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## I. Introduction

The DOE Hydrogen Program is a comprehensive and focused effort launched in fiscal year (FY) 2004 to implement the President's Hydrogen Fuel Initiative. The Program addresses the full range of barriers facing the development and deployment of hydrogen and fuel cell technologies. The mission of the Program is to research, develop, and validate hydrogen production, storage, and fuel cell technologies and to overcome the non-technical barriers to the commercialization of these technologies—with the ultimate goals of reducing oil use and carbon emissions in the transportation sector and enabling clean, reliable energy for stationary and portable power generation.

The Hydrogen Program is a coordinated effort that integrates basic and applied research, technology development and demonstration, and other supporting activities that work to advance hydrogen and fuel cell technologies. The Program includes the Offices of Energy Efficiency and Renewable Energy (EERE), Nuclear Energy, Fossil Energy, and Science. The Department of Transportation also participates in the Hydrogen Fuel Initiative, with activities involving codes and standards development, infrastructure safety, and hydrogen vehicle safety. In FY 2007, Congress appropriated \$274 million for the Hydrogen Fuel Initiative. This represents an increase of \$34 million over the FY 2006 appropriation. The FY 2008 budget request for the initiative is \$309 million (appropriations will not be finalized until after this goes to press).

The Program works with industry through partnerships such as the FreedomCAR and Fuel Partnership, which includes DOE, the U.S. Council for Automotive Research (whose members are Ford Motor Company, General Motors Corporation, and Chrysler LLC) and five major energy companies (BP America, Chevron, ConocoPhillips, ExxonMobil, and Shell). The Partnership examines the pre-competitive, high-risk research needed to develop the technologies for deploying vehicles and infrastructure that will reduce the Nation's dependence on imported oil and minimize harmful emissions.

Hydrogen is a key part of the EERE portfolio, which is working to achieve the goals of the Advanced Energy Initiative by developing a suite of energy efficient and renewable energy technologies to improve the way we power our homes, cars, and businesses.

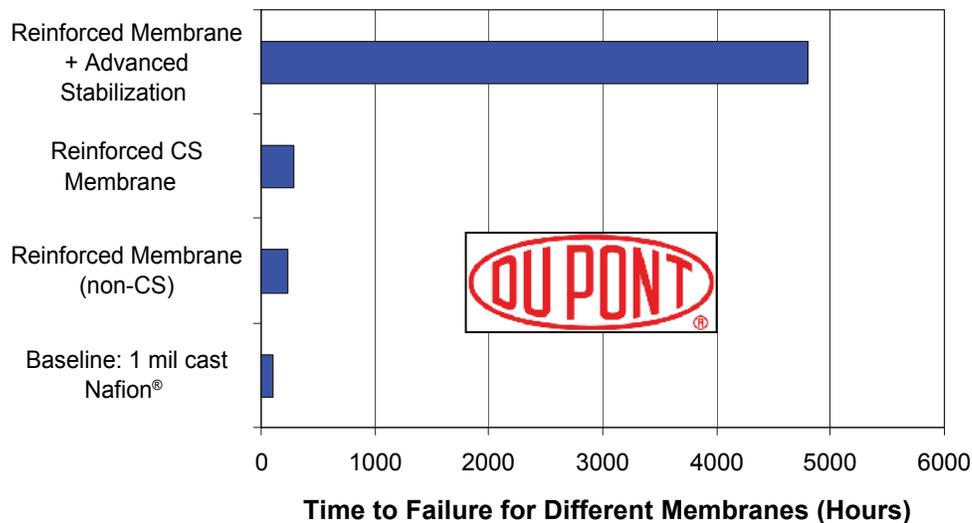
The Hydrogen Program is organized into distinct sub-programs focusing on specific research areas and supporting activities needed to overcome the barriers to hydrogen and fuel cell commercialization. The goals, objectives, and targets of each of the applied research programs are identified in the multi-year program plans for EERE, the Office of Fossil Energy, and the Office of Nuclear Energy; and the basic research areas addressed by the Office of Science are described in *Basic Research Needs for the Hydrogen Economy—Report of the Basic Energy Sciences Workshop on Hydrogen Production, Storage, and Use*. All of these documents are available at [www.hydrogen.energy.gov/program\\_plans.html](http://www.hydrogen.energy.gov/program_plans.html).

In the past year, the Program made significant advances toward its goals and objectives. Highlights of the Program's accomplishments and progress are summarized below.

### **PROGRAM PROGRESS & ACCOMPLISHMENTS**

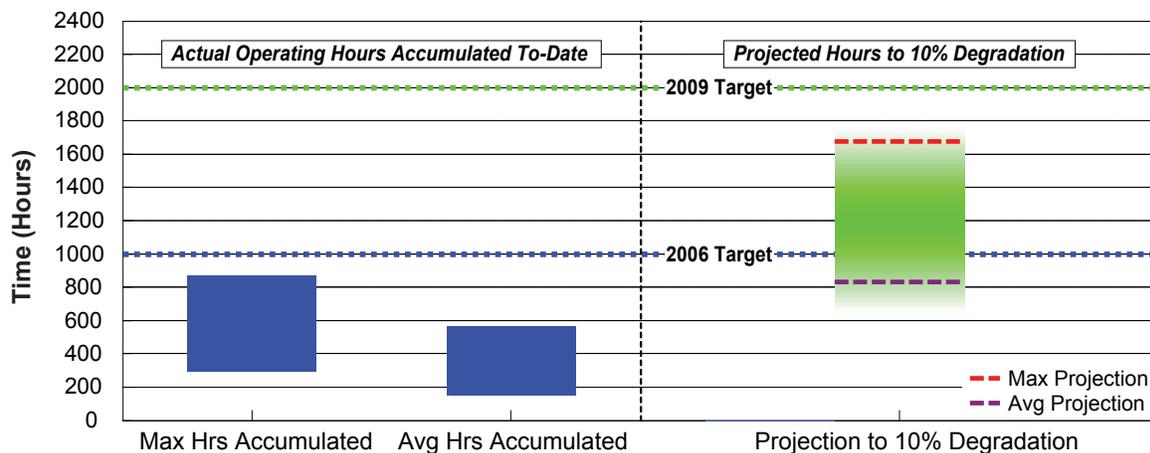
#### **Fuel Cells**

The Fuel Cell sub-program has made significant advances in increasing the durability of membranes and catalysts. DuPont has developed a membrane that operates for almost 5,000 hours (equivalent to 150,000 miles of vehicle operation) with combined humidity and voltage cycling. The bar chart (see following page) shows the time to failure for several membranes: the baseline, Nafion®; a reinforced membrane that provides mechanical stability; a reinforced membrane with chemical stability (obtained by replacing the reactive end groups of the polymer with stable moieties); and a membrane with advanced stabilization for peroxide mitigation. 3M has also developed a single cell with performance (>3,500 hours) that is approaching DOE targets for durability.



In non-precious metal catalyst development, 3M’s Fe-C-N catalysts were operated for more than 1,000 hours with negligible loss in performance, and researchers at the University of South Carolina have progressed from a metal-free carbon-nitrogen catalyst to a carbon composite catalyst with catalytic activities as high as 2 A/cm<sup>2</sup> (4 mg/cm<sup>2</sup> loading at 0.2 V).

DOE’s Learning Demonstration has also shown improvements in the durability of fuel cells operating in real-world environments. Vehicles in the Learning Demonstration have been in operation for over two years, and projections have been made to estimate how long these fuel cells will be able to operate before they reach 10% degradation in fuel cell stack voltage. One team had a projected durability of 1,250 hours, and the average projection over all four teams was 700 hours (additional data will be available in the fall of 2007 and will be reported at the Fuel Cell Seminar). Improved durability is expected with the second generation fuel cell stacks that will be introduced in this project beginning in late 2007. The results from these vehicles will be compared with the 2,000-hour target for 2009.



**DOE Learning Demonstration Fuel Cell Stack Durability: Based on Data Through 2007 Q2**

(Data based on “real-world” operation; range bars created using one data point for each original equipment manufacturer (OEM). Projection using on-road data—degradation calculated at high stack current. “Max Projection” is based on highest nominal projection; “Avg Projection” is based on average nominal projection. The shaded green bar represents an engineering judgment of the uncertainty due to data and methodology limitations.)

## Hydrogen Production

**Hydrogen from Distributed Natural Gas.** Considerable progress was made towards further reducing the cost of hydrogen produced on-site from natural gas. H2Gen completed the fabrication of their first distributed 565 kg/day hydrogen generator. The new system has five times the capacity of their smaller unit. The generator burner significantly reduces the power required, increasing the overall electrical efficiency of the H2Gen small-scale steam methane reforming system. The projected cost of hydrogen from this system at a refueling site—at large production volumes (500 units/yr)—approaches the 2010 target of \$2.50 per gallon-gasoline-equivalent of hydrogen. The knowledge gained from distributed reforming of natural gas is now being applied to bio-derived liquids reforming. The Hydrogen Program is shifting its emphasis to producing hydrogen from bio-derived liquids and is cost-sharing research to address technical challenges.

**Renewable-Based Hydrogen.** A major milestone was achieved by integrating several electrolyzers—two Proton units and a Teledyne unit—into the Wind-to-Hydrogen Project, a collaborative effort between the National Renewable Energy Laboratory and Xcel Energy. The complete system converts wind energy into hydrogen, which is then compressed and stored to be used as a vehicle fuel or to generate electricity. The data collected is being used to validate system models, improve control algorithms, develop testing protocols, and to identify methods for increasing system efficiency and lowering cost. As part of this work, advanced power electronics were developed that allowed power from the wind-turbines—with variable voltages and frequencies—to be used directly by the electrolyzers. These advanced power electronics may reduce the overall system cost by 15% or more by combining functions from the wind turbines and electrolyzers. This work is being closely followed by the Hydrogen Utility Group (HUG). HUG is composed of electric utilities that have identified hydrogen as a potential storage medium for electricity generated from wind and solar energy during low demand times. Using this hydrogen in a fuel cell or other generator to produce electricity during times of high demand would reduce the need for costly peak-power generation while reducing environmental impacts.

Research on other renewable hydrogen production pathways resulted in considerable progress, including efforts in biomass gasification/pyrolysis and solar-powered high-temperature thermochemical, photoelectrochemical, and biological technologies.

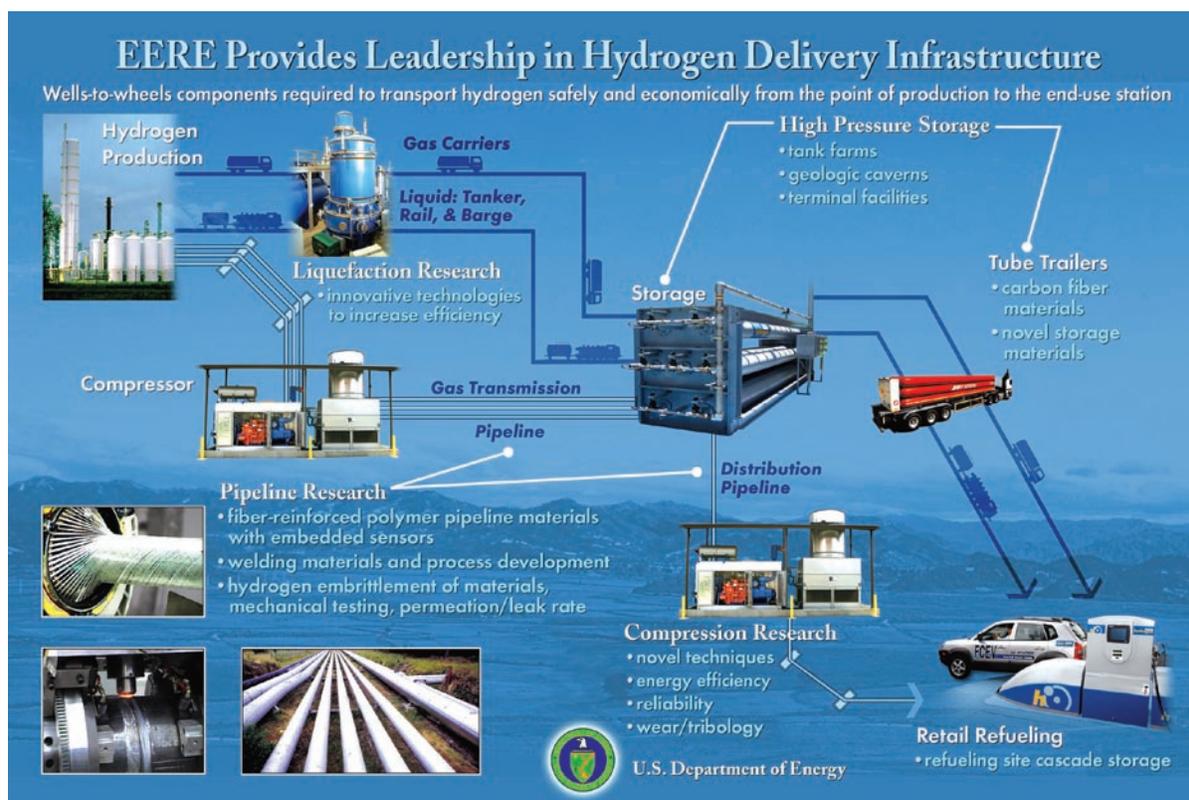
**Hydrogen from Coal.** Significant progress has been made in the area of membrane separation technology for the production of hydrogen from coal. Eltron Research, Inc. developed a dense cermet membrane that demonstrated the potential to meet DOE's 2010 targets at laboratory scale. Eltron plans to scale up from 1.3 lbs/day to 220 lbs/day, and eventually to 4 tons/day. Southwest Research Institute has also demonstrated the potential to meet the 2010 targets by producing self-supported Pd-Cu alloy membranes that have reduced membrane thickness (five microns). Additionally, Aspen Products Group and United Technology Research Corporation have identified promising catalytic and membrane materials that have the potential to perform the water-gas shift reaction and hydrogen separation in one unit (i.e., process intensification).

**Nuclear Hydrogen.** Significant progress has been made in the development and assembly of components into integrated laboratory-scale experiments to test high-temperature hydrogen production processes. In the area of thermochemical cycles, a Sulfur-Iodine (S-I) integrated laboratory-scale (ILS) experiment was assembled at the General Atomics facility in San Diego consisting of three separately developed sections: the sulfuric acid decomposer section (developed at Sandia National Laboratories), a hydriodic acid decomposer section (constructed by General Atomics), and a Bunsen reaction section (provided by the French Commissariat à l'Énergie Atomique). In FY 2008, experimental testing of the S-I ILS will be conducted. Idaho National Laboratory completely assembled a high-temperature electrolysis (HTE) ILS and began experimental operations. In FY 2008, the ILS experiment will consist of three modules, each containing four 60-cell electrolyzer stacks. The ILS experiments are designed to test the unit operations (S-I), electrolyzer cells (HTE), and operating techniques that will be used in the next scale of high-temperature hydrogen production experiments.

## Hydrogen Delivery

Major advances were made in the modeling of hydrogen delivery infrastructure through the H2A Hydrogen Delivery Model. Comprehensive analysis was conducted to determine how to optimize off-board hydrogen storage to adjust for hydrogen demand and supply variations—including those that arise from the hourly, weekly, and seasonal cycles at refueling sites, as well as yearly production plant maintenance outages. Other significant refinements in the analysis included the incorporation of different sizes of refueling sites, improvements in the capital cost estimates for pipelines and compressors, and incorporation of well-to-wheels (WTW) energy use and greenhouse gas emissions data. As this report was going to press, work was being completed on evaluating the potential use of novel carriers for delivery (e.g., chemical hydrides).

Other hydrogen delivery research also led to considerable progress, including efforts in steel and composite pipelines, lower-cost off-board hydrogen storage, and hydrogen liquefaction.



## Hydrogen Storage

In FY 2007, the Storage sub-program made progress in all three classes of materials under investigation—hydrogen adsorbents, reversible metal hydrides, and chemical hydrogen carriers. These achievements involved improvements in operational properties, not just in storage capacity. Examples include the following:

- Based on a “spillover” phenomenon, bridged catalyst metal organic framework (MOF) materials have been independently synthesized and shown to have up to 4 wt% hydrogen capacity at room temperature, a significant temperature improvement (more than 200°C) over current adsorbent materials.

- Ammonia borane was shown to have hydrogen release rates fast enough to supply fuel for an 80 kW fuel cell in a modest-sized reactor at less than 150°C.
- Lithium borohydride infused into a highly porous carbon aerogel structure was found to release hydrogen at a significantly lower temperature (70°C lower) and with a lower weight penalty than with other aerogels.
- Progress was also made in physical storage systems with the successful demonstration of a “cryo-compressed” tank concept onboard a hydrogen-fueled vehicle. The cryo-compressed tank system capacity surpassed the 2007 gravimetric target of 4.5 wt% and was within 20% of the volumetric target of 36 g/L.



**Cryo-Compressed Vessel Installed Onboard the Prius Hydrogen-Fueled Hybrid Vehicle**

### **Basic Research**

The Office of Basic Energy Sciences (BES) within the DOE Office of Science supports fundamental research addressing critical scientific challenges related to hydrogen storage, production, and fuel cells. This basic research complements the applied research and development projects supported by the other offices in the DOE Hydrogen Program.

In FY 2007, the BES Contractors’ Meeting, featuring fundamental research underpinning the advancement of membranes and catalysis (fuel cells), was co-located with the Fuel Cell sub-program presentations at the 2007 DOE Hydrogen Program Merit Review and Peer Evaluation Meeting. In FY 2008, the BES Contractors’ Meeting will feature basic research fundamental to the advancement of hydrogen production (solar and bio-inspired) and will be co-located with other Production sub-program presentations at the 2008 DOE Hydrogen Program Merit Review and Peer Evaluation Meeting. This integrated approach will ensure that discoveries and related conceptual breakthroughs achieved in basic research programs will provide a foundation for the innovative design of materials and processes that will produce improvements in the performance, cost, and reliability of hydrogen production, storage, and use.

In FY 2007, BES made 13 new awards totaling \$11.2 million, over three years, in the areas of hydrogen storage and catalysis. On-board hydrogen storage is considered to be the most challenging aspect for the successful transition to a hydrogen economy. Basic research is essential for identifying novel materials and processes that can provide potential breakthroughs needed to meet the Hydrogen Fuel Initiative (HFI) goals. Catalysis is vital to the success of the HFI due to its integral roles in converting solar energy to chemical energy, producing hydrogen from water or carbon-containing fuels such as coal and biomass, and producing electricity from hydrogen in fuel cells. Breakthroughs in catalytic research would affect the thermodynamic efficiency of hydrogen production, storage, and use, and therefore improve the economic efficiency with which the primary energy sources—fossil, biomass, solar, or nuclear—serve our energy needs.

### **Technology Validation**

In FY 2007, the National Hydrogen Learning Demonstration Project completed its third full year of data collection. Seventy-seven first generation fuel cell vehicles and 12 hydrogen fueling stations are currently in operation (hydrogen for the fueling stations is being supplied by truck and through on-site electrolysis or natural gas reforming).

Teams continue to collect and provide data to the Hydrogen Secure Data Center at the National Renewable Energy Laboratory. Thirty composite data products—which are ranges of technical values that do not identify which company provided the information—have been generated from the collected data. These composite data products cover a number of parameters, such as fuel cell durability and



### Types of Hydrogen Refueling Stations Being Tested as Part of the Learning Demonstrations

efficiency, fuel economy, vehicle driving range, on-board hydrogen storage performance, vehicle and infrastructure safety events, hydrogen impurities detected in samples from refueling stations, and vehicle refueling rates.

As discussed earlier, the fuel cell durability has been projected to be a maximum of 1,250 hours for the first generation vehicles. The goal for the second generation vehicles, being introduced in 2007 and 2008, is 2,000 hours. Data from the four Learning Demonstration teams showed a range of net system efficiency from 52.5% to 58.1%, which is very close to the DOE target of 60%. The vehicle chassis dynamometer fuel economy from the four teams ranged from 49–67 miles per kilogram of hydrogen, and the on-road fuel economy ranged from 32–43 miles per kg. The EPA adjusted dynamometer driving range was between 103 and 190 miles.

Two second generation vehicles, including a plug-in hybrid electric fuel cell vehicle, were introduced to the project this year, and second generation fuel cell vehicles will continue to be demonstrated in FY 2008.

### Safety, Codes & Standards

The Safety, Codes & Standards sub-program continued to develop and distribute safety information tools in FY 2007. The first version of an online *Technical Reference for Hydrogen Compatibility of Materials* was published and is accessible at <http://public.ca.sandia.gov/matlsTechRef/>. The materials guide consists of 14 chapters on six materials classes: plain carbon ferritic steels, low-alloy ferritic steels, high-alloy ferritic steels, austenitic steels, aluminum alloys, and copper alloys. The effects of hydrogen on material properties such as yield and tensile strengths, fracture toughness and threshold stress-intensity factors, fatigue crack growth-rates, fatigue thresholds, and impact energy are discussed.



**Chevrolet Equinox<sup>®</sup> Second Generation Fuel Cell Vehicle**

In addition, with the support of the Hydrogen Safety Panel, the Safety, Codes & Standards sub-program published a revised *Safety Planning Guidance Document for Hydrogen Projects*. This document will serve as a reference for principal investigators on the creation of safety plans, which are required for all DOE-funded projects involving hydrogen. The document includes information on what should be considered when writing a safety plan, including techniques for assessing safety vulnerabilities and mitigating risk.

In FY 2008, the Safety, Codes & Standards sub-program will launch the Web-based *Hydrogen Safety Best Practices Manual*. The manual will address safety culture, safety planning, incident procedures, development of operating procedures, communications, design of facilities and equipment, hydrogen storage and piping systems, and equipment maintenance and integrity.

## Education

On January 24, 2007, the Education sub-program officially launched the Introduction to Hydrogen Safety for First Responders, a seven-module course that provides a basic overview of hydrogen and fuel cells to fire, law enforcement, and emergency medical personnel. The course is available online at [www.hydrogen.energy.gov/firstresponders](http://www.hydrogen.energy.gov/firstresponders), on CD and in print through the DOE Energy Efficiency and Renewable Energy Information Center, at 1-877-EERE-INFO. The Web and CD versions include videos and animations to illustrate key points. A summary poster, suitable for display on fire department bulletin boards, is also available. In the first seven months after its launch, nearly 4,500 users accessed the course on-line and an additional 1,000 accessed it on CD. Users have included fire fighters, fire department education coordinators, fire marshals, fire plans examiners, and law enforcement officers, as well as representatives of industry, government agencies, and the military.

The Education sub-program's public education effort, the "Increase Your H2IQ" project, completed the development of two 30-second radio spots intended to introduce hydrogen and fuel cells to the public and drive them to more information on [www.hydrogen.energy.gov](http://www.hydrogen.energy.gov) (the target demographic is ages 25–55). The spots rolled out in select media markets in September 2007. Also under the "Increase Your H2IQ" banner, the sub-program completed *The Hydrogen Report*, a series of seven podcasts (downloadable audio files) available on [www.hydrogen.energy.gov](http://www.hydrogen.energy.gov) as well as via distribution channels including iTunes. Approximately five minutes in length, each podcast provides a general overview of a hydrogen or fuel cell topic for a non-technical audience—there are segments on fuel cells, hydrogen production, hydrogen delivery, hydrogen storage, safety, and near-term markets, as well as an overview of the DOE Hydrogen Program. Both the radio spots and podcasts are available from [www.hydrogen.energy.gov](http://www.hydrogen.energy.gov) for anyone to download and use.

## Systems Analysis

The Systems Analysis sub-program continued to pursue a strategy focused on the development of core models for hydrogen-associated analysis and on conducting resource, infrastructure, well-to-wheels, and hydrogen quality analysis for different hydrogen production and delivery pathways. Significant progress was made in FY 2007 in the area of scenario analysis and in the development of the Macro-System Model and Directed Technologies' (DTI) HYPRO Model.

DOE completed the 2010–2025 Scenario Analysis for Hydrogen Fuel Cell Vehicles and Infrastructure, which involved an examination of the costs and tradeoffs of different near-term options for hydrogen production, delivery, and utilization, as well as an exploration of the policies that might be most effective in sustaining the early years of hydrogen and fuel cell technology development and adoption. The Scenario Analysis, recommended by the National Academies, included two workshops involving broad participation from industry and explored three vehicle penetration scenarios—which were based on the National Academies' recommendations and industry input—leading to an assessment of the costs and impacts of achieving each scenario. A key conclusion reached was that networks of fueling stations should be established in a limited number of urban centers during the transition period to maximize coverage and permit a cost-effective approach to providing the early infrastructure, i.e., "clusters," rather than "highways." The analysis also considered policies that could be used to help

share the costs of bringing fuel cell vehicles to market, and it led to a number of conclusions, including: 1) transition policies appear to be essential even if hydrogen and fuel cell technology is superior to an advanced hybrid internal combustion vehicle; 2) cost to government is not inordinate or out of line with the level of public support provided for other programs that support national goals; and 3) directed policies of cost-sharing and tax credits over a decade would enable the industry to bring competitive automotive and infrastructure products to the marketplace by 2025 if fuel cell and storage cost targets are met.

The Macro-System Model was developed to link models of different architecture to enable complete hydrogen pathway analysis. The DTI HYPRO model, which enables optimization of the hydrogen production and infrastructure portfolio, was completed. This model was used in the Scenario Analysis to understand hydrogen production options during the initial market penetration of hydrogen fuel cell vehicles.

Also, the Hydrogen Analysis Repository—a searchable online database of past and present hydrogen-related analysis projects and computer models—was developed. Each entry contains, at a minimum, the purpose of the analysis or modeling project and a means to locate more information. The database currently includes approximately 75 analysis projects, of which 30 project entries have been reviewed and published on the repository website, [www.hydrogen.energy.gov/analysis\\_repository/](http://www.hydrogen.energy.gov/analysis_repository/).

## NEW PROJECTS SELECTED AND NEW SOLICITATIONS ISSUED

In FY 2007, the DOE Hydrogen Program competitively selected many new projects to address key barriers in the development of hydrogen and fuel cell technologies. These included:

- Twenty-five projects (\$100.6 million over four years; \$127.6 million with cost share) to conduct RD&D activities in the following areas: improved membranes; water transport; advanced cathode catalysis and supports; cell hardware; innovative concepts; effects of impurities on fuel cell performance and durability; and stationary fuel cell demonstration.
- Thirteen projects (\$11.2 million over three years) to conduct basic research in nanoscale catalysts and novel hydrogen storage materials.
- Six projects (\$8.2 million over four years; \$9.7 million with cost share) to conduct R&D in high-capacity storage materials and materials safety.
- Two projects (\$1.1 million over three years; \$1.4 million with cost share) in hydrogen production from nuclear energy.
- Six projects (\$7.4 million over two to three years; \$9.2 million with cost share) in hydrogen production from coal.
- One project (\$6.0 million over five years; \$7.2 million with cost share) to lead the coordination effort to prepare, review, and promulgate the codes and standards needed to expedite the development and use of hydrogen, fuel cells, and infrastructure technologies.
- Two projects (\$1.2 million over two years) to examine the environmental effects of hydrogen use in transportation and stationary applications, focusing on the impacts of various hydrogen production pathways and use on the oxidative capacity of the atmosphere, long-term stability of the ozone layer, and climatic changes.
- One project (\$0.4 million over two years) to identify and analyze lessons learned from experiences with alternative fuels for stationary power generation, as well as opportunities for using polymer electrolyte membrane (PEM) fuel cells in stationary applications.

In June 2007, the Program announced a new funding opportunity soliciting applicants to conduct R&D in hydrogen and fuel cell systems manufacturing. This solicitation concentrates on the major topics that need to be addressed to reduce the manufacturing costs of hydrogen and fuel cell systems, with a focus on technologies that are near commercialization. Total estimated funding available is \$38 million, pending congressional appropriations, with an expectation of about 15 selected projects and an individual award ceiling of \$4 million. The solicitation closed in October.

## INTERNATIONAL ACTIVITIES

### International Partnership for the Hydrogen Economy

The International Partnership for the Hydrogen Economy (IPHE), which includes 16 member countries and the European Commission (see table on next page), is a forum for governments to work together to advance worldwide progress in hydrogen and fuel cell technology research, development, and deployment. IPHE is also a forum for international R&D managers, researchers, and policymakers to openly share program strategies.

Since its inception, the IPHE has endorsed a total of 30 collaborative projects that cover a broad range of topics including hydrogen production, hydrogen storage, fuel cell technology, demonstration activities of fuel cell technology in small power vehicles and buses, and the socio-economic impacts of hydrogen production. These outstanding projects illustrate the on-going collaborative efforts to advance the organization's goals. For more information, please visit [www.iphe.net/](http://www.iphe.net/).

Members of the International Partnership for the Hydrogen Economy

Australia	Italy
Brazil	Japan
Canada	New Zealand
China	Norway
European Commission	Republic of Korea
France	Russia
Germany	United Kingdom
Iceland	United States
India	

### International Energy Agency

The International Energy Agency's Implementing Agreements provide a mechanism for member countries to share the tasks and costs involved in research activities. The DOE Hydrogen Program participates in two of these—one supporting fuel cell R&D activities and one supporting hydrogen R&D activities.

The IEA Advanced Fuel Cells Implementing Agreement (AFCIA) currently comprises six tasks: Molten Carbonate Fuel Cells, Polymer Electrolyte Fuel Cells, Solid Oxide Fuel Cells, Fuel Cells for Stationary Applications, Fuel Cells for Transportation, and Fuel Cells for Portable Applications. The participating countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, South Korea, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and the United States. The United States participates in all of the AFCIA's tasks except Fuel Cells for Portable Applications. Information about the IEA Advanced Fuel Cells Implementing Agreement is available at [www.ieafuelcell.com](http://www.ieafuelcell.com).

The IEA Hydrogen Implementing Agreement (HIA) is focused on RD&D and analysis of hydrogen technologies. There are currently seven approved tasks under the HIA: Integrated Systems Evaluation, Hydrogen Safety, Hydrogen from Water Photolysis, Bio-hydrogen, Fundamental and Applied Hydrogen Storage and Development, Small Scale Reformers for Onsite Hydrogen Supply, and Wind Energy and Hydrogen Integration. The United States participates in all of these tasks. Members of the HIA are Australia, Canada, Denmark, the European Commission, Finland, France, Germany, Iceland, Italy, Japan, South Korea, Lithuania, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. Greece and Turkey are in the process of joining.

## OTHER PROGRAM ACTIVITIES

### Hydrogen Quality

The quality of hydrogen fuel is expected to play a large role in the ultimate performance and durability of fuel cell systems. Fuel quality affects the lifecycle costs of fuel cell systems—higher quality fuel allows for lower fuel cell system and vehicle costs. On the other hand, higher fuel quality requirements correlate to higher lifecycle costs for hydrogen production, purification, distribution, storage, and analytical systems. To quantify these relationships and to develop a roadmap to define R&D priorities in this cross-cutting area, DOE established the Hydrogen Quality Working Group, which includes participants from the automotive and energy industries, the national laboratories, and the DOE Hydrogen Program. A model is being developed—as a result of the working group’s activities and to support future activities of the group—to analyze the tradeoffs for hydrogen production and fuel cell performance for various levels of hydrogen quality.

### Market Transformation

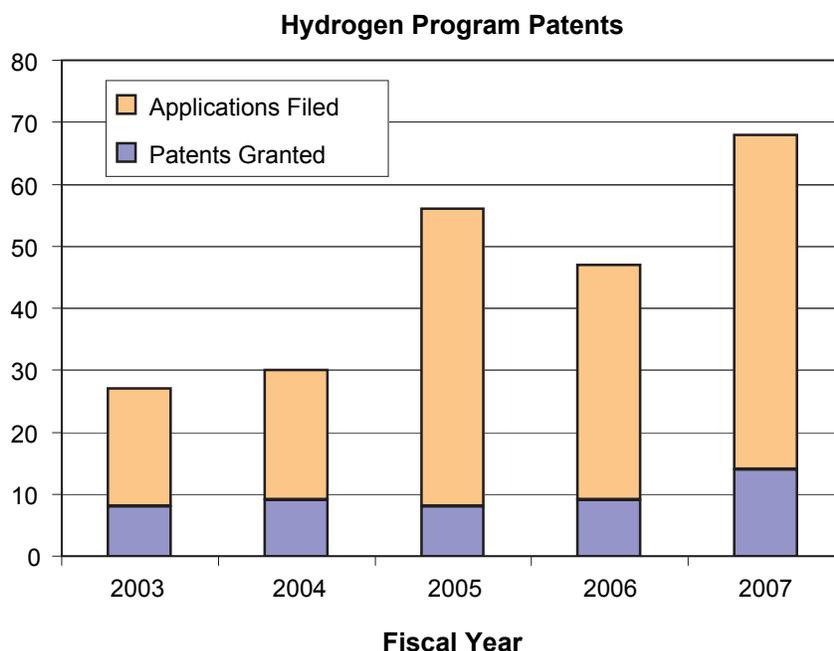
The Hydrogen Program is undertaking market transformation activities to promote early adoption of hydrogen and fuel cell power systems. The goal of these activities is to eliminate the non-technical barriers facing hydrogen and fuel cell technologies, help companies bridge the “valley of death” between development and commercialization, and increase the opportunities for market expansion.

The pathway to fuel cell vehicles will likely include the introduction of direct hydrogen PEM fuel cells in near-term markets with fewer technological challenges than the automobile market. The most promising near-term market opportunities for PEM fuel cells in this size range are in specialty vehicle and backup power applications. PEM fuel cell systems are commercially available for use in these applications, and they offer several potential advantages over current technologies, including lower emissions, lower O&M requirements, longer runtimes, and other improvements in productivity.

The Federal government, through its various agencies, can play a critical role in supporting and enhancing the market introduction of new technologies by being an early adopter of the technology to stimulate initial market niches. The Hydrogen Program is actively collaborating with the Department of Defense to deploy fuel cell lift trucks in several locations, and it is supporting Federal deployments for backup power applications. The Program is also encouraging the private sector to purchase fuel cells. These purchases will generate “market pull” by stimulating demand for certain applications. Higher volume purchases of these technologies are expected to reduce manufacturing costs, increase the domestic supplier network, increase public awareness, and further increase demand in the market. A formal Request for Information (RFI) was issued to obtain industry and government input on the most effective methods to stimulate near-term markets.

### New Patents

One indicator of the robustness and innovative vitality of a research and development program is the number of patents applied for and granted. Each year, the DOE Hydrogen Program tracks the number of patents that are filed by or awarded to projects it sponsors. In FY 2007, 14 new patents were issued for discoveries or technologies developed in DOE Hydrogen Program projects; 54 more applications were filed or are in the process of being awarded.



## EXTERNAL COORDINATION, INPUT, AND ASSESSMENT

### Federal Agency Coordination—the Interagency Working Group and the Interagency Task Force

The President's Executive Order and the Energy Policy Act of 2005 (EPAc 2005) act as drivers for the coordination of federal agencies in using advanced technologies (i.e., hydrogen fuel cells) to meet energy requirements. The President's May 2007 Executive Order calls for federal agencies to start drafting regulations to cut U.S. gasoline consumption by 20% in the next 10 years and to cut emissions of greenhouse gases from motor vehicles. The Environmental Protection Agency (EPA), Department of Transportation (DOT), U.S. Department of Agriculture (USDA), and DOE will be working together to achieve that goal. EPAc 2005 directs the Secretary of Energy to "conduct a research and development program—in consultation with other federal agencies and the private sector—on technologies related to the production, purification, distribution, storage, and use of hydrogen energy, fuel cells, and related infrastructure."

Many federal agencies are involved in hydrogen and fuel cell research, development, demonstration, and deployment. These activities are well coordinated through two interagency groups—one at the staff level and another with senior management participation.

The staff-level Hydrogen and Fuel Cell Interagency Working Group (IWG), co-chaired by DOE and the White House Office of Science and Technology Policy, meets monthly to share expertise and information about ongoing programs and results, to coordinate activities, and to ensure efficient use of taxpayer resources. Two ad-hoc committees provide a forum for more focused collaboration—one supports the coordination of a regulatory framework for a hydrogen economy (led by the Department of Transportation) and the other supports collaboration on biomass-to-hydrogen production and the use of fuel cells for rural and agricultural applications (led by DOE and the Department of Agriculture). The IWG's public website, [www.hydrogen.gov](http://www.hydrogen.gov), serves as a portal to information about all federal hydrogen and fuel cell activities, programs, and news. Among its features is an interactive map developed by the regulatory ad-hoc committee to illustrate the current U.S. statutes and regulations that may be applicable to hydrogen.

The Hydrogen and Fuel Cell Interagency Task Force (ITF) is composed of senior-level agency representatives (at the level of Assistant Secretary or the functional equivalent), and it convened for the first time in August 2007. More than fifteen agencies, including offices and departments within agencies, are represented, and members include hydrogen and fuel cell technology developers, educators, and potential users. The ITF has recognized the opportunity to demonstrate federal leadership through early adoption of hydrogen and fuel cell technologies, and it has set a goal of engaging in interagency coordination to deploy these technologies in early market applications such as emergency/remote power and material handling equipment.

### **DOE Utilizes Expertise from Stakeholder Community and Government Partners**

**Hydrogen and Fuel Cell Technical Advisory Committee.** The Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) was created in 2006 to advise the Secretary of Energy on issues related to the development of hydrogen and fuel cell technologies and to provide recommendations regarding DOE's programs, plans, and activities, as well as safety, economic, and environmental issues related to hydrogen. HTAC members include representatives of domestic industry, academia, professional societies, government agencies, financial organizations, and environmental groups, as well as experts in the area of hydrogen safety.

The HTAC met four times between October 2006 and August 2007. The committee's initial recommendation was to elevate the level of participation in the Interagency Task Force on Hydrogen and Fuel Cells (ITF) to the functional level of Assistant Secretary or higher, to ensure appropriate decision-making membership from each agency. DOE has implemented this recommendation. The committee has completed its first biennial report to the Secretary. As required by EPOA 2005, the Secretary's biennial report to Congress will follow (to be delivered with the FY 2009 budget request), and it will describe HTAC's recommendations, address how DOE will implement those recommendations, and provide an explanation for any recommendations that will not be implemented.

**National Academy of Sciences.** The National Research Council (NRC) of the National Academies provides ongoing technical and programmatic advice to the DOE Hydrogen Program. The NRC conducted a review of the Program between 2002 and 2004 to provide recommendations for improvement, which were outlined in the council's report, *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*.<sup>1</sup> Following this review, in 2005 the NRC established the Committee on Review of the FreedomCAR and Fuel Program, to conduct an independent review of the research and development program of the FreedomCAR and Fuel Partnership (see below for more on the Partnership). This committee used the results of *The Hydrogen Economy* report and referred to its findings to offer recommendations on the technical direction, strategies, funding, and management of the Partnership. The NRC's recommendations regarding the Partnership were published in a 2005 report entitled *Review of the Research Program of the FreedomCAR and Fuel Partnership: First Report*.<sup>2</sup> These reviews are held biennially, and the second-phase review<sup>3</sup> of the Partnership is currently underway.

DOE has addressed the recommendations from both of the NRC's reviews and incorporated many of them into the Program (details are available upon request). Currently, the NRC is also carrying out a study to determine the investments in R&D, demonstrations, education, and infrastructure that will be required for the development of fuel cell technologies and for the successful transition from petroleum- to hydrogen-fueled vehicles in a significant percentage of the U.S. vehicle market by 2020.

**FY 2007 Annual Merit Review and Peer Evaluation.** The DOE Hydrogen Program held its Annual Merit Review from May 15–18, 2007, in Arlington, Virginia. Over 900 people attended the review, and

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<sup>1</sup> National Research Council and National Academy of Engineering, Committee on Alternatives and Strategies for Future Hydrogen Production and Use, *The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs*, (Washington, D.C.: National Academies Press, 2004).

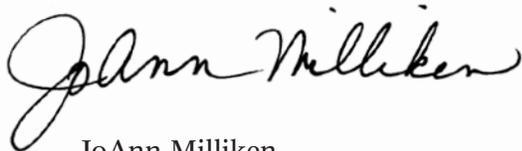
<sup>2</sup> National Research Council of the National Academies; Committee on Review of the FreedomCAR and Fuel Research Program, Phase 1; Board on Energy and Environmental Systems, Division on Engineering and Physical Sciences, Transportation Research Board; *Review of the Research Program of the FreedomCAR and Fuel Partnership: First Report*, (Washington, DC: National Academies Press, 2005).

<sup>3</sup> For more details on the NRC Phase II review, see <http://www8.nationalacademies.org/cp/projectview.aspx?key=48724>

297 projects were presented, of which 161 were peer-reviewed.<sup>4</sup> The Annual Merit Review provides an opportunity for the Program not only to report its accomplishments and progress, but also to obtain an expert peer review of the projects it supports. The Review also provides a forum for promoting collaborations, exchange of ideas, and technology transfer. Reviewers evaluate the Program's projects and make recommendations to the principal investigators and to the Program. DOE uses these evaluations to make project funding decisions for the upcoming fiscal year. This year, there were 171 contributing reviewers—the report compiling their comments is available at [www.hydrogen.energy.gov/annual\\_review.html](http://www.hydrogen.energy.gov/annual_review.html). The next review will be held June 9–13, 2008, in Arlington, Virginia.

### IN CLOSING...

We are pleased to present the *U.S. Department of Energy's 2007 Hydrogen Program Annual Progress Report*. The report is divided into chapters and organized by technology area (e.g., Hydrogen Storage, Fuel Cells, etc.). Each chapter opens with an overview written by a DOE Technology Development Manager that summarizes the progress and accomplishments of this fiscal year. The 326 projects outlined in this document represent the work of the many innovative scientists and engineers supported by the Hydrogen Program. It is they who are responsible for the progress reported herein and the technical accomplishments outlined previously.



JoAnn Milliken  
Program Manager  
DOE Hydrogen Program

<sup>4</sup>Not all of the projects presented were reviewed, because projects are reviewed every two years on a rotating basis, and several fuel cell-related projects from the DOE Office of Science were presented but not reviewed.