I. INTRODUCTION

In cooperation with industry, academia, national laboratories, and other government agencies, the Department of Energy's Hydrogen Program is advancing the state of hydrogen and fuel cell technologies in support of the President's Hydrogen Fuel Initiative. The initiative seeks to develop hydrogen, fuel cell, and infrastructure technologies needed to make it practical and cost-effective for Americans to choose to use fuel cell vehicles by 2020. Significant progress was made in fiscal year 2005 toward that goal.

President Bush participates in refueling of GM's fuel cell vehicle at Shell's hydrogen station in Washington, DC, on May 25, 2005. During this visit, Under Secretary of Energy David K. Garman updated President Bush on progress under the Hydrogen Initiative. President Bush also received technology updates from BP, Chevron, DaimlerChrysler, Ford, GM, Hyundai, and Shell senior managers.

Congress Clears Path for Hydrogen

In 2005, Congress demonstrated overwhelming support for the hydrogen economy through several activities.

Energy Policy Act of 2005. EPAct 05 was signed into law by President Bush on August 8, 2005. Title VIII, the Spark M. Matsunaga Hydrogen Act of 2005, focuses on hydrogen and indicates the strong support of Congress for research, development, demonstration, education, and codes and standards for hydrogen and fuel cell technologies. Title VIII authorizes $3.28 billion for research and development, demonstrations, and studies over five fiscal years aimed at getting hydrogen-powered automobiles on the road by 2020. In addition, numerous other titles call for hydrogen and fuel-cell related tax and market incentives, new studies, collaboration with alternate fuels and renewable energy programs, and broadened demonstrations. The timeline established by Congress matches perfectly with the milestones established by the Department in the Hydrogen Posture Plan published in February 2004 in support of the President's Initiative.

Accompanied by Congressional leaders and Energy Secretary Samuel Bodman in Albuquerque, New Mexico, President Bush signs the Energy Policy Act of 2005 into law.

House Caucus. The House of Representatives launched a Hydrogen and Fuel Cell Caucus on June 28, 2005 with an "End Dependence Day" kick-off in Washington, D.C. The Caucus, co-chaired by U.S. Representatives Charles Dent, Bob Inglis, John Larson and Albert Wynn, is a bipartisan group of House members and industry participants dedicated to promoting hydrogen as an alternative to petroleum-based fuels. The Hydrogen and Fuel Cell Caucus plans to support the President's Hydrogen Fuel Initiative and other hydrogen-related activities. The Senate has a similar organization, the Senate Hydrogen and Fuel Cell Caucus, which is co-chaired by Senators Byron Dorgan and Lindsey Graham.

The House Hydrogen & Fuel Cell Caucus Kicked Off on June 28, 2005

Appropriations. In past years, Congress funded fuel cell and fossil-related hydrogen research through the Interior and Related Agencies Appropriations Act, while basic science and renewable and nuclear-related hydrogen research was funded through the Energy and Water Development (EWD) Appropriations Act. Beginning in FY 2006, Congress will fund all DOE hydrogen activities through the EWD appropriations.

For FY 2005, Congress appropriated $224.7 million for the President's Hydrogen Fuel Initiative compared to the FY 2004 appropriation of $155.8 million. For FY 2006, President Bush requested $259.5 million (appropriations yet to be finalized as of publication date). These numbers include support for hydrogen and polymer fuel cell R&D across four DOE offices – Energy Efficiency and Renewable Energy; Fossil Energy; Nuclear Energy, Science and Technology; and Science – and the Department of Transportation.

International Partnership for the Hydrogen Economy (IPHE) Endorses Ten Hydrogen Projects

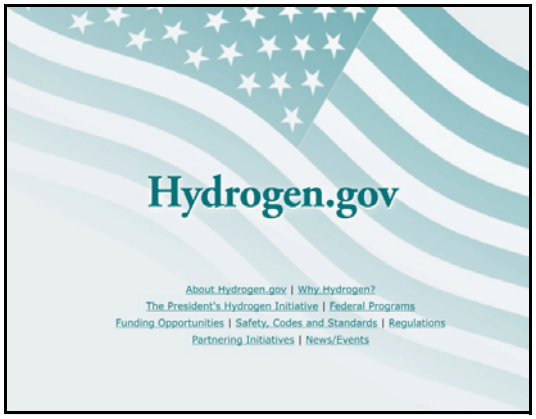
Led by Under Secretary of Energy David K. Garman, the 16-member IPHE Steering Committee met in Kyoto, Japan, on September 14 and 15, 2005, and endorsed ten collaborative hydrogen and fuel cell research, development and demonstration projects. According to Under Secretary Garman, "These efforts have the potential to significantly advance the move towards a hydrogen economy."

All projects are collaborative in nature with multiple IPHE members as sponsors. Results and lessons learned from the projects will be disseminated to all IPHE members and will be made available to the public. These selections are the first IPHE recognition provided to collaborative research projects on hydrogen and fuel cell development. Detailed information is available on the IPHE website (www.iphe.net).

IPHE Projects to Advance Hydrogen Economy

- Hydrogen Delivery Using Natural Gas Pipelines
- Solar Driven High Temperature Thermochemical Production of Hydrogen
- Reversible Solid State Hydrogen Storage for Fuel Cell Power Supply System
- Advanced Membranes
- Fuel Cell Testing, Safety and Quality Assurance (FCTES^{qa})
- Application of Gradient Porous Composite MEAs for Different Types of Fuel Cells
- HyWays - The Development and Detailed Evaluation of a Harmonised "European Hydrogen Energy Roadmap"
- HySafe – Safety of Hydrogen as an Energy Carrier
- Solar Hydrogen From Reforming Of Methane
- Clean Urban Transport For Europe - Ecological City TranspOrt System (CUTE - ECTOS)

Hydrogen Federal Advisory Committee and Interagency Task Force Being Established

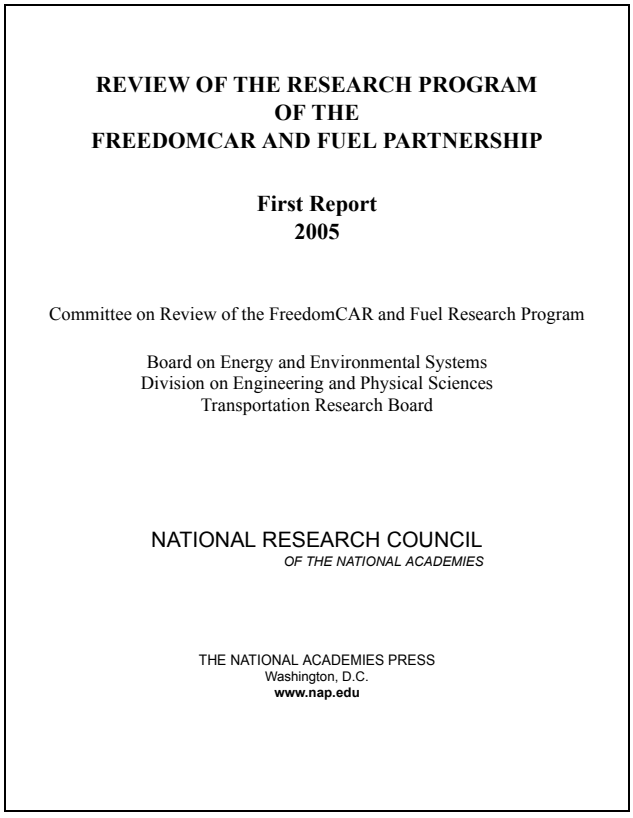


The Energy Policy Act of 2005 authorized establishment of a Hydrogen and Fuel Cell Technical Advisory Committee (HTAC), a follow-on to the Hydrogen Technical Advisory Panel authorized by the Hydrogen Future Act of 1996. This Federal Advisory Committee will be comprised of 12 to 25 expert members from domestic industry, academia, professional societies, government agencies, Federal laboratories, previous advisory panels, as well as financial, environmental, and other appropriate organizations. The Committee will review and make recommendations to the Secretary on (1) the implementation of programs and activities under Title VIII, Hydrogen, of the Act; (2) the safety, economical, and environmental consequences of technologies for the production, distribution, delivery, storage, or use of hydrogen energy and fuel cells; and (3) the Secretary's plan to conduct the programs under Title VIII. The HTAC member selection process and initial meeting will take place in FY 2006.

At the Federal government level, inter-department/agency cooperation is also critical to the success of the President's Hydrogen Fuel Initiative. Shortly after the President's announcement in early 2003, the White House Office of Science and Technology Policy established the interagency Hydrogen Research and Development Task Force. The Task Force serves as the key mechanism for collaboration among the eight Federal agencies that fund hydrogen-related research and development. It developed a web site (www.hydrogen.gov) to widely communicate the goals of the President's Hydrogen Fuel Initiative and encourage greater collaboration and sharing of information on hydrogen technology development activities. The Energy Policy Act of 2005 also underscored the need for interagency collaboration at the federal level by requiring the President to establish a Hydrogen and Fuel Cell Technical Task Force chaired by the Secretary of Energy with representatives from other departments and agencies with hydrogen and fuel cell programs. The act defines numerous planning and execution activities for this task force, all tied to ensuring efficiency in use of taxpayer resources.

National Research Council Reviews FreedomCAR and Fuel Partnership

The DOE engaged the National Academies to review and report on the FreedomCAR and Fuel Partnership, a collaborative effort among the DOE, USCAR (Ford, Chrysler, and General Motors), and five major energy companies (BP, Chevron, ConocoPhillips, ExxonMobil, and Shell). The Partnership seeks to develop advanced vehicle and fueling infrastructure technologies to reduce our Nation's dependence on imported oil and minimize harmful emissions without sacrificing freedom of mobility and freedom of vehicle choice. In August 2005, the National Academies' National Research Council (NRC) press release reported that "the Partnership is well-planned and identifies all major hurdles the program will face," and acknowledged the significant progress already made by the Partnership toward overcoming the many technical barriers. The press release quoted Craig Marks, chair of the NRC review committee and retired Vice President for Technology and Productivity at Allied Signal, Inc., as follows: "The goals of this program are extremely challenging and success is uncertain, but it could have an enormous beneficial impact on energy security and the U.S. economy. Although it is still too early to speculate whether the program will achieve its long-term vision, it is making significant headway."



REVIEW OF THE RESEARCH PROGRAM OF THE FREEDOMCAR AND FUEL PARTNERSHIP

First Report 2005

Committee on Review of the FreedomCAR and Fuel Research Program

Board on Energy and Environmental Systems
Division on Engineering and Physical Sciences
Transportation Research Board

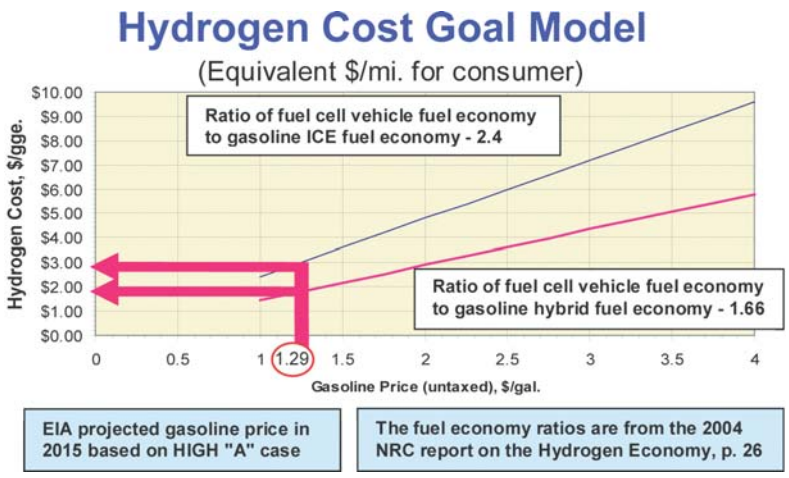
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

The report (available at http://www.nap.edu/books/0309097304/html/) stated that hydrogen storage in vehicles is the program's most difficult long-term challenge. Other areas with key findings and recommendations included safety, codes and standards, systems analysis, environmental effects, and public awareness. This report followed approximately 18 months behind the NRC February 2004 release entitled "The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs." Together, these two important independent assessments of the nation's hydrogen program have provided critical inputs to the strategy and planning for the next decade of hydrogen, fuel cell, and vehicle research and development.

Hydrogen Research Cost Target Revised to Be Energy Resource Independent and Competitive with Future Technologies

The research target for hydrogen production cost has been changed based on anticipated future technologies, including projected gasoline prices and relative fuel economies of future vehicles which will be in competition with the hydrogen fuel cell vehicle. The new methodology provided a hydrogen research cost of $2.00-3.00/gge (delivered, untaxed, 2005$, by 2015), which is independent of the feedstock or delivery pathway used to produce and distribute hydrogen.



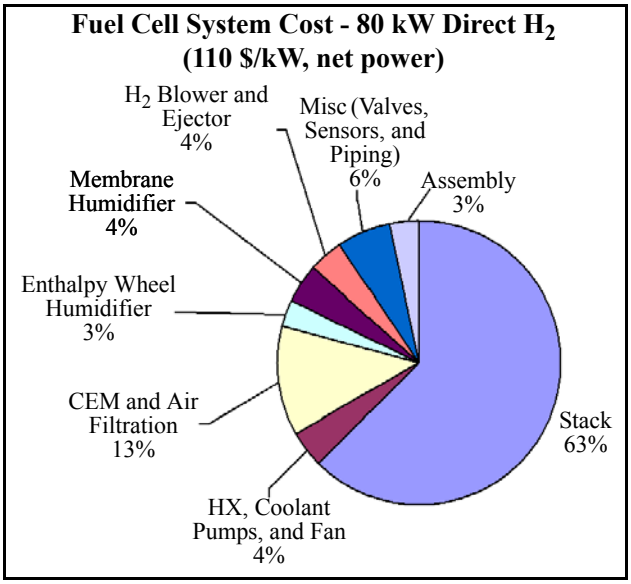
The upper boundary is based on the expected ratio between fuel cell vehicle and evolved gasoline internal combustion engine vehicle fuel economies in 2015, and represents a threshold cost to be used to screen or eliminate pathway options that cannot demonstrate an ability to meet the research goal. The lower boundary is based on the expected ratio between fuel cell vehicle and gasoline hybrid-electric vehicle fuel economies in 2015, and defines a lower hydrogen research cost goal to be used to prioritize projects for resource allocation. The hydrogen goals at both boundaries were then calculated using gasoline prices projected by the Energy Information Administration (EIA) for the year 2015, expressed in 2005 U.S. dollars. In the EIA High A case selected, the U.S. economy is more vulnerable to limited oil supplies from foreign sources due to the increasing world and U.S. oil demand, resulting in higher oil prices.

The hydrogen cost goal may be changed in the future if warranted by changes in vehicle system energy efficiency characteristics and/or gasoline price projections.

Program Continues to Reduce High-Volume Fuel Cell Cost Projections

For hydrogen vehicles to be cost competitive with other technology vehicles, it is critical that the high-volume production cost of fuel cells be competitive with that of other power systems on a net power basis. Therefore, achieving the DOE and FreedomCAR and Fuel Partnership $30/kW cost goal by 2015 is one of the most critical technical targets of the DOE Hydrogen Program.

In the early 1990s, DOE estimated that the high-volume (500,000 units per year) fuel cell cost was approximately $3,000/kW, i.e., two orders of magnitude above our goal. Over the last 15 years, through private and taxpayer investment in research, fuel cell costs have steadily decreased. Analysis by TIAX LLC shows that we are now approaching a high-volume cost of $110/kW (bettering the 2005 target of $125/kW) and continuing to make steady progress toward $30/kW. In



Courtesy of TIAX LLC

FY 2006, DOE will commission and independent peer review of the assumptions and methodology used in this analysis to determine whether the result is valid. Although progress has been substantial, further cost reductions are becoming increasingly challenging as we try to achieve $45/kW by 2010 on the way to the 2015 goal.

Manufacturing R&D for the Hydrogen Economy in Planning Stage

Courtesy of Ballard Power Systems

In early 2005, under the sponsorship of the Manufacturing Interagency Working Group (IWG) of the Committee on Technology, National Science and Technology Council (NSTC), an effort began to focus our nation's manufacturing research and development (R&D) on three priority areas: Manufacturing for the Hydrogen Economy, Nanomanufacturing, and Intelligent and Integrated Manufacturing Systems. DOE has taken the lead on the first of these, and the DOE Hydrogen Program has assumed responsibility within the Department to plan this effort.

The Hydrogen Fuel Initiative focuses on researching, developing, and validating critical hydrogen and fuel cell technologies. As industry prepares for its commercialization decisions on these technologies around 2015, it is crucial that manufacturing processes be developed concurrently to (1) reduce the costs of hydrogen systems to levels competitive with petroleum-based systems, and (2) build the necessary manufacturing infrastructure and supplier base to support the hydrogen economy. In July 2005, DOE began planning by holding a "Workshop on Manufacturing R&D for the Hydrogen Economy." Participants from industry, government, national laboratories, and academia reviewed the current state of R&D and identified manufacturing R&D needs for systems that produce, deliver, store, and use (e.g., fuel cells) hydrogen. The findings of this workshop will be used to prepare an R&D roadmap for release by January 2006.

Hydrogen Program Gains Momentum with New Projects

The breadth and depth of research, development, and demonstration activities within the DOE Hydrogen Program were significantly enhanced during FY 2004 and 2005 with the initiation of new competitively selected projects totaling approximately $510 million ($755 million with private cost share), subject to appropriations. These projects will work to overcome critical technology barriers and to bring hydrogen and fuel cell technology from the laboratory to the showroom. New projects span the following technology areas:

- Basic Science: Selected 70 projects ($64 million over three years) in basic research to address the fundamental science underpinning hydrogen production, storage, and end use.
- Hydrogen Production and Delivery: Began funding 65 new hydrogen production and delivery projects ($107 million over four years) in 2005, covering renewable, nuclear, and coal-based hydrogen production and delivery technologies.
- Hydrogen Storage: Initiated a National Hydrogen Storage Project ($150 million over five years) that includes three Centers of Excellence, over 20 independent projects addressing applied research, and incorporating new basic research projects.
- Fuel Cells: Initiated five projects that address critical fuel cell cost and durability issues for transportation, consumer electronics, and other applications ($13 million over three years).

- Technology Validation: Established a national vehicle and infrastructure "learning demonstration" project ($170 million for four teams over six years) to measure progress and help guide research and development.
- Education: Created three Hydrogen Technology Learning Centers, held pilot "Hydrogen 101" Workshops for state and local governments in six states, and launched middle school and high school curricula and teacher professional development programs ($5 million over five years).

Basic Research Addresses the Program's Key Technical Challenges

The Basic Energy Sciences (BES) office within the DOE Office of Science is a critical member of the DOE Hydrogen Program team, providing fundamental research in the most technically challenging areas facing the Program. This basic work complements the applied research and development projects conducted by the Offices of Energy Efficiency and Renewable Energy; Fossil Energy; and Nuclear Energy, Science and Technology. In May 2005, Secretary of Energy Samuel W. Bodman announced the selection of over $64 million in BES research projects addressing hydrogen and fuel cell technologies in the following five areas:

- Novel Materials for Hydrogen Storage
- Membranes for Separation, Purification, and Ion Transport
- Catalyst Design at the Nanoscale
- Solar Hydrogen Production
- Bio-inspired Materials and Processes

These five technical focus areas were identified during DOE's May 2004 workshop sponsored by BES on "Basic Research Needs for the Hydrogen Economy." The 2005 awards include over 50 preeminent research organizations in 25 states, and typically are funded for three years. A more detailed description of the research as well as listings of the projects awarded in each of the five categories is found in Section II of this report.

Hydrogen-from-Coal Projects Awarded by the Office of Fossil Energy

In FY 2005 the Office of Fossil Energy announced the award of 32 clean coal research projects to advance President Bush's goal to develop a coal-fired zero emissions power plant. This initiative will also advance other energy-related policy initiatives in hydrogen and climate, including the FutureGen zero-emissions power plant of the future. Secretary Bodman stated, "Coal is our most abundant fuel resource. It's important that we find ways to use it in a cleaner, more efficient way in order to provide the energy needed to continue our economic growth and job creation. All of these projects are an investment in our Nation's energy and economic security, present and future." Among the objectives of the research specifically related to hydrogen and fuel cells are (1) improved and new methods of producing pure hydrogen in coal gasification, and (2) hydrogen handling and safe storage.

Projects Awarded for Nuclear Hydrogen Research in FY 2005

The nuclear hydrogen initiative focuses primarily on hydrogen production technologies that utilize high-temperature nuclear reactors to produce hydrogen. In support of the DOE Hydrogen Program, this initiative within the Office of Nuclear Energy, Science and Technology awarded three projects during FY 2005 related to the production of hydrogen via high-temperature processes (thermochemical and high-temperature electrolysis). These awards were to (1) Clemson University for "The Sulfur-Iodine Cycle: Process Analysis and Design Using Comprehensive Phase Equilibrium Measurements and Modeling," (2) Johns Hopkins University for "Silicon Carbide Ceramics for Compact Heat Exchangers," and (3) University of Wisconsin for "Salt Heat Transport Loop: Materials Corrosion and Heat Transfer Phenomena." This important research

paves the way for demonstration of large-scale, emission-free production of hydrogen with nuclear energy, and eventually integrating a hydrogen production demonstration with a Generation IV nuclear reactor.

Learning Demonstration Kicks into High Gear in 2005

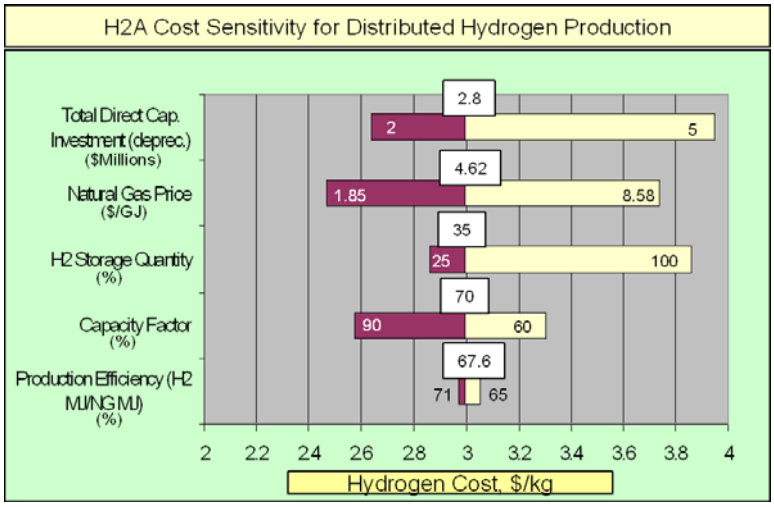
Secretary of Energy Samuel Bodman and Under Secretary David Garman kick off the National Hydrogen Learning Demonstration in Washington, D.C.

The National Hydrogen Learning Demonstration commenced this year with a kick-off event at the National Hydrogen Association Annual Hydrogen Conference 2005 in Washington, D.C. Over the course of five years the four selected teams will work to assess the status of hydrogen infrastructure and fuel cell vehicle technology against time-phased, performance-based targets. Everything from fuel cell durability and efficiency to vehicle range and fuel cost will be tested under a variety of climate and use conditions, employing several hydrogen infrastructure options.

Data acquired through the vehicle and infrastructure technology demonstration projects will be used to refocus research and development, benchmark technology status, and raise public awareness of hydrogen technology. Each project includes a comprehensive safety plan, an activity to assist in developing codes and standards, and a comprehensive, integrated education and training campaign. Teams are DaimlerChrysler and BP, Ford and BP, General Motors and Shell, and Chevron and Hyundai-Kia, and also are supported by hydrogen suppliers, fuel cell suppliers, electric utility and/or gas companies, fleet operators, system and component suppliers, small businesses, universities and government entities. The new Energy Policy Act of 2005 strongly supports the Learning Demonstration effort as an important element of the Program's push toward a 2015 commercialization decision.

H2A Models Support Transparency in Program Analysis Activities

The National Renewable Energy Laboratory, in collaboration with industry, led the Hydrogen Analysis (H2A) group in developing a hydrogen production cost model. The H2A model addresses the need for consistent analysis methodology and transparent reporting independent of hydrogen production pathway. This cash flow analysis tool, which assesses the minimum hydrogen cost (including a profit factor) for a variety of hydrogen production pathways, will be used by the Program, its contractors, and stakeholders to evaluate technologies on a common basis, to assess technology tradeoffs, and to aid systems analysis efforts. The H2A forecourt and central hydrogen production models have been peer reviewed and beta tested using several hydrogen production pathways,



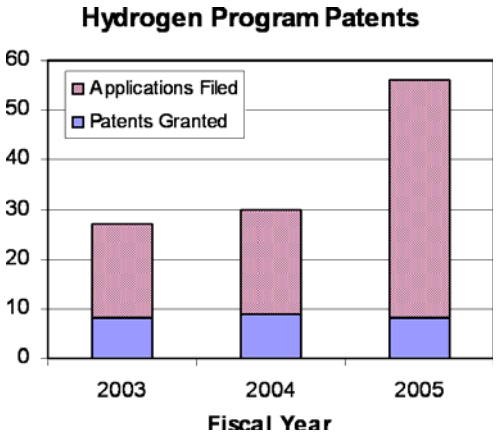
Example H2A Distributed Natural Gas Hydrogen Production Cost Sensitivity Analysis

including coal, natural gas, biomass, electrolysis, and forecourt receiving and dispensing. An H2A model assessing hydrogen delivery options has also been developed and beta tested and will be issued in FY 2006.

The H2A group is composed of members from national laboratories, industry, and academia. In addition, it has sixteen Key Industry Collaborator (KIC) companies which have supported the analysis and model development, providing key recommendations and peer review functions. The production models are currently available through http://www.hydrogen.energy.gov/h2a_analysis.html, so that all interested parties can utilize them.

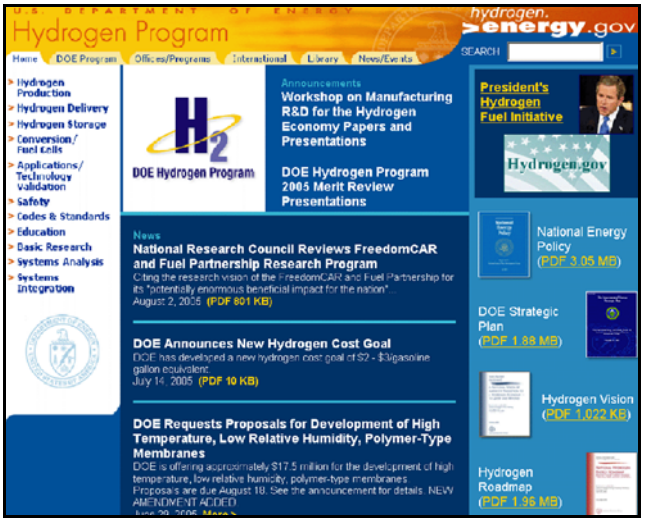
Hydrogen Program Participants Demonstrate Ability to Innovate

One measure of the innovation and robustness of a research and development program is the numbers 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 sponsored by the Program. During FY 2005, eight patents were issued to Hydrogen Program projects, including one international patent. In addition, a large increase in the number of patent applications occurred in 2005 (48) compared to the previous year (22). With over 100 new projects starting in 2005, the Program can expect these numbers to continue to be strong over the next several years. Congratulations to all researchers whose work is critical to the Program's success and is being acknowledged via the patent process.

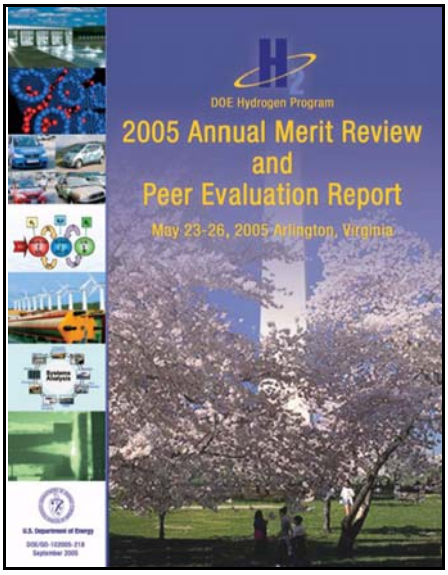


DOE Hydrogen Program Launches New Website

A new DOE website launched in 2005 provides a focal point for all Department of Energy activities under the President's Hydrogen Fuel Initiative. The website includes news, documents, announcements, and descriptions of technologies. It contains convenient links which take the user directly to the hydrogen and fuel cell areas within the office-specific websites of the Offices of Energy Efficiency and Renewable Energy; Fossil Energy; Nuclear Energy, Science and Technology; and Science. The site is developed and maintained by the Systems Integration office of the Program, and its URL is www.hydrogen.energy.gov.



2005 Annual Merit Review and Peer Evaluation Held in Arlington, Virginia



The DOE Hydrogen Program held its annual review in May in Arlington, Virginia. This was the largest review to date, with Principal Investigators (PIs) of 300 projects providing oral briefings or poster presentations. A panel of 150 technical experts covering all aspects of hydrogen and fuel cell technologies conducted peer reviews of 200 of those projects. The findings and recommendations of the peer reviewers are used by the project PIs to guide their future work, and by the Technology Development Managers at DOE to make programmatic and funding decisions for the upcoming fiscal year. Those projects that were not peer reviewed were typically ones that had just started in the six months preceding the May meeting. Hydrogen Program projects from the Offices of Fossil Energy and Nuclear Energy, Science and Technology were also part of the process for the first time. This gave the hydrogen community and its stakeholders the opportunity to see the full breadth and depth of the DOE program in one venue. The Office of Science, whose hydrogen and fuel cell-related awards were announced the same week as the review, provided an overview of its emerging program and will be more fully involved in the 2006 meeting as its projects begin to make progress. The proceedings and final report from the 2005 review can be found on the Program's website at http://www.hydrogen.energy.gov/annual_review05.html. The 2006 meeting is scheduled to be held May 16-19 in Washington D.C.

We are pleased to present the U.S. Department of Energy's Hydrogen Program Annual Progress Report for Fiscal Year 2005. The accomplishments of 286 projects currently sponsored by the Hydrogen Program are presented herein. Preceeding each technology area (e.g., storage, fuel cells, etc.), DOE Technology Development Managers provide an overview that summarizes the progress made in each area. We welcome suggestions for improving the ability of the Hydrogen Program to impact the realization of a hydrogen economy.

Steve Chalk, Program Manager
DOE Hydrogen Program