V.0 Fuel Cells Sub-Program Overview

INTRODUCTION

The Fuel Cells sub-program supports research, development, and demonstration of fuel cell technologies for a variety of stationary, transportation, 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 sub-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 sub-program's portfolio of projects covers a broad range of technologies, including polymer electrolyte membrane fuel cells, direct methanol fuel cells, alkaline fuel cells, and solid oxide fuel cells.

The Fuel Cells sub-program's tasks in the *Fuel Cell Technologies Program 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 sub-program's goal is to advance fuel cell technologies for transportation, portable, and stationary 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 sub-program's key objectives include:

- By 2015, develop a fuel cell system for portable power (<250 W) with an energy density of 900 Wh/L.
- By 2017, 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.
- By 2020, develop distributed generation and micro-CHP fuel cell systems (5 kW) operating on natural gas or liquefied 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.

[1] Note: Targets and milestones were recently revised; therefore, individual project progress reports may reference prior targets. Some targets are still currently under revision, with updates to be published in Fiscal Year 2013.

FISCAL YEAR (FY) 2012 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.

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. The 2012 estimate of this cost is $47/kW, which represents a 36% decrease since 2008 and an 83% decrease since 2002, as depicted in Figure 1. The 36% decrease in projected cost since 2008 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. The 2012 cost analysis estimated the cost of the fuel cell stack to be $20/kW. BOP cost has also been reduced during this time. Major sources of the reduction in BOP cost include modification of the ejector system based on stakeholder input, improved design of the system controller, and reduction of the radiator size. The reduced radiator size was enabled by improvements in stack components, allowing a higher stack operating temperature.

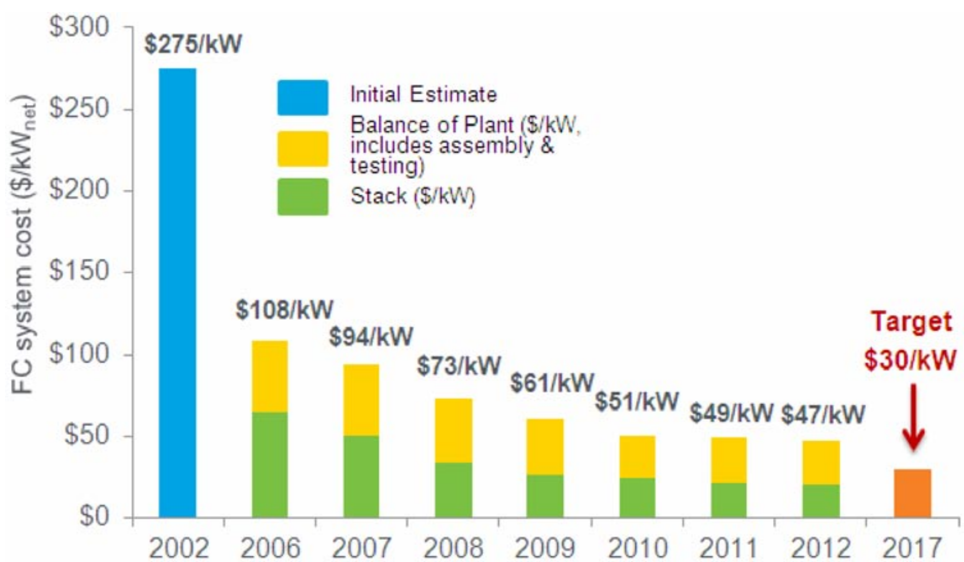


FIGURE 1. Current modeled cost of an 80-kW automotive fuel cell system based on projection to high-volume manufacturing (500,000 units/year)[2]

High durability is also a requirement for commercial fuel cell systems. Average durability (time to 10% voltage degradation) of fuel cell stacks and systems in laboratory testing was 4,000 hours as of April 2012, which represents a doubling in durability since 2006.[3] These durability improvements are all the more impressive given the reduction in PGM loading over the years, with typical PGM content decreasing from 0.6 g/kW in 2007 to <0.18 g/kW in 2012.

[2] DOE Hydrogen and Fuel Cells Program Record #12020, http://hydrogen.energy.gov/pdfs/12020_fuel_cell_system_cost_2012.pdf.
[3] DOE Hydrogen and Fuel Cells Program Record #11003, http://hydrogen.energy.gov/pdfs/11003_fuel_cell_stack_durability.pdf.

Catalysts

Developed dealloyed catalysts that meet mass activity target and show high performance in high current fuel cell testing (General Motors): Dealloyed PtNi and PtCo catalysts developed in a project led by General Motors have high mass activity, 0.46 A/mg_{PGM} for PtCo and 0.52 A/mg_{PGM} for PtNi, exceeding the 2017 mass activity target of 0.44 A/mg_{PGM}. The PtCo catalyst also meets durability targets, with only a 28% loss in mass activity during 30,000 voltage cycles (target <40%). To date, the PtNi dealloyed catalyst does not meet the durability target, but based on analysis of the chemical properties of Co and Ni, GM anticipates that PtNi catalysts with durability similar to that of PtCo will be developed. In addition to their high mass activity, the General Motors dealloyed PtNi catalyst has demonstrated high performance operation in membrane electrode assemblies (MEAs), with performance of a dealloyed $PtNi_3$ cathode at 0.1 mg_{PGM}/cm^2 matching that of a conventional 0.4 mg_{PGM}/cm^2 Pt/C cathode at testing up to 1.5 A/cm^2 (Figure 2). At 1.5 A/cm^2, the $PtNi_3$ cell yielded up to 0.63 V, exceeding the 0.56 V project milestone.

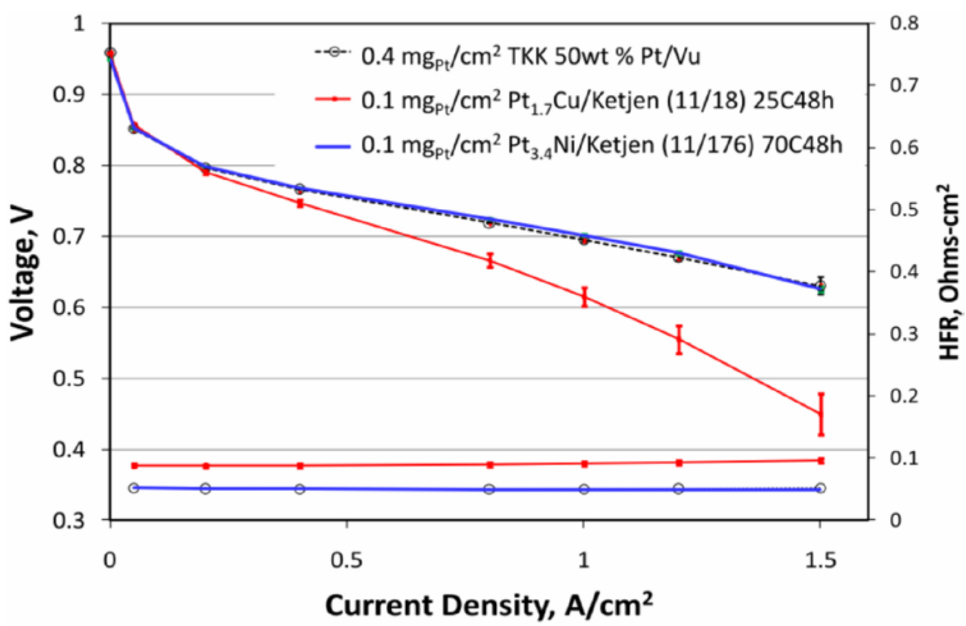


FIGURE 2. MEA performance of PtNi dealloyed catalyst

Reduced PGM total content to 0.14-0.18 g/kW (3M): Improvements in PtNi nanostructured thin film (NSTF) catalysts have enabled performance improvement at high current densities, resulting in PGM total content levels as low as 0.14–0.18 g/kW, depending on operating pressure, at an areal loading of 0.15 mg/cm^2 in MEA testing (Figure 3). This result represents a 15% reduction in PGM total content when compared to the previous generation PtCoMn NSTF catalyst. The operating voltage and temperature at which these results were obtained (approximately 0.6 V and 80ºC, respectively) still need to be increased to enable achievement of the MEA heat rejection requirement. Further development is also required to achieve the 2017 target level of 0.125 g/kW.

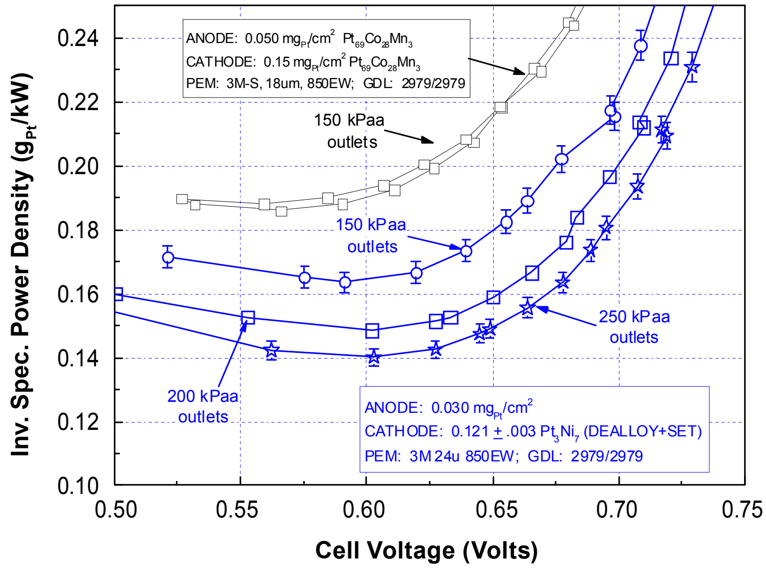
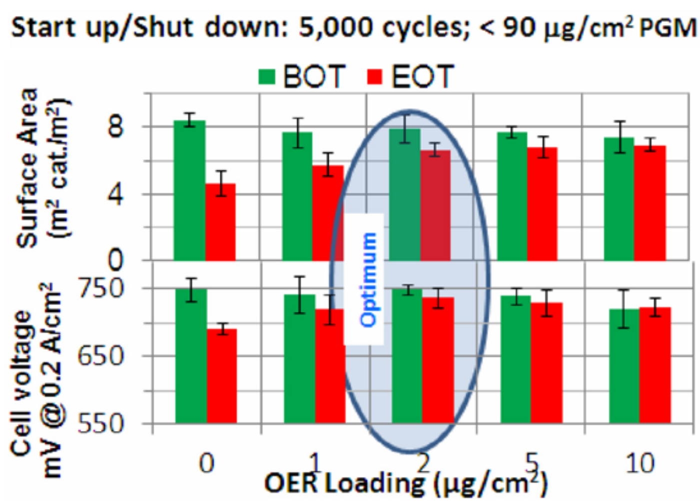


FIGURE 3. PGM total content of NSTF catalysts

Durability

Modified anode and cathode catalysts meet performance milestones with total PGM loading <0.135 mg/cm^2 (3M): Modified NSTF catalysts that include a highly active and durable oxygen evolution catalyst, based on Ru and Ir, are under development at 3M for deposition on both the anode and the cathode. By enhancing oxygen evolution capability, these catalysts suppress excursions to high voltage, and thus mitigate corrosion of catalysts and supports that otherwise may occur under startup, shutdown, and fuel starvation conditions. In 2012, these modified catalysts met all performance milestones with a total PGM loading of 0.135 mg/cm^2, including demonstration of 5,000 startup/shutdown cycles with a maximum cathode voltage of 1.48 V (target: <1.6 V), 200 cell reversals with a maximum anode voltage of 1.65 V (target: <1.8 V), and a tenfold suppression of the anode oxygen reduction reaction activity in the kinetic region (Figure 4).

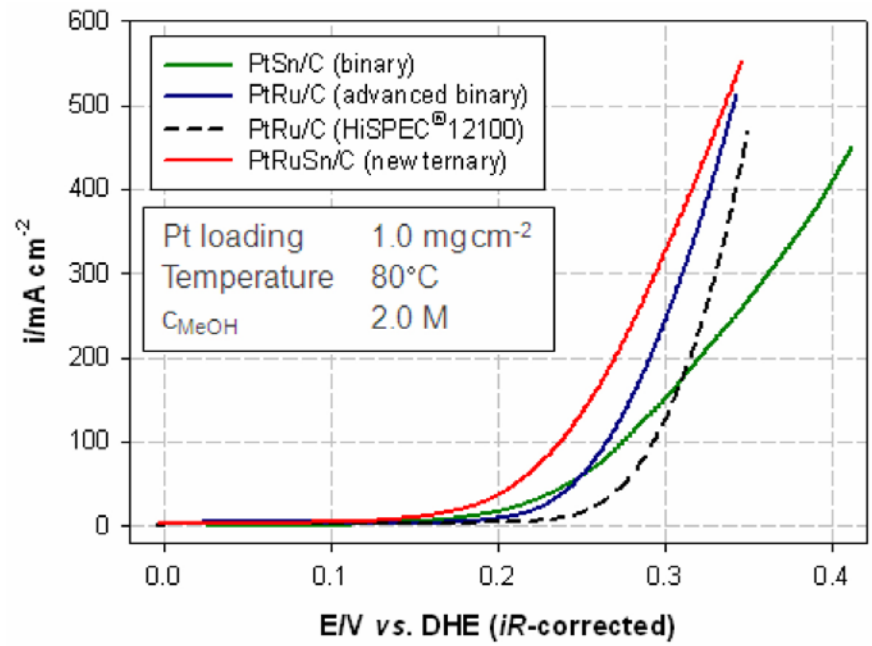


BOT – beginning of test; EOT – end of test; OER – oxygen evolution reaction

FIGURE 4. Effect of cathode oxygen evolution catalyst loading on durability during startup/shutdown

Portable Power

Improved direct dimethyl ether fuel cell performance by 60% (Los Alamos National Laboratory [LANL]): Direct dimethyl ether (DME) fuel cells developed by LANL have demonstrated a 60% increase in power density at 0.5 V since 2011, with performance rivaling that of direct methanol fuel cells (DMFCs) at low current. Direct DME fuel cells benefit from low fuel crossover, eliminating one of the major sources of loss present in DMFCs. The improved DME performance in 2012 is due in part to a new ternary PtRuPd anode catalyst, which outperforms earlier PtRu catalysts in MEA as well as half-cell testing. Progress was also made in DMFC development (Johnson Matthey Fuel Cells), with a new PtRuSn catalyst that combines the low-current performance of PtSn with the high-current performance of PtRu (Figure 5). DMFCs based on the new anode catalyst have demonstrated mass activity of 500 mA/mg_{Pt} at 0.35 V, 150% higher than the FY 2012 milestone.



DHE – dynamic hydrogen electrode

FIGURE 5. A new ternary methanol oxidation catalyst outperforms conventional binary catalysts

Balance of Plant

New humidifier projected to meet $100 cost target (Gore): A humidifier containing a novel composite membrane developed by Gore and an integrated module developed by DPoint is projected to meet the $100 cost target when manufactured at high volume. The module uses a membrane pocket over plate assembly concept, in which the membrane contains a very thin, highly permeable ionomer sandwiched between two microporous polymer supports. Further work is required to improve durability, with current modules showing a 20-30% drop in water transfer rate during 5,500 hours of testing (target: <10% drop over 5,000 hours).

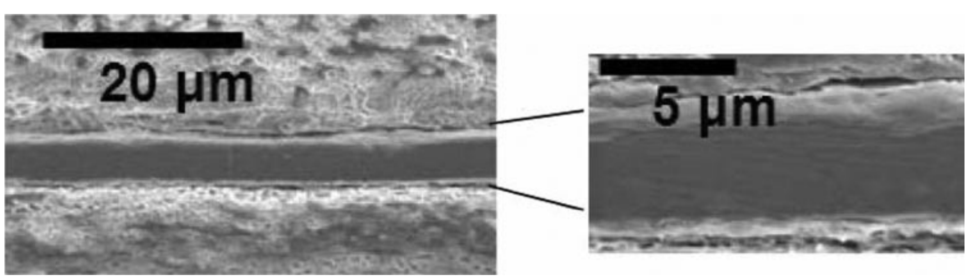
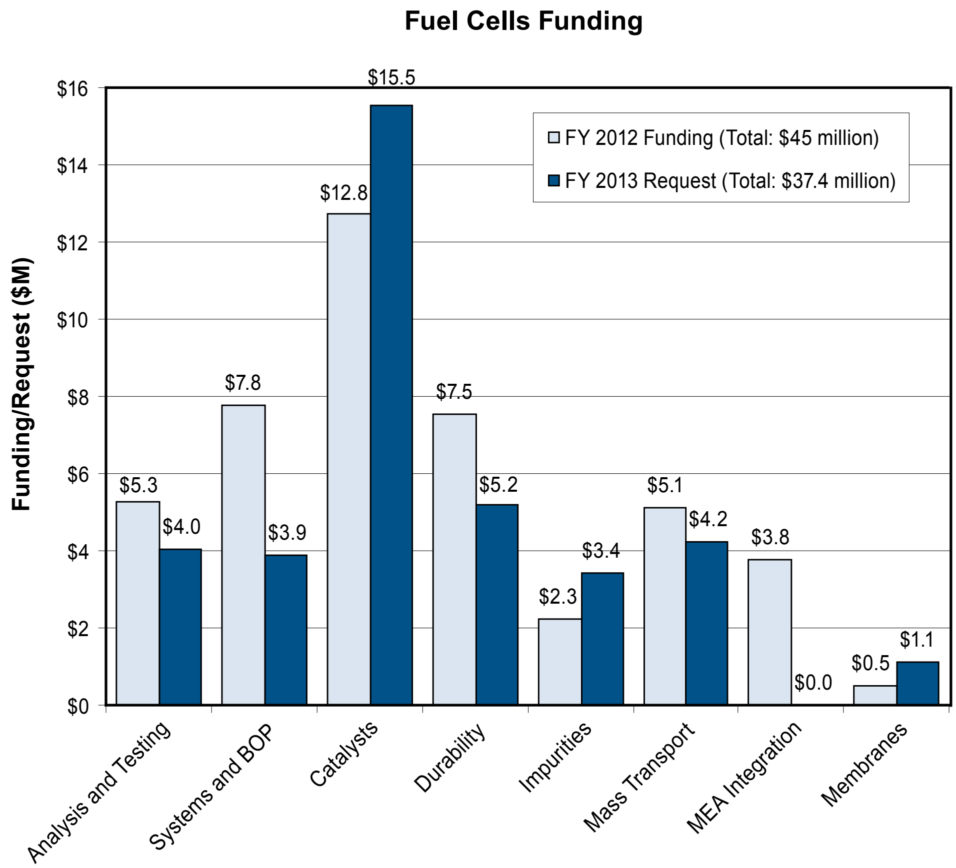


FIGURE 6. The Gore humidifier membrane contains a dense ionomer layer sandwiched between two microporous layers.

BUDGET

The President's FY 2013 budget request calls for approximately $38 million for the Fuel Cell sub-program. The figure below shows the budget breakdown by R&D area for the FY 2012 congressional appropriation of $44 million and the FY 2013 budget request. The sub-program continues to focus on reducing costs and improving durability with an emphasis on fuel cell stack components. In the budget breakdown, Systems and BOP includes projects related to portable and stationary power. New projects were awarded in FY 2012 for BOP and MEA integration. In accordance with reprogramming requirements included in the 2012 House and Senate Appropriation, new projects in FY 2012 were fully funded.



FY 2013 PLANS

In FY 2013, the Fuel Cells sub-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 fuel cells) and a range of fuels (including hydrogen, diesel, natural gas, and bio-derived renewable fuels). Support will continue for R&D that addresses critical issues with electrolytes, catalysts, electrodes, and modes of operation. The sub-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 2013.

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