or related to the content and responses to this RFI; however, EERE may also elect not to issue a FOA. There is no guarantee that a FOA will be issued as a result of this RFI. Responding to this RFI does not provide any advantage or disadvantage to potential applicants if EERE chooses to issue a FOA regarding the subject matter. Final details, including the anticipated award size, quantity, and timing of EERE funded awards, will be subject to congressional appropriations and direction.

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development; this RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this notice will be treated as information only. EERE will review and consider all responses in its formulation of program strategies for the identified materials of interest that are the subject of this request. EERE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that EERE is under no obligation to acknowledge receipt of the information received or

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provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind EERE to any further actions related to this topic.

Proprietary Information

Because information received in response to this RFI may be used to structure future programs and FOAs and/or otherwise be made available to the public, **respondents are strongly advised to NOT include any information in their responses that might be considered business sensitive, proprietary, or otherwise confidential.** If, however, a respondent chooses to submit business sensitive, proprietary, or otherwise confidential information, it must be clearly and conspicuously marked as such in the response.

Responses containing confidential, proprietary, or privileged information must be conspicuously marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Federal Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

If your response contains confidential, proprietary, or privileged information, you must include a cover sheet marked as follows that identifies the specific pages containing confidential, proprietary, or privileged information:

> **Notice of Restriction on Disclosure and Use of Data:**
> Pages [List Applicable Pages] of this response may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for the purposes described in this RFI [Enter RFI Number]. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

In addition, (1) the header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure," and (2) every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

Evaluation and Administration by Federal and Non-Federal Personnel

Federal employees are subject to the non-disclosure requirements of a criminal statute, the Trade Secrets Act, 18 USC 1905. The Government may seek the advice of qualified non-Federal personnel. The Government may also use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The respondents, by submitting their response,

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consent to EERE providing their response to non-Federal parties. Non-Federal parties given access to responses must be subject to an appropriate obligation of confidentiality prior to being given the access. Submissions may be reviewed by support contractors and private consultants.

Request for Information Categories and Questions

Category 1: Input on Stakeholders' Perspectives and Interest in the Optima Initiative (5 page limit on responses)

BETO and VTO seek information on perspectives and interest in work that may support the Optima initiative; specifically, information on identifying additional areas of research that universities and other stakeholders are interested in contributing and collaborating. With the initiation of activities in the broader Optima effort, the goal of this request is to ensure the completeness of the list of benefits, challenges, gaps, and opportunities, and to identify how best to integrate efforts across a broad range of stakeholders.

1) Please provide information regarding activities you are currently working on that may support and/or complement the Optima Thrust I (SI) work. In your response, please describe relevant facilities, equipment and/or capabilities that could support the Optima effort and specific technical challenges these facilities would help to overcome.
2) Please provide information regarding potential new activities that could support and/or complement the Optima Thrust I (SI) work. In your response, please describe relevant facilities, equipment and/or capabilities, how interested parties could collaborate with the larger Optima effort, and how the new activities could complement, rather than duplicate, the Optima work currently underway at the DOE national laboratories.
3) Please provide information regarding activities you are currently working on that may support and/or complement the Optima Thrust II (ACI) work. In your response, please describe relevant facilities, equipment and/or capabilities that could support the Optima effort and specific technical challenges these facilities would help to overcome.
4) Please provide information regarding potential new activities that could support and/or complement the Optima Thrust II (ACI) work. In your response, please describe relevant facilities, equipment and/or capabilities, how interested parties could collaborate with the larger Optima effort, and how the new activities could complement, rather than duplicate, the Optima work underway at the DOE national laboratories.
5) Please provide information regarding your awareness of other research, activities or existing work on co-optimization of fuels and vehicle engines of which DOE should be aware.

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Category 2: Input on Barriers to Market Acceptance and Deployment (5 page limit on responses)

Through initial stakeholder engagement activities, BETO and VTO recognize the following major barriers to concurrently deploying new fuels and advanced engines:

- Public Perception and Consumer Acceptance
- Policy and Regulation
- Low Cost (relative to business as usual for both fuels and vehicles)
- Low GHG Impacts (refiners/distributors must realize an advantage over current fuels)
- High Volume (production of new fuels or blends must be on par with current demand to motivate vehicle manufacturers to switch technologies)
- Infrastructure Compatibility (fuel that is compatible with existing infrastructure can be brought to market sooner)

1) Are there additional barriers or nuances that should be considered? If so, please describe.
2) Without relying on regulation, how could the Optima effort generate significant market pull? For example, could green marketing generate consumer demand?
3) What is the value proposition (real or perceived) to consumers that would enable a price differential? How does this alter the strategy for market entry of co-optimized fuels and vehicles?
4) Is there a value proposition for fuel providers that would improve the chances of an Optima fuel being brought to market?
5) Are you aware of any innovative business models for the introduction of new fuels that could be optimized to enable value distribution across the entire supply chain?
6) What is the best strategy for transitioning new engine or fuel production technology to the marketplace? When and how should research be shared with industry or partners?

Category 3: Input on Technical ACI Fuel and Vehicle Engine Interactions (5 page limit on responses)

Initial stakeholder engagement activities have suggested ACI engine strategies may require new fuels to achieve very low emissions and fuel economy benefits over a broad operating (load/speed) range. However, options other than relying solely on fuel and/or engine architecture changes need to be explored to meet the aggressive targets proposed for the Optima initiative. For example, development of engines and engine management systems capable of detecting fuel properties, technologies allowing on-board fuel adaptation (e.g., separation, reformation), and on-line engine optimization strategies could make it possible to best utilize a range of new fuels and achieve the greatest benefits.

Through initial stakeholder engagement activities, BETO and VTO recognize that tighter specifications for diesel and biomass-derived diesel fuels and fuel components could help enable improved efficiencies and emissions of current compression ignition technologies, albeit with uncertain cost and GHG impacts. ACI engines and fuels may be well suited to applications across the light-duty to heavy-duty continuum, and a shift from diesel in heavy-duty engines to gasoline-range ACI fuels may relieve pressures on refiners to address the projected increase in diesel/gasoline demand over the next several decades. For market adoption, it may be advantageous to use the same fuels for both SI and ACI engines (assuming earlier adoption of a new SI fuel). Through initial stakeholder engagement activities, BETO and VTO recognize that engine manufacturers 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.

1) What do you perceive as the most critical technology gaps that must be overcome to achieve success with advanced combustion modes from both an engine and low GHG gas fuel perspective?
2) Are there efficiency or other performance advantages to multi-fuel combustion modes? Beyond infrastructure and consumer acceptance how can the additional equipment costs associated with multi-fuel combustion modes be justified?
3) How would you define or bound ACI fuel property requirements and specifications? Should they be more or less strict (i.e., do engine systems need to become more flexible or tolerant of fuel variability)?
4) What fuels and/or blendstocks would you suggest for additional ACI research and why? In your response, please reference relevant fuel and/or engine data.
5) Relative to vehicle emissions controls and after-treatment approaches, what areas of ACI research need additional effort?
6) Are there computationally efficient numerical simulation approaches that have the needed chemical kinetic and fluid dynamic fidelity to identify how fuel properties impact ACI combustion?

Request for Information Response Guidelines

Responses to this RFI must be submitted electronically to OptimaRFI@ee.doe.gov no later than 5:00pm Eastern Time on January 8, 2016. Responses must be provided as attachments to an email. It is recommended that attachments with file sizes exceeding 25MB be compressed (i.e., zipped) to ensure message delivery. Responses must be provided as a Microsoft Word (.docx) attachment to the email, and no more than 5 pages in length, 12 point font, 1 inch margins. Only electronic responses will be accepted.

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Please specify the category (Category 1, Category 2, or Category 3) that you are responding to. Respondents may answer as many or as few questions as they wish. If you wish to provide input to more than one category of interest, you should submit a separate response for each category. Each such response must not exceed 5 pages in length. If, for example, you respond to questions under two different categories (e.g., Category 1 and Category 3), you may submit a separate 5-page response for each category (for a total of 10 pages).

EERE will not respond to individual submissions or publish publicly a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

Respondents are requested to provide the following information at the start of their response to this RFI:

- Company / institution name
- Company / institution contact
- Contact's address, phone number, and e-mail address.
- Stakeholder group(s) your response reflects (include all that apply from list below):
    - Academia
    - Research laboratory
    - Government
    - Industry
    - Other (Please specify)