

Fuel Cell Catalyst is a quarterly newsletter linking government and industry fuel cell activities.

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### 2004 Year in Review:

The past year saw more advances in fuel cell technology, in both the R&D and policy arenas.

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## 2004 Fuel Cell News Highlights

**2**004 was a year of steady technical, policy, and market progress in the fuel cell community. The biggest news items of 2004 were related to markets and policy initiatives.

### STATIONARY & BACKUP POWER APPLICATIONS

Market success in 2004 includes the introduction of products for the Japanese residential co-generation market. Major companies such as Tokyo Gas with Ebara-Ballard and Shin-Nihon-Sekiyu (New Japan Petroleum) introduced products in 2004.

Back-up power and stationary power markets also emerged in 2004. Back-up power applications – which include fuel cell use in un-interruptible power supply (UPS) systems – became a fertile market for the hydrogen-fueled PEM fuel cells of companies such as Plug Power, Ballard, and ReliOn. Plug Power reported significant sales of its GenCore product (a 5-kW PEMFC system), and Ballard Power Systems and ReliOn each introduced 1-kW PEMFC products.

The commercial stationary power fuel cell market was also significantly advanced in 2004, primarily due to the significant sales of FuelCell Energy's Direct FuelCell® products. In 2004, FuelCell Energy (FCE) had 42 systems either sold or installed. These installations primarily comprise the 250-kW DFC 300® molten carbonate fuel cell product in applications that include wastewater treatment, industrial, university, and utility grid support. Significantly, the installation and operation of the world's largest fuel cell is being demonstrated by FCE in a 1.0-MW plant operating on digester gas in King County, Washington.

### TRANSPORTATION APPLICATIONS

The past year also brought significant automotive sector fuel cell news. The Clean Urban Transport for Europe (CUTE) project of the European Union successfully tested fuel cell buses in nine European cities covering a distance of more than 40,000 km in 2004. Fuel cell concept cars were manufactured and tested by nearly every major automobile manufacturer. And several manufacturers have announced the significant technical advance of successful cold-weather start-up and operation of PEM fuel cells.

### INFRASTRUCTURE

The most significant transportation infrastructure story in 2004 was the policy initiative introduced by California Governor Arnold Schwarzenegger. On April 20, Governor Schwarzenegger announced plans for the California Hydrogen Highway Network, initiating a huge volunteer effort to establish a plan for the introduction of hydrogen fueling infrastructure throughout California. The plan was developed with high level support from nearly every automobile, energy, and infrastructure company, many universities, regulatory and policy organizations, and non-governmental organizations.

Certainly much more occurred in 2004, but the policy initiative of the California Hydrogen Highway and the significant market introduction of stationary and back-up fuel cell products in the U.S. and residential fuel cells in Japan deserve special mention.

JACOB BROUWER, PH.D., ASSOCIATE DIRECTOR,  
NATIONAL FUEL CELL RESEARCH CENTER

“The biggest news items of 2004 were related to markets and policy initiatives.”

## 2004 Fuel Cell Activities in the States

In 2004, state governments continued to explore ways in which they can participate in and take advantage of the coming hydrogen economy.

Political leaders continue to see the wisdom of investing in technology that will bring jobs as well as clean and efficient power generation.

### Demonstration Program

California led state-wide initiatives in both size and scope of fuel cell related programs when Governor Schwarzenegger unveiled his plan to create the California Hydrogen Highways Network, a public/private partnership designed to create a hydrogen infrastructure by 2010.

### Legislative Initiatives

Renewable Portfolio Standards (RPS) topped the list of state-level initiatives in 2004. A typical RPS sets a benchmark for energy producers to generate a stated level of power from renewable fuels or highly efficient power generating methods by a given date.

Colorado voters passed an initiative requiring power generators to increase renewable energy power generation by 10 percent by the year 2015. The initiative included fuel cells as an eligible renewable technology.

Pennsylvania and New York also led favorable fuel cell efforts. New York set out to add 3,700 megawatts of renewable resource generation capacity to meet a target of 25 percent power generation from renewables by 2013. Pennsylvania's RPS mandates that, by 2020, 18 percent of all of the energy generated in the Commonwealth be from specified resources and technologies. Fuel cells are included among the eligible technologies in both Pennsylvania's and New York's Renewable Portfolio Standard.

Currently, 18 states and the District of Columbia have an RPS, with a handful of them categorizing fuel cells as renewable resources.

In 2005, the US Fuel Cell Council will continue to track and weigh in on federal and state initiatives designed to advance the commercialization of fuel cell technology.

BUD DEFLAVIIS, DIRECTOR OF GOVERNMENT AFFAIRS, US FUEL CELL COUNCIL

# Review of DOE's Hydrogen, Fuel Cells & Infrastructure Technologies Program

The Hydrogen, Fuel Cells & Infrastructure Technologies Program of the U.S. Department of Energy (DOE) expanded significantly in 2004. Following are highlights of programmatic and technical accomplishments in the Program for 2004.

### PROGRAMMATIC HIGHLIGHTS

- ◆ *Awards:* Awarded more than \$425 million (\$675 million with private cost share) in new projects in 2004. The investment will advance hydrogen production and delivery technologies, support hydrogen storage "Centers of Excellence" and materials development projects, demonstrate vehicle and infrastructure technologies under real-world conditions, and reduce cost and improve durability of fuel cells for consumer electronics and other applications.
- ◆ *Planning:* Released a new Research, Development and Demonstration Plan that addresses recommendations made by the National Research Council and reflects technological progress. The Program's enhanced systems analysis and system integration capabilities are detailed in this new Plan.
- ◆ *Hydrogen Production:* Sponsored 4 workshops in 2004 in the areas of hydrogen separation and purification, water electrolysis by utilities, renewable electrolysis, and hydrogen production via direct fermentation.
- ◆ *Codes & Standards:* Sponsored a workshop to understand and organize fuel purity codes & standards efforts.
- ◆ *Systems Analysis:* Sponsored the Systems Analysis Workshop to identify and better coordinate systems analysis efforts.
- ◆ *Fuel Cells:* An independent review panel conducted a technical evaluation of the status, progress, and potential of on-board fuel processing technology. Based on the recommendations of this panel, on-board fuel processing research was discontinued.

### TECHNICAL ACCOMPLISHMENTS

- ◆ Reduced the high-volume cost of automotive fuel cells from \$275/kW (2002) to \$200/kW (2004) using innovative processes developed by national labs and fuel cell developers for depositing platinum catalyst.
- ◆ Reduced the cost of natural gas-based hydrogen production from \$5.00 per gallon gasoline equivalent (gge) in 2003 to \$3.60 per gge using innovative reforming and purification technologies. This cost includes co-production of electricity.
- ◆ Developed a pressure swing adsorption (PSA) system, delivering 99.999% pure hydrogen from a steam methane reformer that achieved a 2 to 4 times cost reduction compared with commercially available units.
- ◆ Exceeded the 2005 target for photobiological hydrogen production by increasing the light utilization efficiency of absorbed sunlight energy to 15%.
- ◆ Identified numerous opportunities for improving membrane and MEA durability to achieve the 2005 target of 5,000 hours.
- ◆ Documented a 5-fold gain in specific activity of nanostructured thin film catalysts over Pt/C and demonstrated membranes with 2 to 5 times higher conductivity than Nafion®;
- ◆ Achieved the 2005 target for platinum loading in an electrocatalyst.

The 2004 Annual Progress Report of the DOE Hydrogen Program is available online at <http://www.eere.doe.gov/hydrogenandfuelcells>.

NANCY GARLAND, PH.D., TECHNOLOGY DEVELOPMENT MANAGER  
HYDROGEN, FUEL CELLS & INFRASTRUCTURE TECHNOLOGIES, U.S. DEPARTMENT OF ENERGY, AND  
MELISSA LOTT, ADVANCED AUTOMOTIVE TECHNOLOGY ANALYST, QSS GROUP, INC.

(Opposite, far right top) Plug Power fuel cell unit at Robins Air Force Base, located in Georgia. The unit, which uses natural gas, is located at a Fire Station and has cogeneration capability to supplement the domestic water heater.

The National Energy Technology Laboratory, in partnership with private industries, is leading the development and demonstration of high efficiency solid oxide fuel cells (SOFCs) and fuel cell turbine hybrid power generation systems for distributed generation (DG) markets. The U.S. Department of Energy Office of Fossil Energy DG Fuel Cell Program has three major aspects: the Solid State Energy Conversion Alliance (SECA), Fuel Cell Coal-Based Systems and the High Temperature Electrochemistry Center.

SECA, the main thrust of the DG Fuel Cell Program, is designed to move fuel cells out of limited niche markets into widespread market applications by making them available at a cost of \$400/kW or less through the mass customization of common SOFC modules by the year 2010. SECA fuel cells will operate on fuels such as natural gas, diesel, coal gas and hydrogen.

## INDUSTRIAL TEAM PROGRESS

SECA has six industrial teams working on designs and manufacturing that can be mass-produced at costs that are ten-fold less than current costs. Overall, the SECA Program is progressing extremely well leading up to Phase I prototype testing starting in FY 2005. All of the industry teams made exceptional progress in FY2004 by completing conceptual designs and testing stack configurations showing increased power densities and fuel utilization, control system reference designs, and reformers that demonstrate sustained output and thermal cyclic capability.

- ◆ In May 2004, Acumentrics field tested a propane-fueled unit that includes advancements developed under SECA.
- ◆ SiemensWestinghouse advances led to a thinner, more conductive electrolyte layer that could reduce temperature while increasing power for increased lifetime and reduced cost. The team has achieved more than 0.3W/cm<sup>2</sup> with its HPD designs, almost a doubling of power density over tubular designs.
- ◆ General Electric achieved a power density of more than 0.4 W/cm<sup>2</sup> at 0.7V, while maintaining a fuel utilization of 88 percent. This is more than 0.1W/cm<sup>2</sup> above Phase I requirements.
- ◆ The Cummins-SOFCo team demonstrated sustained output and thermal cyclic capability of their reformer process. The Cummins reformer operated for 2,900 hours at steady state and cyclic operation, matching all Phase I requirements. SOFCo achieved 2,000 hours of uninterrupted, steady-state operation while fueling a 1-kW SECA unit with natural gas.
- ◆ At the beginning of FY 2005, FuelCell Energy combined its Canadian SOFC operations, formerly known as Global Thermoelectric Corporation, into its lead product development sub-contractor, Versa Power Systems.
- ◆ Delphi achieved a power density of around 0.6 W/cm<sup>2</sup>. In July 2004, the company demonstrated its SECA Generation 3 SOFC using fuel gas extracted from coal. This is the second test to demonstrate successful use of coal gas to produce power cleanly and efficiently with SECA fuel cell technology.

Major automotive and truck manufacturers are collaborating with industry teams to pursue growth in auxiliary power unit (APU) applications. BMW has an arrangement with Delphi to put a compact fuel cell APU in its trucks by 2007. The National Aeronautics and Space Administration's (NASA) interest in SECA technology has led to extensive collaboration to use fuel cells as APUs for airplanes and eventually for propulsion in the Next Generation Clean Aircraft Power and Propulsion (NEXCAP) program.

## CORE TECHNOLOGY PROGRAM PROGRESS

The SECA core technology program (CTP) is made up (cont. pg 4)



## Status of DOD Fuel Cell Demonstration Programs

To date, the U.S. Department of Defense (DoD) Residential Proton Exchange Membrane (PEM) Fuel Cell Demonstration Program has seen fifty fuel cells installed, and thirty-four units have completed their one-year demonstrations. The U.S. Army Engineer Research and Development Center — Construction Engineering Research Laboratory (USA ERDC — CERL), has funded the DoD PEM Fuel Cell Demonstration Program in fiscal years (FY) 2001 — 2004. Each year, proposals are accepted to install, maintain, and monitor fuel cells, ranging in size from 1 to 20 kW, at U.S. military-associated sites.

Performance monitoring conducted on each PEM unit provides the basis for aggregate studies of availability, reliability, fuel cell stack and component life, siting and interconnection issues, and other factors. The locations of these installations are chosen to maximize diversity in environment and application in order to study a wide range of issues. Proposals for potential new projects were received in the 4th quarter of 2004. Contract awards for selected new projects are expected by April 2005.

The DoD Climate Change Fuel Cell Project, initiated by Congress in FY1995, managed by USA ERDC — CERL, provides rebates of \$1000/kW — up to one third of the cost of the fuel cell purchase price — to applicants fielding U.S. manufactured fuel cells. The purpose of this project is to expedite the market introduction of fuel cells. To date, applicants have received more than \$30 million in grants through this project for fuel cell power plants installed at numerous locations throughout the world. A total of 234 fuel cells have been supported by this project, which include PAFC, PEM, and MCFC technologies.

In 2004, awards were made for 26 fuel cells totaling \$6.0 million (FY2003 funds). In 2005, approximately \$1.2 million will be available for rebates. Interested applicants can watch for a solicitation to be advertised by the Bonneville Power Administration in the 2nd quarter of 2005. More information on both the Climate Change and the PEM Demonstration projects can be found at <http://www.dodfuelcell.com>.

WILLIAM TAYLOR, U.S. ARMY ENGINEERING R&D CENTER,  
CONSTRUCTION ENGINEERING RESEARCH LAB

# Calendar

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## Hannover Fair 2005

Hannover, GERMANY - 11-15 April 2005.

Visit <http://www.fair-pr.com/> for more information.

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## 6th Annual SECA Workshop & Core Technology Peer Review

Monterey, California, USA - 18-21 April 2005.

Visit <http://www.seca.doe.gov/> for more information.

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## Small Fuel Cells 2005

Washington, DC, USA - 27-29 April 2005.

Visit <http://www.knowledgefoundation.com/> for info.

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## 2005 Ohio Fuel Cell Symposium

Cleveland, Ohio, USA - 10-11 May 2005.

Visit <http://www.fuelcellsohio.org/> for more information.

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## 2005 DOE Hydrogen Program Review

Arlington, Virginia, USA - 23-26 May 2005.

Visit <http://www.eere.energy.gov/> for more information.

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(from pg. 3) of researchers from industry, suppliers and manufacturers, as well as from universities and national laboratories, all working to provide breakthrough solutions to critical issues facing SECA. Yearly solicitations address these priorities. In FY 2004, 11 projects were selected in the second CTP solicitation. Selections under a third solicitation are expected in April 2005 for materials and fuel processing. The topics and sub-topics within these areas of interest are as follows:

- ◆ Seals - Rigid, High-Strength Sealing Concepts and Innovative Sealing Concepts.
- ◆ Interconnect - Material for SOFC Cathode/Interconnect Interface and Identify/develop Interconnect Materials.
- ◆ Electrodes - Infiltration of Active Elements into SOFC Electrode Structures and Quantification and Understanding of Cr Poisoning of Cathode Activity.
- ◆ Fuel Processing - Sulfur and Carbon Tolerant Diesel Fuel Reforming Catalysts, Alternative Reforming Concepts, and Technology for Logistic Fuel Applications.

### SUMMARY

SECA funding continues to grow to over \$50 million. Similar activities exist in other parts of the world. For example, in direct response to SECA, Japan's New Energy Development Organization (NEDO) has started a new National SOFC Program funded at US\$16 million per year for four years.

Achieving the SECA goals should result in the wide deployment of the SOFC technology in large high volume markets. Less expensive materials, simple stack and system design, and high volume markets are the three criteria that must be met by a fuel cell system to compete in today's energy market. Near zero emissions, fuel flexibility, modularity, high efficiency, and simple CO<sub>2</sub> capture will provide a national payoff that increases as markets grow.

MARK WILLIAMS, FUEL CELL PRODUCT MANAGER,  
NATIONAL ENERGY TECHNOLOGY LABORATORY

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