August 2006

Hydrogen Program Goal-Setting Methodologies

Report to Congress

(ESECS EE-4015)

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Introduction

This report addresses section 1819 of Public Law 109-58, also referred to as the Energy Policy Act of 2005. Section 1819 states:

> *"Not later than 1 year after the date of enactment of this Act, the Secretary shall submit to Congress a report evaluating methodologies to ensure the widest participation practicable in setting goals and milestones under the hydrogen program of the Department, including international participants."*

In response to section 1819, the United States Department of Energy (DOE) delivers this report to document the level of participation by national and international entities in, and the openness of, the process of setting goals and milestones in the DOE Hydrogen Program (Program).

This report describes DOE's process for setting the goals of the Program and the extent of international participation in that process. The Program incorporated input from its diverse stakeholder community using planning workshops, public comment opportunities, independent third-party reviews, and targeted outreach to technology experts. The report also summarizes planning documents used by DOE and catalogs the main planning workshops that have helped to define research and development (R&D) priorities and technical targets. This report also provides examples of how external input has shaped the development of Program goals and milestones.

Background

The Program supports President Bush's vision, as expressed in the 2006 State of the Union address, of reducing America's addiction to oil.[1] The President's Hydrogen Fuel Initiative, launched in 2003, commits $1.2 billion over five years to accelerate research, development and demonstration of hydrogen and fuel cell technologies.[2] These technologies can ultimately help shift America's primary transportation fuel from petroleum, which is increasingly imported, to hydrogen, which can be produced using a wide variety of domestic feedstocks. Development of hydrogen energy will help ensure that the United States (U.S.) has an abundant, reliable, and affordable supply of clean energy to maintain the Nation's prosperity throughout the 21st century.

The mission of the Program is to research, develop and validate hydrogen production, delivery, storage and fuel cell technologies so that hydrogen from diverse domestic resources can be used in a clean, safe, reliable and affordable manner in hydrogen fuel cell vehicles and stationary power applications. If the research is successful, the U.S. could realize the energy, environmental and economic benefits of a hydrogen economy. The goals and milestones of the Program support the timeline of the President's vision. The high-level objectives are the product of extensive discussions, roadmapping activities and open workshops with government, industry,

[1] Bush, George W. "2006 State of the Union Address." Capitol, Washington. 28 Jan. 2003. Available on the Web at <http://www.whitehouse.gov/stateoftheunion/2006/>.
[2] Office of the President. "Hydrogen Fuel: A Clean and Secure Energy Future." 30 Jan. 2003. Available on the Web at <http://www.whitehouse.gov/news/releases/2003/01/20030130-20.html>.

national laboratory, non-profit and university stakeholders, and participants representing both domestic and international organizations. Lower-level goals and milestones connect to the high-level goals in planning documents and incorporate expert and stakeholder opinion in every phase of development and review.

DOE Hydrogen Program High-Level Goals

At the highest level, the Program goals are set to be competitive with the projected performance and cost requirements of vehicles and fuels in the U.S. For example, the cost target for hydrogen production is tied to the Energy Information Administration's projections of gasoline prices; the cost of hydrogen at the pump should be equivalent on a cost-per-mile basis to the estimated fuel cost of operating vehicles on gasoline. Similarly, the cost of an automotive fuel cell system must be competitive with the cost of an internal combustion engine drivetrain.

In general, high level Program goals are in exact agreement with the FreedomCAR and Fuel Partnership (Partnership) goals. The Partnership provides a mechanism for helping to identify vehicle and fuel goals appropriate for the North American market. The Partnership is a unique public-private partnership among the following members: DOE, BP America, Chevron Corporation, ConocoPhillips, Exxon Mobil Corporation, Shell Hydrogen LLC and the United States Council for Automotive Research (USCAR)—a legal partnership among the DaimlerChrysler Corporation, Ford Motor Company and General Motors Corporation.

According to its guiding document, *The FreedomCAR and Fuel Partnership Plan,* the Partnership is "an effort to examine and advance the pre-competitive, high-risk research needed to develop the component and infrastructure technologies necessary to enable a full range of affordable cars and light trucks, and the fueling infrastructure for them that will reduce the dependence of the nation's personal transportation system on imported oil and minimize harmful vehicle emissions, without sacrificing freedom of mobility and freedom of vehicle choice. The partners jointly conduct technology roadmapping, determine technical requirements, suggest R&D priorities, and monitor the R&D activities necessary to achieve the Partnership's Research Goals."[3] The exact structure and management processes of the Partnership are outlined fully in the Plan.

The overall goals of the Hydrogen Program are the hydrogen-related major goals of the Partnership, listed in Table 1. DOE works within and outside the Partnership to develop, eliminate, reassess, modify or adopt these high-level goals. Though these goals are established and modified via internal deliberations among members of the Partnership, external information from outside the Partnership, including that provided by international organizations, is always used as an input to the process.[4] DOE provides the results of research projects, independent reviews and technology workshops to inform the process of determining the high-level goals of

[3] *The FreedomCAR and Fuel Partnership Plan* is publicly available on the Web at <http://www.eere.energy.gov/vehiclesandfuels/pdfs/program/fc_fuel_partnership_plan.pdf>.

[4] The FreedomCAR Partnership, an agreement between USCAR and DOE, initially developed the goals. After the 2003 launch of the Hydrogen Fuel Initiative, the five energy partners joined the Partnership (renamed the FreedomCAR and Fuel Partnership) and accepted the established goals and targets. After the expansion of the Partnership, all members have participated in developing new goals or modifying existing goals.

the Partnership and modifying them, where necessary (see Case Study: Fuel Processing Go/No-go Decision).

Table 1: FreedomCAR and Fuel Partnership Goals[3]

FreedomCAR and Fuel Partnership
Technology-Specific 2010 and 2015 Research Goals[5]

This table summarizes the key technical goals for the 2010 and 2015 timeframes. The technical teams will identify the need for additional goals, as appropriate, for proposal to the Executive Steering Group.

- To ensure reliable systems for future fuel cell powertrains with costs comparable to conventional internal combustion engine/automatic transmission systems, the goals are:
    - Electric Propulsion System with a 15-year life capable of delivering at least 55kW for 18 seconds, and 30kW continuous at a system cost of $12/kW peak.
    - 60% peak energy-efficient, durable fuel cell power system (including hydrogen storage) that achieves a 325 W/kg power density and 220 W/L operating on hydrogen. Cost targets are at $45/kW by 2010 ($30/kW by 2015).[6]
- To enable clean, energy-efficient vehicles operating on clean, hydrocarbon-based fuels powered by internal-combustion powertrains, the goal is:
    - Internal combustion engine powertrain systems costing $30/kW, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards.
- To enable reliable hybrid electric vehicles that are durable and affordable, the goal is:
    - Electric drivetrain energy storage with 15-year life at 300 Whr per vehicle with discharge power of 25 kW for 18 seconds and $20/kW.
- To enable the transition to a hydrogen economy, ensure widespread availability of hydrogen fuels, and retain the functional characteristics of current vehicles, the goals are:
    - Demonstrated hydrogen refueling with developed commercial codes and standards and diverse renewable and non-renewable energy sources with a cost of energy from hydrogen equivalent to gasoline at market price, assumed to be $2.00-3.00 per gallon gasoline equivalent produced and delivered to the consumer independent of pathway by 2015.[7]
    - On-board Hydrogen Storage Systems demonstrating specific energy of 2.0 kWh/kg (6 weight percent hydrogen), and energy density of 1.5 kWh/liter at a cost of $4/kWh by 2010 and specific energy of 3.0 kWh/kg (9 weight percent hydrogen), 2.7 kWh/liter, and $2.00/kWh by 2015.
    - Internal combustion engine powertrain systems operating on hydrogen with a cost target of $45/kW by 2010 and $30/kW in 2015, having a peak brake engine efficiency of 45%, and that meet or exceed emissions standards.

[5] Cost references based on calendar year 2001 dollar values. Where power (kW) targets are specified, those targets are to ensure that technology challenges that would occur in a range of light-duty vehicle types would have to be addressed.
[6] Does not include vehicle traction electronics.
[7] Based on lower heating value of hydrogen; allows over 300-mile range.

- To enable lightweight vehicle structures and systems, the goal is:
    - Material and manufacturing technologies for high volume production vehicles which enable/support the simultaneous attainment of:
        - 50% reduction in weight of vehicle structure and subsystems
        - affordability, and
        - increased use of recyclable/renewable materials.

The goals, and the progress toward them, are reviewed in an open manner. In August 2005, the National Research Council (NRC) of the National Academies completed a review of the FreedomCAR and Fuel Partnership and recognized that it is "well-planned and identifies all major hurdles the program will face," and that it "has already made an excellent start."[8] The charge to the NRC committee responsible for the review specifically identified the importance of goals and milestones. One of the committee's major responsibilities was to "[r]eview the challenging high-level technical goals and timetables for government and industry R&D efforts in the various technical areas."[9] The committee assessed in this regard that "[t]he partners of the FreedomCAR and Fuel Partnership have done a commendable job of establishing explicit goals for a wide variety of technologies…."[10] As is NRC procedure, the review process included the posting of committee meeting dates on a publicly-accessible website and all meetings, barring committee deliberations, were advertised and open for public attendance. The National Research Council will conduct biennial reviews of the Partnership and the related DOE programs.

[8] National Academies of Science. "'Clean' Vehicle Research Initiative on Track, But Many Challenges Ahead." 2 Aug. 2005. Available on the Web at <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=11406>.
[9] National Research Council. *Review of the Research Program of the FreedomCAR and Fuel Partnership.* Washington, D.C.: The National Academies Press. 2005. p.3.
[10] Ibid. p.41

Case Study: Fuel Processing Go/No-Go Decision

In 2004, DOE undertook a go/no-go decision process to assess the potential of research activities related to on-board processing of fuels, such as gasoline, natural gas and ethanol, to create hydrogen for use in a fuel cell in a vehicle. Both DOE and the Partnership had high-level cost and performance goals for on-board fuel processing, which was viewed as a bridging technology in the transition to the hydrogen economy. The go/no-go process was initiated because DOE, and members of the Partnership, questioned whether the research activities could achieve the established goals for on-board fuel processing in a timeframe to decrease overall oil consumption during the transition to the hydrogen economy.

The DOE requested that the Hydrogen Program System Integration Office at the National Renewable Energy Laboratory (NREL) convene an independent review panel of industry and academic experts to review data, conduct interviews and provide a technical recommendation about on-board fuel processing based upon the status, progress and potential of the technology to meet the DOE's and the Partnership's established goals. NREL issued a Federal Register notice encouraging external input to the panel from the public in the form of position papers and speakers on the topic. The Independent Review Panel (Panel) developed a recommendation utilizing this input, as well as surveys of the existing literature, DOE reports and interviews with fuel cell and fuel processor developers and users. According to the Panel's recommendation, on-board fuel processing would not achieve the DOE's and the Partnership's goals. The Panel recommended a "no-go" decision, citing the lengthy start-up time and energy penalty of start-up as areas where on-board fuel processing would not satisfy the system targets. The Panel also submitted recommendations on how on-board fuel processing research could continue with better potential for progress.

Using the input from the Panel and other Program information, DOE convened a Go/No-Go Decision Team, which recommended discontinuing research and development activities related to on-board fuel processing.[11] The DOE presented its decision to the Partnership where it served as a basis for the Partnership's decision to also remove its on-board fuel processing goal. Although only Partnership members have the authority to set and change Partnership goals, their decision to remove the on-board fuel processing goal and DOE's decision to remove its goal and discontinue R&D were based upon an important external input process which was undertaken in a public manner.

Detailed Planning

The high-level Program goals are supported by lower-level goals, technical targets and milestones, which are documented in the technology roadmaps and research, development and demonstration plans. These research plans are critical to keeping the Program on track and are the result of activities which involve and depend upon input from a broad range of domestic and international stakeholders.

[11] DOE. "On-Board Fuel Processing Go/No-Go Decision: DOE Decision Team Committee Report (Revised)." Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. August 2004. Available on the Web at <http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/committee_report.pdf>.

In November 2001, DOE convened a workshop of senior executives representing the energy and transportation industries, universities, environmental organizations, Federal and State government agencies, and national laboratories to discuss the potential role for hydrogen systems in America's energy future. The intent of the meeting was to identify a common vision for the hydrogen economy, the timeframe in which such a vision could be expected to occur, and the key milestones that would need to be accomplished to get there. The report, *A National Vision of America's Transition to a Hydrogen Economy – To 2030 and Beyond (Vision)*, which was published in February 2002, documents the results from this workshop.[12]

Following the Vision workshop, DOE convened a National Hydrogen Energy Roadmap Workshop in April 2002 to identify the path forward to achieving the vision. Here, domestic and international experts from industry, academia, national laboratories, and Federal and State agencies engaged in discussions to identify the current status of the technology, the critical challenges to making the technologies cost- and performance-competitive with other technologies and the research gaps and needs in technology and infrastructure areas related to hydrogen. These discussions were documented and the results were included in the *National Hydrogen Energy Roadmap (Roadmap)*, published in November 2002.[13]

The *Fuel Cell Report to Congress* was developed in early 2003 in accordance with a request in the Conference Report accompanying Public Law 107-63, enacted in November 2001.[14] This report outlined the economic and technical barriers to the use of fuel cells and included input from stakeholders representing 100 public and private sector organizations, including many international organizations and companies that participated in open meetings held across the Nation or provided independent comment and review.

The two major planning workshops and the report to Congress were critical to establishing the path forward for Federal activities supporting hydrogen technology research and development. The *Vision*, *Roadmap* and the *Fuel Cell Report to Congress* represent significant stakeholder input and identify the contributing individuals or organizations, including international organizations such as Air Liquide, Ballard Power Systems, BP, Honda, Stuart Energy (now owned by Hydrogenix), Kyocera, Natural Resources Canada, Motorola, Nissan, Panasonic, PDVSA/Citgo, Saudi Aramco, Shell, Siemens Westinghouse Power and Toyota.

Also in 2003, DOE used the portions of the *Roadmap* created for each of the key activities in the Hydrogen Program to develop the *Multi-Year Research, Development and Demonstration Program Plan* (MYPP) for the DOE Hydrogen, Fuel Cell and Infrastructure Program. The draft was subsequently posted to the Program website, with notices placed on the website and in the Federal Register, for public comment between June 3 and August 15, 2003. A primary

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[12] DOE. *A National Vision of America's Transition to a Hydrogen Economy – To 2030 and Beyond.* Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. February 2002. Available on the Web at <http://www.hydrogen.energy.gov/pdfs/vision_doc.pdf>.

[13] DOE. *National Hydrogen Energy Roadmap.* Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. November 2002. Available on the Web at <http://www.hydrogen.energy.gov/pdfs/national_h2_roadmap.pdf>.

[14] DOE. *Fuel Cell Report to Congress (ESECS EE-1973).* Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. February 2003. Available on the Web at <http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/fc_report_congress_feb2003.pdf>.

component of a 2002-2004 review by the National Research Council and the National Academy of Engineering of the National Academies was to assess the effectiveness of the MYPP and to provide recommendations for improvement (this review was conducted previous to the National Academies' review of the Partnership noted on page 5). Again, the panel's review of the Program included posting of the dates and times of the panel's open meetings. The NRC published a report outlining the recommendations of the review titled *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*.[15] The committee was "impressed by how well the hydrogen program has progressed,"[16] but also provided feedback on improvements that could be made. These included expansion of the MYPP structure to include plans on the work of the Offices of Science, Fossil and Nuclear Energy.

Technology-focused roadmap workshops have helped to initially develop plans for research programs and sub-programs and have also been used to establish technical targets. These workshops bring together domestic and international experts from industry, academia, national laboratories and government to discuss technology status and potential and to develop a clear picture of the path forward and the role of the Federal Government on that path. A July 2005 workshop initiated the development of the *Roadmap on Manufacturing R&D for the Hydrogen Economy*. DOE, in collaboration with the U.S. Department of Commerce, sponsored a workshop, which was open to the public and was advertised on the Department's website. The participants, totaling over 100, included representatives from the Federal Government, domestic and foreign industry, universities, national laboratories who provided input on the research needs for hydrogen and fuel cell manufacturing. International organizations represented included Air Liquide, Ballard Power Systems, Japan Steel Works, and Toyota. The draft report was completed and posted to the Program website for comment on January 24, 2006, and was available for review for 120 days by the hydrogen and fuel cell community and those at-large. Other DOE hydrogen technology-focused workshops are identified in Table 2.

Table 2: DOE Hydrogen Program Technology Workshops

Workshop	Date
Fuel Cells for Portable Power Workshop	January 2002
Fuel Cells for Buildings and Stationary Applications Roadmap Workshop	April 2002
Hydrogen Storage Materials Workshop	August 2002
Workshop on Compressed and Liquefied Hydrogen Storage	October 2002
Education Plan Workshop	December 2002
Hydrogen Storage "Think Tank" Meeting	March 2003

[15] National Research Council/National Academy of Engineering. *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*. Washington, D.C.: The National Academies Press. 2004. Available on the Web at <http://fermat.nap.edu/catalog/10922.html>.
[16] Ibid. p.6.

Non-Platinum Electrocatalysts Workshop	March 2003
Strategic Directions for Hydrogen Delivery Workshop	May 2003
Workshop on Basic Research Needs for the Hydrogen Economy	May 2003
Workshop on Electrolysis Production of Hydrogen from Wind and Hydropower Proceedings	September 2003
Hydrogen Codes and Standards Coordinating Committee Fuel Purity Specifications Workshop	April 2004
Workshop on Hydrogen Production via Direct Fermentation	June 2004
Hydrogen Systems Analysis Workshop	July 2004
Electrolysis-Utility Integration Workshop proceedings	September 2004
Workshop on Hydrogen Separations and Purification Technologies	September 2004
Hydrogen Pipeline R&D Project Review Meeting	January 2005
Hydrogen Delivery High-Pressure Tanks and Analysis Project Review Meeting	February 2005
Fuel Cell Operations at Sub-Freezing Temperatures Workshop	February 2005
Hydrogen Safety Risk Assessment Workshop	March 2005
Fuel Cell Pre-Solicitation Workshop	May 2005
Workshop on Manufacturing R&D Technologies for the Hydrogen Economy	July 2005
Hydrogen Pipeline Working Group Workshop	August 2005
Hydrogen Delivery and On-Board Storage Analysis Workshop	January 2006
Hydrogen Transition Analysis Workshop	January 2006
Hydrogen Safety Risk Assessment II Workshop	March 2006

Most recently, in May 2006, DOE hosted a Plug-In Hybrid Vehicle Workshop to gather information on current status, barriers and research needs for the development of the technology necessary to enable commercialization of plug-in hybrid vehicles. Over 120 experts from national laboratories, automobile industry, energy industry, utilities and universities representing U.S. and international organizations came together to provide input and make recommendations regarding the potential of the technology and the possible Federal role in developing plug-in

hybrid vehicles. The results of the workshop will be used to generate a report, which DOE will submit to the FreedomCAR and Fuel Partnership for its consideration. Technologies developed for plug-in hybrid vehicles could impact the design of future fuel cell vehicles.

Program Implementation

The research and development activities of the Hydrogen Program address the goals and milestones in the Program planning documents. The projects funded by the Program are awarded using competitive solicitations which are open for proposal submission and independently reviewed for selection. International organizations and companies are welcome to submit proposals and are awarded research projects if selected in the independent review process and if they fulfill specific criteria, such as those required by the Federal Acquisition Regulations (e.g., demonstrated benefit to the U. S.). Each year, experts peer-review projects funded by the Program to assess their progress. Periodically, technology-specific workshops are held to assess potential of the technology and progress against targets.

The Hydrogen Program utilizes pre-solicitation workshops to involve hydrogen and fuel cell stakeholders in the development of potential funded R&D topics and to inform stakeholders of the procedures for applying for Federal funding. These workshops are open to the public and advertised on the website. In March 2003, DOE hosted a pre-solicitation workshop for the planned Hydrogen Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project solicitation.[17] This workshop included over 100 representatives from the domestic and international automobile industry, energy industry, and supplier organizations.[18] DOE representatives discussed the planned topic, structure, cost-sharing and other requirements of the solicitation to ensure that potential participants were informed of the process of application. As a result of the solicitation, four project teams are currently participating in the Demonstration and Validation Project, known as the Learning Demonstration Project. Each team includes a multi-national automobile company and energy company and participants include: BP, Chevron Corporation, DaimlerChrysler, Ford Motor Company, General Motors, Hyundai-Kia and Shell Hydrogen, LLC.

Also in 2003, DOE hosted the Hydrogen Storage Grand Challenge Pre-Solicitation Meeting to provide information to the technical community about the solicitation, and to provide a forum for representatives from national laboratories, universities, small businesses, and industry to interact and explore potential partnerships. As a result, the three Centers of Excellence created through the solicitation include over 30 organizations collaborating on solving the technical barriers to hydrogen storage in materials.

In preparation for releasing a major fuel cell research solicitation, with an anticipated Federal share of $70 million, the Program undertook an extensive, input-driven planning process to develop the topics for the solicitation. One month prior to an open Pre-Solicitation Workshop

[17] DOE. "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project Solicitation." 10 March 2006. Available on the Web at <http://www1.eere.energy.gov/hydrogenandfuelcells/2003_solicitation_notice.html>.

[18] DOE. "Attendee of Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project Pre-Solicitation Workshop." 19 March 2003. Available on the Web at <http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/presolicitation_attendees_031903.pdf>.

held in conjunction with the Program's May 2005 Annual Merit Review, the DOE developed and issued a potential Scope of Work for public comment on the Program website. The public submitted comments and questions, as well as suggestions for other potential topics. The Pre-Solicitation Workshop included over 300 attendees. At the workshop, questions and public comments were collected and addressed and then used to modify the solicitation before release.[19] The fuel cell solicitation, issued on January 24, 2006, included a topic supporting international stationary fuel cell research and demonstration activities to encourage collaboration between researchers in the U.S. and other countries.

As mentioned above, each May DOE convenes the Program Annual Merit Review where the status, accomplishments and research plans of DOE-funded applied research, technology development and demonstration projects are independently evaluated by experts. The review brings together scientists and engineers conducting research funded by the Program, including those involved in basic research projects in key technical areas. This meeting has open registration and is advertised on the Program website. Most recently, in May 2006, the Annual Merit Review included over 800 attendees, of which nearly 90 were international participants. Reviewers who have expertise in the specific area of the Program are selected to provide feedback on the projects, which is used to make decisions about future funding, research directions and research potential. In addition to identified reviewers, any attendee is welcome to review projects of interest to them. In the 2005 and 2006 reviews, representatives from Brazil, the European Commission, Japan and Russia formally participated as presenters and/or reviewers. All reviewers, including international participants, are welcome to provide comments on the overall Program portfolios in each of the key activities related to their expertise. Comments are posted on the DOE website[20] in the *Annual Merit Review and Peer Evaluation Report*, which is published every year.

Technology progress and status workshops provide opportunities to periodically reassess progress and status of a particular technology, which in turn provides feedback into the goal and milestone assessment processes. In February 2005, DOE sponsored a Fuel Cell Operations at Sub-Freezing Temperatures Workshop to predict the likely effects of freezing temperatures on fuel cell operation, to identify and prioritize the technical barriers associated with freezing or sub-freezing temperatures and to develop a research, development and demonstration plan to overcome these barriers. This workshop was advertised to the public and had open registration. Over 50 participants attended, including representatives from fuel cell component and stack manufacturers, analysts, researchers, domestic government officials, and an official from Korea, and provided input on the status of the technology. As a result of this workshop, DOE refined the fiscal year 2006 fuel cell solicitation topics to include the effects of sub-freezing temperatures on fuel cell components to attempt to address some of the challenges identified in the workshop.

These progress and status workshops contribute directly and indirectly to DOE input to the Tech Team activities carried out under the Partnership. The Tech Teams develop roadmaps outlining

[19] DOE. "DOE Fuel Cell Pre-Solicitation Workshop." 9 March 2006. Available on the Web at <http://www1.eere.energy.gov/hydrogenandfuelcells/wkshp_fuelcell.html>.
[20] DOE. "Annual Merit Reviews." Available on the Web at <http://www.hydrogen.energy.gov/annual_review05.html>

the goals and milestones for each technology area. The individual technology roadmaps are posted on the FreedomCAR and Fuel Partnership section of the DOE website[21] and are publicly accessible to the domestic and international public and stakeholder community.

Established international coordination and collaboration activities allow Hydrogen Program R&D managers the opportunity to interact with their counterparts in other countries and other Federal agencies. The International Partnership for the Hydrogen Economy (IPHE) is a forum for international R&D managers, researchers and policymakers to openly share program strategies. The IPHE, which includes 16 nations and the European Commission as outlined in Table 3, establishes world-wide collaboration between the hydrogen and fuel cell research programs of member governments. For example, in June 2006, IPHE members convened a workshop in Lyon, France to openly set high-level goals and establish research priorities for international collaborative activities. Such discussions are also useful for each of the member countries to use in refining their programmatic goals. The International Energy Agency provides a mechanism for member countries to task and cost-share research activities through two Implementing Agreements, one supporting hydrogen activities and one supporting fuel cell activities. Informal discussions with other countries provide opportunities to develop bilateral research agreements and openly share data.

Table 3: Membership of International Partnership for the Hydrogen Economy

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

The Energy Policy Act of 2005 includes important provisions for coordinating across the Federal Government and for obtaining independent advice on our hydrogen efforts from outside the Department. In June 2006, the Secretary of Energy announced members of the Hydrogen Technical Advisory Committee (HTAC). HTAC will advise the Secretary on issues related to the development of hydrogen and fuel cell technologies and will give recommendations to the Secretary regarding DOE's programs, plans, and activities, as well as safety, economic, and environmental issues related to hydrogen. The Interagency Hydrogen and Fuel Cell Technical Task Force coordinates the efforts of the Office of Science and Technology Policy; the Departments of Energy, Transportation, Defense, Commerce, and Agriculture; the Office of Management and Budget; National Science Foundation; Environmental Protection Agency; National Aeronautics and Space Administration; and other agencies as appropriate. Through the

[21] DOE. "FreedomCAR and Fuel Partnership Teams." 10 May 2006. Available on the Web at <http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/freedomcar/fc_teams.html>

activities and meetings of the task force, the Department of Energy is able to gather input on hydrogen and fuel cell activities and goals from the other agencies.

Conclusion

DOE's Hydrogen Program utilizes public processes that are open to international organizations to ensure the widest participation practicable in its planning and implementation procedures. The high-level targets are established in collaboration with the public-private FreedomCAR and Fuel Partnership in order to ensure sufficient discourse with the private sector responsible for commercializing the technologies. The systems-driven rationale for establishing the targets, as well as the documentation of the higher and lower-level milestones, is shared with the broad domestic and international stakeholder community.

DOE develops and posts all of the hydrogen-related planning documents with goals and milestones for the program on the Program and/or FreedomCAR websites. The Hydrogen Program has initiated this rigorous and transparent development and review process to encourage input from the diverse body of hydrogen and fuel cell stakeholders. These documents are utilized within the international hydrogen and fuel cell community, so much so that other countries and companies outside the FreedomCAR and Fuel Partnership readily recognize U.S. targets and benefit from the U.S. planning activities.[22, 23]

The Program, as part of a Federal agency, openly encourages participation from all interested parties and uses tools available to the Federal Government, such as the U.S. Government website, the Federal Register and public comment periods, to ensure that any party that wishes to get involved can do so. Already, there is a great deal of input from non-domestic stakeholders, many of whom conduct research in support of the Program. For example, non-domestic companies are taking advantage of the technical expertise and staff at the national laboratories by establishing Work For Others and Cooperative Research and Development Agreements.[24]

The primary driver of the Hydrogen Fuel Initiative is reducing U.S. energy dependence on imported supplies of energy. Other nations have different price points and performance requirements for hydrogen fuel cell vehicles to compete with conventional technologies. In Europe and Asia, hydrogen may not need to be $2.00 - $3.00 per gallon of gasoline equivalent to be attractive to the consumer because fuel prices are not the same as in the U.S. In countries outside the U.S., vehicle range of less than 300 miles per tank may be acceptable to the consumer because customers travel shorter distances. DOE's high-level goals reflect the stringent requirements for the technologies to be competitive in the US market. The input requested by

[22] Ballard Power Systems, based in Vancouver, Canada, has published its technology roadmap, explicitly comparing its performance against the DOE fuel cell durability, freeze start capability, power density, and stack cost targets. Ballard Power Systems. "Fuel Cell Technology: Technology Roadmap." Available on the Web at <http://www.ballard.com/be_informed/fuel_cell_technology/roadmap>.

[23] HyNet, a private sector network supporting the development of a Hydrogen and Fuel Cell Roadmap for the countries of the European Commission, referenced the DOE hydrogen storage capacity target as a baseline against which various technologies are compared. HyNet. "Towards a European Hydrogen Energy Roadmap: Preface to HyWays – the European Hydrogen Energy Roadmap Integrated Project." 12 May 2004. p.17. Available on the Web at <http://www.hynet.info/publications/docs/HYNET-roadmap_Executive_Report_MAY2004.pdf>.

[24] For example, Toyota Motor Company has contracted Savannah River National Laboratory to conduct R&D activities. Similar agreements exist between national laboratories and other companies.

DOE in its goals and milestones development at all levels is in place to ensure that all domestic and international organizations interested can participate in the Program in a coordinated fashion. Cooperation across international boundaries is a critical step to ensuring that the U.S. can realize the full potential benefits of a hydrogen economy.