Medium and Heavy Duty Fuel Cell Electric Truck Targets

DATE: 6/10/2016

SUBJECT: Request for Information (RFI): DE-FOA-0001600

DESCRIPTION: This RFI pertains to setting technology targets for fuel cell electric trucks (FCET). These targets will help drive early markets for medium and heavy duty (MD/HD) trucks which utilize hydrogen fuel cell technology.

BACKGROUND: Fuel cell technology provides a means to create net zero emission vehicles (ZEV) for larger weight classes due to scalability and comparable performance to conventional powertrains. Research activities supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), Fuel Cell Technologies Office (FCTO) are focused on developing technology targets for FCETs to facilitate the growth of hydrogen (H_2) and fuel cell technology. Making the transition from fossil fuel-powered to fuel cell powered trucks will help reduce greenhouse gas emissions, improve domestic energy security, and improve air quality. The MD/HD market spans multiple weight classes (i.e. class 3-8 or 10,000-80,000+ lbs.) and vocational uses (i.e. delivery van, tractor trailer, flatbed, etc.). Today, MD/HD trucks account for 28% of petroleum use in the U.S. transportation sector [EIA 2015].

A key activity within FCTO with industry input, is setting technology targets for future years (e.g., 2020 targets) based on what is required to be competitive with incumbent or other advanced technologies. These targets can then be used by stakeholders to help track performance and set technology benchmarks. Currently, FCTO tracks technology targets for hydrogen production, delivery, storage, and fuel cells for light-duty vehicles.

PURPOSE: The purpose of this RFI is to solicit feedback from truck operators, truck and hydrogen tank manufacturers, fuel cell manufacturers, station equipment designers, and other related stakeholders on issues related to fuel cell electric truck targets. 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 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 identifying 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 DE-FOA-0001600. 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, 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.

QUESTIONS: The proposed specifications and targets are summarized in Tables 1 and 2. The summary information in Table 1 provides example design values for a set of 12 representative trucks based on analysis and design of vehicle performance metrics. The proposed targets in Table 2 are based on previously published FCTO light duty fuel cell electric vehicle and fuel cell electric bus targets. Some targets are a function of truck classification (i.e. weight class and vocation), and FCTO seeks input on developing target ranges for MD/HD FCET's. Please respond to both the general questions (A-G) and specific questions (1-22). Responses to the RFI should address one or more of the following:

General Questions

A. Relevance of the target parameters
B. Appropriateness of target values when applied to MD/HD trucks
C. Recommendations for adjusting targets for the MD/HD market
D. Adequacy of target table footnotes and/or need for additional supporting information
E. Recommendations for additional targets
F. Status of fuel cell technologies in comparison to targets
G. Potential Research & Development (R&D) areas

In addition to comments regarding the above content of Tables 1 and 2, please also address the questions below where you can provide valuable insight. Questions that do not apply to your organization can be left blank.

Specific Questions

Company Background

1. Please provide any relevant company/organization background information regarding your interest/involvement in alternative fuel vehicles. This could include: current vehicle fleet operation details, vehicle retrofit experience, pressurized storage tank design, alternative fuel production and distribution, and other relevant information.
2. Does your company/organization have interest in hydrogen and fuel cell technology for MD/HD vehicles? Why or why not?
3. Please provide any additional input on requirements/needs/challenges or other factors that could help develop targets for MD/HD FCET's to guide research and development and enable commercially viable systems.

Vehicle Operations

4. When buying a new truck, what are the most important factors that are considered (e.g. performance, payload, cost, etc.)?

5. Does your truck fleet currently include any alternative fuel vehicles (e.g. CNG, biofuels, electric, fuel cell, etc.)? What factors influenced your decision to add these vehicles to your fleet?
6. Does your company/organization have interest in using more alternative fuel vehicles in the future? Have you considered FCETs? Why or why not?
7. What MD/HD truck applications make the most sense to convert to hydrogen fuel cells from your perspective and why?
8. Please provide any additional input on requirements/needs/challenges or other factors that could help develop targets for MD/HD FCET's to guide research and development and enable commercially viable systems.

Fuel Storage and Retrofits

9. What are the advantages and disadvantages between using pressurized hydrogen storage at 700 bar and 350 bar from your perspective? Which storage pressure makes the most sense for the medium and heavy duty markets and why?
10. What design considerations are necessary for safely housing high pressure gas storage on board a vehicle?
11. What requirements are necessary for integrating fuel tanks (diesel, gasoline, CNG, H_2, etc.)? What about electric drive components (batteries, power electronics, fuel cell systems, etc.)?
12. Is other equipment typically housed on the side rail or behind the cab of the truck (e.g. batteries, tool box, compressors, etc.)? List other relevant examples regarding design considerations or requirements.
13. What are the greatest challenges you encounter when retrofitting a vehicle?
14. Provide any additional input related to onboard hydrogen storage and/or retrofitting trucks with hydrogen fuel cell technology in terms of technical/performance targets/requirements.

Cost

15. Assuming comparable range and performance between FCETs and conventional trucks, would you be willing to invest more money into FCETs to have a more eco-friendly fleet? How much more per vehicle and with what payback time?
16. What are the projected costs to design, manufacture, purchase and install a custom high pressure storage tank? How do these costs differ depending on the storage pressure? How do these costs relate to manufacturing volume?
17. What are the projected costs to design, manufacture, purchase and install the fuel cell and other powertrain components? How do these costs relate to manufacturing volume?
18. What component/system/subsystem either part of the truck or fuel/fueling infrastructure related is of most concern?
19. Provide your cost requirement for hydrogen fuel and how it relates to a specific truck application and FCET cost.
20. Provide any additional information on needs/challenges/requirements from a cost perspective that would help develop targets to guide research and development and enable commercially viable FCET's.

Market Drivers and Competitiveness

21. What are the main market drivers for your interest in fuel cell MD/HD trucks and over what time frame? State specifically why they offer (or can offer) a competitive advantage over alternative vehicles.
22. What are your highest priority targets to make fuel cell MD/HD trucks competitive and what level of investment do you consider essential to meet these targets? What time frame is realistically required in order to meet these targets?

Please provide any additional input on requirements/needs/challenges or other factors that could help develop targets for MD/HD FCET's to guide research and development and enable commercially viable systems.

Respond to both the General Questions (A TO G) and the Specific Questions (1-22).

Table 1: Proposed Specifications for MD/HD FCET's

Vehicle	Motor Continuous Power (kW)	Fuel Cell Power (kW)	Onboard Hydrogen Stored[1] (kg)	Vehicle Range[2] (miles)
Class 2 Van	135	155	7	150
Class 3 Enclosed Van	140	155	9	160
Class 3 School Bus	185	190	9	150
Class 3 Service	150	175	7	150
Class 4 Delivery Van	165	170	19	200
Class 5 Utility	205	245	9	150
Class 6 Construction	155	170	14	200
Class 7 School Bus	145	145	12	150
Class 8 Construction	170	140	22	200
Class 8 Line haul	355	375	80	400
Class 8 Refuse	235	245	20	150
Class 8 Tractor Trailer	260	265	62	400

[1] Assumes hydrogen is stored on the side rails of the vehicle. The available wheelbase and a minimum ground clearance of 10 inches was chosen to dimensionally constrain the amount of packaging space for hydrogen storage.

[2] Vehicle range is specified considering data collected from the Vehicle Inventory and Use Survey (VIUS) (U.S. Census Bureau, 2002: http://www.census.gov/svsd/www/vius/2002.html).

Table 2: Proposed Targets for MD/HD FCET's

Characteristic	Proposed Target (2025)					
	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
	Vehicle Operation[1]					
Fuel Economy[2] [miles per kg]	26	20	18	16	14	12
Vehicle Lifetime [years/miles]	12/500,000					
Power Plant Lifetime[3,4] [hours]	25,000					
Power System Cost[3] [$/kW]	160					
Scheduled and Unscheduled Maintenance Cost[5] [$/mile]	0.4					
Vehicle Range [miles]	300[6]					
	Fuel Cell System[1]					
FC System Power Density [W/L]	850					
FC System Specific Power [W/kg]	650					
	Hydrogen Storage[1,7]					
Storage Tank Gravimetric Capacity[8] [kg H_2/kg storage tank]	5[9]					
Storage Tank Volumetric Capacity[8] [kg H_2/100 L]	3.8/2.2[10]					
Hydrogen Storage System Cost[11] [$/kg H_2 stored]	266					
Operation Cycle Life (1/4 tank to full) [cycles]	2,500					
System Fill Rate[12] [kg H_2/min]	5					

1 Reference targets for vehicle operation, fuel cell system, and hydrogen storage are taken from the fuel cell bus data record and Multi-Year Research, Development, and Demonstration (MYRD&D) Plans:
Fuel Cell Bus Record: http://www.hydrogen.energy.gov/pdfs/12012_fuel_cell_bus_targets.pdf
Fuel Cell MYRD&D: http://energy.gov/sites/prod/files/2014/12/f19/fcto_myrdd_fuel_cells.pdf
Hydrogen Storage MYRD&D: http://energy.gov/sites/prod/files/2015/05/f22/fcto_myrdd_storage.pdf
Vehicle Technologies Multi Year Program Plan:
http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/vt_mypp_2011-2015.pdf

2 Note that one kg of hydrogen is approximately the same energy content as one diesel gallon equivalent (DGE). However, the fuel cell can be about 2-3 times more efficient than conventional engine technology.

[3] The power system is defined as the fuel cell, battery, and traction drive systems. The fuel cell system includes supporting subsystems such as the air, fuel, coolant, and control subsystems. The traction drive system includes power electronics and the electric drive. Hydrogen storage system components are excluded.

[4] According to an appropriate duty cycle.

[5] Excludes mid-life overhaul of power plant.

[6] A 300 mile range should meet the demand for many MD/HD applications. Other vocational uses may require less or more range between 150 and 500 miles (i.e. refuse truck and tractor trailer respectively).

[7] Targets are based on the lower heating value of hydrogen, 33.3 kWh/kg H2. Targets are for a complete system, including tank, material, valves, regulators, piping, mounting brackets, insulation, added cooling capacity, and all other balance-of-plant components. All capacities are defined as usable capacities that could be delivered to the fuel cell power plant. All targets must be met at the end of service life (approximately 2,500 cycles).

[8] Capacities are defined as the usable quantity of hydrogen that can be delivered to the power plant divided by the total mass/volume of the storage tank, including all stored hydrogen. Tank designs that are conformable and have the ability to be efficiently packaged onboard vehicles may be beneficial even if they do not meet the full volumetric capacity targets. Capacities must be met at end of service life.

[9] Applies to a 100 L tank at 700 bar. Larger tanks that meet this target could reach a gravimetric capacity of 9%. Capacity for 350 bar storage is expected to be slightly less than the 700 bar case.

[10] Volumetric capacity is shown for 700 bar and 350 bar storage pressure respectively.

[11] Hydrogen storage system cost includes the storage tank and relative balance of plant components and does not include fuel cost [http://hydrogen.energy.gov/pdfs/11007_h2_threshold_costs.pdf]. For material-based storage technologies, the impact of the technology on the hydrogen cost, e.g., off-board cooling, off-board regeneration of chemical hydrogen storage materials, etc., must be taken into account.

[12] This fueling rate could correspond to truck specific fueling islands located at truck stops for more rapid refueling.

Table Comments

Vehicle Operation

Fuel economy targets have been set for each weight class to reduce the confusion of one normalized target that would span all weight classes. Power system cost has been normalized based on the fuel cell stack size required for each vehicle. This cost accounts for all fuel cell system components except for the hydrogen storage system. The vehicle range target suggested is comparable to light duty vehicles at 300 miles, however, some truck designs may require more or less range depending on vocational use. Lifetime targets and maintenance costs suggested are based on fuel cell bus targets.

Fuel Cell System

Fuel cell system targets are proposed to be independent of truck classification. Reference targets are currently normalized to account for system scalability and this scalability will account for the large span of truck weight classes and power demands.

Hydrogen Storage

Gravimetric and volumetric capacity are both expected to increase incrementally as hydrogen storage volume increases on larger trucks. System fill rate may also need to increase to accommodate reasonable full fill times for large amounts of hydrogen storage (e.g. 50 kg). All other storage targets are not anticipated to vary much from the light duty targets.

REQUEST FOR INFORMATION RESPONSE GUIDELINES: Responses to this RFI must be submitted electronically to FCTrucktargets@ee.doe.gov no later than 5:00pm (ET) on 7/11/2016. 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.

Please identify your answers by responding to a specific question or topic if possible. Respondents may answer as many or as few questions as they wish.

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.