U.S. Department of Energy
Advanced Research Projects Agency – Energy

Request for Information (RFI)
DE-FOA-0001978
on
High-Efficiency Internal Combustion Engine Development

Objective:

The Advanced Research Projects Agency – Energy (ARPA-E) of the US Department of Energy is seeking information concerning the current state of development of advanced, high-efficiency internal combustion engines (ICEs) suitable for light truck and SUV applications, as well as an indication of the potential of these engines to meet future vehicle performance, fuel efficiency and emissions requirements. The target vehicle application of interest for the ICEs is in the light-duty 6,001-8,500 lbs GVWR range (in the EPA LDT classification), and includes full-size pickup trucks and sport utility vehicles (SUVs).

ARPA-E seeks information on (i) the current status of technical development of any high-efficiency ICE that is suitable for, and capable of meeting the performance, utility and emissions requirements of the above target vehicle application, and (ii) what further technical developments are required before such an engine can be successfully integrated into a target vehicle, as a necessary technical demonstration before the commercialization of that engine can be achieved.

ARPA-E is seeking information on ICEs that currently exist at an advanced level of development, albeit still prior to commercialization and full-scale production. ARPA-E is not interested in unproven ICE technologies, or technologies that have not yet been reduced to practice in the form of operating engines, or engines that do not yet exist in the size and power range suitable for the target vehicle application. Depending on the responses to this RFI, ARPA-E may consider the rapid initiation of one or more funded collaborative research projects to advance the state of the art of high-efficiency ICEs with the potential for substantial fuel savings in light-duty trucks and SUVs.

Please carefully review the REQUEST FOR INFORMATION GUIDELINES below. Please note, in particular, that the information you provide will be used by ARPA-E solely for program planning, without attribution. **THIS IS A REQUEST FOR INFORMATION (RFI) ONLY. THIS NOTICE DOES NOT CONSTITUTE A FUNDING OPPORTUNITY ANNOUNCEMENT (FOA). NO FOA EXISTS AT THIS TIME.**

Background:

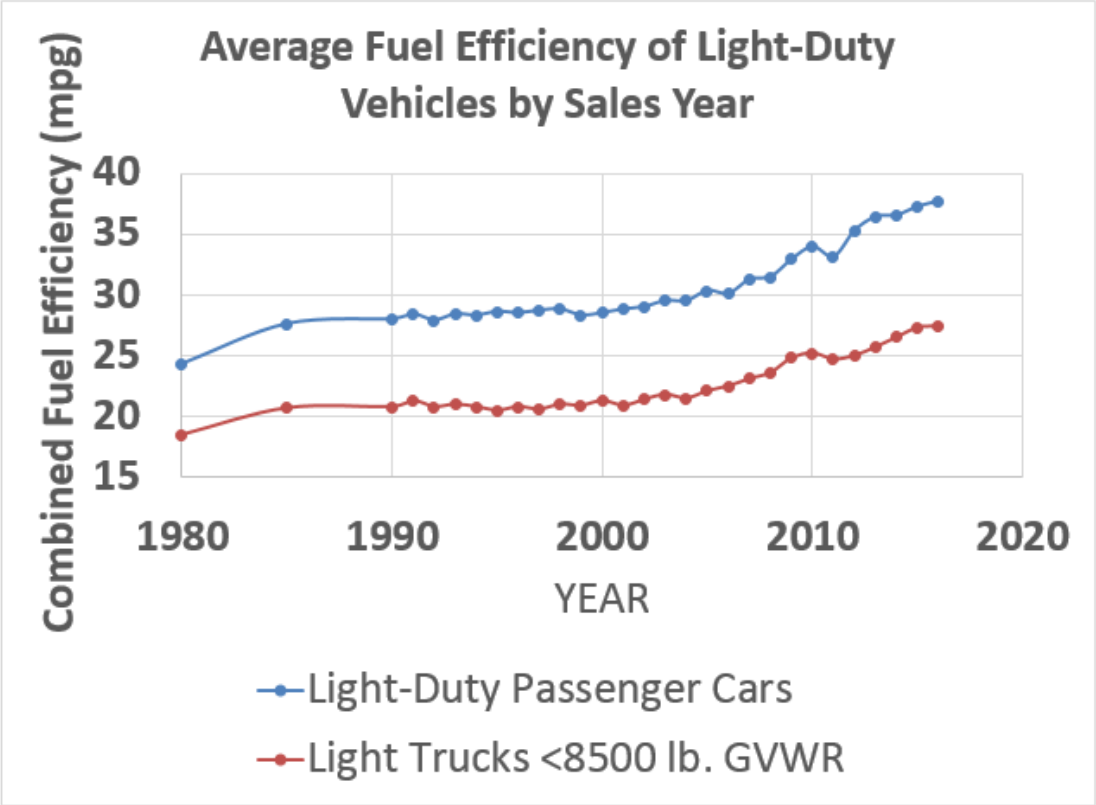
The United States' light-duty vehicle fleet (GVWR <8,500 lbs) currently travels a total of 2.8 trillion vehicle miles annually, and consumes around 9.0 million barrels of oil (equivalent) per day mainly in the form of gasoline fuel (EIA Annual Energy Outlook, 2018). The heavy-duty fleet consumes a further 2.9 million barrels of oil (equivalent) per day of (mainly) diesel fuel in covering an additional annual distance of roughly 0.3 trillion vehicle miles traveled (VMT).

ARPA-E's founding principles include funding R&D to reduce US energy imports, to reduce the emissions associated with the production and consumption of energy, to improve the energy efficiency of energy production, storage, transmission distribution and end usage, and to improve US competitiveness. Reducing the fuel consumption of the light-duty vehicle fleet is thus clearly an imperative for ARPA-E.

While the light-duty vehicle fleet has become significantly more energy efficient in recent years, the prospect of stagnating vehicle fuel efficiency and steadily increasing VMT will necessarily lead to an increase in energy consumption by the light-duty vehicle fleet, and could potentially result in an increase in energy imports required for transportation purposes.

Future fuel efficiency improvements for light-duty vehicles will be achieved through the commercialization and implementation of a mix of well-established fuel efficiency technologies, including engine downsizing and boosting, engine efficiency improvements, vehicle light-weighting, aerodynamic drag reduction, tire rolling resistance reduction, waste heat or energy recovery, auxiliary and parasitic load reduction, the use of multi-speed and other high-efficiency transmissions, vehicle electrification and hybridization (across the range from mild- to strong- hybridization, with or without the use of plug-in energy storage systems).

Compared to other light-duty vehicles (such as passenger cars), light trucks (pickup trucks) and SUVs have unique powertrain requirements, due to their higher vehicle weight, and greater vehicle payload-carrying and trailer-towing requirements. Hybridization of light trucks, while certainly achievable, is proving elusive due to issues of powertrain complexity, weight, cost, packaging, range and sustained payload-carrying and towing capability. As a result, it is conceivable that conventional powertrains (engines and transmissions, perhaps with mild hybridization) will continue to dominate the light truck market for some time.



(Data in the chart above is from the US Department of Transportation, Bureau of Transportation Statistics (BTS), 2018. "Average fuel efficiency of light-duty vehicles".)

ARPA-E is interested in developing transformative technologies in the automotive engine area. Specifically, for the purposes of this RFI, ARPA-E is interested in finding out about the current status of existing and emerging high-efficiency gasoline ICEs that are suitable for conventional and mild hybrid light truck and SUV applications. Engine technologies that currently exist, that meet the specifications and targets detailed below (including power rating), and that have already been reduced to practice, but have not yet reached commercialization, are of specific interest.

Purpose and Need for Information:

The purpose of this RFI is solely to solicit input for ARPA-E's consideration, and to inform the possible formulation of future ARPA-E projects or programs intended to further the research and development of high-efficiency gasoline ICEs, including those suitable for light-truck and SUV applications.

ARPA-E will not provide funding or compensation for any information submitted in response to this RFI, and ARPA-E may use non-confidential information submitted to this RFI without any attribution to the source. This RFI provides the broader research and development community with an opportunity to contribute facts, data, information and projections regarding the current state of the art of high-efficiency ICE R&D, and the potential for further fuel efficiency improvements in future conventional and hybrid gasoline-fueled light-duty vehicle applications.

REQUEST FOR INFORMATION GUIDELINES:

No material submitted for review will be returned and there will be no formal or informal debriefing concerning the review of any submitted material. ARPA-E may contact respondents to request clarification or seek additional information relevant to this RFI. All responses provided will be considered, but ARPA-E will not respond to individual submissions or publish publicly any response or a compendium of responses. **Respondents shall not include any information in their response to this RFI that might be considered proprietary or confidential**. However, respondents should indicate in their responses if additional confidential or proprietary information exists that would be helpful to ARPA-E in assessing respondents' ICE technologies. ARPA-E may contact respondents to request clarification or seek additional information relevant to this RFI.

Depending on the responses to this RFI, ARPA-E may consider the rapid initiation of one or more funded collaborative research projects to advance the state of the art of high-efficiency gasoline ICEs with the potential for substantial fuel savings in future light-duty vehicles.

Responses to this RFI should be submitted in PDF format to the email address

ARPA-E-RFI@hq.doe.gov by **5:00 PM Eastern Time on September 21st, 2018**. Emails should conform to the following guidelines:

- Please insert "Response to RFI DE-FOA-0001978 - <your organization name>" in the subject line of your email.
- In the body of your email, include your name, title, organization, type of organization (e.g. university, non-governmental organization, small business, large business, federally funded research and development center (FFRDC), government-owned/government-operated (GOGO), etc.), email address, and telephone number.
- Responses to this RFI are limited to no more than 10 pages in length (12 point font size).
- Respondents should include non-proprietary results, data, information and figures that describe their current ICE technology (that meets the target requirements of this RFI), the current state of development of that technology, as well as any plans that they have for the further development of that technology.
- **ARPA-E encourages responses to each of Sections A, B and C below:**

A. Current Status:
Respondents must describe the current status of development of their existing ICE suitable for light truck and SUV applications. Include data and descriptions as applicable to describe how the ICE currently performs with regard to the technical metrics listed in the Table below.

Parameter	Metric	ARPA-E Comment	Current Status
Application or target vehicle of interest	Light duty truck (full-size pickup truck or SUV)	GVWR 6,001-8,500 lbs (in the EPA LDT Classification).	

Powertrain type of interest	Internal combustion engine (ICE)	Multi-cylinder engine capable of transient operation. (Fuel cell electric and battery electric propulsion systems are not of interest for this RFI).	
Power rating	>175 kW	Peak engine power.	
Area of interest	Multi-cylinder ICE	Single-cylinder research engines are not of interest for this RFI.	
Fuel of interest	Pump gasoline	E10 is acceptable.	
Maximum single point brake thermal efficiency (%)	≥35 at a speed and load of interest to light truck performance applications.	Engine dynamometer test results of this capability must have been demonstrated to date.	

B. Future Development Status:

Respondents must describe the potential future status of development of their existing ICE suitable for light truck applications. Include data, information and descriptions as required to indicate the potential of attaining the technical metrics and targets listed in the Table below. Describe the target baseline vehicle which would be used for vehicle integration (preferably a high production volume 2018 light-truck or SUV), in order to demonstrate the performance, emissions and fuel efficiency capability of the ICE within **2 or 3 years of further engine research and development effort**. ARPA-E has provided questions in the Future Development column of the Table to help guide the responses.

Parameter	Metric	Target	Future Development
Application vehicle of interest	Light-duty truck (full-size pickup truck or SUV).	GVWR 6,001-8,500 lbs (in the EPA LDT Classification).	Is vehicle integration achievable within 2 or 3 years with further development?
Power rating	>175kW	Peak engine power.	Is fully transient operation in a target vehicle of interest capable of being demonstrated within 2 or 3 years with further development?
Engine mass	≤300kg		Can this be achieved within 2 or 3 years with further

			development? If not, what mass can be achieved?
Maximum single point brake thermal efficiency	≥40%	At what engine speed and load?	Can this peak efficiency be achieved within 2 or 3 years with further development? If not, what efficiency can be achieved?
HWFET cycle brake thermal efficiency	≥37%	Chassis dynamometer testing using target vehicle.	Can this cycle-averaged efficiency can be achieved within 2 or 3 years with further development? If not, what cycle-averaged efficiency can be achieved?
FTP75 emission transient cycle brake thermal efficiency	≥33%	Chassis dynamometer testing using target vehicle.	Can this cycle-averaged efficiency can be achieved within 2 or 3 years with further development? If not, what cycle-averaged efficiency can be achieved?
Transient regulated emissions	Must be able to achieve Tier 3 Bin 30/LEV III SULEV30 with or without exhaust after-treatment system.	EPA standard, or equivalent CARB standard.	Can fully transient emissions compliance be achieved within 2 or 3 years with further development? If not, what emissions levels can be achieved?
Powertrain Cost	≤50$/kW This includes engine, complete hybrid system costs (if any), exhaust after-treatment, engine accessories and transmission.	In production volumes of greater than 10k/year.	Is this cost achievable, and can it be demonstrated (at least through a techno-economic analysis) within 2 or 3 years with further development? If not, what powertrain cost can be achieved?
Packaging	Engine and transmission must be capable of being packaged in the baseline vehicle.		Can this be demonstrated within 2 or 3 years with further development? If not, what packaging constraints are there that would prevent this?
Real-world fuel consumption demonstration	Technology must be able to demonstrate at least a 30% improvement over the baseline vehicle fuel consumption under real-	Reasonable real-world driving cycles should be described in	Can this be demonstrated within 2 or 3 years with further development? If not, what real-world fuel consumption improvements can be achieved?

	world city and highway driving conditions.	this RFI response.	
Vehicle utility	Must meet the baseline vehicle performance requirements, including acceleration, top speed, gradeability, startability, operating temperature range, NVH, driveability, vehicle range, towing capability and ease of use.	Reasonable baseline vehicle utility levels should be described in this RFI response.	Can this be demonstrated within 2 or 3 years with further development? If not, what levels of vehicle utility can be achieved?

C. Team and Capabilities.

Respondents must briefly describe their organization's engine development capabilities, including a candid assessment of any essential engine development or vehicle integration capabilities and/or technologies that the Respondent's organization does not currently possess.

Topics Not of Interest:

ARPA-E is not interested in ICEs that have yet to be developed, demonstrated or reduced to practice. For the purposes of this RFI, ARPA-E is not interested in engines that are not currently operating in the power range suitable for the target vehicle application, or engines that do not meet the specifications laid out in Sections A and B above. For the purposes of this RFI, ARPA-E is not interested in receiving information on fuel cell technology, electric drives, battery-powered vehicles, alternative fuels or other fuel efficiency automotive technologies not related to high-efficiency gasoline ICEs.