FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

U.S. Department of Energy
Golden Field Office

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

Funding Opportunity Announcement Number:

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DATE: July 16, 2008

FROM: Stephanie N. Carabajal, Contracting Officer

TO: All Prospective Applicants

SUBJECT: Amendment No. 002 to Announcement No. DE-PS36-08GO98009, Research, Development, and Demonstration of Fuel Cell Technologies for Automotive, Stationary, and Portable Power Applications

The Announcement is amended as follows:

1. Under **Part I. – Funding Opportunity Description**, the introductory description of Topic 2 Innovative Concepts is deleted in its entirety and replaced with the following:

   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 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. Applications which directly address the Hydrogen Program's technical goals and targets published in the Multi-Year Program Plan [1] (and some of which are included in this FOA) are strongly encouraged.

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

   Topic 2A Innovative Fuel Cell and System Materials and **Topic 2B Innovative Fuel Cell Component Structures** remain unchanged.

All other parts of the Announcement remain unchanged.

DATE: July 7, 2008

FROM: Stephanie N. Carabajal, Contracting Officer

TO: All Prospective Applicants

SUBJECT: Amendment No. 001 to Announcement No. DE-PS36-08GO98009, Research, Development, and Demonstration of Fuel Cell Technologies for Automotive, Stationary, and Portable Power Applications

The Announcement is amended as follows:

2. Under **Part I. – Funding Opportunity Description**, the title of Topic 1C is changed from "Durable Anode Catalysts" to "Durable Catalysts." In addition, Topic 1C is deleted in its entirety and replaced with the following:

   Topic 1C Durable Catalysts
   DOE is seeking durable anode and cathode catalysts and supports for direct hydrogen-fueled fuel cells that enhance stability under start-up/shut-down 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 electrode 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 including multiple (>100) start-up/shut-down cycles 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 remains unchanged.

3. Under **Part I. – Funding Opportunity Description**, Topic 7B is deleted in its entirety and replaced with the following:

   Topic 7B Fuel Cell-Powered Material Handling Equipment
   The Battelle Memorial Institute showed that PEM fuel cells have the potential to provide a value proposition when used in a multiple shift operation [8]. Battery-

powered forklifts are typically powered by lead-acid batteries that can provide enough power for one 8-hour shift. A disadvantage of the battery-powered forklift is battery change-out and downtime, which impacts productivity and increases costs of operation. In a typical operation, battery change-out takes 20-45 minutes. Due to slow charging speed, multiple shift operations must typically keep extra batteries charged and available. While PEM fuel cell-powered lift trucks require more capital investment than incumbent alternatives, they provide significant savings in operation and maintenance.

Packaged solutions for PEM fuel cell systems (5 to 20 kW) fueled by hydrogen capable of powering a Class 1, 2 or 3 lift truck for a minimum of 10 hours of continuous operation and 5000 total hours are sought to fill demand at facilities that operate multiple shifts per day. Indoor operations at facilities are strongly encouraged particularly for continuously used forklift trucks running two or three shifts per day when multiple battery change-outs may be required. The target markets for this Topic include, but are not limited to, commercial distribution centers used by wholesalers or retailers for products, such as grocery produce and consumable or durable goods.

For this sub-topic, the applicant team will include, at a minimum, expertise in fuel cell lift truck development and integration, battery hybridization, hydrogen fuel dispensing, fuel delivery logistics, and relevant material handling power needs.

Applications should describe at a minimum: a complete fuel cell power system designed for powering lift truck systems; lift truck retrofit specifications (as applicable); hydrogen fuel storage and dispensing system including installation, commissioning, maintenance, and decommissioning capable of supporting the lift truck hydrogen fill requirements for the specified operations (system shall be capable of safely dispensing fuel into the proposed fuel cell lift truck); weather shelter for dispensing operations; and a plan for obtaining all necessary government approvals and permits for all aspects of the dispensing system. The cost of lift truck equipment, excluding the fuel cell power system, is the responsibility of the material handling facility user and should not be included as part of the application.

Expected Outcomes:

- 5 to 20 kW fuel cell systems delivered, installed on material handling equipment, and operated at the customer site(s) (for example, distribution center).

- Periodic performance reports documenting results from operating delivered systems. Reports should include any safety or performance data and issues identified during the operation of the units.

All other parts of the Announcement remain unchanged.

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PART I – FUNDING OPPORTUNITY DESCRIPTION

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.

[1] Energy Density is for a single fuel charge.

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].

Prior to the development of this Funding Opportunity Announcement (FOA), 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 FOA will be focused on achieving the technical performance and cost targets. Additionally, the scope of this FOA includes demonstrations of stationary and SOFCs operating under real-world conditions. (Fuel cell vehicles are being demonstrated in the Technology Validation part of the DOE's Hydrogen Activities). This FOA also includes market transformation activities, focusing on acquiring data from real-world fuel cell operation, eliminating non-technical barriers, and increasing opportunities for market expansion of hydrogen fuel cell technologies. 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.

This FOA is open to nonprofit and for-profit private entities, institutions of higher education, and state and local governments. Further information on applicant eligibility can be found in Part III of this FOA. A minimum cost sharing of 20% for research and development and a minimum of 50% for demonstration and market transformation will be required for awards issued under this FOA.

Teaming arrangements are strongly encouraged among industry (such as fuel cell developers, catalyst/membrane suppliers, and component developers), federal laboratories, and universities to take advantage of the best complementary expertise and technologies available from the different organizations. If appropriate expertise is available in-house, teaming with external organizations is not required.

A separate National Laboratory Call (DE-PS36-08GO98010), titled "Laboratory Call for Research, Development, and Demonstration of Fuel Cell Technologies for Automotive, Stationary, and Portable Power Applications," offers opportunities for National Laboratories 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 over 2-4 years, with no predetermined division of funding between the two announcements.

Table 1 – Technical Targets for Automotive Applications: 80-kW_e (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 B.
[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 6 Fuel Cell System Demonstrations
Topic 6A Stationary PEM Power Systems
Topic 6B Solid Oxide Fuel Cell Power Systems

Topic 7 Market Transformation Activities
Topic 7A Emergency Backup Power Systems
Topic 7B Fuel Cell-Powered Material Handling Equipment

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 B, 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 developing 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 B) 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.
- Effects 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 B) 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 national laboratory 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.

Topic 6 Fuel Cell System Demonstrations

Topic 6A Stationary PEM Power Systems

Stationary PEM fuel cell systems have not achieved durability targets. DOE is interested in supporting the development and demonstration of reliable/durable small-scale stationary fuel cell power systems developed from a global market perspective. This Topic seeks to develop and test prototype integrated, new-generation, small distributed PEM fuel cell systems (1 to 5 kW; larger units which are responsive to this Topic description and that can be completed within the budget limitations listed in Part II.E will be considered) fueled by direct hydrogen, reformed natural gas or other gaseous hydrocarbon, or biomass-derived fuel. CHP is desirable but not required. For CHP applications, a case needs to be made that the balance between heat and electrical power provided by the CHP system will match the requirements of the intended application while maintaining the overall efficiency benefits. Packaged solutions for small fuel cell systems, with 40,000 hour durability, 40% electrical efficiency and with a cost of $750/kW (at production volumes) are sought. Research and development should focus on system level issues including: new system design; modularity; system modeling and integration; balance of plant; electronic control systems for optimal heat and power management; grid connection; a fully integrated fuel processor; system safety; energy/environmental life cycle analysis; benchmarking and verification of components and systems; and recycling and disposal.

The intent is to demonstrate the market viability of the proposed fuel cell system and to help expedite the commercial application of the technology. The applicant must provide convincing arguments and justification for the demonstration based on market needs, the readiness of the technology for the proposed application, potential energy saved, emissions reduced, and market potential. Preference will be given to applications that cover as many technical and economic issues as appropriate, to achieve synergy between component technologies, system integration, and fuel processing. To address issues involving interfacing with the grid, the applicant must show expertise in the area of grid interconnectivity, either through in-house expertise or through teaming with an entity such as a utility.

To increase the benefit, demonstrations that raise the visibility of fuel cells or increase public awareness of fuel cells are encouraged.

Responses to this Topic should be structured in two tasks, which need not be sequential. Task I will be a system development effort ending with the testing of a prototype system that meets the 2011 targets in Table 2. Task II will consist of demonstration of full-scale systems in the field at a site or sites relevant to the application/market selected by the applicant. Multiple units are required. The site(s) selected must be located in the U.S. The demonstration should include failure mode analysis and a projection of system lifetime.

The system development effort (Task I) should be a smaller component (< 50% of the project duration) of the overall project. There will be a go/no go decision point at the end of Task I for continuation to a final configuration. The applicant should state quantitative criteria, based on the technical targets in Table 2, that will be used to make this decision.

Topic applications should describe a 1 to 5 kW prototype fuel cell demonstration leading to systems capable of 40,000 hours of operation, 40% electrical efficiency (without CHP), and a cost of $750/kW at production volumes. Where applicable, grid interconnectivity issues should be clearly identified and addressed, and appropriate expertise in this area should be presented. The demonstration site location(s) should be identified and justified. The proposed demonstration should operate for at least 2 years, not including fuel cell power plant fabrication and installation.

Expected Outcomes:

- Operating data from several identical field units at a customer site
- Degradation analysis including failure mode analysis
- Projection of system lifetime.

Topic 6B Solid Oxide Fuel Cell Power Systems

DOE is interested in supporting the development and demonstration of fuel cell power systems based on SOFCs. The DOE Office of Fossil Energy supports coal-fueled, MW-scale systems for electricity generation through its SECA Program. Unlike the SECA Program, DOE's Office of Energy Efficiency and Renewable Energy seeks to develop and field test a prototype integrated, small SOFC system (not fueled by coal) in the 1-5 kW_e range (larger systems which are responsive to this topic description and which can be completed within the budget limitations listed in Part II.E will be considered). High visibility demonstrations are encouraged. The demonstration site, which must be located in the U.S., should be identified and justified, and the proposed demonstration should last a minimum of one year.

Applications submitted to this Topic should clearly state the status of the applicant's current stack and system technology and any improvements to be made in the proposed project.

Within the above constraints, the actual application (i.e., market) is left up to the applicant, but a clear discussion of the market potential (value proposition, market size, etc.) needs to be included in the application. The intent is to demonstrate the market viability of the proposed fuel cell system and to help expedite the commercial application of the technology.
Possible markets/applications include critical power, remote power, and auxiliary power units (APUs). Also, CHP systems are an area of interest, as they benefit from the high grade waste heat from SOFCs. For CHP applications, a case needs to be made that the balance between heat and electrical power provided by the CHP system will match the requirements of the intended application while maintaining the overall efficiency benefits. Where applicable, grid interconnectivity issues should be clearly identified and addressed, and appropriate expertise in this area should be present, either through in-house expertise or through teaming with an entity such as a utility. As applicable, a pathway to meeting the DOE 2011 technical targets listed in Table 2 for stationary power applications (especially 40,000 hours durability, 40% electrical efficiency, and a cost of $750/kW at production volumes) and Table 5 for APUs should be provided.

The fuel to be used will depend on the particular application selected; however, it should be readily available. Biofuels are of interest. Also, the method of handling the fuel's sulfur content should be addressed, especially for liquid hydrocarbon fuels.

Any development work leading to the field demonstration unit should focus on system level issues, and the rationale and necessity for carrying out these activities as they relate to the proposed demonstration should be established. Examples of system level issues include new system design, system modeling & integration, balance of plant components (heat exchangers, insulation, etc.), grid connection, thermal cycling, and fully integrated fuel processor development.

Expected Outcomes:
Demonstration of an integrated SOFC system in the field at a site relevant to the application/market selected by the applicant.

- Operating data from at least one field unit at a customer site.
- Degradation analysis including failure mode analysis.
- Projection of system lifetime.

Table 5 – Technical Targets for Auxiliary Power Units [a]

Characteristic	Units	2010	2015
Specific power	W / kg	25	25
Power density	W / L	25	25
Efficiency @ rated power [b]	% LHV	35	40
Cost [c]	$ / kW_e	1000	500
Cycle capability (from cold start) over operating lifetime	number of cycles	150	250
Durability	hours	20,000	35,000
Start-up time	min	15-30	15-30

[a] Targets are currently under review
[b] Electrical efficiency only—does not include any efficiency aspects of the heating or cooling likely being provided.
[c] Cost based on high-volume manufacturing quantities (100,000 units / year)

Topic 7 Market Transformation Activities

DOE is interested in supporting market transformation projects, i.e., those that will provide DOE with data from systems operating under real-world conditions, eliminate non-technical barriers, and increase opportunities for market expansion of hydrogen fuel cell technologies. A study by Battelle Memorial Institute, "Identification and Characterization of Near-term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets," showed that PEM fuel cells have the potential to provide (1) backup service at lower total cost than 2 kW battery-only backup systems and (2) material handling service at a lower cost than lead acid battery and combustion engine systems under certain types of operations [8].

This Topic aims to increase the number of commercially available fuel cell systems, expand practical user operating experiences, generate volume for the fuel cell supply chain, increase private equity confidence, and validate performance. Furthermore, this Topic seeks to increase market pull for existing and new-generation fuel cell power systems.

The intent is to demonstrate the market viability of the proposed fuel cell system and to help expedite the commercial application of the technology. The applicant must provide convincing arguments and justification for how this application will benefit/bolster the supply base; will increase user confidence; is competitive in the market place in terms of value provided; has favorable reduced lifecycle cost compared to incumbent technologies (e.g., lead acid batteries or combustion engines) without tax incentives with a reasonable chance of approaching parity through short-term technology or mass production improvements. Furthermore, through this Topic, DOE seeks to gather real-world data from units in the hands of customers to validate performance and to identify issues with commercial systems. The applicant should address what data will be made available and how this data can be used to meet these ends.

The focus of the application should be on actual cost and performance experiences rather than specific proprietary product information. Projects awarded will demonstrate reliability and maintainability to develop a track record of fuel cell operation. Preference will be given to applications that provide the greatest number of units for the lowest cost while demonstrating market viability as outlined above. In addition, preference will be given to those projects that include the greatest private sector cost share. Leveraging of resources through state and local government energy program participation is strongly encouraged.

Topic 7A Emergency Backup Power Systems

Packaged solutions for small PEM fuel cell power systems (1 to 10 kW) fueled by hydrogen capable of a minimum of 72 hours of continuous operation and 100 total hours each year for 10 years are sought to fill demand at the local and state level for backup applications serving the needs of markets including, but not limited to, first responders, emergency services, 911 centers, and communications centers.

For this sub-topic, the applicant team will consist of, at a minimum, the backup power developer/installer having expertise in the area of grid interconnectivity and power users, such as first responders, emergency services, 911 centers, and communications centers. Applications should include: complete fuel cell systems including DC-AC inverters (as needed); uninterruptable power supply battery backup (as needed); and site preparation and installation costs.

Expected Outcomes:

- 1 to 10 kW fuel cell systems delivered, installed, and operated at the customer site(s).
- Periodic performance reports documenting results from operating delivered systems. Reports should include any issues identified during the operation of the units.

Topic 7B Fuel Cell-Powered Material Handling Equipment

The Battelle Memorial Institute showed that PEM fuel cells have the potential to provide a value proposition when used in a multiple shift operation [8]. Battery-powered forklifts are typically powered by lead-acid batteries that can provide enough power for one 8-hour shift. A disadvantage of the battery-powered forklift is battery change-out and downtime, which impacts productivity and increases costs of operation. In a typical operation, battery change-out takes 20-45 minutes. Due to slow charging speed, multiple shift operations must typically keep extra batteries charged and available. While PEM fuel cell-powered lift trucks require more capital investment than incumbent alternatives, they provide significant savings in operation and maintenance.

Packaged solutions for PEM fuel cell systems (5 to 20 kW) fueled by hydrogen capable of powering a Class 2 or 3 lift truck for a minimum of 10 hours of continuous operation and 5000 total hours are sought to fill demand at commercial distribution centers that operate multiple shifts per day. The target market for this Topic is commercial distribution centers used by wholesalers or retailers for products, such as grocery produce and consumable or durable goods.

For this sub-topic, the applicant team will include, at a minimum, expertise in fuel cell lift truck development and integration, battery hybridization, hydrogen fuel dispensing, fuel delivery logistics, and wholesale or retail distribution center material handling power needs.

Applications should describe at a minimum: a complete fuel cell power system designed for powering lift truck systems; lift truck retrofit specifications (as applicable); hydrogen fuel storage and dispensing system including installation, commissioning, maintenance, and decommissioning capable of supporting the lift truck hydrogen fill requirements for the specified operations (system shall be capable of safely dispensing fuel into the proposed fuel cell lift truck); weather shelter for dispensing operations; and a plan for obtaining all necessary government approvals and permits for all aspects of the dispensing system. The cost of lift truck equipment, excluding the fuel cell power system, is the responsibility of the wholesale or retail distribution center user and should not be included as part of the application.

Expected Outcomes:

- 5 to 20 kW fuel cell systems delivered, installed on material handling equipment, and operated at the customer, i.e., distribution center, site(s).
- Periodic performance reports documenting results from operating delivered systems. Reports should include any safety or performance data and issues identified during the operation of the units.

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.
8. K. Mahadevan, Battelle Memorial Institute, "Identification and Characterization of Near-term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets"; http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pemfc_econ_2006_report_final_0407.pdf.

PART II – AWARD INFORMATION

A. TYPE OF AWARD INSTRUMENT

DOE anticipates awarding grants and/or cooperative agreements under this program announcement. If it is determined that a cooperative agreement is the appropriate award instrument, a description of the federal involvement will be included in a special award condition.

B. ESTIMATED FUNDING

A separate National Laboratory Call (DE-PS36-08GO98010), titled "Laboratory Call for Research, Development, and Demonstration of Fuel Cell Technologies for Automotive, Stationary, and Portable Power Applications," offers opportunities for National Laboratories 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. Since awards resulting from these parallel announcements are expected to begin in FY 2009, no FY 2008 funding is available for new awards.

C. MAXIMUM AND MINIMUM AWARD SIZE

Ceiling (i.e., the maximum amount for an individual award made under this announcement): See Part II.E for estimates of the anticipated award for each topic area.

Floor (i.e., the minimum amount for an individual award made under this announcement): See Part II.E for estimates of the anticipated award for each topic area.

D. EXPECTED NUMBER OF AWARDS

DOE anticipates making approximately 54 awards total under both parallel announcements explained above, depending on the size of the awards.

E. 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

F. PERIOD OF PERFORMANCE

The anticipated period of performance for projects will range from 2 to 4 years. For some of the projects, the overall project duration, called a project period, will be subdivided into two or more phases, or “budget periods,” with continuation from one budget period to the next being dependent on satisfactory performance of the first budget period (including passing a go/no-go decision point).

PART III - ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS.

All types of domestic entities are eligible to apply, except other Federal agencies, Federally Funded Research and Development Center (FFRDC) Contractors, and nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995.

Foreign participants are not eligible as the prime applicant; however, foreign participants are allowed as subrecipients to a domestic applicant.

B. COST SHARING

The cost share must be at least 20% of the total allowable costs for research and development projects (Topics 1-5) and at least 50% of the total allowable costs for demonstration and commercial application projects (Topics 6-7) and must come from non-Federal sources unless otherwise allowed by law. The sum of the Government share, including FFRDC contractor costs if applicable, and the recipient share of allowable costs equals the total allowable cost of the project.

C. OTHER ELIGIBILITY REQUIREMENTS

Federally Funded Research and Development Center (FFRDC) Contractors

FFRDC contractors are not eligible for an award under this announcement, but they may be proposed as a team member on another entity's application subject to the following guidelines:

Authorization for non-DOE FFRDCs. The Federal agency sponsoring the FFRDC contractor must authorize in writing the use of the FFRDC contractor on the proposed project and this authorization must be submitted with the application. The use of a FFRDC contractor must be consistent with the contractor's authority under its award.

Authorization for DOE FFRDCs. The cognizant contracting officer for the FFRDC must authorize in writing the use of a DOE FFRDC contractor on the proposed project and this authorization must be submitted with the application. The following wording 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."

Value/Funding. The value of, and funding for, the FFRDC contractor portion of the work will not normally be included in the award to a successful applicant. Usually, DOE will fund a DOE FFRDC contractor through the DOE field work proposal system and other FFRDC contractors through an interagency agreement with the sponsoring agency.

Cost Share. The applicant's cost share requirement will be based on the total cost of the project, including the applicant's and the FFRDC contractor's portions of the effort.

FFRDC Contractor Effort. The FFRDC contractor effort, in aggregate, shall not exceed 50% of the total estimated cost of the project, including the applicant's and the FFRDC contractor's portions of the effort.

Responsibility. The applicant, if successful, will be the responsible authority regarding the settlement and satisfaction of all contractual and administrative issues, including but not limited to, disputes and claims arising out of any agreement between the applicant and the FFRDC contractor.

PART IV – APPLICATION AND SUBMISSION INFORMATION

A. ADDRESS TO REQUEST APPLICATION PACKAGE

Application forms and instructions are available at Grants.gov. To access these materials, go to http://www.grants.gov, select "Apply for Grants," and then select "Download Application Package." Enter the CFDA and/or the funding opportunity number located on the cover of this announcement and then follow the prompts to download the application package. **(Also see Section H of this Part below.)**

B. LETTER OF INTENT AND PRE-APPLICATION

1. Letter of Intent

A Letter of Intent is not required.

2. Pre-application

A Pre-application is not required.

C. CONTENT AND FORM OF APPLICATION

All applicants must complete the mandatory forms and any applicable optional forms (e.g., SF-LLL- Disclosure of Lobbying Activities), in accordance with the instructions on the forms and the additional instructions below. **Files that are attached to the forms must be in Adobe Portable Document Format (PDF) unless otherwise specified in this announcement**.

1. SF 424 - Application for Federal Assistance

Complete all required fields in accordance with the pop-up instructions on the form. **To activate the instructions, turn on the "Help Mode" (Icon with the pointer and question mark at the top of the form.)** The list of certifications and assurances referenced in Field 21 can be found at http://management.energy.gov/business_doe/business_forms.htm, under Certifications and Assurances.

Note: The dates and dollar amounts on this form should pertain to the entire project period, not just the first year, first phase, or other subset of the project period.

2. Other Attachments Form

Submit the following files with your application by attaching them to the Other Attachments Form. Click on "Add Mandatory Other Attachment" to attach the Project Narrative. Click on "Add Optional Other Attachment," to attach the other files.

a. 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", and click on "Add Optional Other Attachment" to attach.

b. Project Narrative File - Mandatory Other Attachment

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 V.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, 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 VIII.D for instructions on how to mark proprietary application information.

Save all of the Project Narrative information in a single file named "Narrative.pdf", and click on "Add Mandatory Other Attachment" to attach.

The Narrative should include the following sections:

i. <u>Cover Page</u>
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 V.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 V.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 V.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.

c. 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", and click on "Add Optional Other Attachment" to attach.

d. 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, and are not prohibited by the funding restrictions in this announcement (See PART IV.G). Save the information in a single file named "Budget.pdf", and click on "Add Optional Other Attachment" to attach.

e. 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), and click on "Add Optional Other Attachment" to attach.

f. 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, 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. Use up to 10 letters of the FFRDC name (plus .pdf) as the file name, and click on “Add Optional Other Attachment” to attach.

g. Authorization for non-DOE or DOE FFRDCs File

If an FFRDC is proposed as a subcontractor (or subrecipient), a special authorization is required as described in Part III.C. Save the authorization for all FFRDCs in a single file named “FFRDC_Auth.pdf”, and click on “Add Optional Other Attachment” to attach.

h. Letters of Commitment File

If a third party, (i.e., a party other than the organization submitting the application) proposes to provide all or part of the required cost sharing, the applicant must include a letter from the 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 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”, and click on “Add Optional Other Attachment” to attach.

3. SF-LLL Disclosure of Lobbying Activities

If applicable, complete SF-LLL. Applicability: If any funds other than federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the grant/cooperative agreement, you must complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying.”

Summary of Required Forms/Files
Your application must include the following documents:

Name of Document	Format	File Name
1. SF 424 - Application for Federal Assistance	PureEdge Form	N/A
2. Other Attachments Form: Attach the following files to this form:	N/A	N/A
a. Project Summary/Abstract File	PDF	Abstract.pdf
b. Project Narrative File	PDF	Narrative.pdf
c. Personnel Resume File	PDF	Resumes.pdf
d. Budget File - SF 424A - Budget Information for Non-Construction Programs	PDF	Budget.pdf
e. Subaward Budget File(s), if applicable	PDF	See Instructions
f. Budget for DOE/NNSA FFRDC Contractor File(s), if applicable (Field Work Proposal).	PDF	See Instructions
g. FFRDC Authorization File, if applicable	PDF	FFRDC_Auth.pdf
h. Letters of Commitment File, if applicable	PDF	CLTP.pdf
3. SF-LLL Disclosure of Lobbying Activities, if applicable	PureEdge Form	N/A

D. SUBMISSIONS FROM SUCCESSFUL APPLICANTS

If an applicant is selected for negotiation of an award, DOE reserves the right to request additional or clarifying information for any reason deemed necessary, including, but not limited to:

- Indirect cost information
- Budget justification and other budget information
- Name and phone number of the Designated Responsible Employee for complying with national policies prohibiting discrimination (See 10 CFR 1040.5)
- Representation of Limited Rights Data and Restricted Software, if applicable
- Environmental Questionnaire for National Environmental Policy Act (NEPA) determination.

E. SUBMISSION DATES AND TIMES

Pre-application Due Date

Pre-applications are not required.

Application Due Date

Applications must be received by August 27, 2008, 11:59 PM Eastern Time. You are encouraged to transmit your application well before the deadline. The grants.gov Helpdesk is NOT available after 9:00 PM Eastern Time. **APPLICATIONS RECEIVED AFTER THE DEADLINE WILL NOT BE REVIEWED OR CONSIDERED FOR AWARD.**

F. INTERGOVERNMENTAL REVIEW

This program is not subject to Executive Order 12372 – Intergovernmental Review of Federal Programs.

G. FUNDING RESTRICTIONS

Cost Principles**.** Costs must be allowable in accordance with the applicable Federal cost principles referenced in 10 CFR Part 600. The cost principles for commercial organizations are in FAR Part 31.

Pre-award Costs**.** Recipients may charge to an award resulting from this announcement pre-award costs that were incurred within the ninety (90) calendar day period immediately preceding the effective date of the award, if the costs are allowable in accordance with the applicable Federal cost principles referenced in 10 CFR part 600. Recipients must obtain the prior approval of the contracting officer for any pre-award costs that are for periods greater than this 90 day calendar period.

Pre-award costs are incurred at the applicant's risk. DOE is under no obligation to reimburse such costs if for any reason the applicant does not receive an award or if the award is made for a lesser amount than the applicant expected.

H. SUBMISSION AND REGISTRATION REQUIREMENTS

1. Where to Submit

APPLICATIONS MUST BE SUBMITTED THROUGH GRANTS.GOV, AGAINST THIS ANNOUNCEMENT, TO BE CONSIDERED FOR AWARD. You cannot submit an application through Grants.gov unless you are registered. Please read the registration requirements below carefully and start the process immediately.

Submit electronic applications through the "Apply for Grants" function at www.Grants.gov. If you have problems completing the registration process or submitting your application, call Grants.gov at 1-800-518-4726 or send an email to support@grants.gov.

2. Registration Process Requirements

There are several one-time actions you must complete in order to submit an application through Grants.gov (e.g., obtain a Dun and Bradstreet Data Universal Numbering System (DUNS) number, register with the Central Contract Registry (CCR), register with the credential provider, and register with Grants.gov). See http://www.grants.gov/applicants/get_registered.jsp. Use the Grants.gov Organization Registration Checklist at http://www.grants.gov/section3/OrganizationRegCheck.pdf to guide you through the process. IMPORTANT: During the CCR registration process, you will be asked to designate an E-Business Point of Contact (EBIZ POC). The EBIZ POC must obtain a special password called "Marketing Partner identification Number" (MPIN).

Applicants, who are not registered with CCR and Grants.gov, should allow at least 21 days to complete these requirements, as you must COMPLETE ALL STEPS of the one-time registration process before you can submit your first application through Grants.gov.

IMPORTANT NOTICE TO POTENTIAL APPLICANTS: When you have completed the process, you should call the Grants.gov Helpdesk at 1-800-518-4726 to verify that you have completed the final step (i.e. Grants.gov registration).

Microsoft Vista and Office 2007 Compatibility

Grants.gov is currently incompatible with both the new Microsoft (MS) Vista Operating System and the new Microsoft (MS) Office 2007 versions of Word, Excel, and Power Point. In order to create and submit your application to Grants.gov, you must use a computer with a previous version Microsoft Operating System, such as Windows XP.

If you attach a file created using MS Office 2007, you will not get an error message when you submit the application. HOWEVER, your entire application will not be processed or accepted at Grants.gov and will not reach DOE. Grants.gov can accept applications with attachments created in MS Office 2007 if the attachments are saved in the prior format. See the http://www.grants.gov/assets/Vista_and_office_07_Compatibility.pdf for detailed instructions on how to do this. A file created in MS Office 2007 can be identified by the "x" at the end of the file extension, for example "sample.docx" for a Word file. Contact Grants.gov at 1-800-518-4726 with any questions.

3. Questions

ALL Questions relating to the registration process, system requirements, how an application form works, or the submittal process must be directed to Grants.gov at 1-800-518-4726 or support@grants.gov. Part VII, Section A. of this announcement explains how to submit other questions to DOE, relative to the content and requirements of this announcement.

4. Application Receipt Notices

After an application is submitted, the Authorized Organization Representative (AOR) will receive a series of five e-mails. It is extremely important that the AOR watch for and save each of the emails. It may take up to 2 business days from application submission to receipt of email Number 2. You will know that your application has reached DOE when the AOR receives email Number 5. You will need the Submission Receipt Number (email Number 1) to track a submission. The titles of the five e-mails are:

Number 1 - Grants.gov Submission Receipt Number
Number 2 - Grants.gov Submission Validation Receipt for Application Number
Number 3 - Grants.gov Grantor Agency Retrieval Receipt for Application Number
Number 4 - Grants.gov Agency Tracking Number Assignment for Application
Number 5 - DOE e-Center Grant Application Received

The last email will contain instructions for the AOR to register with the DOE e-Center. If the AOR is already registered with the DOE e-Center, the title of the last email changes to: Number 5 – DOE e-Center Grant Application Received and Matched. This email will contain the direct link to the application in IIPS. The AOR will need to enter their DOE e-Center user id and password to access the application.

Part V - APPLICATION REVIEW INFORMATION

A. REVIEW 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 has been proposed; and (5) the proposed project is responsive to the objectives of the funding opportunity 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 Topics 1-6, 40% for Topic 7)

- 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 Topics 5-7).
- 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 (project for Topic 7) to achieve DOE's technical targets (or market transformation activities objectives for Topic 7) 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 (or achieve the goals stated in the

topic description for Topic 7). 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 Topics 1-7)

- 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 Topics 1-6, 30% for Topic 7)

- 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 (except for Topic 7).

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 V.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. Selection

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

3. 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; (3) the Government needs additional information to determine that the recipient is capable of complying with the requirements in 10 CFR part 600; and/or (4) 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 by December 2008 and making awards by February 2009.

Part VI - AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. Notice of Selection and Debriefings

DOE will notify applicants selected for award. This notice of selection is not an authorization to begin performance. (See Part IV.G with respect to the allowability of pre-award costs.)

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.

2. Notice of Award

A Notice of Financial Assistance Award issued by the contracting officer is the authorizing award document. It normally includes, either as an attachment or by reference: 1. Special Terms and Conditions; 2. Applicable program regulations, if any; 3. Application as approved by DOE; 4. DOE assistance regulations at 10 CFR part 600, or, for Federal Demonstration Partnership (FDP) institutions, the FDP terms and conditions; 5. National Policy Assurances To Be Incorporated As Award Terms; 6. Budget Summary; and 7. Federal Assistance Reporting Checklist, which identifies the reporting requirements.

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

1. Administrative Requirements

The administrative requirements for DOE grants and cooperative agreements are contained in 10 CFR part 600 (See: http://ecfr.gpoaccess.gov), except for grants made to FDP institutions. The FDP terms and conditions and DOE FDP agency specific terms and conditions are located on the National Science Foundation web site at http://www.nsf.gov/awards/managing/fed_dem_part.jsp.

2. Special Terms and Conditions and National Policy Requirements

The DOE Special Terms and Conditions for Use in Most Grants and Cooperative Agreements are located at http://management.energy.gov/business_doe/business_forms.htm under

Award Terms. The National Policy Assurances To Be Incorporated As Award Terms are located at http://management.energy.gov/business_doe/business_forms.htm under Award Terms.

3. **Intellectual Property Provisions**

   The standard DOE financial assistance intellectual property provisions applicable to the various types of recipients are located at http://www.gc.doe.gov/financial_assistance_awards.htm. Special data provisions are applicable to this program.

4. **Statement of Substantial Involvement**

   Either a grant or cooperative agreement may be awarded under this program announcement. If the award is a cooperative agreement, the DOE Specialist and DOE Project Officer will negotiate a Statement of Substantial Involvement with the selected applicant prior to award.

C. REPORTING

Reporting requirements will be identified on the Federal Assistance Reporting Checklist, DOE F 4600.2, attached to the award agreement. A sample of the Checklist can be found at https://www.eere-pmc.energy.gov/procurenet/FinancialAssistance/Forms/DOE_Forms/DOEF4600_2.doc.

Specific reporting requirements for all awards resulting from this announcement will include:

- Quarterly Technical Progress Reports
- Quarterly Financial Status Reports
- 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

PART VII - QUESTIONS/AGENCY CONTACTS

A. QUESTIONS

Questions regarding the content of the announcement must be submitted through the "Submit Question" feature of the DOE Industry Interactive Procurement System (IIPS) at http://e-center.doe.gov. Locate the program announcement on IIPS and then click on the "Submit Question" button. Enter required information. You will receive an electronic notification that your question has been answered. DOE will try to respond to a question within 3 business days, unless a similar question and answer have already been posted on the website. Potential applicants are encouraged to read all posted Q&A prior to posting a new question.

Questions relating to the registration process, system requirements, how an application form works, or the submittal process are not answered via the DOE IIPS "Submit Question" feature, and must be directed to Grants.gov at 1-800-518-4726 or support@grants.gov. DOE cannot answer these questions. (See Part IV, Section H.)

B. AGENCY CONTACT(S)

Name: Melissa Wise

E-mail: H2FuelCells@go.doe.gov

Telephone: (303) 275-4907

All questions should be submitted through the "Submit Question" feature of IIPS. (See Part A of this Part, above.)

PART VIII - OTHER INFORMATION

A. MODIFICATIONS

Notices of any modifications to this announcement will be posted on Grants.gov and the DOE Industry Interactive Procurement System (IIPS). You can receive an email when a modification or an announcement message is posted by joining the mailing list for this announcement through the link in IIPS. When you download the application at Grants.gov, you can also register to receive notifications of changes through Grants.gov.

B. GOVERNMENT RIGHT TO REJECT OR NEGOTIATE

DOE reserves the right, without qualification, to reject any or all applications received in response to this announcement and to select any application, in whole or in part, as a basis for negotiation and/or award.

C. COMMITMENT OF PUBLIC FUNDS

The contracting officer is the only individual who can make awards or commit the Government to the expenditure of public funds. A commitment by other than the contracting officer, either explicit or implied, is invalid.

D. PROPRIETARY APPLICATION INFORMATION

Patentable ideas, trade secrets, proprietary or confidential commercial or financial information, disclosure of which may harm the applicant, should be included in an application only when such information is necessary to convey an understanding of the proposed project. The use and disclosure of such data may be restricted, provided the applicant includes the following legend on the first page of the project narrative and specifies the pages of the application which are to be restricted:

"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."

To protect such data, each line or paragraph on the pages containing such data must be specifically identified and marked with a legend similar to the following:

"The following contains proprietary information that (name of applicant) requests not be released to persons outside the Government, except for purposes of review and evaluation."

E. EVALUATION AND ADMINISTRATION BY NON-FEDERAL PERSONNEL

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.

F. INTELLECTUAL PROPERTY DEVELOPED UNDER THIS PROGRAM

Patent Rights. The Government will have certain statutory rights in an invention that is conceived or first actually reduced to practice under a DOE award. 42 U.S.C. 5908 provides that title to such inventions vests in the United States, except where 35 U.S.C. 202 provides otherwise for nonprofit organizations or small business firms. However, the Secretary of Energy may waive all or any part of the rights of the United States subject to certain conditions. (See "Notice of Right to Request Patent Waiver" in paragraph G below.)

Rights in Technical Data. Normally, the Government has unlimited rights in technical data created under a DOE agreement. Delivery or third party licensing of proprietary software or data developed solely at private expense will not normally be required except as specifically negotiated in a particular agreement to satisfy DOE's own needs or to insure the commercialization of technology developed under a DOE agreement.

Special Protected Data Statutes. This program is covered by a special protected data statute. The provisions of the statute provide for the protection from public disclosure, for a period of up to 5 years from the development of the information, of data that would be trade secret, or commercial or financial information that is privileged or confidential, if the information had been obtained from a non-federal party. Generally, the provision entitled, Rights in Data – Programs Covered Under Special Protected Data Statutes, (10 CFR 600 Appendix A to Subpart D), would apply to an award made under this announcement. This provision will identify data or categories of data first produced in the performance of the award that will be made available to the public, notwithstanding the statutory authority to withhold data from public dissemination, and will also identify data that will be recognized by the parties as protected data.

G. NOTICE OF RIGHT TO REQUEST PATENT WAIVER

Applicants may request a waiver of all or any part of the rights of the United States in inventions conceived or first actually reduced to practice in performance of an agreement as a result of this announcement, in advance of or within 30 days after the effective date of the award. Even if such advance waiver is not requested or the request is denied, the recipient will have a continuing right under the award to request a waiver of the rights of the United States in identified inventions, i.e., individual inventions conceived or first actually reduced to practice in performance of the award. Any patent waiver that may be granted is subject to certain terms and conditions in 10 CFR 784.

Domestic small businesses and domestic nonprofit organizations will receive the patent rights clause at 37 CFR 401.14, i.e., the implementation of the Bayh-Dole Act. This clause permits domestic small business and domestic nonprofit organizations to retain title to subject inventions. Therefore, small businesses and nonprofit organizations do not need to request a waiver.

H. NOTICE REGARDING ELIGIBLE/INELIGIBLE ACTIVITIES

Eligible activities under this program include those which describe and promote the understanding of scientific and technical aspects of specific energy technologies, but not those which encourage or support political activities such as the collection and dissemination of information related to potential, planned or pending legislation.

I. NOTICE OF RIGHT TO CONDUCT A REVIEW OF FINANCIAL CAPABILITY

DOE reserves the right to conduct an independent third party review of financial capability for applicants that are selected for negotiation of award (including personal credit information of principal(s) of a small business if there is insufficient information to determine financial capability of the organization).

J. NOTICE OF POTENTIAL DISCLOSURE UNDER FREEDOM OF INFORMATION ACT

Applicants should be advised that identifying information regarding all applicants, including applicant names and/or points of contact, may be subject to public disclosure under the Freedom of Information Act, whether or not such applicants are selected for negotiation of award.

REFERENCE MATERIAL

Appendix A – DEFINITIONS

"Amendment" means a revision to a Funding Opportunity 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 Funding Opportunity Announcement.

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

"Authorized Organization Representative (AOR)" is the person with assigned privileges who is authorized to submit grant applications through Grants.gov on behalf of an organization. The privileges are assigned by the organization's E-Business Point of Contact designated in the CCR.

"**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 Funding Opportunity 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.

"**Cooperative Agreement**" means a Financial Assistance instrument used by DOE to transfer money or property when the principal purpose of the transaction is to accomplish a public purpose of support or stimulation authorized by Federal statute, and Substantial Involvement (see definition below) is anticipated between DOE and the Applicant during the performance of the contemplated activity.

"**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.

"Central Contractor Registry (CCR)" is the primary database which collects, validates, stores and disseminates data in support of agency missions. Funding Opportunity Announcements which require application submission through Grants.gov require that the organization first be registered in the CCR at http://www.grants.gov/CCRRegister.

“Credential Provider” is an organization that validates the electronic identity of an individual through electronic credentials, PINS, and passwords for Grants.gov. Funding Opportunity Announcements which require application submission through Grants.gov require that the individual applying on behalf of an organization first be registered with the Credential Provider at https://apply.grants.gov/OrcRegister.

“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

“E-Business Point of Contact (POC)” is the individual who is designated as the Electronic Business Point of Contact in the CCR registration. This person is the sole authority of the organization with the capability of designating or revoking an individual’s ability to submit grant applications on behalf of their organization through Grants.gov.

“E-Find” is a Grants.gov webpage where you can search for Federal Funding Opportunities in FedGrants. http://www.grants.gov/search/searchHome.do

"**Financial Assistance**" means the transfer of money or property to an Applicant or Participant to accomplish a public purpose of support authorized by Federal statute through Grants or Cooperative Agreements and sub-awards. For DOE, it does not include direct loans, loan guarantees, price guarantees, purchase agreements, Cooperative Research and Development Agreements (CRADAs), or any other type of financial incentive instrument.

“Federally Funded Research and Development Center (FFRDC)” means a research laboratory as defined by Federal Acquisition Regulation 35.017.

“Funding Opportunity Announcement (FOA)” is a publicly available document by which a Federal agency makes known its intentions to award discretionary grants or cooperative agreements, usually as a result of competition for funds. Funding opportunity announcements may be known as program announcements, notices of funding availability, solicitations, or other names depending on the agency and type of program.

"Grant" means a Financial Assistance instrument used by DOE to transfer money or property when the principal purpose of the transaction is to accomplish a public purpose of support or stimulation authorized by Federal statute, and no Substantial Involvement is anticipated between DOE and the Applicant during the performance of the contemplated activity.

“Grants.gov” is the “storefront” web portal which allows organizations to electronically find and apply for competitive grant opportunities from all Federal grant-making agencies. Grants.gov is THE single access point for over 900 grant programs offered by the 26 Federal grant-making agencies. http://www.grants.gov

“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.

“Marketing Partner Identification Number (MPIN)” is a very important password designated by your organization when registering in CCR. The E-Business Point of Contact will need the MPIN to login to Grants.gov to assign privileges to the individual(s) authorized to submit applications on behalf of your organization. The MPIN must have 9 digits containing at least one alpha character (must be in capital letters) and one number (no spaces or special characters permitted).

"**Participant**" for purposes of this Funding Opportunity Announcement only, 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 Funding Opportunity 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 Funding Opportunity 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 Funding Opportunity Announcement.

"**Substantial Involvement**" means involvement on the part of the Government. DOE's involvement may include shared responsibility for the performance of the Project; providing technical assistance or guidance which the Applicant is to follow; and the right to intervene in the conduct or performance of the Project. Such involvement will be negotiated with each Applicant prior to signing any agreement.

"**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 --

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 B1 for electrocatalysts, Table B2 for catalyst supports, Table B3 for membrane/MEA chemical stability, and Table B4 for membrane/MEA mechanical durability, respectively, as derived from **References 2 and 3**. Table B1 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 B1
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	$\leq$60% loss of initial catalytic activity
Polarization curve from 0 to $\geq$1.5 A/cm^{2**}	After 0, 1k, 5k, 10k, and 30k cycles	$\leq$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	$\leq$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 B2
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 B3 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 B4 Membrane Mechanical Cycle and Metrics (Test using a MEA)		
Cycle	**Cycle 0% RH (2 min) to 90°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		