PROGRAM ANNOUNCEMENT TO NATIONAL LABORATORIES FOR SUBMISSION OF APPLICATIONS FOR RESEARCH AND DEVELOPMENT PROJECTS

OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

Laboratory Call for Research, Development, and Demonstration of Fuel Cell Technologies for Automotive, Stationary, and Portable Power Applications

DE-PS36-08GO98010

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AGENCY: Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Golden Field Office

ACTION: FY2008 Program Announcement: Laboratory Call for Research, Development, and Demonstration of Fuel Cell Technologies for Automotive, Stationary, and Portable Power Applications

I. SUMMARY

The Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) is requesting applications to support the President's Hydrogen Fuel and Advanced Energy Initiatives in developing a pathway to the widespread commercialization of hydrogen and fuel cell technologies. To support these initiatives, this DOE Hydrogen Program Announcement ("Announcement" or "Lab Call") seeks to fund research that will lead to the development of cost-competitive, durable automotive, stationary, and portable fuel cell power systems.

A separate Funding Opportunity Announcement (DE-PS36-08GO98009), titled "Research, Development, and Demonstration of Fuel Cell Technologies for Automotive, Stationary, and Portable Power Applications," offers opportunities for nonprofit or for profit private entities, institutions of higher education, and state and local governments to submit applications as primary applicants. These two announcements are parallel to each other and projects will be evaluated and selected using the same criteria. The total DOE funding available for all new awards selected from both announcements is estimated to be $130,500,000, with no predetermined division of funding between the two announcements. Applications selected under this Lab Call will be funded directly through the laboratory contract and will be subject to the terms and conditions of the laboratory contract.

A. Eligible Applicants

The primary applicant submitting applications for this Announcement must be a National Laboratory as defined by Section 2 of the Energy Policy Act of 2005. National Laboratories (Labs) include: Ames Laboratory; Argonne National Laboratory; Brookhaven National Laboratory; Fermi National Accelerator Laboratory; Idaho National Laboratory; Lawrence Berkeley National Laboratory; Lawrence Livermore National Laboratory; Los Alamos National Laboratory; National Energy Technology Laboratory; National Renewable Energy Laboratory; Oak Ridge National Laboratory; Pacific Northwest National Laboratory; Princeton Plasma Physics Laboratory; Sandia National Laboratory; Savannah River National Laboratory; Stanford Linear Accelerator Center; and Thomas Jefferson National Accelerator Facility. The Labs may team with industry, academic organizations and/or other Federal labs as appropriate, but teaming is not required. It is the burden of the primary applicant to obtain the appropriate approval to conduct the proposed work for this EERE Announcement if the applicant is part of the National Nuclear Security Administration (NNSA).

Foreign participants are allowed as subrecipients to a National Laboratory.

B. Cost Share

This Announcement does not require cost share by Labs. However, cost share will be required for institutions of higher education, nonprofit or for-profit private entities, and state and local governments who team with the Lab primary applicant. The non-Lab portion of the budget will require 20% cost sharing of the subrecipient's cost for applied research and/or development from non-federal sources. Federally Funded Research and Development Centers (FRRDCs) that partner with the primary Lab applicant, who are not included in the list of Labs under Section 2 of the Energy Policy Act of 2005, are not required to cost share.

C. Applications

Applications are to be prepared for the complete project period. See Part III of this Announcement below for application preparation instructions, and Part IV for Evaluation Criteria and procedures. Part V identifies additional general requirements that are also applicable.

D. Application Submittal Address

Applications must be submitted through the DOE Industry Interactive Procurement System (IIPS) at http://e-center.doe.gov. Instructions on how to submit an application or an application amendment and how to register, submit questions, and view questions and answers are located in Appendix B and on the web site at http://e-center.doe.gov. Click on the "Help" button.

Prepare all required files in accordance with the instructions in this Announcement prior to starting the transmission process. Submit the entire application package in one IIPS session (i.e., do not logoff before all the files are submitted).

When you are ready to submit your application, go to http://e-center.doe.gov and complete the IIPS cover page. Enter the project title and the name of the principal investigator/project director, in the "Subject" block. Then attach each file in the corresponding block in accordance with the IIPS guidance. Follow the instructions for submitting the application.

If you have any problems accessing information or submitting your application, contact the Help Desk at 1-800-683-0751 and select option 1, or send an email to HelpDesk@pr.doe.gov.

ONLY APPLICATIONS SUBMITTED THROUGH IIPS WILL BE CONSIDERED FOR AWARD.

Applications submitted through IIPS constitute submission of electronically signed applications. The name of the authorized organizational representative (i.e., the administrative official, who, on behalf of the proposing organization, is authorized to make certifications and assurances or to commit the applicant to the conduct of a project) must be typed in the signature block on the form to be accepted as an electronic signature. Do not submit a scanned copy of the signed document.

In order to submit an application, you must be authorized by the applicant (i.e., institution or business entity) to submit an application on its behalf and you must register in IIPS. You are encouraged to register as soon as possible. You only have to register once to apply for any DOE award.

To register go to http://e-center.doe.gov and follow the registration instructions.

Amendments to this Announcement will be posted on IIPS.

If you register in IIPS, you may join this Announcement mailing list to receive an email when an amendment or an Announcement message is posted. To view amendments and Announcement messages, locate the Announcement on IIPS and click on the folder next to the Announcement number or follow the directions for "Locate Solicitation."

E. Application Due Dates and Times

Applications must be received by **August 27, 2008**, no later than **11:59 PM Eastern Time**. You are encouraged to transmit your application well before the deadline. APPLICATIONS, INCLUDING ALL APPLICATION FILES, RECEIVED AFTER THE DEADLINE, AS DEMONSTRATED BY THE IIPS DATE/TIME STAMP, WILL NOT BE REVIEWED OR CONSIDERED FOR AWARD.

F. Further Information or Questions and Answers

Questions regarding the content of the Announcement must be submitted through the "Submit Question" feature of IIPS at http://e-center.doe.gov. Locate the Announcement on IIPS and then click on the "Submit Question" button. Enter the required information. You will receive an electronic notification that your question has been answered. DOE will respond to a question within 3 business days, unless a similar question and answer have already been posted on the website.

Responses to questions may be viewed through the "View Questions" feature (button at the top of the page). If no questions have been answered, a statement to that effect will appear. You should periodically check "View Questions" for new questions and answers.

Questions regarding how to submit questions or to view responses can be e-mailed to the IIPS HELP Desk at helpdesk@pr.doe.gov or by calling 1 (800) 683-0751. Questions must be submitted no later than 3 business days prior to the closing date.

II. FUNDING OPPORTUNITY INFORMATION

A. Scope

The Department of Energy (DOE) seeks to fund research that will lead to the development of cost-competitive and durable automotive, stationary, and portable fuel cell power systems (see Technical Targets in Tables 1, 2, 3). The DOE's goals for hydrogen and fuel cells are driven by the following:

- Hydrogen Fuel Initiative (HFI), announced by President Bush in 2003
- Energy Policy Act (EPAct) 2005 (Public Law 109-58) Section 805
- Advanced Energy Initiative (AEI), announced by President Bush in 2006
- Energy Independence and Security Act (EISA) of 2007 (Public Law 110-140)
- Input from both the:
    - Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) and
    - FreedomCAR and Fuel Partnership

The HFI aims to make hydrogen fuel cell vehicles and fueling stations available to consumers during the next decade by accelerating research in hydrogen-related technologies. Following the announcement of the HFI, the FreedomCAR Partnership (DOE's partnership with U.S. automotive companies for the advancement of hydrogen and other advanced vehicle technologies) was expanded to include U.S. fuel companies, forming the FreedomCAR and Fuel Partnership. The HFI was codified and further authorized through 2020 by EPAct 2005, which also directed the federal government to become a first adopter of fuel cell technologies and included federal purchase requirements for fuel cells in fleet and electric power applications. Beginning in 2006, the AEI provided a 22% increase in clean energy research funding to reduce U.S. dependence on oil and natural gas. Based on both the passage of EISA and on HTAC recommendations to the Secretary of Energy, DOE has expanded its RD&D program to increase emphasis on stationary and portable fuel cells for near-term market applications.

Fuel cell vehicles can lead to substantial energy savings and reductions in imported petroleum and carbon emissions. To realize these benefits, DOE has established targets for automotive, stationary and portable fuel cell applications. The DOE targets for automotive applications were derived with input from the FreedomCAR and Fuel Partnership. These targets, shown in Table 1, include direct hydrogen fuel cell power systems that have a peak efficiency of 60%, a power density of 650 W/L, a specific power of 650 W/kg and cost $45/kW by 2010 ($30/kW by 2015).

For stationary applications, the DOE seeks polymer electrolyte membrane (PEM) fuel cell or solid oxide fuel cell (SOFC) power systems that reach a peak efficiency of at least 40%, with a 40,000-hour lifetime and a cost of $750/kW by 2011. Targets for stationary PEM fuel cell systems are shown in Table 2.

Fuel cells for portable electronics are also of interest, as they can help establish fuel cells in the market place. Targets for fuel cells in consumer electronics, as shown in Table 3, include an energy density[1] of 500 Wh/L at a cost of $3/W.

Additional technical performance and cost targets have been developed for components and sub-systems that comprise a complete fuel cell system. The targets are revised periodically, and have been updated since the publication of the Hydrogen Program's Multi-Year Program Plan [1].

1 Energy Density is for a single charge.

Prior to the development of this Laboratory Call, the DOE issued two Requests for Information regarding possible topics (one for fuel cell RD&D and one for early markets for hydrogen and fuel cells) and held a pre-solicitation workshop [2]. The topics of research and development sought through this Announcement will be focused on achieving the technical performance and cost targets. In addition, as technology progresses, interactions between components in an operating fuel cell must be addressed. In particular, the technologies must be scalable to be suitable across the spectrum of vehicle, stationary, and portable platforms.

Table 1 – Technical Targets for Automotive Applications: 80-kWe (net) Integrated Transportation Fuel Cell Power Systems Operating on Direct Hydrogen [a]

Characteristic	Units	2010	2015
Energy efficiency @ 25% of rated power [b]	%	60	60
Energy efficiency @ rated power	%	50	50
Power density	W / L	650	650
Specific power	W / kg	650	650
Cost	$ / kW_e	45	30
Transient response (time from 10% to 90% of rated power)	s	1	1
Cold start up time to 50% of rated power @–20°C ambient temperature @+20°C ambient temperature	 s s	 30 5	 30 5
Start up and shut down energy [c] from -20°C ambient temperature from +20°C ambient temperature	 MJ MJ	 5 1	 5 1
Durability with cycling	hours	5,000 [d]	5,000 [d]
Unassisted start from low temperatures [e]	°C	-40	-40

[a] Targets exclude hydrogen storage, power electronics and electric drive.
[b] Ratio of DC output energy to the lower heating value (LHV) of the input fuel (hydrogen). Peak efficiency occurs at about 25% rated power.
[c] Includes electrical energy and the hydrogen used during the start-up and shut-down procedures.
[d] Based on test protocols in Appendix C.
[e] 8-hour soak at stated temperature must not impact subsequent achievement of targets.

Table 2 – Technical Targets for Integrated Stationary [a] Fuel Cell Power Systems (≤ 5 kW) Operating on Reformate [b]

Characteristic	Units	2011
Electrical energy efficiency @ rated power [c]	%	40
Combined Heat and Power (CHP) energy efficiency @ rated power [d]	%	80 [e]
Cost [f]	$ / kW_e	750
Transient response time (from 10% to 90% power)	S	< 3
Cold start-up time to rated power @ -20ºC ambient (continuous use application)	min	<30
Survivability (minimum and maximum ambient temperature)	ºC ºC	-35 +40
Durability @ <10% rated power degradation	hours	40,000
Noise	dB(A)	<55 @ 10 m
Emissions (combined NO_X, CO, SO_X, hydrocarbon, particulates)	g / 1000 kWh	<1.5

[a] These targets were established for PEM stationary power systems. Additional targets are currently under review for SOFC stationary systems. Previous SOFC targets were established by the Solid State Energy Conversion Alliance (SECA) under the Office of Fossil Energy [3].
[b] Includes fuel processor, stack and all ancillaries.
[c] Ratio of DC output energy to the LHV of the input fuel (natural gas or liquified petroleum gas (LPG)) average value at rated power over life of power plant.
[d] Ratio of DC output energy plus recovered thermal energy to the LHV of the input fuel (natural gas or LPG) average value at rated power over life of power plant
[e] For LPG, efficiencies are 1.5 percentage points lower than natural gas because the reforming process is more complex.
[f] Includes projected cost advantage of high-volume production (2,000 units / year). Cost does not include integrated auxiliaries, battery, and power regulator necessary for unassisted start.

Table 3 – Technical Targets for Fuel Cells for Portable Electronics (sub-Watt to 50 Watt)

Characteristic	Units	2010
Specific power	W / kg	50
Power density	W / L	50
Energy density	Wh / L	500
Cost	$ / W	3
Lifetime	Hours	2,000

Applications are sought in the following topic areas:

Topic 1 Catalyst Studies
Topic 1A Ultra-low PGM Cathode Catalysts
Topic 1B Non-PGM Catalysts
Topic 1C Durable Anode Catalysts

Topic 2 Innovative Concepts
Topic 2A Innovative Fuel Cell and System Materials
Topic 2B Innovative Fuel Cell Component Structures

Topic 3 Fuel Cell Degradation Studies
Topic 3A Cell Degradation Studies
Topic 3B Accelerated Testing Validation
Topic 3C System and Air Impurities Effects

Topic 4 Transport within the PEM Stack
Topic 4A Transport Studies
Topic 4B Freeze Effects

Topic 5 Portable Power
Topic 5A Improved Materials for Portable Power (alternative-fuel fuel cells)
Topic 5B Portable Electronics Balance of Plant and Packaging

Topic 1 Catalyst Studies

DOE is soliciting research in the area of electrocatalysis to improve catalyst performance through a better understanding of the electrochemical reaction mechanisms and improved engineering of the electrocatalyst layers in a fuel cell. Research should be directed at improving catalyst activity and durability while decreasing catalyst cost. Theoretical modeling and *ex situ* experimental research increasing the understanding of state-of-the-art fuel cell electrodes are encouraged. However, this work should be coupled with the design, synthesis, and fabrication of improved catalysts and electrodes as well as testing and demonstration of improved catalysts in a membrane electrode assembly (MEA).

Of particular interest are studies that may elucidate paths to decreased platinum group metals (PGM) in the fuel cell. These include studies to determine structure/property relationships and their effect on the oxygen reduction reaction (ORR) and also side reactions (such as peroxide formation/destruction), as well as studies investigating how best to incorporate a catalyst into the electrode structure (such as studies of catalyst-ionomer interactions, catalyst-support interactions, and the influence of electrode structure on catalyst performance). Also of interest are catalyst degradation mechanisms and how the different fuel cell operating conditions (such as high temperature and/or low relative humidity (RH), low temperature and high RH, high potential, and potential cycling) affect catalyst and electrode performance and durability.

The application should clearly state the status of the applicant's current catalyst technology as it relates to the state-of-the-art and include a discussion of how any proposed catalyst development work will meet the DOE 2010 targets and/or have the potential to meet the DOE 2015 targets listed in Table 4. Teaming is encouraged to ensure relevant materials are investigated. The application should encompass work from first-principles to MEA testing. An effort including integrated theory and modeling, detailed structural and mechanistic studies, materials synthesis, and testing in a fuel cell environment is encouraged.

Topic 1A Ultra-low PGM Cathode Catalysts

Applications are sought to investigate catalysts that will lead to platinum group metal (PGM) content lower than the DOE 2015 target for total PGM content of 0.2 g PGM/kW and approach 0.1 g PGM/kW while meeting the other 2015 electrocatalyst targets (see Table 4). Due to volatility in the metals market and increasing Pt prices, it is unlikely catalyst cost targets will be met at the 2015 PGM loading targets derived in previous years using Pt costs current for that time. Therefore, PGM loading must be reduced beyond the 2015 target if the cost target is to be met. This reduction may be accomplished through development of new PGM alloys, through approaches that increase activity of current PGM and PGM alloy catalysts, through approaches that increase the utilization of the PGM in the catalysts, and/or through other novel approaches. The application should provide sufficient justification that the approach can reduce total platinum content beyond the DOE 2015 target of 0.2 g PGM/kW and approach 0.1 g PGM/kW at catalyst loadings of 0.1 mg PGM/cm^2.

The applicant's approach to the development of ultra-low precious metal cathode catalysts must be clearly described, and the technical and economic viability of the proposed catalyst material must be justified. The expected effects of the approach on catalyst durability should be addressed. Accelerated lifetime tests to determine the long-term durability of new cathode catalysts under realistic conditions are required. Applicants should use the Accelerated Stress Test (AST) Protocols developed by the Fuel Cell Technical Team (FCTT) of the FreedomCAR and Fuel Partnership, presented in Appendix C, for durability testing. These protocols are under review and may be changed prior to negotiation of award. Additional protocols may be proposed to supplement these protocols. Applications should address mass transport issues that may arise for some strategies at very low PGM loadings, and provide for development of viable supports that would allow an increase in thickness of the catalyst layer without substantial transport losses if needed. In addition, applications should clearly define the quantitative criteria upon which go/no-go decisions will be based.

Expected Outcomes:
Expected outcomes include delivery of an operating single cell (active area ≥ 50 cm^2) and short stack to a DOE-designated site for testing. Go/no-go decisions based on the quantitative criteria agreed upon by DOE will be made prior to single cell testing and prior to scale-up to a short stack.

Topic 1B Non-PGM Catalysts

DOE is seeking durable non-PGM catalysts with an open circuit voltage (OCV) of 0.9V (or higher) under H_2/air conditions, specifically cathode catalysts capable of 300 A/cm^3 at >800 $mV_{IR\text{-}free}$ (based on the volume of the supported catalyst). A better understanding of the active site in non-PGM catalysts is needed and fundamental studies of the ORR mechanisms and any degradation mechanisms should be included. The work should address mass transport limitations and include developming viable supports that would allow an increase in loading and/or thickness for non-PGM catalysts if needed. A discussion of how the identity of the active sites affects design of the catalyst layer structure and mass transport should be included. The work plan should include a discussion of the durability testing required to show viability. In addition, applications should clearly define the quantitative criteria upon which go/no-go decisions will be based.

Expected Outcomes:
Expected outcomes include an operating single cell (active area ≥ 50 cm^2) and short stack to be supplied to a DOE-designated site for testing. Go/no-go decisions based on the quantitative criteria agreed upon by DOE will be made prior to single cell testing and prior to scale-up to a short stack.

Topic 1C Durable Anode Catalysts

DOE is seeking durable anode catalysts for direct hydrogen-fueled fuel cells that exhibit very low oxygen reduction activity to enhance stability under start-stop conditions, during which local potentials can approach 1.5 V. Anode catalysts that can withstand fuel starvation and the mixed potentials that can result from start-up/shut-down procedures are desired. The catalysts must be stable under both fuel and oxidant open circuit conditions. *In situ* studies of catalyst degradation mechanisms are of interest, including the effects of catalyst-support interactions, catalyst particle size, and catalyst structure. The approach must have the potential to increase catalyst durability while maintaining or improving activity and cost of current anode materials. The application should clearly state the status of the applicant's current catalyst technology as it relates to the state-of-the-art and include a discussion of how any proposed catalyst development work will meet the DOE 2010 targets and/or have the potential to meet the DOE 2015 targets listed in Table 4. The work plan should include sufficient durability testing to show viability. In addition, applications should clearly define the quantitative criteria upon which go/no-go decisions will be based.

Expected Outcomes:
Expected outcomes include an operating single cell (active area ≥ 50 cm^2) and short stack to be supplied to a DOE-designated site for testing. Go/no-go decisions based on the quantitative criteria agreed upon by DOE will be made prior to single cell testing and prior to scale-up to a short stack.

Table 4 – Technical Targets for Electrocatalysts for Transportation Applications

Characteristic	Units	Stack Targets [a]	
		2010	2015
Platinum group metal total content (both electrodes)	g / kW (rated)	0.3	0.2
Platinum group metal (PGM) total loading [b]	mg PGM / cm^2 electrode area	0.3	0.2
Cost	$ / kW	5 [c]	3 [c]
Durability with cycling Operating temp ≤80°C Operating temp >80°C	Hours Hours	5,000 [d] 2,000	5,000 [d] 5,000 [d]
Electrochemical area loss [e]	%	<40	<40
Electrocatalyst support loss [e]	mV after 100 hours @ 1.2V	<30	<30
Mass activity [f]	A / mg Pt @ 900 $mV_{iR\text{-}free}$	0.44	0.44
Specific activity [f]	µA / cm^2 @ 900 $mV_{iR\text{-}free}$	720	720
Non-Pt catalyst activity per volume of supported catalyst	A / cm^3 @ 800 $mV_{IR\text{-}free}$	>130	300

[a] Targets are currently under review.
[b] Derived from performance data at rated power targets specified in Table 3.4.13 of Reference 1.
[c] Based on 2002 dollars, platinum cost of $450 / troy ounce = $15 / g, loading <0.2 g / kW_e and cost projected to high volume production (500,000 stacks per year).
[d] Includes typical driving cycles.
[e] Tested per GM protocol (Mathias, M.F., et al., *Interface* (Electrochemical Society), Fall 2005, p. 24).
[f] Test at 80°C / 120°C H_2 / O_2 in MEA; fully humidified with total outlet pressure of 150 kPa; anode stoichiometry 2; cathode stoichiometry 9.5.

Topic 2 Innovative Concepts

Innovative concepts with the potential for radical improvements in performance, durability, cost, and/or manufacturing are of interest. The primary thrust of this topic is the development of new materials for fuel cells; however, new structures and/or morphologies which use existing materials will be considered if a strong case is made for their benefit.

Applications should clearly demonstrate the potential benefits of the proposed innovative concept in terms of durability, cost, and performance compared to conventional PEM fuel cell technology for automotive or stationary applications. The application should clearly state the status of the applicant's current stack and/or component technology as it relates to the state-of-the-art and include a discussion of how any proposed development work will meet the DOE 2010 targets and/or have the potential to meet the appropriate DOE 2011/2015 targets [1].

Teaming is encouraged and should include an organization with first-hand knowledge of PEM fuel cell science and operation.

Topic 2A Innovative Fuel Cell and System Materials

Areas of research interest include (but are not limited to) low-cost durable materials suitable for long-term use in the fuel cell system environment. Specific examples of interesting materials concepts include (but are not limited to):

- Non-carbon supports with superior corrosion resistance and electrical and structural properties at least as good as carbon.
- Mixed-conduction (ionic/electronic) catalyst supports to reduce or eliminate the need for electrolyte in the catalyst layer.
- Non-carbon gas diffusion layer (GDL) with superior corrosion resistance; electrical and structural properties at least as good as carbon at comparable cost; and stable wetting properties and physical dimensions.
- Development of low-cost metallic bipolar plates that meet DOE requirements [1].
- Chemically and mechanically stable seal materials.
- Low-cost materials for compact, high performance membrane-based water transport exchangers. Materials must endure cycles and stresses imposed during automotive fuel cell operation.

Expected Outcomes:
The primary objective of Topic 2A is to fabricate and demonstrate the new concept through:

- Appropriate hardware (based on the materials developed) for independent testing:
  - an operating single cell MEA (active area ≥ 50 cm^2) or
  - an operating component based on the material developed
- Delivery of the hardware to DOE for third party testing.
- Formal cost estimate using commonly accepted methods.

Topic 2B Innovative Fuel Cell Component Structures

Possible concepts include, but are not limited to:

- Innovative in-cell thermal management to avoid excessive temperature gradients between reaction sites and cooling media, especially at very high current density.
- Graded (in three dimensions) cell component properties (chemical and morphological) to facilitate species transport as discussed in Topic 4.

As much as possible, the innovative fuel cell component structures should be generic and applicable to a wide segment of the fuel cell community.

Expected Outcomes:
The primary objective of Topic 2B is to fabricate and demonstrate the new concept through:

- Delivery of an operating fuel cell (active area ≥ 50 cm^2) to DOE for third party testing.
- Formal cost estimate using commonly accepted methods.

Topic 3 Fuel Cell Degradation Studies

DOE durability targets for stationary and transportation fuel cells are 40,000 hours and 5,000 hours, respectively, under realistic operating conditions including load cycling and start/stop. For transportation fuel cells, transient operation includes [4]:

- 17,000 start/stop cycles
- 1,650 freeze cycles
- 1,200,000 load cycles.

The effects of the cycles are [5]:

- Up-transient – hydrogen starvation
- Down-transient – differential pressure imbalance
- Dynamic operation (load cycling) – enhanced corrosion and membrane mechanical stress
- Low power – high voltage (corrosion of catalysts and/or supports)
- Off – oxygen ingression to anode, support corrosion

In addition to the foregoing cycles associated with normal operation, there is the potential for unplanned cycles associated with system failure caused by non-stack components. Such system shutdowns reportedly account for 85-90% of system failures [6,7]. Fuel cells must be able to withstand off-specification operating conditions caused by unplanned system malfunctions.

Topic 3A Cell Degradation Studies

Although significant progress has been made toward demonstrating a membrane material capable of withstanding combined load and humidity cycles, MEAs meeting durability targets while also meeting other DOE technical targets (such as catalyst loading) are still needed. Stable interfaces between the cell components also need to be demonstrated.

DOE is soliciting research in the area of fuel cell degradation. Research is sought in improving understanding of degradation of fuel cell materials and components. If extensive *ex situ* experimentation is proposed, a strong case must be made that the *ex situ* data accurately describes *in situ* behavior. The results are intended to guide component, cell, and stack development efforts to improve durability by identifying degradation mechanisms and proposing mitigation strategies.

Applicants should use the AST Protocols (presented in Appendix C) to isolate and elucidate degradation mechanisms. The AST Protocols, developed by the Fuel Cell Technical Team of the FreedomCAR and Fuel Partnership, are under review and may be changed prior to negotiation of award. Protocols that measure component durability behavior under cycling conditions but do not distinguish between degradation mechanisms are discouraged for this effort.

Teaming is strongly encouraged. The team should include a stack integrator and relevant component suppliers.

Applicants must define a standard plate-to-plate fuel cell package in their application. Sufficient technical detail must be provided on the cell package to establish general applicability. Preference will be given to applications that define a plate-to-plate fuel cell package with all components and materials that approach the DOE 2015 targets. *Ex situ* and *in situ* analytical and characterization techniques should be described.

Applications are sought which address the durability of the plate-to-plate fuel cell package in the areas of:

- Fundamental materials degradation mechanisms.
- Impact of microstructure on performance and durability.
- Component microstructure stability in three-phase region of reactant gas, electrolyte, and catalyst.
- Interface stability (plate/GDL, GDL/electrode, catalyst/support, electrode/membrane).
- Bipolar plate and GDL interactions and effect of (hydrophobicity and structural) stability on water management and flow field stability.
- Correlation of durability to local cell operating conditions.

- Parametric aging studies (current density, temperature, relative humidity).
- Correlation of performance drop to changes in structure and/or chemistry.
- Development of kinetic and materials models of the aging process.
- Effect of material degradation and structural changes on water management.
- Experimental data for water management models: degradation of hydrophobic materials properties (contact angle, porosity, permeability, cell resistance, etc.) with known automotive cycle stressors (e.g., freeze).
- Effects of degradation of other components (e.g., seal, bipolar plates, membranes, impurities) on the degradation of components responsible for water management.

Component-level (anode, cathode, membrane, GDL, etc.) degradation models should feed into a cell-level degradation model including interactions at the interfaces.

Expected Outcomes:

- Validated *ex situ* and *in situ* analytical tools
- Integrated degradation models at the component, interface, and cell levels
- Compilation of data generated
- Identification of degradation mechanisms and recommendations for mitigation
- Public dissemination of the model and instructions for use

Topic 3B Accelerated Testing Validation

Fuel cells, especially for automotive propulsion, must operate over a wide range of operating and cyclic conditions. The desired operating range encompasses temperatures from below the freezing point to well above the boiling point of water, humidity from ambient to saturated, and half-cell potentials from 0 to >1.5 volts. Furthermore, the anode side of the cell may be exposed to both hydrogen and air simultaneously during start/stop cycles.

The severity in operating conditions is greatly exacerbated by the transient and cyclic nature of the operating conditions. Both cell and stack conditions cycle, sometimes quite rapidly, between high and low voltages, temperatures, humidities, and gas compositions. The cycling results in physical and chemical changes, sometimes with catastrophic results.

This Topic seeks applications to develop and demonstrate experimental correlation of *ex situ* accelerated stress tests (such as the AST protocol outlined in Appendix C) to *in situ* real-time degradation. Methodologies for validation, including experimental approach and statistical analyses, must be described in detail.

Expected Outcomes:

- Correlation of process conditions to degradation (temperature, relative humidity, cycling, current density, etc.).
- Correlation of ASTs to real-world component and cell behavior.
- Recommended alternative ASTs that more accurately gauge *in situ* component behavior.

Topic 3C System and Air Impurities Effects

DOE is seeking research in the area of impurity effects, excluding anode/hydrogen fuel studies.

Significant progress has been made in identifying and understanding the impact of fuel-born impurities such as H_2S, CO_x, and NH_3 on fuel cell performance and durability. However, there is a need to investigate the effects of impurities derived from cell and system components and from the air used at the cathode (NO_X, SO_X, chlorides, etc.). System-derived impurities/poisons might include lubricants from rotating equipment and compounds such as plasticizers resulting

from aging of system or cell components (e.g., seals, carbon-based plates). Air impurities studies should focus on those contaminants that cannot be easily filtered out or otherwise removed.

DOE is seeking applications which address air impurities, system impurities, or both. The team should include participants with knowledge of likely contaminants.

Successful applicants will be required to participate in a DOE impurities working group.

Expected Outcomes:

- Parametric studies of the effect of poisons on cell performance and durability
- Compilation and public dissemination of the data generated during the course of the project
- Identification of poisoning mechanisms and recommendations for mitigation
- Model of impurity effects on cell performance and durability

Topic 4 Transport within the PEM Stack

Topic 4A Transport Studies

Fuel cell operation relies on effective mass transport of species through individual components and across the interfaces between components. Among these species are hydrogen, oxygen, water, protons, and electrons. Transport behavior is a function of operating conditions and component properties such as microstructure and surface properties. A better understanding of mass transport in the fuel cell, especially of water, has the potential to lead to improved designs and more efficient systems.

For example, effective management of the water produced in the fuel cell can alleviate flooding of the catalysts and drying out of the membrane over the full operating temperature range. Ineffective water management leads to liquid-phase water blockage and mass-transport-limited performance or decreased protonic conductivity in the membrane and catalyst layers due to dehumidification of the ionomer. The designs and properties of the gas diffusion layers, gas flow fields in bipolar plates, catalyst layers, and membranes affect water management and operation under all operating conditions including subfreezing conditions. Transportation and stationary fuel cells must be able to operate in environments where ambient temperatures fall below 0°C.

DOE is soliciting research to better understand mass, ionic, and electronic transport in PEM fuel cells. Research is sought in the areas of modeling and *in situ* and *ex situ* experiments to provide data for validation of the transport models developed here. If extensive *ex situ* experimentation is proposed, a strong case must be made that the *ex situ* data accurately describe *in situ* operation. The validated model is intended to guide component, cell, and stack development efforts to improve performance by identifying rate-limiting steps and proposing strategies to increase transport.

The goal of this Topic is to develop an understanding (not design-specific) of the water, gas, and electronic/protonic transport in the fuel cell (i.e., membrane, GDL, microporous layers, catalyst layers, flow channels, and their interfaces). How the materials' structural and surface properties affect transport and performance and how these properties change during operation (e.g., degradation effects) are of interest.

Effects of the GDL structure, GDL/bipolar plate interface, catalyst/support/ionomer interfaces in the catalyst layer, and catalyst layer/membrane interface on mass (H_2O, H^+, H_2, O_2) and electron transport are also of interest. *In situ* measurements of structure (porosity, pore structure), concentration (water content, oxygen concentration, H^+ concentration), surface chemistry

(internal pore chemistry and wetting properties), and flux of species of interest are desirable for model validation. This work should result in the ability to measure and model mass and electronic/protonic transport in each layer and interface in an MEA as a function of variables including but not limited to temperature, pressure, relative humidity, current density, and time. The model should be able to predict fuel cell package (plate-to-plate inclusive) performance using plate, GDL, and MEA chemical and structural data under a full range of operating conditions.

The investigations should not be restricted to any one component but rather address the entire cell package and the interactions between components. Applications may address individual facets of transport such as water management or electronic conduction, but comprehensive applications will be favored.

Teaming is strongly encouraged to ensure that models are founded on real-world requirements. Team members might include a component manufacturer, stack developer, and university or lab with modeling and/or analytical capabilities. However, the team leader should be an established expert in fuel cell technology and operation with respect to water, gas, and/or electronic/protonic transport. Extensive interaction between modeling efforts and experimental measurements will be required to validate the models for real-world application.

Applicants must define a standard plate-to-plate fuel cell package in their application. Sufficient technical detail on the cell package must be provided to establish general applicability. Preference will be given to applications that define a plate-to-plate fuel cell package with all components and materials that approach the DOE 2015 targets. *Ex situ* and *in situ* analytical and characterization techniques should be described.

Applications should address:

- Generation of near- and long-term materials (chemical, physical, and microstructural) property data to develop/validate models.
- Development of understanding of cell component interactions and interfaces/structures.
- Generation of experimental data on species movement in the cell/stack during operation and transients.
- Development of test protocols and tools for *in situ* observation of transport behavior.
- Modeling/study of the ionomer/catalyst/support interfaces
- Macroscopic and nanoscale (molecular level) interface characterization (property and composition distribution such as hydrophobicity gradients).
- Methods to quantify internal surface properties of porous materials (porosity, structure, permeability, capillary forces, hydrophobicity/hydrophilicity, etc.)

Expected Outcomes:

- Validated transport model including all component physical and chemical properties
- Public dissemination of the model and instructions for exercise of the model
- Compilation of the data generated in the course of model development and validation
- Identification of rate-limiting steps and recommendations for improvements to the plate-to-plate fuel cell package.

Topic 4B Freeze Effects

DOE also seeks applications that will develop a better understanding of the effects of freeze/thaw cycles on PEM fuel cell components, cells, and stacks with the aim of using the information to guide mitigation strategies. Applicants should describe how proposed studies will lead to a better understanding of these effects and, ultimately, to generic mitigation measures.

Increased understanding from this activity should be evident in a parametric analysis of the physical effects of water freezing on the cell components that can be validated through *ex situ* and *in situ* testing.

Applications should address at least one of the following issues:

- Improved understanding of effects of freezing and thawing on cell components.
- Identification of failure modes during freezing, including morphological changes and localized stresses in fuel cell components associated with phase transition.
- Delineation of water movement under temperature gradients and multiphase transport in porous media (MEA, GDL) under freezing conditions.
- Understanding kinetics of phase change in fuel cell materials such as the GDL and microporous layer.
- Tailoring materials and components to enhance freeze tolerance and increase GDL/catalyst ductility.

Expected Outcomes:

- Parametric analysis of the physical effects of water freezing on the cell components and identification of failure modes. Parameters might include water content, rate of temperature drop, and component physical properties such as thickness. Alternative analyses will be considered and should be consistent with the issues addressed.
- The parametric analysis should result in a model that can be validated through *ex situ* and *in situ* testing.
- Compilation and public dissemination of the data generated during the course of the project.
- Recommended mitigation strategies for reducing the impact of freeze/thaw effects.

Topic 5 Portable Power

DOE targets for portable electronics fuel cell systems are presented in Table 3. Achieving these targets requires advancements at the cell component level as well as at the system packaging level.

Topic 5A Improved Materials for Portable Power (alternative-fuel fuel cells)

For fuel cells to meet the needs of consumer electronics, reductions in cost are required. In addition, for some applications, a reduction in size of a factor of five or more is also required. To meet these requirements, improved materials are needed. DOE is seeking research in the area of improved materials for alternative-fuel (direct methanol, direct ethanol, biofuel, etc.) fuel cells to help decrease the size and cost of fuel cells for consumer electronics. Topics of interest include: anode and cathode catalysts with improved activity, decreased Pt content, increased selectivity, and increased durability; and low-cost membranes with low crossover and high proton conductivity.

The application should clearly state the status of the applicant's current materials set as it relates to the state-of-the-art and include a discussion of how the proposed development work will result in materials for systems that will meet the DOE 2010 targets listed in Table 3. The applicant must clearly describe the strategy that will lead to the desired improvements and the expected effects of the approach on other properties of interest (such as durability when addressing cost and vice versa). Accelerated lifetime tests to determine the long-term durability of new materials under realistic conditions are required. In addition, applications should clearly define the quantitative criteria upon which go/no-go decisions will be based.

Expected Outcomes:
Expected outcomes will include an MEA and multi-cell array to be supplied to a DOE-designated site for testing. Go/no-go decisions based on the quantitative criteria agreed upon by DOE will be made prior to scale-up to a multi-cell array.

Topic 5B Portable Electronics Balance of Plant and Packaging

Achieving technical and economic goals for portable electronic applications requires that component and subsystem functions be integrated and designed for manufacture and assembly. Consumer electronics fuel cell systems require low-cost, rugged, shock-resistant balance of plant components that operate in any physical orientation, have low system weight and volume, and provide consumer/user and environmental safety through effective fuel containment. This necessitates miniaturized subsystems that have thermal and mechanical integration, low pressure drop, and design simplicity to eliminate components and/or subsystems. Passive components and closely integrated subsystems are highly desirable.

DOE seeks projects to design, develop, fabricate, and validate fuel cell power systems for consumer electronics applications that meet the 2010 technical targets presented in Table 3 and to assess the market readiness of the proposed fuel cell system. A large effort in cell component development is not desired. Validation will be accomplished through testing of a small, but statistically significant, number of pre-commercial, fully-engineered units under real-world conditions of climate, handling, and duty cycles. The focus will be on size, power output, cost, ruggedness/durability, and fueling.

Potential specific components and subsystems are: high-efficiency thermal barriers; fluid handling equipment; multi-function equipment; and low-power, highly efficient ancillaries (power conditioners, pumps, fans). Applications must address determination of durability using measures such as mean time between failures (MTBF) of individual components and subsystems.

Applications should describe the performance of the applicant's current package relative to state-of-the-art battery technology and fuel cell technology and clearly describe the strategy that will lead to the desired improvements.

Expected Outcomes:
The expected outcome of Topic 5B is an integrated consumer electronics fuel cell system. In addition, testing of this system is required to verify whether it meets the packaging goals listed in Table 3 when operated in actual end-user equipment and environments using real-world duty cycles.

References

1. Hydrogen, Fuel Cells & Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan, October 2007 (http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/) and currently under review.
2. Hydrogen, Fuel Cells & Infrastructure Technologies Program: DOE Fuel Cell Pre-Solicitation Workshop (http://www1.eere.energy.gov/hydrogenandfuelcells/wkshp_fuelcell_jan08.html).
3. Solid State Energy Conversion Alliance (SECA) – Minimum Requirements for Industrial Team (http://www.netl.doe.gov/technologies/coalpower/fuelcells/seca/minrequire.html).
4. S. Motupally, UTC, Crete Degradation Workshop September 2007, Crete, Greece, private communication.
5. F. Finsterwalder, DaimlerChrysler, Crete Degradation Workshop September 2007, Crete, Greece, private communication.

6. S. Wessel, Ballard, Crete Degradation Workshop, September 2007, Crete, Greece, private communication.
7. P. Moçotéguy, EDF, Crete Degradation Workshop, September 2007, Crete, Greece, private communication.

B. Budget

A separate Funding Opportunity Announcement (DE-PS36-08GO98009), titled "Research, Development, and Demonstration of Fuel Cell Technologies for Automotive, Stationary, and Portable Power Applications," offers opportunities for nonprofit or for-profit private entities, institutions of higher education, and state and local governments to submit applications as primary applicants. These two announcements are parallel to each other and projects will be evaluated and selected using the same criteria. The total funding ceiling for all new awards selected from both announcements will be approximately $130,500,000, with no predetermined division of funding between the two announcements. DOE anticipates making approximately 54 awards total under both parallel announcements, with the period of performance for projects ranging from 2 to 4 years.

Since awards resulting from these parallel announcements are expected to begin in FY 2009, no FY 2008 funding is available for new awards.

C. Anticipated Award Size

The anticipated total DOE award size for projects under each Topic Area (i.e. for Topic 1, it is estimated that up to $40,000,000 of DOE funds will be split among up to 7 projects) in this announcement is:

Topic Area	Estimated Number of Awards	Estimated Total DOE Funding
Topic 1	up to 7	up to $40M
Topic 2	up to 3	up to $5M
Topic 3	up to 6	up to $20M
Topic 4	up to 6	up to $20M
Topic 5	up to 3	up to $7.5M
Topic 6*	up to 4	up to $10M
Topic 7*	up to 25	up to $28M
Total	up to 54	up to $130.5M

* Only applicable to Funding Opportunity Announcement DE-PS36-08GO98009. Topics 6 and 7 are NOT APPLICABLE to this Lab Call.

III. APPLICATION PREPARATION INSTRUCTIONS

A. Application Preparation

You must complete the mandatory forms in accordance with the instructions on the forms and the additional instructions below.

1. Field Work Proposal File
Applicants must complete a DOE Field Work Proposal in accordance with the requirements in DOE Order 412.1 Work Authorization System. This order and the DOE Field Work Proposal form are available at http://management.energy.gov/business_doe/business_forms.htm. Save this form in a file named "FWP".

2. Project Summary/Abstract File
The Project Summary/Abstract must contain a summary of the proposed activity suitable for dissemination to the public. It should be a self-contained document that identifies the name of the applicant; the project director/principal investigator(s); the topic (and subtopic) area under which the application is being submitted (example, Topic 1A); the project title; the objectives of the project; a description of the project, including methods to be employed; the potential impact of the project (i.e., benefits, outcomes); and major participants (for collaborative projects). Applicants are cautioned that this document should not include any proprietary information, trade secrets, or other confidential business, financial, or sensitive information as DOE may make it available to the public. The project summary must not exceed 1 page when printed using standard 8.5" by 11" paper with 1" margins (top, bottom, left and right) with font not smaller than 11 point. Save this information in a file named "Abstract.pdf".

3. Project Narrative File
The Project Narrative should provide a clear description of the work to be undertaken and how you plan to accomplish it. It should address each of the merit review criteria and sub-criteria listed in Part IV.A.2. Provide sufficient information so that the reviewers will be able to evaluate the application in accordance with these merit review criteria.

The project narrative must not exceed 20 pages (excluding the Bibliography/References Cited section), including cover page, table of contents, bibliography, charts, graphs, maps, photographs, and other pictorial presentations, when printed using standard 8.5" by 11" paper with 1 inch margins (top, bottom, left, and right). EVALUATORS WILL REVIEW ONLY THE NUMBER OF PAGES SPECIFIED IN THE PRECEDING SENTENCE. Any pages that exceed this maximum number of pages will be removed and will not be considered during the evaluation. The font must not be smaller than 11 point. Do not include any Internet addresses (URLs) that provide information necessary to review the application because the information contained in these websites will not be reviewed. See Part III.B for instructions on how to mark proprietary application information.
Save all of the Project Narrative information in a single file named "Project Narrative.pdf".

The Narrative should include the following sections:

i. Cover Page

The Narrative cover page must indicate the name of the organization; the announcement number; the project title; both technical and business points of contact (include name, title, address, phone number, and email address); the Topic (and Subtopic) area under which the application is being submitted (example, Topic 1A); and all of the project participants (subcontractors, consultants, etc.).

ii. Project Description/Technical Concept

This section should be used to address all of the sub-criteria for evaluation criterion 1 listed in Part IV.A.2. The technical concept should be described in detail. A clear, concise statement of the specific objectives/aims of the proposed project should be included as well as a discussion of the relevancy of these objectives to the FOA Topic description to which the application is being submitted.

iii. Work Plan

This section should be used to address all of the sub-criteria for evaluation criterion 2 listed in Part IV.A.2. All of the activities/tasks required to perform the project should be identified and described. The roles of and work to be performed by any team members should be made clear. At least one milestone per year and one go/no go decision point, including the decision criteria, should be identified. This section should include a timeline/project schedule, such as a Gantt chart, showing all of the important activities/tasks of the project.

iv. Qualifications/Facilities

This section should be used to address all of the sub-criteria for evaluation criterion 3 listed in Part IV.A.2. It is not necessary to repeat information included in the Personnel Resume File as this file will be used for the merit review. Only identify facilities, equipment, and other resources that are directly applicable to the proposed project. If the purchase of equipment, which is strongly discouraged, is required to perform the work proposed then include an explanation of its necessity. Include the number of hours or percent time that all key personnel will be involved in this project.

v. Bibliography/References Cited, if applicable

Provide a bibliography of any references cited in the Project Narrative. Each reference must include the names of the authors, the article and journal title, book title, volume number, page numbers, and year of publication. Include only bibliographic citations. Applicants should be especially careful to follow scholarly practices in providing citations for source materials relied upon when preparing any section of the application.

The combined length of the Project Narrative Sections i.-iv., listed above, must be within the specified 20 page limit. Section v. (Bibliography/References Cited) is not included in this 20 page limit.

4. Budget File

SF 424 A Excel, Budget Information – Non-Construction Programs File

You must provide a separate budget for each year of support requested and a cumulative budget for the total project period. Use the SF 424 A Excel, "Budget Information – Non Construction Programs" form on the Applicant and Recipient Page at http://management.energy.gov/business_doe/business_forms.htm. You may request funds under any of the Object Class Categories as long as the item and amount are necessary to perform the proposed work, meet all the criteria for allowability under the applicable Federal cost principles. Save the information in a single file named "Budget.pdf."

5. Personnel Resume File

Provide a resume for key personnel, including major subrecipients and consultants. This should include (at a minimum) education and training, professional experience, and relevant publications. Each resume must not exceed 3 pages when printed on 8.5" by 11" paper with 1 inch margins (top, bottom, left, and right) with font not smaller than 11 point. Save all resumes in a single file named "Resumes.pdf".

6. Authorization for DOE National Labs File
The cognizant Contracting Officer must authorize in writing the use of a Lab contractor on the proposed project and this authorization must be submitted with the application. The following language is acceptable for this authorization.

"Authorization is granted for the _____ Laboratory to participate in the proposed project. The work proposed for the laboratory is consistent with or complementary to the missions of the laboratory and will not adversely impact execution of the DOE assigned programs at the laboratory."

Save the authorization in a file named "Authorization.pdf."

7. Subaward Budget File(s), if applicable
You must provide a separate budget (i.e., budget for each year and a cumulative budget) for each subawardee that is expected to perform work under the prime applicant. Use the SF 424 A Excel, "Budget Information - Non Construction Programs form." These forms are found on the Applicant and Recipient Page at http://management.energy.gov/business_doe/business_forms.htm. Save each Subaward budget in a separate file. Use up to 10 letters of the subawardee's name (plus .pdf) as the file name (e.g., energyres.pdf).

8. Budget for DOE/NNSA Federally Funded Research and Development Center (FFRDC) Contractor File(s), if applicable
If a DOE/NNSA FFRDC contractor is to perform a portion of the work as a subrecipient, a DOE Field Work Proposal must be provided in accordance with the requirements in DOE Order 412.1 Work Authorization System. This order and the DOE Field Work Proposal form are available at http://management.energy.gov/business_doe/business_forms.htm. Save this document in a file using up to 10 letters of the FFRDC name (plus .pdf) as the file name.

9. Letters of Commitment File
Applications which include a non-National Lab partner and require cost share must include a letter from the partner or third party stating that it is committed to providing a specific minimum dollar amount of cost sharing. The letter should also identify the proposed cost sharing (e.g., cash, services, and/or property) to be contributed. Letters must be signed by the person authorized to commit the expenditure of funds by the entity. Letters of Commitment from parties (excluding DOE/NNSA FFRDCs required to submit a Field Work Proposal in Part III.A.7 above) participating in the project, exclusive of vendors, who will not be contributing cost share, but will be integral to the success of the project should be included as well. Provide all of this information in a single file named "CLTP.pdf".

10. Summary of Required Forms/Files
The applicant must submit the following attachments in IIPS:

IIPS Designation	Attach the Following Documents	File Name
Application	Field Work Proposal	FWP
Project Summary	Project Summary/Abstract	Abstract
Project Narrative	Project Narrative	Project Narrative
Budget Form	Form SF-424A	Budget
Attachment 1	Personnel Resume	Resumes
Attachment 2	Authorization for DOE National Labs	Authorization
Attachment 3	Subaward Budget File(s), if applicable	See Instructions in Part III.A.7
Attachment 4	DOE/NNSA FFRDC Budget File(s), if applicable	See Instructions in Part III.A.8
Attachment 5	Letters of Commitment, if applicable	CLTP

B. Proprietary Application Information

It should be noted that application information and data submitted directly from a Lab cannot be considered proprietary; although, information and data submitted by a non-laboratory third party partner(s) may be considered proprietary.

Applications submitted in response to this Program Announcement may contain trade secrets and/or privileged or confidential commercial or financial information which the applicant and/or industrial partners do not want to be used or disclosed for any purpose other than evaluation of the application. The use and disclosure of such data may be restricted, provided the applicant marks the cover sheet of the application with the following legend, specifying the pages of the application which are to be restricted in accordance with the conditions of the legend:

> "The data contained in pages _____ of this application have been submitted in confidence and contain trade secrets or proprietary information, and such data shall be used or disclosed only for evaluation purposes, provided that if this applicant receives an award as a result of or in connection with the submission of this application, DOE shall have the right to use or disclose the data herein to the extent provided in the award. This restriction does not limit the Government's right to use or disclose data obtained without restriction from any source, including the applicant."

Further, to protect such data, each page containing such data shall be specifically identified and marked, including each line or paragraph containing the data to be protected with a legend similar to the following:

> "Use or disclosure of the data set forth above is subject to the restriction on the cover page of this application."

It should be noted, however, that data bearing the aforementioned legend may be subject to release under the provisions of the Freedom of Information Act (FOIA), if DOE or a court determines that the material so marked is not actually proprietary and, thus, not exempt under the FOIA. The Government assumes no liability for disclosure or use of unmarked data and may use such data for any purpose.

Applicants are hereby notified that DOE intends to make all applications submitted available to non-Government personnel for the sole purpose of assisting DOE in its evaluation of the applications. These individuals will be required to protect the confidentiality of any specifically identified proprietary information obtained as a result of their participation in the evaluation.

IV. APPLICATION REVIEW INFORMATION

A. Criteria

1. Initial Review Criteria

Prior to a comprehensive merit evaluation, DOE will perform an initial review to determine that (1) the applicant is eligible for an award; (2) the information required by the announcement has been submitted; (3) all mandatory requirements are satisfied; (4) the minimum required cost share, if any, has been proposed; and (5) the proposed project is responsive to the objectives of the announcement. If an application fails to meet these requirements, it may be deemed non-responsive and eliminated from full Merit Review.

2. Merit Review Criteria

The following merit review evaluation criteria will be used in the comprehensive evaluation of applications. For each criterion, the weighting (out of a total of 100%) is indicated to show the relative importance.

Criterion 1: Technical Concept (55% for all Topics)

- The overall relevance and applicability of the proposed technical concept and approach to the objectives of the Topic under which the application was submitted.
- The technical viability of the proposed concept, including evidence of experimental data and prior results.
- The innovation of the proposed technology and the potential for the proposed concept to advance the state of the art of fuel cell technologies for automotive, stationary, and/or portable applications. Automotive applications or combined automotive/stationary applications will be given higher preference than stationary or portable power applications alone (excluding Topic 5).
- The degree to which the key technical risk areas of the proposed concept are identified and the reasonableness of the proposed strategies to address them, including consideration of the impact on other fuel cell system components. This includes the clarity of understanding by the applicant of the fundamental principles and limitations of the proposed technical approach.
- The potential of the proposed concept to achieve DOE's technical targets specified in the FOA Topic Description (where applicable), including the adequacy of the projections provided by the applicant to show potential to meet these targets. Addressing the ability to meet a larger number of technical targets simultaneously will be viewed more favorably than focusing on only one or two technical targets.

Criterion 2: Work Plan (30% for all Topics)

- The adequacy, clarity, and reasonableness of the work plan, including the description of each task/activity necessary to complete the project.
- The likelihood of success of the proposed work plan to meet the project goals.
- The appropriateness of the milestones and project schedule.
- The adequacy, clarity and timing of proposed go/no-go decision points as well as the quantitative criteria upon which these go/no-go decisions are based.
- The adequacy of the proposed project organization to facilitate project success, including the approach to managing the team and ensuring communication among team members.
- The clarity and appropriateness of the roles of the team members.
- The commitment of the team members, including the presence of letters of commitment.

Criterion 3: Qualifications and Facilities (15% for all Topics)

- The adequacy of the education, professional training, technical/business related skills, and work experience of the Principal Investigator and other key personnel, including personnel from major subcontractors.
- The capability of the proposed team to comprehensively address all aspects of the proposed project.
- The relevant experience of each organization on the proposed team in performing similar work.
- The level and reasonableness of the time commitment of the PI and other key personnel, including personnel from major subcontractors, assigned to the proposed project.
- The adequacy of the applicant's existing facilities, and those of subcontractors, proposed for completing the work.
- The reasonableness and necessity of any request for new facilities and/or equipment to meet the project objectives.

3. Other Selection Factors

The selection official may consider the following program policy factors in the selection process:

- Selection of applications to achieve a balance of complementary technologies and projects, in conjunction with existing projects funded by the DOE Hydrogen Program, to meet the overall goals and objectives of the Program.
- Selection of applications that leverage federal funds to optimize advancement of programmatic goals.
- Selection of applications with applicant cost share above the minimum level required.
- Selection of applications involving a diversity of proposing organizations (type and size).
- Geographic distribution of applicants within the U.S.

B. Review and Selection Process

1. Merit Review

Applications that pass the initial review will be subjected to a merit review in accordance with the guidance provided in the "Department of Energy Merit Review Guide for Financial Assistance and Unsolicited Proposals." This guide is at http://www.management.energy.gov/documents/meritrev.pdf.

After passing the initial review, applications will undergo a merit review process where applications are evaluated, scored, and ranked according to the Evaluation Criteria for applications listed in Part IV.A.2 above. The merit review committee will make recommendations to the selection official as to whether or not each application is determined to have sufficient merit to be considered for funding based exclusively on the strengths and weaknesses of the application.

2. Non-governmental Reviewers

In conducting the merit review evaluation, the Government may seek the advice of qualified non-federal personnel as reviewers. The Government may also use non-federal personnel to conduct routine, nondiscretionary administrative activities. The applicant, by submitting its application, consents to the use of non-federal reviewers/administrators. Non-federal

reviewers must sign conflict of interest and non-disclosure agreements prior to reviewing an application. Non-federal personnel conducting administrative activities must sign a non-disclosure agreement.

3. Selection

The selection official will consider the merit review recommendation, program policy factors, and the amount of funds available in making selection decisions.

4. Notice of Selections and Debriefings

DOE will notify applicants selected for award. This notice of selection is not an authorization to begin performance.

Organizations whose applications have not been selected will be advised as promptly as possible. For applicants who do not pass the initial review, this notice will consist of the findings of the initial review as determined by DOE/Golden Field Office. For applicants who go forward to the comprehensive review, this notice will consist of the consensus strengths and weaknesses as determined by the Merit Review Committee and will constitute the debriefing.

5. Discussions and Award

The Government may enter into discussions with a selected applicant for any reason deemed necessary, including but not limited to: (1) the budget is not appropriate or reasonable for the requirement; (2) only a portion of the application is selected for award; and/or (3) special terms and conditions are required. Failure to resolve satisfactorily the issues identified by the Government will preclude award to the applicant.

C. Anticipated Notice of Selection and Award Dates

DOE anticipates notifying applicants selected for negotiation of an award in December 2008 and making awards by February 2009.

V. GENERAL CONDITIONS

A. Partial Awards

DOE reserves the right to support or to not support all, or any part of, any application. Unsuccessful applications will not be returned.

B. Debarred and Suspended Parties

Applicants must not make any sub-award or permit any sub-award to any party which is debarred, suspended, or is otherwise excluded from or ineligible for federal awards. The list of parties excluded from federal procurement and non-procurement programs can be accessed through the Excluded Parties List System (EPLS) at http://epls.arnet.gov.

C. National Environmental Policy Act (NEPA) Requirements

All applicants selected for negotiations shall complete the necessary NEPA compliance requirements in coordination with their local DOE Field Office. Documentation of the completed NEPA documentation will need to be provided prior to awarding funding for the project. Applicants are restricted from taking an irreversible action prior to DOE reaching a final NEPA decision regarding a proposed project. Irreversible actions include demolition of existing buildings, site clearing, ground breaking, construction, and/or site-specific detailed design. Provided DOE has authorized the work, this restriction does not preclude the applicant from developing plans, preliminary designs, or performing other necessary support work prior to DOE reaching its final NEPA decision.

D. Reporting

In addition to the technical and financial progress reports typically provided by Labs to DOE, reporting requirements will include the following:

- Annual presentations at the DOE Hydrogen Program Annual Merit Review and Peer Evaluation Meeting (typically in Washington, D.C.)
- Annual presentations at DOE/FreedomCAR and Fuel Partnership Fuel Cell Technical Team Meetings (typically in Detroit, MI)
- Annual submissions to the DOE Hydrogen Program's Annual Progress Report
- Project Safety Plan

E. Intellectual Property Developed Under This Program

Patent Rights in any inventions that are conceived or first actually reduced to practice under awards made from this Announcement and any rights in technical data created under such awards, will be governed by the terms and conditions of the Management and Operating (M&O) Contract of the applicant or applicants receiving an award and also will be governed by any applicable class patent waivers executed for that M&O Contract.

F. Data Protection Statute

This program is covered by a special data protection statute. See Energy Policy Act of 2005, P.L. 109-58, Section 810. The provisions of the statute provide for the protection from public disclosure, for a period of up to five years for data first produced in the performance of funded activities.

APPENDIX A – DEFINITIONS

"Amendment" means a revision to a Program Announcement.

"Applicant" means the legal entity or individual signing the Application. This entity or individual may be one organization or a single entity representing a group of organizations (such as a Consortium) that has chosen to submit a single Application in response to a Program Announcement.

"Application" means the documentation submitted in response to a Program Announcement. NOTE: Application is referred to as Proposal in IIPS.

"Award" means the written documentation executed by a DOE Contracting Officer, after an Applicant is selected, which contains the negotiated terms and conditions for providing Financial Assistance to the Applicant. A Financial Assistance Award may be either a Grant or a Cooperative Agreement.

"Budget" means the cost expenditure plan submitted in the Application, including both the DOE contribution and the Applicant Cost Share.

"Consortium (plural consortia)" means the group of organizations or individuals that have chosen to submit a single Application in response to a Program Announcement.

"Contracting Officer" means the DOE official authorized to execute Awards on behalf of DOE and who is responsible for the business management and non-program aspects of the Financial Assistance process.

"Cost Sharing" means the respective share of Total Project Costs to be contributed by the Applicant and by DOE. The percentage of Applicant Cost Share is to be applied to the Total Project Cost (i.e., the sum of Applicant plus DOE Cost Shares) rather than to the DOE contribution alone.

"Data Universal Numbering System (DUNS) Number" is a unique nine-character identification number issued by Dun and Bradstreet (D&B). Organizations must have a DUNS number prior to registering in the CCR. Call 1-866-705-5711 to receive one free of charge. http://www.grants.gov/applicants/request_duns_number.jsp

"Federally Funded Research and Development Centers" (FFRDCs) conduct research for the United States Government. They are administered in accordance with U.S Code of Federal Regulations, Title 48, Part 35, Section 35.017 by universities and corporations. A list of FFRDCs can be found at http://www.nsf.gov/statistics/nsf06316/.

"Industry Interactive Procurement System (IIPS)" is DOE's Internet-based procurement system which allows access to DOE's business opportunities database, allows user registration and submittal of Applications: http://e-center.doe.gov/.

"Key Personnel" means the individuals who will have significant roles in planning and implementing the proposed Project on the part of the Applicant and Participants, including FFRDCs.

"Participant" for purposes of this Program Announcement, means any entity, except the Applicant substantially involved in a Consortium, or other business arrangement (including all parties to the Application at any tier), responding to the Program Announcement.

"Project" means the set of activities described in an Application, State plan, or other document that is approved by DOE for Financial Assistance (whether such Financial Assistance represents all or only a portion of the support necessary to carry out those activities).

“Proposal” is the term used in IIPS meaning the documentation submitted in response to a Program Announcement. Also see Application.

“Recipient” means the organization, individual, or other entity that receives a Financial Assistance Award from DOE, is financially accountable for the use of any DOE funds or property provided for the performance of the Project, and is legally responsible for carrying out the terms and condition of the award.

"Selection" means the determination by the DOE Selection Official that negotiations take place for certain Projects with the intent of awarding a Financial Assistance instrument.

"Selection Official" means the DOE official designated to select Applications for negotiation toward Award under a subject Program Announcement.

"Total Project Cost" means all the funds to complete the effort proposed by the Applicant, including DOE funds (including direct funding of any FFRDC) plus all other funds that will be committed by the Applicant as Cost Sharing.

APPENDIX B – INDUSTRY INTERACTIVE PROCUREMENT SYSTEM (IIPS) 3.5

FOR HELP, CONTACT THE IIPS HELP DESK AT 1-800-683-0751 (SELECT OPTION 1)
OR AT IIPS_HELPDESK@E-CENTER.DOE.GOV

1. Locate Announcement/Amendments
   - Go to the IIPS website at http://e-center.doe.gov
   - Click on "Browse Opportunities" and scroll down to view DOE Financial Assistance Opportunities (Viewing "Opportunities by Contracting Activity" is recommended.) Click on the "Browse Financial Asst." button **OR** Click on the "Login" button if you are already registered. Click on the radio button that says "IIPS - Financial Assistance" and click on the "Login" button again. Enter User Name and Password. Click on any of the options for viewing the Funding Opportunity Announcement, whichever is easiest for you to locate the Announcement. (Viewing "Opportunities by Contracting Activity" is recommended.)
   - Click on folder (or blue arrow depending on your server) next to the "Golden Field Office"
   - Locate and click on the Announcement number to view the "Financial Assistance Opportunity."
   - Scroll to the bottom of the page, where you will find the attached announcement, under "Full Announcement & Other Files."

2. View Announcement Messages/Amendments
   - Click on the folder next to the Announcement number to view amendments and announcement messages.

3. IIPS Registration

An applicant only has to register once on IIPS. This registration is permanent and is used for all IIPS submissions. If the applicant has already registered, it is unnecessary to register again. If an applicant has not previously registered, it is encouraged to register in IIPS at least 14 days prior to the Announcement closing date. To register:

   - Go to the IIPS website at http://e-center.doe.gov.
   - Click on the "Register" button.
   - Click on the radio button next to, "Check this box for IIPS" and then click on the "Proceed to Form" button.
   - Read the "Notice of Disclaimer" and click on "I Accept" if you are in agreement. (Clicking on "I Decline" will return you to the main registration page.)
   - Complete the Registration Form. Also print this page, which contains your password, for future reference.
   - Click on "Submit Registration." Applicants will receive a confirmation of receipt of registration.
   - Applicants will also receive an email confirming successful registration. If an applicant does not receive this email confirmation within one business day, contact the IIPS Help Desk.

4. Join Mailing List

It is highly recommended that applicants join the mailing list, to receive announcement messages.

   - To do so, follow the direction in item 1. Locate Announcement, and then click on the "Join Mailing List" button, enter the required information, and submit.
   - After an applicant has joined the mailing list, the applicant will receive an email each time an announcement message is posted.
   - However, the applicant should visit the announcement page periodically to ensure receipt of the latest information.

5. Electronic Submission

Applications must be submitted in accordance with the instructions in the announcement.

6. Electronic Signature

Applications submitted through IIPS constitute submission of electronically signed applications. The name of the authorized organizational representative (i.e., the administrative official, who, on behalf of the proposing organization, is authorized to commit the applicant to the conduct of a project) must be typed in the signature block on the form to be accepted as an electronic signature. A scanned copy of the signed documents is not required.

7. Submit Application

Applicants are strongly encouraged to submit applications at least 48 hours prior to the deadline for submissions to ensure timely submission and allow time to resolve any possible transmission problems. To submit an application, follow these steps:

Step 1 – Prepare Application

All required files necessary for a complete application package should be prepared in accordance with the instructions in the announcement prior to starting the transmission process. Files should be completed, organized and named as instructed in Announcement part entitled "Application Content" before proceeding to submit an application. Applicants should submit the entire package in one IIPS session (do not logoff before all the files are attached).

Step 2 – Create Application

- Enter the IIPS website at http://e-center.doe.gov.
- Click on the "Login" button.
- Click on the radio button that says, "IIPS - Financial Assistance" and click on "Login" button again.
- Enter your user name (as shown on your registration email confirmation) and password. Note: These are case sensitive.
- Click on any of the options for viewing the Announcement (Opportunity), whichever is easiest for you to locate the announcement. (Viewing "Opportunities by Contracting Activity" is recommended.)
- Click on the folder (or blue arrow) next to the Golden Field Office.
- Locate the Announcement for which you are applying and click on it.
- Click on the "Create Application" button and complete the information on the application Cover Page. In order for DOE to accurately identify each application, applicants must enter a unique project title in the "Subject" line.
- Click on "Continue".

Step 3 – Attach Application

- Click on "Attach Application".
- Scroll to the bottom of the page and attach each file in the corresponding block on the page, as outlined in the announcement, and then click on "Submit." Up to 10 files may be attached. Keep file sizes to a minimum to ensure a shorter transmission time. Be patient while your files upload.
- IIPS will provide a "Submission Confirmation" with a tracking number, please print this page for your records

Once the applicant begins the "Create Application" process, there will be a record created in IIPS. Therefore, applicants must verify that duplicate applications were not inadvertently created in IIPS. If a duplicate was created, follow the steps outlined in Appendix B, Item 9.a.

In the event that two or more applications are received from the same applicant with the same unique project title, only the application with the LATEST transmission start time will be considered for review. The application must be received on time.

8. Multiple Applications for Unique Projects

An applicant may submit more than one application under the same announcement; however, each application must be uniquely titled. For each application, the applicant is required to follow the instructions in "Submit Application." Each application must be complete and shall not rely upon another application as submission of the required documents.

9. Deletion of Applications

I. To delete an application (including all files) from IIPS:
To delete or withdraw an application or an application file, contact the IIPS Help Desk requesting the application to be removed. The following information is required when requesting to have an application deleted:
   A. Registered User's Name as well as User Name of requestor (if different)
   B. Email address of the registered user as well as requester (if different)
   C. Company/University Name
   D. Complete Announcement Number
   E. Complete Proposal Tracking Number
   F. Date Submitted (optional)

In addition, if an application is deleted after the closing date, inform the Contract Specialist shown on the announcement, via email.

II. To submit a revised application:
After the Help Desk has removed the requested application, follow the steps in "Submit Application" to submit a revised application (i.e. cover page and all required files).

III. To submit a revised file:
After the Help Desk has removed the requested file from your application:
- Locate the announcement.
- Click on the yellow folder next to the announcement number.
- Click on the cover page of your submission, click on the "Attach Application" link, and attach the revised file. Files received past the due date will not be reviewed.

10. IIPS Questions

View the "IIPS Frequently Asked Questions" by clicking on the "Help" button and scrolling to the bottom of the page. You may also contact the IIPS Help Desk at 1-800-683-0751 (select Option 1) or at IIPS_HelpDesk@e-center.doe.gov for questions regarding the operation of IIPS.

11. Submit a Question on the Content of the Announcement

"Locate Announcement", then click on the "Submit Question" button and enter required information. You will receive an electronic notification when your question has been answered. DOE EERE will respond to a question within 5 business days, unless a similar question and answer have already been posted.

12. View Questions and Answers

"Locate Announcement", then click on the "View Questions" button. If no questions have been submitted and answered, a statement to that effect will appear. Potential applicants should periodically check the IIPS website for new questions and answers.

IIPS Resources A-Z IIPS User Guide—anything and everything the applicant would ever want to know about IIPS. This user guide can be found at: http://e-center.doe.gov/doebiz.nsf/Help?OpenForm by scrolling to the bottom of the page.

APPENDIX C: DOE CELL COMPONENT ACCELERATED STRESS TEST PROTOCOLS FOR PEM FUEL CELLS

(Electrocatalysts, Supports, Membranes, and Membrane Electrode Assemblies)

March 2007

Fuel cells, especially for automotive propulsion, must operate over a wide range of operating and cyclic conditions. The desired operating range encompasses temperatures from below the freezing point to well above the boiling point of water, humidity from ambient to saturated, and half-cell potentials from 0 to >1.5 V. Furthermore, the anode side of the cell may be exposed to hydrogen and air during different parts of the driving and start/stop cycles.

The severity in operating conditions is greatly exacerbated by the transient and cyclic nature of the operating conditions. The cell/stack conditions cycle, sometimes quite rapidly, between high and low voltages, temperatures, humidities, and gas compositions. The cycling results in physical and chemical changes, sometimes with catastrophic results.

This document describes test protocols to assess the performance and durability of fuel cell components intended for automotive propulsion applications. The goal of this testing is to gain a measure of component durability and performance of electrocatalysts and supports, membranes, and membrane electrode assemblies (MEAs) for comparison against 2010 DOE targets contained in **Reference 1**. The resulting data may also help to model the performance of the fuel cell under variable load conditions and the effects of aging on performance.

These protocols are intended to establish a common approach for determining and projecting the durability of polymer electrolyte membrane (PEM) fuel cell components under simulated automotive drive cycle conditions.

This document is not intended to be comprehensive as there are many issues critical to a vehicular fuel cell (e.g., freeze/thaw cycles) that are not addressed at this time. Additional issues will be addressed in the future. Furthermore, it is recognized that the cycles specified herein have not been fully correlated with data from stacks and systems operated under actual drive cycles. Therefore, additional tests to correlate these results to real world lifetimes is needed, including actual driving, start/stop, and freeze/thaw cycles.

The durability of catalysts can be compromised by platinum (Pt) sintering, particle growth, and dissolution, especially at high electrode potentials; this sintering/dissolution is accelerated under load cycling. Durability of catalyst supports is another technical barrier for stationary and transportation applications of PEM fuel cells. Corrosion of high-surface area carbon supports poses significant concerns at high electrode potentials and is accelerated during start/stop cycles and during higher temperature operation (>100 °C).

Membranes are another critical component of the fuel cell stack and must be durable and tolerate a wide range of operating conditions including low humidity (20 to 100% RH) and high temperature (-40 to 120 °C for transportation applications and >120 °C for stationary applications). The low operating temperature and the humidity requirements of current membranes add complexity to the fuel cell system that impacts the system cost and durability. Improved membranes are needed that perform better and are less expensive than the current generation of polymer membranes.

The associated testing protocols and performance metrics are defined in Table C1 for electrocatalysts, Table C2 for catalyst supports, Table C3 for membrane/MEA chemical stability, and Table C4 for membrane/MEA mechanical durability, respectively, as derived from **References 2 and 3**. Table C1 is under review by the Fuel Cell Tech Team.

The specific conditions and cycles are intended to isolate effects and failure modes and are based on assumed, but widely accepted, mechanisms. For example, the electrocatalyst cycle is different from the support cycle because they suffer from different degradation mechanisms under different conditions. Similarly, membrane/MEA chemical degradation is distinguished from mechanical degradation.

Durability screening at conditions and under cycles different from those presented here-in are acceptable provided that the developer can provide:

- conclusive/convincing evidence that the cycle/conditions do not compromise separation/isolation of degradation mechanisms

- degradation rates extrapolated to the conditions/cycles prescribed here-in

Data to be reported, if applicable, at each point on the polarization curves and during steady-state and variable load operation include, but are not limited to:

- Ambient temperature and pressure
- Cell voltage
- Cell current and current density
- Cell temperature
- Cell resistance, if available (along with test conditions)
- Fuel inlet and outlet temperature
- Fuel flow rate
- Fuel inlet and outlet pressure
- Fuel inlet dew point
- Air inlet and outlet temperature
- Air flow rate
- Air inlet and outlet pressure
- Air inlet dew point
- Fuel and air quality
- Coolant inlet temperature
- Coolant outlet temperature
- Coolant flow rate

Pre-test and post-test characterization of cell and stack components should be performed according to developer's established protocols. At the discretion of the developer, tests should be terminated when hydrogen crossover exceeds safe levels.

References

1. Hydrogen, Fuel Cells & Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan, August 2006 (http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/).
2. Mathias, M., et al., "Two Fuel Cells in Every Garage?" Interface Vol. 14, No 3, Fall 2005.
3. Mathias, M., et al., "Can Available Membranes and Catalysts Meet Automotive PEFC Requirements?" Presentation at ACS Meeting, Philadelphia, August 2004.

Table C1
Electrocatalyst Cycle and Metrics
(This Protocol is Under Review)

Cycle	Step change: 30 s at 0.7 V and 30 s at 0.9 V. Single cell 25 - 50 cm^2	
Number	30,000 cycles	
Cycle time	60 s	
Temperature	80ºC	
Relative Humidity	Anode/Cathode 100/100%	
Fuel/Oxidant	Hydrogen/N_2	
Pressure	150 kPa absolute	
Metric	**Frequency**	**Target**
Catalytic Activity*	Beginning and End of Life	≤60% loss of initial catalytic activity
Polarization curve from 0 to ≥1.5 A/cm^{2**}	After 0, 1k, 5k, 10k, and 30k cycles	≤30 mV loss at 0.8 A/cm^2
ECSA/Cyclic Voltammetry	After 1, 10, 30, 100, 300, 1000, 3000 cycles and every 5000 cycles thereafter	≤40% loss of initial area
*Activity in A/mg @ 150 kPa abs backpressure at 900mV iR-corrected on H_2/O_2, 100% RH, 80°C		
** Polarization curve per USFCC "Single Cell Test Protocol" Section A6		

Table C2
Catalyst Support Cycle and Metrics

Cycle	Hold at 1.2 V for 24 h; run polarization curve and ECSA; repeat for total 200 h. Single cell 25 - 50 cm^2	
Total time	Continuous operation for 200 h	
Diagnostic frequency	24 h	
Temperature	95ºC	
Relative Humidity	Anode/Cathode 80/80%	
Fuel/Oxidant	Hydrogen/Nitrogen	
Pressure	150 kPa absolute	
Metric	**Frequency**	**Target**
CO_2 release	On-line	**<10% mass loss**
Catalytic Activity*	Every 24 h	≤60% loss of initial catalytic activity
Polarization curve from 0 to ≥1.5 A/cm^{2**}	Every 24 h	≤30 mV loss at 1.5 A/cm^2 or rated power
ECSA/Cyclic Voltammetry	Every 24 h	≤40% loss of initial area
*Activity in A/mg @ 150 kPa abs backpressure at 900 mV iR-corrected on H_2/O_2, 100% RH, 80 °C		
**Polarization curve per USFCC "Single Cell Test Protocol" Section A6		

Table C3
MEA Chemical Stability and Metrics

Test Condition	**Steady state OCV, single cell 25 - 50cm^2**	
Total time	200 h	
Temperature	90 ºC	
Relative Humidity	Anode/Cathode 30/30%	
Fuel/Oxidant	Hydrogen/Air at stoics of 10/10 at 0.2 A/cm^2 equivalent flow	
Pressure, inlet kPa abs (bara)	Anode 250 (2.5), Cathode 200 (2.0)	
Metric	**Frequency**	**Target**
F^- release or equivalent for non-fluorine membranes	At least every 24 h	No target – for monitoring
Hydrogen Crossover (mA/cm^2)*	Every 24 h	$\leq$20 mA/cm^2
OCV	Continuous	$\leq$20% loss in OCV
High-frequency resistance	Every 24 h at 0.2 A/cm^2	No target – for monitoring
*Crossover current per USFCC "Single Cell Test Protocol" Section A3-2, electrochemical hydrogen crossover method		

Table C4
Membrane Mechanical Cycle and Metrics
(Test using a MEA)

Cycle	**Cycle 0% RH (2 min) to 90^{o}C dewpoint (2 min), single cell 25 - 50 cm^2**	
Total time	Until crossover >10 sccm or 20,000 cycles	
Temperature	80ºC	
Relative Humidity	Cycle from 0% RH (2 min) to 90 ^{o}C dewpoint (2 min)	
Fuel/Oxidant	Air/Air at 2 SLPM on both sides	
Pressure	Ambient or no back-pressure	
Metric	**Frequency**	**Target**
Crossover*	Every 24 h	$\leq$10 sccm
*Crossover per USFCC "Single Cell Test Protocol" Section A3-1, pressure test method with 3 psig N_2		