MODIFICATION

All modifications to the Request for Information (RFI) are highlighted in yellow in the body of the RFI.

Mod. No.	Date	Description of Modifications
000001	05/29/2014	Revised the Closing Date to June 9, 2014. Revised the information regarding the Pre-Solicitation Workshop at the 2014 Annual Merit Review.

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REQUEST FOR INFORMATION
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Fuel Cell Technologies Office
Request for Information (RFI): Research and Development Needs and Technical Barriers for Fuel Cells
DE-FOA-0001133 Amendment 000001

DATE: May 5, 2014

CLOSING DATE: June 9, 2014

SUBJECT: Request for Information (RFI) on Research and Development Needs and Technical Barriers for Fuel Cells

DESCRIPTION: The Fuel Cell Technologies Office (FCTO) is seeking feedback from the research community and relevant stakeholders to assist in the development of topics for a potential Funding Opportunity Announcement (FOA) for fuel cells and fuel cell systems designed for transportation, stationary, and early market applications as well as cross-cutting stack and balance of plant (BOP) component technology.

BACKGROUND: The Fuel Cell Technologies Office (FCTO) is a key component of the Department of Energy (DOE) Energy Efficiency and Renewable Energy (EERE) research and development (R&D) portfolio which aims to provide clean, safe, secure, affordable, and reliable power from diverse domestic resources. Benefits of fuel cells include increased energy security and reduced criteria pollutants and greenhouse gas emissions. Research and development undertaken by the Fuel Cells Program is focused on reducing the cost, increasing the durability, and increasing the performance of fuel cell systems. A more detailed description of the Fuel Cells Program, including technical and cost targets, can be found in the Multi-Year Research, Development and Demonstration Plan at:
http://energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-program-multi-year-research-development-and-10
Revised automotive targets can be found in the U.S. DRIVE Fuel Cell Technical Team Roadmap at:
http://energy.gov/eere/vehicles/downloads/us-drive-fuel-cell-technical-team-roadmap

PURPOSE: The purpose of this RFI is to solicit feedback on R&D needs for and technical barriers to the widespread commercialization of fuel cells for transportation, stationary, and early market segments. Feedback from industry, academia, research laboratories, government agencies, and other stakeholders is sought. FCTO is specifically interested in information on R&D needs and priorities concerning the development of low-cost fuel cell components and pathways leading to improved fuel cell performance

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and durability. Input received from this RFI will be considered prior to FCTO issuing a fuel cell FOA (subject to Congressional appropriations).

FCTO will also hold a Pre-Solicitation Workshop at the 2014 Annual Merit Review on specific topics that will help to determine the scope of the FOA. This Workshop will provide the fuel cell and supplier community with an opportunity to discuss potential R&D topics to be included in the FOA in greater detail and could include breakout meetings to assist in further defining the scope of specific topic areas. The workshop is planned for Monday, June 16, from 6:00 to 8:30pm at the Wardman Park Marriott in Washington, D.C. Additional information regarding the Workshop will be provided on the FCTO website at: http://energy.gov/eere/fuelcells/requests-information

FCTO will consider five key questions when deciding which topical areas to address in a future FOA:

1. What will be the impact of investing in the topical area if successful?
2. Will FCTO funding make a large difference relative to what the private sector and other funding entities are already doing?
3. Is the topical area open to new ideas, new approaches, and new performers?
4. Will investment by FCTO result in enduring economic benefit?
5. Is investment in the topical area a proper role of government?

DISCLAIMER AND IMPORTANT NOTES: This RFI is not a 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. FOA 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 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-0001133. 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.

REQUEST FOR INFORMATION CATEGORIES AND QUESTIONS:

Information is sought with responses primarily addressing R&D impact, needs and priorities in the following six categories:

<u>**CATEGORY 1**: **Catalysts and supports**</u>

Cost studies have indicated that catalysts are a major factor determining polymer electrolyte membrane fuel cell (PEMFC) stack costs, in large part due to the cost of the platinum group metal (PGM) catalyst needed. As a result, FCTO has made significant investments in increasing cathode catalyst activity and reducing PGM content. Catalyst function and robustness are inextricably linked to the support.

- **Ultralow PGM oxygen reduction reaction (ORR) catalysts**–MEAs with ORR mass activity at 0.9 V of 0.6 A/mg_{PGM} and above have been demonstrated recently, exceeding the DOE target of 0.44 A/mg_{PGM}. MEAs with PGM loadings approaching the target of 0.125 mg_{PGM}/cm^2 have been reported. However, at these low loadings, performance at high current density is lower than expected and appears to be limited by mass transfer effects. Durability issues remain, especially maintaining performance at high current density/high power. Some of the durability issues appear to be associated with the carbon supports and the upper potential limit to which the catalysts and supports are subjected, especially during start/stop cycles and fuel starvation events. However, there are engineering solutions that can limit the potential the catalysts experience and mitigate the effects of start/stop events. FCTO is interested in feedback regarding:

1.1 Given the recent improvements in technology and market forces, are the DOE catalyst targets still appropriate and do they adequately address the relevant performance and durability issues? If not, what should the catalyst targets be? (For example, should a target operating potential at some high current density be specified, or losses at a current density other than 0.8 or 1.5 A/cm^2 be specified?)
1.2 Are the DOE accelerated stress tests (ASTs) and test protocols still appropriate? Should catalyst durability protocols be adjusted due to the presence of engineering solutions that can limit the potential seen by the catalyst in the vehicle?
1.3 Are impurity effects on the cathode sufficiently understood? Should there be more effort in determining effects of fuel contaminants, air impurities, and system-derived contaminants on the ORR catalysts, especially at low PGM loadings?

- **Non-PGM catalysts** – Great strides have been made in increasing the activity and durability of non-precious metal ORR catalysts in recent years. However, activity is still substantially below the DOE target, and durability approaching that needed for automotive applications has not yet been observed. FCTO is interested in feedback regarding:

1.4 How should FCTO balance work to develop non-PGM vs. PGM catalysts? What is the most appropriate apportionment of effort between the two approaches?
1.5 Relative to PGM work, how much focus/effort should be devoted to the following areas?
   - Improving non-PGM catalyst layer design to minimize transport losses.
   - Improving non-PGM catalyst durability.
   - Determining the active sites and ORR mechanism for the different classes of non-PGM catalysts. Do we need a better understanding of non-PGM catalysis to be able to improve activity to the desired levels?

1.6 Should the non-PGM catalyst R&D focus on a particular type of catalyst?
1.7 Should FCTO encourage greater use of combinatorial methods to develop non-PGM catalysts?

- **Catalyst supports** – Carbon-based catalyst supports have enabled the development of dispersed Pt catalysts and low Pt loaded MEAs. However, carbon supports are susceptible to corrosion, and carbon support corrosion has been identified as a key degradation mechanism during field

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testing of fuel cell systems. Carbon based supports are especially susceptible to corrosion during stop/start cycling and fuel starvation events where the potential can exceed 1.5 V. Alternative supports are being investigated, but have yet to match carbon in terms of its combination of high surface area, high electrical conductivity, ability to disperse PGM catalysts, and low cost. System engineers have developed mitigation strategies to limit the potential the supports experience during start/stop cycling, but these strategies come at an increased cost. Given these issues, FCTO is interested in feedback regarding:

1.8 Durable carbon supports – Is there a need for research to develop high surface area durable carbon supports (graphitized carbon, carbon nanotubes, carbon nanofibers, graphene, doped graphene, etc.)? Does DOE need carbon support targets other than for durability? If so, what should the targets be?
1.9 Durable non-carbon supports- Is there a need for research to develop high surface area durable non-carbon supports? If so, what should the targets be?
1.10 Is R&D required to address corrosion at potentials above 0.9 V, or are system mitigation strategies that limit voltage during transient conditions sufficient?
1.11 How many cycles should be targeted to address catalyst support durability under transient operation conditions (start/stop cycles)? What should the voltage limits and cycling conditions be?

CATEGORY 2: Membrane electrode assembly (MEA) component integration

The interactions between catalyst, support, catalyst layer ionomer, membrane, and GDLs can have a large impact on PEMFC performance and durability. Recent work has shown that catalyst ink formulations and processing conditions can have a significant impact on MEA performance and durability. Other studies have demonstrated the effects of GDLs on cold-start performance, and the effects of membranes and membrane additives on catalyst performance. A better understanding of the interactions between MEA components is needed to optimize performance and meet DOE 2020 performance targets for their respective application (transportation and/or stationary applications, including CHP). FCTO is interested in feedback regarding:

2.1 What issues need to be addressed to minimize and stabilize resistances associated with mass transport and electronic/protonic conduction through interfaces and between cell components?
2.2 Can catalyst utilization be further improved through electrode optimization studies?
2.3 Is further improvement in understanding of electrode architecture, including ionomer structure and pore structure, required for electrode optimization?
2.4 What new approaches could optimize water transport to minimize flooding and membrane dry-out?
2.5 Should FCTO encourage greater use of combinatorial methods to optimize electrode composition?
2.6 What are the main durability concerns related to integrating the various MEA components with advanced materials sets? What testing is required to validate interface/MEA stability over the range of conditions the MEA is subjected to in the automotive drive cycle in real-world usage? What level of validation is required (ex-situ, cell, stack)?

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2.7 Do new materials sets (alloy and core-shell catalysts, non-carbon supports, hydrocarbon membranes, new membranes capable of higher temperature operation) present different integration issues that need to be addressed?
2.8 Are non-PGM catalysts sufficiently mature to justify electrode optimization and MEA integration studies?

CATEGORY 3: Stack and component operation and performance

Two major obstacles to widespread commercialization of PEMFCs are mass transport limitations and insufficient durability. Increased understanding of these issues would guide component, cell, and MEA development for durability and performance. Interface issues are particularly important and affect MEA integration, durability, and operation.

- **Durability studies** – Durability is one of the main barriers to penetration of fuel cell technology into the marketplace. Transportation and stationary systems have not yet met DOE durability targets. The latest results from company fleets participating in the FCEV Learning Demonstration indicate the highest company-average projected durability is 2,500 hours with 10% stack voltage degradation. Durability in a bus has been demonstrated at >10,000 hours. Stationary systems have quite different durability requirements, including lifetimes of 40,000-80,000 hours, though under less aggressive cycling conditions. Several accelerated testing protocols have been developed to attempt to accelerate specific degradation mechanisms and provide insight into ageing. FCTO is interested in feedback concerning the following issues related to durability:

3.1 The appropriateness of the current durability targets and ASTs. FCTT AST and Polarization Curve protocols for PEMFCs are available at http://www.uscar.org/guest/teams/17/U-S-DRIVE-Fuel-Cell-Tech-Team). Are the specified conditions still appropriate (temperature, pressure, potential ranges, etc.)? Do the tests effectively isolate different degradation modes/mechanisms? Are the tests accelerated enough, and are they appropriate for new material sets such as non-carbon catalyst supports, non-PGM catalysts, alloy catalysts, and novel membrane chemistries? Should a startup/shutdown durability target be added?
3.2 Much of the FCTO effort has focused on membrane and catalyst durability during cycling, and catalyst support durability during start/stop and fuel starvation events. Given the current advanced automotive material sets and system engineering, are these still the key issues to address to increase durability of PEMFCs? What conditions are most responsible for degradation or most closely tied to limited durability in the applications of interest (including non-automotive applications)?
3.3 Are materials solutions necessary for degradation induced by startup/shutdown and hydrogen starvation, or are engineering solutions sufficient? For other degradation modes?
3.4 What components are limiting the durability of current state-of-the-art PEMFC systems?
3.5 Do durability issues specific to stationary or non-transportation need to be addressed?
3.6 At what levels are durability issues best addressed (component, MEA, stack or system level?)
3.7 Do durability issues specific to low or ultralow PGM loadings, alloy catalysts, or non-PGM catalysts need to be addressed? Is the current recommended cycling protocol (0.6-1.0 V) adequate?

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3.8 Do advanced materials sets present new impurity issues beyond those captured by previous FCTO-supported impurity studies?

- **Transport studies** – Fuel cell operation relies on effective mass transport of species through individual components and across the interfaces between components. A better understanding of mass transport in the fuel cell has the potential to lead to improved designs and more efficient systems. FCTO is soliciting feedback on transport related issues in fuel cells, including but not limited to:

3.9 What further work is required to address water transport/flooding/membrane dry-out issues?

3.10 Is additional work on freeze startup required?

3.11 How can local oxygen transport limitations associated with low catalyst loadings be improved?

3.12 Is current understanding of electrode architecture sufficient to allow meaningful transport modeling?

3.13 Are properties and changes in properties measured at near equilibrium conditions relevant given the high frequency of cycling observed in a fuel cell vehicle? Are dynamic measurements of transport parameters needed?

3.14 Are new techniques or analytical methods needed to measure transport properties/parameters (such as O_2 transport in thin film ionomer layers)?

3.15 How effective are current transport models in describing the transport issues affecting performance in a PEMFC? Are property/performance relationships sufficiently developed to predict or model transport? Are ageing and degradation of materials sufficiently addressed to predict end-of-life transport behavior? What areas and/or components need more work?

3.16 Are new materials needed to improve transport properties (new membranes, GDLs, MPLs, etc.)?

CATEGORY 4: **Automotive balance-of-plant component development**

Successful development of low-cost, high-performance, durable balance-of-plant (BOP) components that are qualified for automotive duty is critical if overall system reliability, cost, and performance targets are to be achieved. The majority of PEMFC system failures and forced outages for PEMFC systems are caused by balance of plant events.

Air management for PEMFC systems is a challenge because state-of-the-art compressor technologies are not suitable for automotive fuel cell applications. In addition, thermal and water management for PEMFC systems are issues. PEMFC operation at lower temperatures results in a small difference between the operating and ambient temperatures necessitating large heat exchangers and humidifiers. These components increase the cost and complexity of the system and increase parasitic power requirements, reducing overall system efficiency.

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The size and weight of current automotive fuel cell system BOP (e.g., compressor/expander, heat exchangers, humidifiers, and sensors) must be reduced to meet the packaging requirements for automobiles. Reducing the cost automotive BOP components is also a critical need.

This RFI seeks insight into BOP components for fuel cell systems that address the following priorities:

- Air handling
- Water management
- Thermal management
- Sensors

FCTO is seeking feedback on the following questions for automotive and stationary systems. Specify to which system comments apply.

4.1 What are the main BOP issues that need to be addressed?
4.2 Which issues are best addressed by industry and which could benefit from federally funded R&D activities?
4.3 Are new sensors needed?
4.4 Can engineering or materials approaches eliminate the need for certain BOP components or subsystems?
4.5 Can solutions be verified/validated ex-situ?

CATEGORY 5: Fuel cell systems for stationary and emerging market applications

Stationary fuel cell systems, including combined heat and power (CHP) systems, are being deployed in increasing numbers. Several fuel cell technologies being developed for stationary applications are of interest to FCTO, including PEMFCs, molten carbonate fuel cells, phosphoric acid fuel cells, alkaline fuel cells, and solid oxide fuel cells operating under 600°C. New markets and applications for stationary fuel cells continue to emerge. Some stationary applications, including use of fuel cells to power data centers and telecommunications towers, provide early markets for fuel cells, helping to develop a manufacturing supply chain and increase public acceptance of fuel cell technology. Other applications, including fuel cells for residential and commercial CHP, could enable significant energy savings and reductions in greenhouse gas emissions. Further R&D is required to accelerate the pace of stationary fuel cell adoption in all markets. FCTO seeks the following information on stationary fuel cells:

5.1 What technical factors are limiting stationary systems? What areas of R&D would be most effective in advancing fuel cell technology for stationary and emerging markets?
5.2 What applications can have the most impact on improving the rate of acceptance of fuel cell systems into the market? On moving down the volume-cost curve for fuel cell components or stacks?
5.3 What applications can have the greatest environmental benefits and greatest impact on US energy resources?
5.4 What are the achievable lifetime, efficiency, emissions, and cost for fuel cell systems in the various applications?
5.5 Are the DOE targets for stationary applications still appropriate?

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5.6 Are there emerging markets where DOE targets would be helpful or appropriate for developing the technology for that market?
5.7 For stationary applications the DOE 2020 targets for durability are 60,000 hours for a 1-10 kW residential CHP system and 80,000 hours for a 100 kW-3 MW CHP system. What are the best methods for durability testing for these stationary applications? What acceleration methods can compress the durability tests to a reasonable time while mimicking the degradation modes seen in real-world use in stationary applications? What are the failure mechanisms observed in real-world operation? Fuel cell? BOP? Be specific.
5.8 What are the potential emerging market applications?
5.9 Early markets for fuel cells can accelerate development of fuel cells for transportation and other longer-term markets, and can lower cost through development of supply chains and economies of scale for common components. Which early market applications could have the biggest impacts on commercialization of fuel cell vehicles? Are there any early markets that are irrelevant to transportation fuel cells?

CATEGORY 6: Subject areas for programmatic consideration

FCTO is interested in stakeholder feedback regarding where federal funding can have the most impact in advancing fuel cell technology and the relative importance and priority of specific fuel cell R&D Topic Areas, including the Technical Topic Areas listed above in Categories 1-5.

6.1 What is the relative importance and priority of specific fuel cell R&D Topic Areas, including the Topic Areas listed above?
6.2 What is the relative importance and priority the FCT Office should place on cell, stack, and system R&D for automotive, stationary, portable power, and early market applications?
6.3 What issues must the federal government address for fuel cells to be a success?
6.4 What issues should be left to industry to address?
6.5 What is the relative value of applied near-term (<5 year) research versus longer-term research?
6.6 What is the relative importance and priority of R&D on stack components versus BOP components?
6.7 Are changes to the existing DOE targets required? Please provide justification for any proposed modifications.

REQUEST FOR INFORMATION RESPONSE GUIDELINES: Responses to this RFI must be submitted electronically to fuelcellresearchneeds@ee.doe.gov no later than 5:00pm (EDT) on June 9, 2014. Each response must be provided as a Microsoft Word (.docx) document. Institutions providing input on more than one of the above categories should provide a separate document for each category, with the file name containing the category number and the institution name (e.g. if Company X is submitting responses to categories 1 and 2, two separate documents should be submitted with filenames "Category 1 - Company X.docx" and "Category 2 - Company X.docx"). Each response document should be no more than 2 pages in length, 12-point font, and 1-inch margins. Total attachment size should be less than 25MB to ensure message delivery. Only electronic responses will be accepted.

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.

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EERE will not respond to individual submissions or publish 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.