V.1 Fuel Cells Sub-Program Overview

Introduction

The Fuel Cells Sub-Program supports research and development of polymer electrolyte membrane fuel cells (PEMFCs) including fuel cell stack components, fuel processors for stationary applications, and balance-of-plant components. Transportation applications (direct hydrogen fuel cells for vehicles) are the primary focus of the sub-program since substituting domestically produced hydrogen for petroleum-based fuel in light-duty vehicles will significantly reduce dependence on foreign oil, diversify energy resources, and reduce pollution and greenhouse gas emissions. PEMFCs are currently the technology of choice for light-duty vehicles because they have fast start capability and operate at low temperatures. The sub-program has also supported small-scale stationary power, portable power (direct methanol fuel cells) and auxiliary power unit applications (solid oxide fuel cells) in the past. Appropriations shortfall and congressionally directed activities delayed progress on these activities in FY 2006. In some applications, stationary, portable and auxiliary applications have a higher price and shorter lifetime threshold for market entry than transportation applications. When fuel cells start to enter these markets, there will be learning that leads to system simplification, consumer awareness and education, and the development of a manufacturing base.

In FY 2006, significant advances were made in the following areas: low- and non-platinum catalysts, membranes, electrodes, membrane electrode assemblies (MEAs), recycling/remanufacturing of MEAs, and analysis of water transport and freeze effects. Funding limitations in FY 2006 forced sharp cutbacks or suspension of research on stationary fuel cells, fuel processing, portable power, auxiliary power units, and balance-of-plant components. Funding to continue these research efforts is included in the FY 2007 budget request. Research projects on chemical and physical hydrogen sensors were completed in 2006, and there are no plans to continue DOE research in this area. The sub-program awarded 12 new projects aimed at increasing the durability and shelf life of polymer electrolyte-type membranes while simultaneously bringing down cost. The projects will seek to extend the operating range of these membrane materials to higher temperatures (120°C peak) and lower relative humidity (<10% relative humidity at 80°C). Project selections from a broader solicitation issued in FY 2006 should result in new awards in early FY 2007. This solicitation could provide up to $100 million over four years for fuel cell R&D in the following topic areas: improved fuel cell membranes, water transport within the stack, advanced cathode catalysts and supports, cell hardware, innovative fuel cell concepts, effects of impurities on fuel cell performance and durability, and stationary fuel cell demonstrations involving international and intergovernmental partnerships.

Goal

Develop and demonstrate fuel cell power system technologies for transportation, stationary and portable applications.

Objectives

The primary focus is on fuel cells for transportation applications, with the following objectives:

- By 2010, develop a 60% peak-efficient, durable, direct hydrogen fuel cell power system for transportation at a cost of $45/kW; by 2015, a cost of $30/kW.

The secondary focus is on stationary power and other early market fuel cell applications to establish the manufacturing base, with the following objectives:

- By 2011, develop a distributed generation PEM fuel cell system operating on natural gas or liquefied petroleum gas that achieves 40% electrical efficiency and 40,000 hours durability at $400-$750/kW.[1]

[1] Milestone delayed from 2010 to 2011 due to appropriations shortfall and Congressionally directed activities

- By 2010, develop a fuel cell system for consumer electronics (<50 W) with an energy density of 1,000 Wh/L.
- By 2010, develop a fuel cell system for auxiliary power units (3-30 kW) with a specific power of 100 W/kg and a power density of 100 W/L.

FY 2006 Technology Status

The sub-program continues to focus on materials, components, and enabling technologies that will contribute to the development of low-cost, reliable fuel cell systems. Cost and durability are the major challenges for fuel cell systems. Air, thermal, and water management for fuel cells are also key issues. Size and weight are approaching targets, but further reductions are needed to meet packaging requirements for commercial systems. The current sub-program organization reflects the focus on component-level R&D directed at critical technology barriers. Twelve new R&D projects were initiated in FY 2006 to focus on developing high-temperature, low relative humidity membrane materials suitable for use in PEM-type fuel cells. Efforts to evaluate, understand and mitigate failure mechanisms are also receiving increased emphasis through research at the national laboratories, the National Institutes of Standards and Technology, and fuel cell developers. These efforts are being enhanced by the use of advanced imaging techniques for in situ and post-mortem analysis of fuel cell stacks and MEAs. The Technology Validation sub-program (see Section VI) will provide fuel cell vehicle and stationary power data under real-world conditions and, in turn, supply valuable results to help refine and direct future activities for fuel cell R&D.

The Multi-Year Research, Development and Demonstration Plan was updated in August 2006. The task activities have been reorganized around components (membranes, electrodes, membrane electrode assemblies, gas diffusion layers, bipolar plates, seals, and balance of plant components), supporting analysis, and benchmarking and characterization activities. Task areas are also included for stationary and other early market fuel cells (portable power and auxiliary power units) and for development of innovative concepts for fuel cell systems.

Targets, which vary by application, have been established for fuel cell cost, efficiency, durability, power density, specific power, transient response time, start-up time, and emissions, among others. Key performance indicators include *cost* for transportation fuel cells R&D and *electrical efficiency* for stationary fuel cells R&D. For transportation applications, the 2005 cost target has been met. The 2005 cost of a hydrogen-fueled 80-kW fuel cell power system is $110/kW, compared to the 2005 target set at $125/kW. For stationary systems, the 2005 target of 32% electrical efficiency at full power was met.

FY 2006 Accomplishments

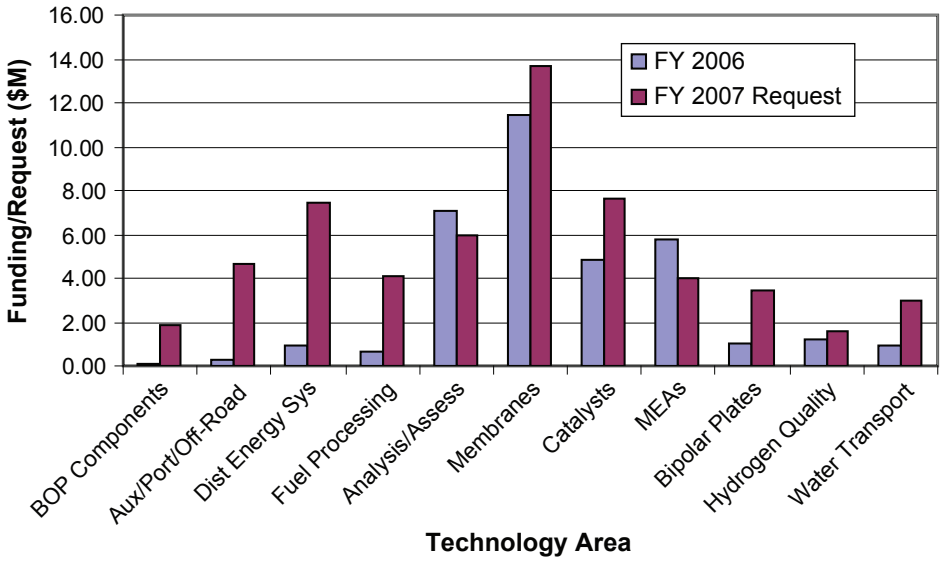
- Demonstrated 5,000 hrs durability with 4,000 hrs accelerated cyclic durability and 1,000 hrs accelerated constant load durability on a 20-cell rainbow stack incorporating a reinforced membrane developed by DuPont and a UTC peroxide mitigation strategy (UTC/DuPont).
- Achieved state-of-the-art Pt-alloy mass activities (0.26 A/mg_{Pt}) in durable MEAs made with an innovative catalyst structure: a continuous platinum (Pt) film deposited over a nanostructured thin film of crystalline, organic whiskers. Also demonstrated a pathway towards 20,000-hr MEA lifetime under accelerated near open-cycle-voltage load cycle test conditions using an improved Nafion®-based ionomer (3M).
- Fuel cell researchers and developers are using the NIST Neutron Imaging Facility to study water transport at varying temperatures and humidity conditions in real time. Polarization curves and water content images can be obtained simultaneously (NIST).
- Developed sample preparation, imaging, and compositional analysis techniques utilizing transmission electron microscopy, to elucidate the complex nano-scale structure of PEM fuel

cell catalyst layers. High-resolution imaging and microanalysis of cross-sectional, intact MEAs allows for differentiation between the materials comprising the catalyst layers and is being used to correlate microstructure with performance and identify MEA degradation mechanisms (ORNL).

- Developed mixed-metal Pt monolayer electrocatalysts that demonstrate a 4x improvement in Pt kinetic activity and mass activity in a fuel cell consistent with a loading of less than 0.2 mg Pt/kW; use of gold overlayers in the catalysts shows promise for reducing potential cycling damage (BNL).

Budget

The President's 2007 Budget Request (subject to Congressional appropriation) emphasizes R&D on fuel cell stack components (membranes, MEAs, bipolar plates, and advanced catalysts) while also supporting R&D for distributed stationary power generation and fuel processing; portable, auxiliary, and off-road power applications; balance-of-plant (BOP) components; and analysis. As recommended by the 2004 National Research Council report, the Fuel Cell Sub-Program continues to increase government funding for high-risk R&D that can lead to breakthroughs in fuel cell materials and component designs that lower costs, improve durability and increase reliability. The graph below shows the budget breakdown by major sub-program areas for the 2006 Congressional appropriation and the 2007 budget request.



2007 Plans

Cost and durability of stack components, i.e., membranes, catalysts, bipolar plates, membrane electrode assemblies, etc., will continue to be a key focus of the Fuel Cell Sub-Program in FY 2007. Characterization, evaluation, and analysis to provide insights into fuel cell operation, especially characterization of behavior that leads to performance decay and failure, will be emphasized. Selections from the major fuel cell solicitation will be made with plans to initiate the projects in FY 2007, depending on appropriations.

Valri Lightner
Fuel Cell Team Lead
Department of Energy
Hydrogen, Fuel Cells & Infrastructure Technologies, EE-2H 1000
Independence Ave., SW, Washington, D.C. 20585-0121
Office: (202) 586-0937
Valri.Lightner@ee.doe.gov