V.0 Fuel Cells Program Overview

INTRODUCTION

The Fuel Cells program supports research, development, and demonstration of fuel cell technologies for a variety of transportation, stationary, and portable applications, with a primary focus on reducing cost and improving durability. These efforts include research and development (R&D) of fuel cell stack components, system balance-of-plant (BOP) components, and subsystems, as well as system integration. The program seeks a balanced, comprehensive approach to fuel cells for near-, mid-, and longer-term applications. Existing early markets and near-term markets include portable power, backup power, auxiliary power units, and specialty applications such as material handling equipment. In the mid- to long-term, development of fuel cells for transportation applications is a primary goal due to the significant reduction in the nation's energy and petroleum requirements that would result from market availability of high-efficiency fuel cell electric vehicles. Development of fuel cells for distributed power generation (e.g., combined heat and power (CHP) for residential and commercial applications) is also underway. The program's portfolio of projects covers a broad range of technologies, including polymer electrolyte membrane (PEM) fuel cells, direct methanol fuel cells, alkaline membrane fuel cells, and solid oxide fuel cells.

The program's fuel cell tasks in the *Fuel Cell Technologies Office Multi-Year Research, Development and Demonstration Plan* are organized around development of components, stacks, sub-systems, and systems; supporting analysis; and testing, technical assessment, and characterization activities. Task areas for fuel cell system and fuel processor sub-system development for stationary power generation applications are included, as are those for early market fuel cell applications, such as portable power, and for the development of innovative concepts for fuel cell systems.

GOAL

The program's goal is to advance fuel cell technologies for transportation, stationary, and portable applications to make them competitive in the marketplace in terms of cost, durability, and performance, while ensuring maximum environmental and energy-security benefits.

OBJECTIVES[1]

The program's key objectives include:

- Develop a 60% peak-efficient, direct-hydrogen fuel cell power system for transportation, with 5,000-hour durability, that can be mass-produced at a cost of $30/kW ($40/kW by 2020).
- By 2020, develop distributed generation and micro-CHP fuel cell systems (5 kW) operating on natural gas or liquid petroleum gas that achieve 45% electrical efficiency and 60,000-hour durability at an equipment cost of $1,500/kW.
- By 2020, develop medium-scale CHP fuel cell systems (100 kW–3 MW) that achieve 50% electrical efficiency, 90% CHP efficiency, and 80,000-hour durability at a cost of $1,500/kW for operation on natural gas and $2,100/kW when configured for operation on biogas.
- By 2020, develop a fuel cell system for auxiliary power units (1–10 kW) with a specific power of 45 W/kg and a power density of 40 W/L at a cost of $1,000/kW.

FISCAL YEAR (FY) 2013 STATUS AND PROGRESS

Cost reductions and improvements in durability continue to be the key challenges facing fuel cell technologies. In addition, advances in air, thermal, and water management are necessary for improving fuel cell performance; some stationary applications would benefit from increased fuel flexibility; and, while fuel cells are approaching their targets for power density and specific power, further progress is required to achieve system packaging requirements necessary for commercialization.

[1] Note: Targets and milestones were recently revised; therefore, individual project progress reports may reference prior targets.

One of the most important metrics is the projected high-volume manufacturing cost for automotive fuel cells, which the program tracks on an annual basis. In 2013, the program introduced several changes in the cost projection assumptions, including an increase in platinum price and an added requirement that the model system must meet the heat rejection target. These changes resulted in an increase in the projected cost status to $55/kW in 2013. However, if previous year status numbers are updated to include the new assumptions and requirements made in the 2013 analysis, the 2013 cost status still represents a more than 50% decrease from the 2006 status, as depicted in Figure 1. This decrease stems in part from a reduction in platinum group metal (PGM) loading and an increase in cell power density, allowing the design of smaller and less expensive stacks.

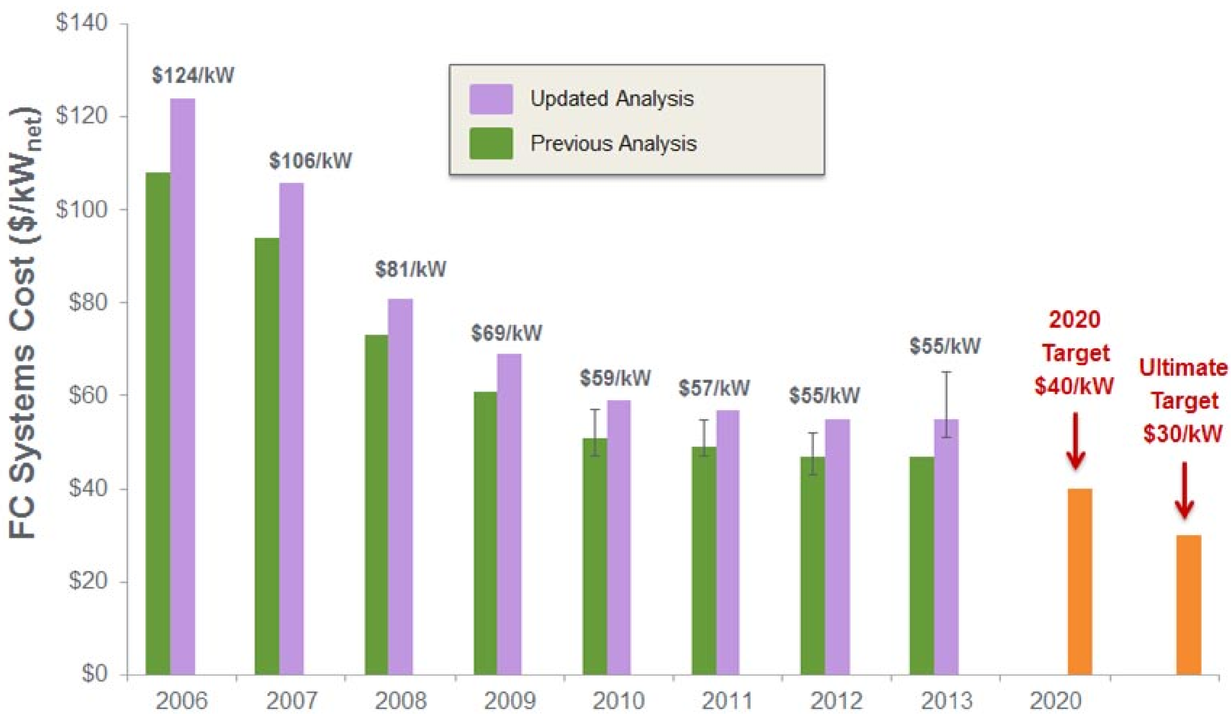

Figure 1. Modeled cost of an 80-kW automotive fuel cell system based on projection to high-volume manufacturing (500,000 units/year).[2]

To enable vehicle commercialization, the program is targeting cost reduction to $40/kW by 2020. Long-term competitiveness with alternative powertrains is expected to require further cost reduction to $30/kW, which represents the program's ultimate cost target. The $40/kW target, which represents a new target introduced in 2013, was selected with input from the U.S. DRIVE Partnership and from a Request for Information (RFI).

The program sponsors technical working groups on the topics of durability, transport modeling, and catalysis. These working groups, comprised of representatives from DOE-funded R&D projects, met in 2013 to exchange information, create synergies, share experimental and computational results, and collaboratively develop methodologies for and understanding of further R&D needs in the topical areas. Additional R&D needs examined in 2013 include the requirement for improved and standardized rotating disk electrode (RDE) testing techniques for ex situ catalyst screening. This need was addressed by issuing a RFI seeking input from the research community on proposed standards for RDE testing. Input from the RFI process will be used to issue a standard protocol and list of best practices, which will enable the RDE technique to provide more value and will make cross-laboratory comparison of RDE results possible.

[2] DOE Hydrogen and Fuel Cells Program Record #13012, http://hydrogen.energy.gov/pdfs/13012_fuel_cell_system_cost.pdf.

Catalysts

- **Developed dealloyed catalysts that meet mass activity target and show high performance in high current fuel cell testing (General Motors):** Dealloyed platinum-nickel (PtNi) and platinum-cobalt (PtCo) catalysts developed in a project led by General Motors have high oxygen reduction reaction (ORR) mass activity, 0.6 A/mg_{PGM} for PtCo and up to 0.75 A/mg_{PGM} for PtNi, exceeding the 2017 mass activity target of 0.44 A/mg_{PGM}. Both catalysts also meet the voltage cycling durability target, maintaining a mass activity greater than 0.26 A/mg_{PGM} after 30,000 voltage cycles (Figure 2). In addition to their high mass activity, both catalysts have demonstrated high performance operation at high current in membrane electrode assemblies (MEAs). At 1.5 A/cm^2, the $PtNi_3$ and $PtCo_3$ MEAs both met the 0.56 V project milestone (Figure 3).

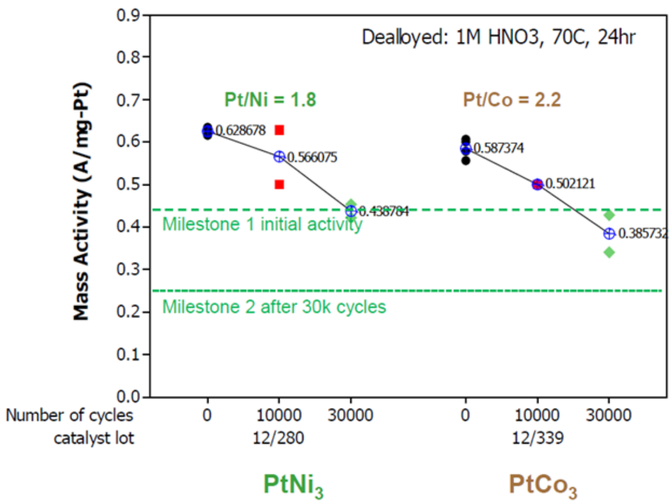

FIGURE 2. Mass activity of dealloyed PtNi and PtCo cathode catalysts measured in MEAs at beginning of life and after 10,000 and 30,000 cycles between 0.6 and 1.0 V.

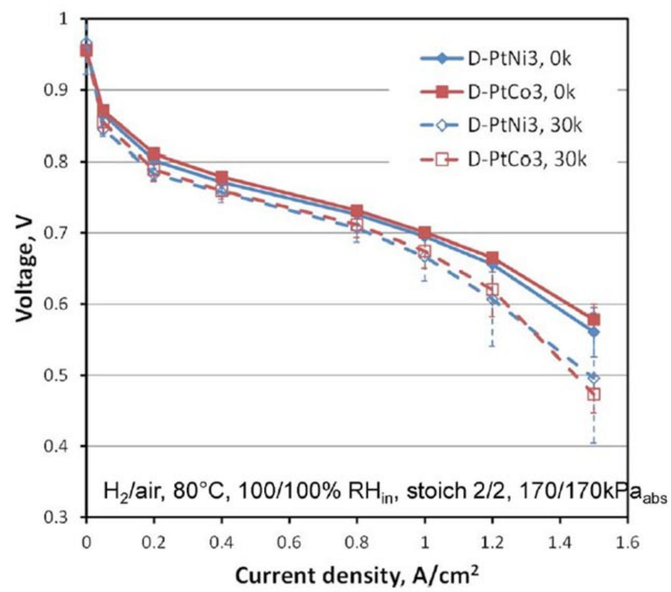

FIGURE 3. MEA performance of PtNi and PtCo dealloyed catalysts.

- **Developed meso-structured catalysts with specific activity 8X that of platinum (Argonne National Laboratory):** A new annealing process has enabled Argonne National Laboratory to modify PtNi nanostructured thin film (NSTF) catalysts to achieve greatly enhanced ORR activity. The annealing process decreases the surface roughness of the nanowhiskers and increases crystallite grain size through coalescence, producing a surface with predominantly (111) facets. Testing of the resulting meso-structured thin film (MSTF) catalysts using the RDE technique has demonstrated an 8X increase in specific activity over polycrystalline Pt, and a 2X increase over PtNi NSTF.
- **Developed scaled-up production procedure for non-precious cathode catalysts, up to 30 g batches (Northeastern University):** A project led by Northeastern University has developed multiple high-performance catalysts free of platinum group metals. MEAs containing an iron charge-transfer-salt (Fe-CTS) catalyst developed at the University of New Mexico have demonstrated current densities of over 100 mA/cm^2 at 0.8 V internal resistance-free. The catalyst experienced almost no degradation when subjected to the Nissan catalyst durability voltage cycling protocol. Scale up of the synthesis procedure by Pajarito Powders has enabled production of 30 g batches, with performance approaching that of the lab-scale produced catalyst.

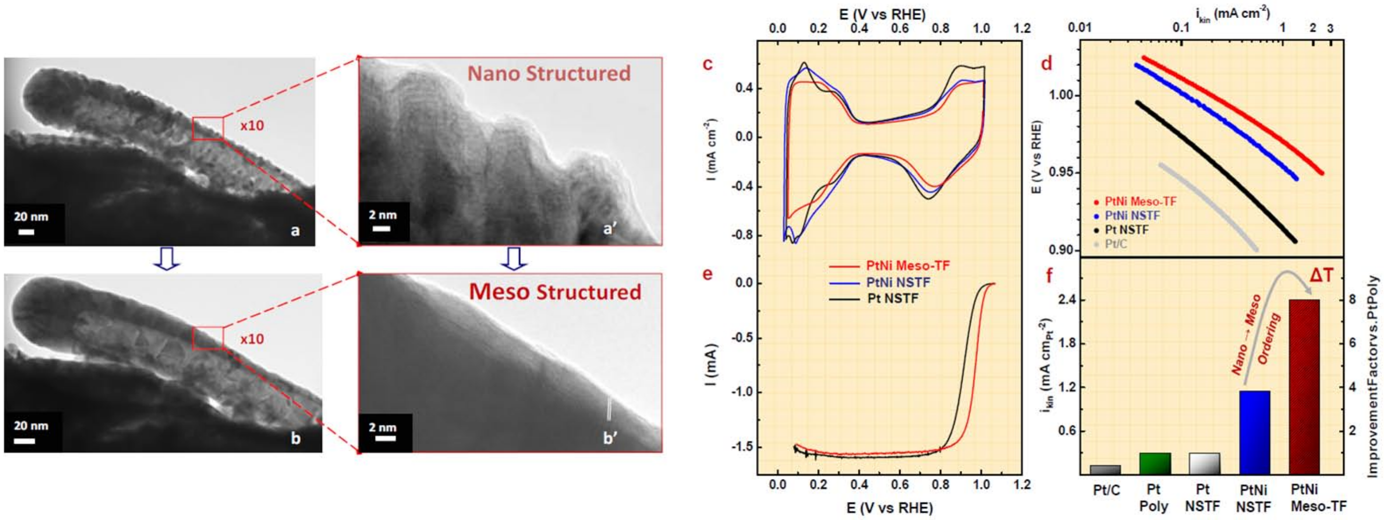

FIGURE 4. In situ transmission electron microscopy transition from nanostructured into mesostructured thin film: (a)-(b) annealing between room temperature and 400°C on a single whisker that induce the ordering from randomly oriented to a homogeneous structure with crystalline domains; cyclic voltammetry on the thin-film-based catalysts: (c) Pt-NSTF, PtNi-NSTF, and PtNi-MSTF; (e) the ORR polarization curves; (d) Tafel plots; and (f) specific activities at 0.95 V and improvement factor versus Pt-Poly (and Pt-NSTF).

Membranes

Developed low-cost fabrication methods for dimensionally-stabilized membranes (Giner, Inc.): Development of an improved fabrication procedure has enabled Giner to produce high-performance mechanically-supported membranes based on their dimensional stabilization technology. In 2013, Giner's mechanical deformation technique for support fabrication was down-selected for further development. Improvements in the release process from the micromolds enabled achievement of porosity up to 60% with stable, high-modulus polysulfone. Dimensionally stabilized membranes have already demonstrated excellent mechanical properties, but the laser-drilling technique previously used for fabrication is not suitable for low-cost manufacturing. Current low-volume production cost of the membrane supports using the new mechanical deformation technique is \$50-100/m^2. The technique is compatible with roll-to-roll processing methods, and is projected to be capable of approaching \$10/m^2 at high volume, which would enable achievement of the program's target of \$20/m^2 for complete membrane production (support plus ionomer) at high volume.

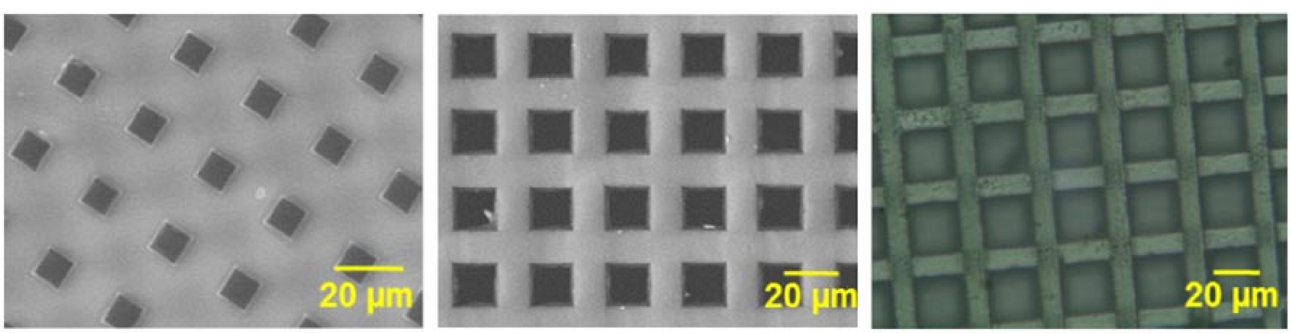

FIGURE 5. Progress in membrane supports generated by mechanical deformation—left: 11-µm pores, 15% porosity; center: 16-µm pores, 33% porosity; right: 22-µm pores, 62% porosity.

MEA Integration

Achieved PGM total content of 0.17 g/kW while meeting heat rejection target (3M Company): Improvements in MEAs containing PtNi NSTF catalysts have enabled performance improvement at high current densities, resulting in PGM total content levels as low as 0.17 g/kW at 150 kPa_{abs} (Figure 6). While the program has demonstrated similar PGM total content levels in previous year, this year's results mark a major improvement since they were achieved for the first time at a high operating temperature of 90°C and voltage of 0.69 V, conditions that satisfy the DOE heat rejection target, $Q/\Delta T \leq 1.45$. When compared to PGM total content measured at 0.69 V in 2012, this year's results mark a 20% improvement. Further development is required to achieve DOE's target level of 0.125 g/kW, and to simultaneously meet durability targets.

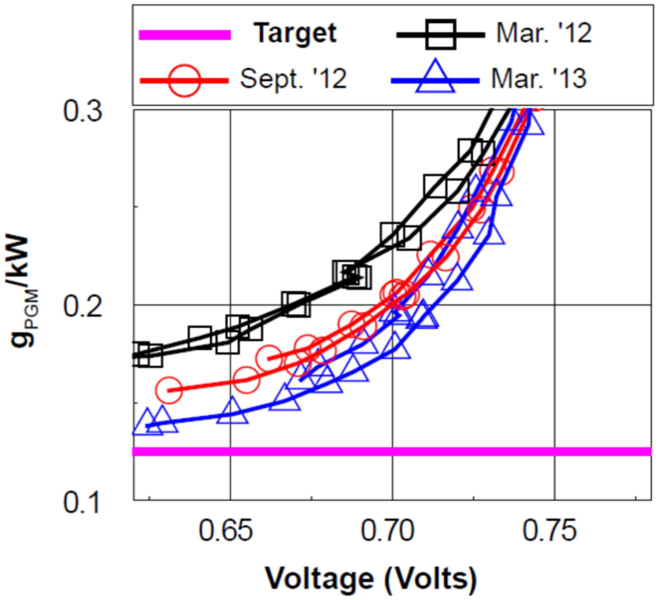

FIGURE 6. PGM total content of MEAs containing NSTF catalysts.

BUDGET

The President's FY 2014 budget request calls for approximately $37.5 million for the Fuel Cells program. Figure 7 shows the budget breakdown by R&D area for the FY 2013 congressional appropriation of $42.4 million and the FY 2014 budget request. The program continues to focus on reducing costs and improving durability with an emphasis on fuel cell stack components. In the budget breakdown, the systems and BOP categories include projects related to portable and stationary power. New projects were awarded in FY 2013 for non-precious catalysts, membranes, and MEA integration. Funding Opportunity Announcement (FOA) funds allocated in FY 2014 will be spent on expected alternate awards from the previous R&D solicitation. The Fuel Cells program does not plan to have a FOA issued for awards funded in FY 2014.

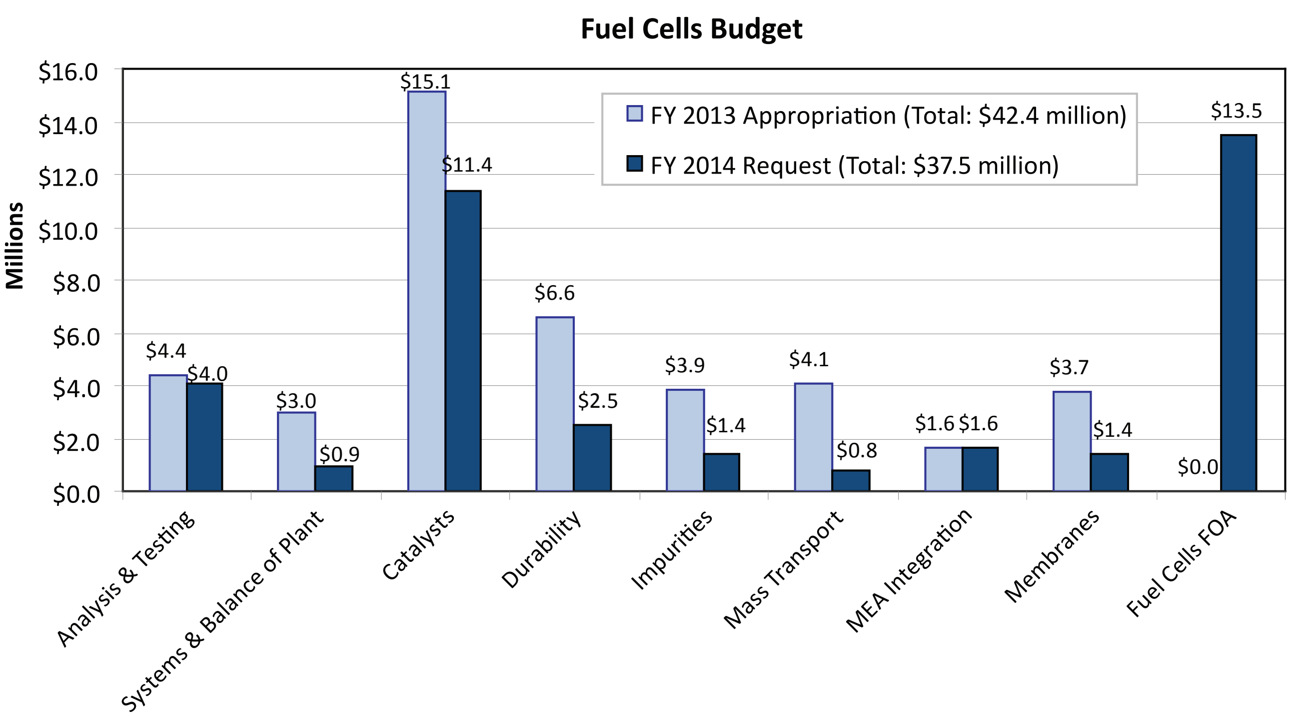

FIGURE 7. Fuel Cells program budgets in 2013 and 2014. FOA funds allocated in FY 2014 will be spent on expected alternate awards from previous R&D solicitation.

FY 2014 PLANS

In FY 2014, the Fuel Cells program will continue R&D efforts on fuel cells and fuel cell systems for diverse applications, using a variety of technologies (including PEM, solid oxide, and alkaline membrane fuel cells) and a range of fuels (including hydrogen, natural gas, and bio-derived renewable fuels). A workshop in February will provide a forum to exchange information and discuss R&D needs to reduce the cost and complexity of removing impurities from natural gas, LPG, biogas, associated petroleum gas, diesel, and biodiesel for fuel cell applications. Support will continue for R&D that addresses critical issues with electrolytes, catalysts, electrodes, and modes of operation, with an emphasis on durability improvement. The program will also continue its emphasis on science and engineering with a focus on component integration at the cell and stack level, as well as on integration and component interactions at the system level. Emphasis will continue to be placed on BOP component R&D, such as air compressors that can lead to lower cost and lower parasitic losses. Ongoing support of modeling will guide component R&D, benchmarking complete systems before they are built and enabling exploration of alternate system components and configurations. Cost analysis efforts have been expanded beyond transportation applications to also include distributed power generation systems (including CHP) and systems for emerging markets for a variety of fuel cell technologies; further detailed results of these analyses are expected in FY 2014. Updates to target values will be released in a revision of the *Multi-Year Research, Development and Demonstration Plan*, which is scheduled for release in FY 2014.

Dr. Dimitrios Papageorgopoulos
Fuel Cells Team Lead
Fuel Cell Technologies Office
U.S. Department of Energy
1000 Independence Ave., SW
Washington, D.C. 20585-0121
Phone: (202) 586-5463
Email: Dimitrios.Papageorgopoulos@ee.doe.gov