Request for Information (RFI) DE-FOA-0001510: Research, Development and Business Strategies Needs for Hydrogen and Automotive Polymer Electrolyte Membrane (PEM) Fuel Cells

DATE: March 29, 2016
SUBJECT: Request for Information (RFI)

Modification 000002

The purpose of this modification is to change the RFI Deadline to 04/10/2016, 5:00pm (ET). All changes to this document have been highlighted.

Modification 000001

The purpose of this modification is to extend the RFI Deadline to 04/15/2016, 5:00pm (ET). All changes to this document have been highlighted.

Description

The Fuel Cell Technologies Office (FCTO) is seeking feedback from the research community, relevant stakeholders, and industry on technical and economic barriers for fuel cell-related technologies. In particular, FCTO seeks information regarding:

- Research and development (R&D) needs to improve performance and reduce cost of bipolar plates for polymer electrolyte membrane fuel cells (PEMFCs);
- The high startup cost for hydrogen refueling stations, which may be caused by extensive installation and permitting efforts or low equipment utilization; and
- Innovative research topics that may not currently be part of the FCTO portfolio but could potentially be appropriate for future efforts or funding opportunity announcements.

Background

Successful commercialization of PEMFCs for automotive applications requires cost reductions and durability improvements at the component and system level. Bipolar plates are projected to be one of the highest fuel cell cost items at high production volumes and are a key component in determining fuel cell performance and durability of an automotive fuel cell system. Bipolar plates that meet performance and cost targets established by FCTO are part of the strategy for meeting overall system cost targets.

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The other major factor in commercialization of automotive PEMFCs is availability and cost reductions of hydrogen fuel. The high cost of hydrogen fuel to the fuel cell vehicle user may be attributed, in part, to permitting on a site without existing gaseous fuel such as compressed natural gas or the lack for fuel demand by privately owned vehicles to cover the high capital equipment investment.

Purpose

The purpose of this RFI is to solicit feedback from industry, academia, research laboratories, government agencies, and other stakeholders on issues related to:

1. Bipolar plates for automotive fuel cell applications;
2. Co-location of hydrogen stations with existing Compressed Natural Gas (CNG) stations;
3. Mobile hydrogen refueling delivery service;
4. Open Topic/Research

FCTO is specifically interested in information on cost avoidance and its effect on fuel prices. 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.

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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 3-8 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-0001510. 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.

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Request for Information Categories and Questions

Category 1: Bipolar plate technology advancement

Key characteristics for bipolar plates, the status of current technology, and technical targets for those characteristics are listed in the table below. Input is solicited on the current status of the technology, on the appropriateness and completeness of existing characteristics, and on R&D needs to enable achievement of the targets. Please provide R&D needs and priorities for each of the following topics:

1. Materials
   1. What materials (ferritic steels, non-ferritic steels, aluminum, other metals or alloys, or other materials) provide the most potential to meet bipolar plate cost, durability and performance targets for automotive applications? What is the state of the art for these and what are their status compared to DOE's 2020 targets? What R&D is required to further advance it?
   2. What is required to advance the state of the art of existing coatings to improve performance, cost and durability? What can be done to improve the adhesion and minimize the interfacial contact resistances?
   3. Are there advanced materials or coatings that would enable future improvements beyond the 2020 targets?

2. Process Improvements
   1. What improvements are required for current manufacturing processes (e.g. stamping, hydroforming, etc.)? Are there opportunities to reduce manufacturing costs by applying coatings to the substrate material prior to plate forming?
   2. Can advanced manufacturing processes (e.g. additive manufacturing application in prototyping) be used in achieving:
      - cost reduction;
      - weight reduction;
      - materials development?
   3. Are improvements possible in low-cost manufacturing methods for:
      - assembly;
      - coating substrate prior to forming;
      - double- or single-sided stamping;
      - bonding;
      - multiple flow fields on a single plate?
   4. Are there advances required in process quality control to lower manufacturing costs?

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3. Technology barriers

1. Novel corrosion protection
    - Are there lessons to be learned from other industries or technologies?
    - Can we design stamp able coatings that provide adequate corrosion protection?
2. Optimized fluid and thermal flow
    - Are there advances in current forming processes required to optimize mass transport?
    - Is there any issue with thermal management to be addressed through precompetitive R&D?
    - Can advanced designs incorporate gas diffusion media (GDM) functionality into the bipolar plate, eliminating the need for GDM?
3. Is adequate modeling done on various aspects of bipolar plates such as corrosion, degradation, mass transport? Can high performance computing be of value? If so in what ways?

4. Testing, Durability and Targets

1. Are bipolar plate durability test and accelerated stress test protocols required? If so what can be used as a baseline for these tests?
2. Are foundational studies on bipolar plate degradation and mitigation approaches required to advance fuel cell durability?
3. Do the questions asked in this RFI suggest any changes in the table below? If so, what are these suggestions?

Technical Targets: Bipolar Plates			
Characteristic	**Units**	**2015 Status**	**2020 Targets**
Cost[a]	$ / kW_{net}	7[b]	3
Plate weight	kg / kW_{net}	<0.4[c]	0.4
Plate H_2 permeation coefficient[d]	Std $cm^3/(sec\ cm^2 Pa)$ @ 80°C, 3 atm 100% RH	0[e]	$<1.3 \times 10^{-14}$[f]
Corrosion, anode[g]	µA / cm^2	No active peak[h]	<1 and no active peak
Corrosion, cathode[i]	µA / cm^2	<0.1[b]	<1
Electrical conductivity	S / cm	>100[j]	>100
Areal specific resistance[k]	Ohm-cm^2	0.006[h]	0.01
Flexural strength[l]	MPa	>34 (carbon plate)[m]	>25
Forming elongation[n]	%	20–40[o]	40

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a. Costs projected to high volume production (500,000 80 kW systems per year), assuming MEA meets performance target of 1000 mW/cm2.
b. Cost when producing sufficient plates for 500,000 systems per year. DOE Hydrogen and Fuel Cells Program Record 15015, "Fuel Cell System Cost – 2015." http://www.hydrogen.energy.gov/program_records.html
c. C.H. Wang (Treadstone), "Low-cost PEM Fuel Cell Metal Bipolar Plates," 2012 Annual Progress Report, http://www.hydrogen.energy.gov/pdfs/progress12/v_h_1_wang_2012.pdf.
d. Per the standard gas transport test (ASTM D1434).
e. C.H. Wang (Treadstone), private communication, October 2014.
f. Blunk, *et al*, J. Power Sources 159 (2006) 533-542.
g. pH 3 0.1ppm HF, 80°C, peak active current $<1x10^{-6}$ A/cm^2 (potentiodynamic test at 0.1 mV/s, -0.4V to +0.6V (Ag/AgCl)), de-aerated with Ar purge.
h. A. Kumar, M. Ricketts, and S. Hirano, "Ex-situ evaluation of nanometer range gold coating on stainless steel substrate for automotive polymer electrolyte membrane fuel cell bipolar plate," Journal of Power Sources 195 (2010): 1401-1407, September 2009.
i. pH 3 0.1ppm HF, 80°C, passive current $<5x10^{-8}$ A/cm^2 (potentiostatic test at +0.6V (Ag/AgCl) for >24h, aerated solution.
j. O. Adrianowycz (GrafTech), "Next Generation Bipolar Plates for Automotive PEM Fuel Cells," 2009 Annual Progress Report, http://www.hydrogen.energy.gov/pdfs/progress09/v_g_2_adrianowycz.pdf
k. Includes interfacial contact resistance (on as received and after potentiostatic test) measured both sides per Wang, *et al*. J. Power Sources 115 (2003) 243-251 at 200 psi (138 N/cm^2).
l. ASTM-D 790-10 Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
m. D. Haack et al. (Porvair), "Carbon-Carbon Bipolar Plates," 2007 Annual Progress Report, http://www.hydrogen.energy.gov/pdfs/progress07/v_b_3_haack.pdf
n. Per ASTM E8M-01 Standard Test Methods for Tension Testing of Metallic Materials, or demonstrate ability to stamp generic channel design with width, depth, and radius.
o. M. Brady et al. (Oak Ridge National Laboratory), "Nitrided Metallic Bipolar Plates," 2010 Annual Progress Report, http://www.hydrogen.energy.gov/pdfs/progress10/v_I_1_brady.pdf.

Category 2: Co-location of hydrogen stations with existing Compressed Natural Gas (CNG) stations

The availability of hydrogen fueling stations in places where Fuel Cell Electric Vehicles (FCEVs) will be deployed, as well as the cost to equip and operate these stations, are key challenges to the adoption of FCEVs. As the market for FCEVs expands, fueling infrastructure will need to grow to support the expansion. A September 2014 report by Sandia National Laboratories titled "Transitioning the Transportation Sector: Exploring the Intersection of Hydrogen Fuel Cell and Natural Gas Vehicles"[1] concluded that co-locating hydrogen stations with CNG stations may represent an opportunity for synergies and cost reductions for either public-access stations or limited-access fleet stations, reflecting experience with handling compressed gaseous fuels, the opportunity to use existing natural gas infrastructure and supply chain, and potential benefits from clean fuel diversification. According to the Alternative Fuels Data Center, more than 800 CNG stations dispense gaseous transportation fuel across the United

[1] http://energy.gov/sites/prod/files/2015/02/f19/2015-01_H2NG-Report-FINAL.pdf

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States, with at least one station in 45 of the 50 states.[2] More than half of these stations are available for public use. [3]

- What costs are avoided or reduced by co-locating hydrogen (H2) with CNG refueling?
- Are safety codes and standards compatible?
- CNG is used largely for heavy or medium trucks – what logistic challenges are there for co-locating hydrogen for medium or light duty vehicles?
- What are the safety challenges?
- Are there other advantages to co-location?
    - Would co-locating enable station operators to take advantage of common supply chains, common equipment, economies of scale for storage tanks, operations and maintenance processes?
    - Would co-locating allow a customer base for station operators to be broader because more than one transportation segment is being served?
    - What other feedback can you provide?

Category 3: Mobile hydrogen refueling delivery service

Recognizing the cost challenges to build and operate hydrogen stations during an early market launch of FCEVs, the use of mobile hydrogen storage and dispensing systems may provide early-market FCEV customers with convenient, accessible, and reliable refueling, and also provide hydrogen fuel suppliers with a lower-cost compared to stationary hydrogen fueling station investments. To support the launch of new markets for FCEVs in the US, mobile hydrogen refueling systems could complement the initial build of clustered networks of hydrogen stations, thereby reducing the overall costs to build and operate the number of hydrogen stations necessary to provide FCEV customer refueling service for a given region or state. Mobile transport systems could potentially store, transport, and dispense hydrogen into FCEVs through an on-board system mounted on a medium or heavy duty truck. Such mobile stations could also be used to convey "concierge" or premium refueling service directly to FCEV customers, such as fueling at their residences or work places. This concept may offer an early approach before widespread hydrogen infrastructure development is realized.

If a mobile refueling system or "fuel-to-you" type of refueling option were to be available:

[2] http://www.afdc.energy.gov/fuels/stations_counts.html
[3] http://www.cngnow.com/vehicles/refueling/Pages/information.aspx

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- What would be an appropriate business model or value proposition to make this concept viable?

- What industries would be the likely fuel distributors? Fuel makers? Bulk fuel distributors, home heating oil/other retail energy providers? Other?

- What code or permitting challenges will likely by encountered for residual and work place refueling?

- What would be the road safety or regulatory issues associated with deploying a mobile refueling truck?

- Could the fuel-to-you concept work for corporate fleets? Why or why not?

- Would independently-owned dealership franchises be willing to offer third party home or workplace refueling services at the point-of-sale?

- What are the costs of deploying a (one) mobile refueler as a demonstration in terms of capital equipment and operating cost?

- What net payback time (in years) would be needed to make this investment acceptable?

- Would the car buyers be more likely to buy FCEVs even if fuel cost was higher than at a gasoline station? If yes, how much higher cost would car buyers be willing to pay (in increased percentage terms)?

- How much hydrogen fuel volume dispensed i.e. kilograms per day is necessary for a mobile refueler to offer a competitive cost?

Category 4: Open Topic/Research

The objective of this category is to identify novel, non-incremental technologies that facilitate one or more of the overall Fuel Cell Technologies Office's (FCTO) goals but are not represented in a significant way in the FCTO's existing program plans or current project portfolios. Projects should support high-risk, proof-of-concept research to develop a unique technology concept, either in an area not currently supported by the FCTO or as a potential enhancement to an ongoing focused technology area. The full spectrum of technologies and/or non-hardware solutions relevant to

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efficient and environmentally friendly hydrogen and fuel cell transportation technologies will be considered.
For reference, below is an example list of current technology roadmaps, reports, and information on current FCTO projects:

- Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan
- 2015 Annual Progress Report: DOE Hydrogen and Fuel Cells Program
- 2015 Annual Merit Review and Peer Evaluation Report

Specific topics not already covered are solicited and the benefits or potential impact (e.g. petroleum or emissions reductions) should be provided.

Request for Information Response Guidelines

Responses to this RFI must be submitted electronically to FY16FCTONeedsandStrategies@ee.doe.gov no later than 5:00pm (ET) on April 10, 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 4 pages in length, 12 point font, 1 inch margins. Only electronic responses will be accepted.

Please identify your answers by responding to a specific question or topic if applicable. 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.

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