Secretary of Energy's First Biennial Report to Congress Responding to Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) Findings and Recommendations during Fiscal Year 2007

Foreword

Section 807(d) of the Energy Policy Act of 2005 (EPACT), P.L. 109-58, states that the Secretary of Energy (Secretary) shall transmit, with the fiscal year (FY) 2009 Budget request, his first biennial report to Congress describing any recommendations made by the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC or Committee). EPACT states that the report shall include a description of how the Secretary has implemented or plans to implement the recommendations, or an explanation of the reasons that a recommendation will not be implemented. On September 10, 2007, the HTAC completed its first report, describing the Committee's recommendations from its deliberations during FY 2007. The Vice-Chair of the Committee delivered the report to the Secretary on October 26, 2007. The *Secretary's First Biennial Report* responds to the *Hydrogen and Fuel Cell Technical Advisory Committee Biennial Report to the Secretary of Energy* (HTAC report).

HTAC was established under EPACT to advise the Secretary on programs and activities under Title VIII, Hydrogen. The Committee's charter is to review and make recommendations to the Secretary on: 1) the implementation of programs and activities under Title VIII of EPACT; 2) the safety, economic, and environmental consequences of technologies for the production, distribution, delivery, storage, or use of hydrogen energy and fuel cells; and 3) the plan called for by section 804 of EPACT, also known as the *Hydrogen Posture Plan* (Posture Plan).

The Posture Plan is a high-level document that presents a coordinated plan for research, development, and demonstration (RD&D) activities that directly relate to hydrogen and fuel cells across the Department of Energy (DOE or the Department) and portions of the Department of Transportation (DOT), known collectively as the Hydrogen Program (the Program) and corresponding exactly to the crosscutting activities comprising the President's Hydrogen Fuel Initiative, announced in January 2003. DOE activities, known collectively as the DOE Hydrogen Program, include all hydrogen-related programs of the Offices of Energy Efficiency and Renewable Energy (EERE), Fossil Energy, Nuclear Energy, and Science. Beginning in FY 2009, EERE's hydrogen R&D will include activities within both the Hydrogen Technology budget and the Vehicle Technologies budget. Specifically, Technology Validation; Safety, Codes and Standards; and Education activities will be moved to Vehicle Technologies, while Fuel Cell and Storage R&D and Systems Analysis will remain in Hydrogen Technologies. Hydrogen production activities will be supported by the Offices of Fossil Energy, Nuclear Energy, and Science in FY 2009. The Office of Science supports basic research related to renewable hydrogen production, fuel cells and hydrogen storage. The Posture Plan refers readers to the Multi-Year RD&D Plans prepared by individual DOE or DOT offices, detailing the multi-

year program agenda, entities involved, program and subprogram milestones, technical and non-technical challenges, and approaches for addressing those challenges.

HTAC held its first meeting in October 2006, and held three subsequent meetings during FY 2007. During these meetings, the Committee focused on elements 1 and 3 of its charter, as stated above: reviewing the implementation of programs and activities under Title VIII and the December 2006 *Hydrogen Posture Plan*.

The HTAC report commended the DOE Hydrogen Program for using best management practices such as peer reviews in solicitation processes, assessment of technical progress, individual project selection and monitoring, and overall program management. The Committee found the Posture Plan to be well thought out and comprehensive, and outlined several positive features of the plan. The Committee's report also identified a number of gaps or areas for improvement in the Posture Plan, as outlined in their recommendations. The body of this report is organized by the elements of the Committee's charter, as was the HTAC report. It presents the recommendations of the HTAC and DOE's response to those recommendations.

Section I: Implementation of Program and Activities under Title VIII, Hydrogen, Energy Policy Act of 2005

HTAC Recommendation I.1

The operational structure of the Interagency Task Force on Hydrogen and Fuel Cells, required by EPACT section 806, should include participation at a functional level of the Assistant Secretary or higher to ensure appropriate decision-making membership from each participating agency. The Committee recommends that the Interagency Task Force be charged with developing a "National Hydrogen and Fuel Cells Action Plan" to guide interagency cooperation and collaboration on hydrogen and fuel cells.

On November 12, 2006, the Committee recommended the formation of an Interagency Task Force with Assistant Secretary-level or higher membership from each participating agency (see Attachment 5). The Committee is pleased that DOE adopted this recommendation and is hopeful that the newly created Interagency Task Force on Hydrogen and Fuel Cells (inaugural meeting held on August 1, 2007) will foster a higher level of commitment to implementation of the President's Hydrogen Fuel Initiative by all participating agencies. Effective interagency coordination and involvement of decision-makers who can influence program execution within their respective agencies is especially important in order to address cross-cutting issues related to codes and standards development, public education, training of code officials and first responders, and development of programs and incentives that can stimulate commercialization of hydrogen and fuel cell technologies (including federal procurement programs and the potential for creating a temporary program to address liability issues during the transition). A "National Hydrogen and Fuel Cells Action Plan" would serve to identify the particular actions that are needed, the roles and responsibilities of the respective agencies, and the timelines for completion. The Interagency Task Force is best positioned to facilitate federal procurement of hydrogen and fuel cell systems.

The Committee believes that the proposed National Hydrogen and Fuel Cells Action Plan (the "Interagency Plan") should orient the Hydrogen program to the overall energy strategy of the United States. Assuming the nation's high level energy goals are a significant reduction of dependence on oil imported from politically sensitive parts of the world and management of energy resources in a carbon constrained environment, it is likely hydrogen will play a prominent role. The Interagency Plan should depict the role of hydrogen in the context of the evolving nation's overall energy strategy.

DOE Response I.1

The Department agrees that an Interagency Task Force (ITF) with participation at the functional level of Assistant Secretary will improve interagency coordination and foster a higher level of commitment to development and deployment of hydrogen and fuel cell systems. The ITF, which includes senior management-level representatives of more than 15 Federal agencies, convened for the first time on August 1, 2007. At that meeting, members agreed to focus their efforts on facilitating Federal leadership of early technology adoption, in accordance with Sections 782 and 783 of the Energy Policy Act of 2005. Subsequent meetings on December 18, 2007, and April 15, 2008, covered commercially available fuel cell products and Federal user experiences with hydrogen and fuel cell systems; models and tools for financing projects; and the energy, environmental, and economic benefits of fuel cell deployment by Federal agencies. Prior to the December 2007 meeting, the Program worked individually with each agency through the ITF and the staff-level Interagency Working Group (IWG) to compile past, current, and potential Federal hydrogen and fuel cell research, development, deployment, and education activities. This catalog of activities, together with project financing information and templates, will comprise an action plan for Federal adoption.

HTAC Recommendation I.2

Funding for the hydrogen program should be increased at least to the $3.275 Billion authorized by EPACT Title VIII for FY 2006 to FY 2010, commensurate with its importance to national security, environmental quality, climate change mitigation, and global technology competitiveness.

The Committee believes that faster progress can be made with more funding for the DOE Hydrogen Program. Certain important activities are not being adequately funded, including exploratory research activities in both the "basic" and "applied" research programs and efforts in renewably generated hydrogen. Funding for hydrogen delivery and for longer-term hydrogen production efforts has been too low and should be increased. More funding is needed for activities directed towards overcoming market barriers (such as education, training, development of codes and standards, technology validation, and early adoption provisions such as those called for by sections 782 and 783 of EPACT). Specifically, the Committee supports funding a federal procurement program for stationary, portable and micro fuel cells at $20 million in the first year for a total of $345 million for a 5 year program as authorized in EPACT. The Committee also supports financial and regulatory incentives (inclusive of current tax credits) at the federal level for both fuel cell and hydrogen systems. The Committee urges stability in funding provided for basic and applied research, since consistent commitment and resources are needed to foster

innovation and a vibrant, active scientific community and to keep researchers in universities, national labs, and industry labs engaged and committed to projects. The Committee strongly opposes earmarking of the hydrogen budget and finds that this has had a negative effect on the program. The Committee supports unencumbered budgets that allow the Secretary to allocate funding in accordance with the program's well-considered plans and priorities.

DOE Response I.2

From fiscal years 2004 through 2008, the President's Budgets included $1.27 billion for the Hydrogen Fuel Initiative (i.e., the Hydrogen Program), consistent with the President's commitment (announced in the State of the Union in January 2003) to request $1.2 billion over five years. Congress appropriated $1.17 billion of the requests over the same time frame. The Hydrogen Program budget request is $268 million in FY 2009. In addition, hydrogen and fuel cell R&D is supported by other Federal agencies, including the National Aeronautics and Space Administration, Department of Defense, National Science Foundation, and others.

HTAC Recommendation I.3

The Committee believes that national policies will be necessary to overcome market barriers to hydrogen and fuel cell systems during the transition period, and supports the development and passage of policies directed towards overcoming these barriers.

There are significant economic and institutional barriers that inhibit or prevent hydrogen and fuel cells systems from moving from the technology readiness phase into consumer markets and widespread commercialization. Policies and incentives will be needed to enable these technologies to compete with conventional fuels and technologies. The Committee supports development of policies and incentives that help to overcome barriers to public acceptance and market entry. For instance, the lack of a track record with hydrogen limits the availability of reasonably priced insurance from commercial insurance providers; a program to provide coverage during the transition period would facilitate infrastructure formation. These policies should be designed to generate "market pull" rather than "technology push" and should provide consistent support throughout the transition period, after which the policies should phase down and expire. In addition, longer term incentive programs are needed to provide certainty for suppliers, investors, manufacturers and customers to maximize the benefits of such initiatives.

DOE Response I.3

DOE agrees that policies and incentives can help stimulate the market for hydrogen and fuel cells. Fuel cells are currently eligible for a Federal tax credit of up to $1000/kW, as authorized by Section 1336 of EPACT 2005. In addition, DOE has established new opportunities in the form of loan guarantees under EPACT Title VII. Hydrogen and fuel cell technologies are eligible under this new program.

Section II: Safety, Economical, and Environmental Consequences of Technologies for the Production, Distribution, Delivery, Storage, or Use of Hydrogen and Fuel Cells

HTAC Recommendation II.1

The Committee recommends that DOE continue the Technology Validation activity for fuel cell vehicle and fueling infrastructure technologies and capture the synergistic benefits that would be accrued by providing additional funding for demonstrations of fleet, stationary and portable power applications.

The Committee finds that the learning demonstrations being cost-shared by DOE through the Technology Validation activity have been extremely valuable in providing real-world data to test and validate the safety, performance, reliability, operating costs, and efficiency of fuel cell vehicles and fueling stations. Given the technology lead times involved, it is critical that the validation effort be continued beyond FY 2008 to evaluate the status of next-generation technologies and continue to develop a credible database of real-world performance and reliability. Deployment of additional vehicles in a variety of geographic regions will help to improve the statistical significance of the data and to provide information critical for codes and standards development and insurance underwriting. Fleet, stationary, and portable power applications are closer to commercialization and less dependent on large-scale infrastructure development than other applications such as private vehicle operation. The addition of these demonstrations can validate these nearer-term technologies in public settings, contribute information to the safety and performance database, and accelerate manufacturing of components and systems, thereby accelerating commercialization. Further, the Committee believes that a like program for stationary power generation fuel cells (both distributed and central station) should be expanded. It is possible that such a program could be part of a federal procurement program, which provides some amount of cost share for the deployment of fuel cell systems throughout the federal government for a variety of stationary, portable and transportation applications.

DOE Response II.1

The fuel cell vehicle and hydrogen infrastructure learning demonstration has been valuable in providing real-world data to validate the safety, performance, reliability, operating costs, and efficiency of fuel cell vehicles and hydrogen fueling stations. Feedback from DOE's industry partners has been very positive, and confirms that the data generated from the program has been highly useful. The current plan is to continue the learning demonstration into FY 2010 to provide data on a variety of second generation vehicles and advanced hydrogen refueling stations. The Department is currently formulating plans for phase 2 of the technology validation activity.

The Hydrogen Program decided to focus its technology validation efforts on fuel cell vehicles because the transportation sector accounts for 67% of the nation's oil use[1] and 33% of total CO_2

[1] Oak Ridge National Laboratory, Transportation Energy Data Book: Edition 25, (2006), "Table 1.13 Consumption of Petroleum by End-Use Sector, 1973-2005, "1-17

emissions[2]. Fuel cell use in the stationary and portable power sectors will not impact oil use as much as fuel cell use in transportation. As a result, most of the funding in the Technology Validation subprogram supports transportation activities. However, recognizing the synergies between transportation and stationary applications, and the benefits in terms of CO_2 emissions reductions in stationary power generation, the Program has initiated stationary hydrogen and fuel cell validation activities within other subprograms. For example, in 2007 the Hydrogen Production and Delivery subprogram supported a demonstration at the National Renewable Energy Laboratory's Distributed Energy Resource Test Facility, which integrates wind based hydrogen production via electrolysis with a polymer electrolyte membrane (PEM) fuel cell to feed power back to the grid. This project has provided valuable information on integrated renewable hydrogen systems, including interface and grid connectivity issues. Furthermore, the Program is currently funding five stationary PEM fuel cell demonstrations under its Fuel Cell subprogram to demonstrate integrated systems and to validate technologies in a real world environment.

Section III: Plan Called for under Section 804 of the Energy Policy Act of 2005 (the December 2006 *Hydrogen Posture Plan*)

HTAC Recommendation III.1

The Posture Plan should more fully describe the market risks associated with developing hydrogen as an energy carrier.

A complete understanding of the risks and benefits is essential to create an understanding of why it is important to pursue hydrogen as an energy carrier and why the government needs to be involved. Hydrogen and fuel cells have the potential to address the nationally important issues of energy security, environmental quality, carbon emissions reductions, and global technology competitiveness. The risks, including technical performance, cost-competitiveness, fueling infrastructure development, market acceptance, and regulatory roadblocks, create the need for government risk-sharing throughout the research, development, and technology deployment timeline and lay the groundwork for the federal role.

DOE Response III.1

DOE agrees, and to address this HTAC recommendation, future Hydrogen Program planning documents will more clearly describe the market risks and the potential role of government in addressing the risks. Future planning documents will also provide the results of DOE's most recent analysis of the potential benefits of hydrogen as an energy carrier as appropriate.

The Hydrogen Program is pursuing an approach that focuses first on resolving critical path technology barriers. Codes and standards and public education are being addressed concurrently with the research to overcome near-term institutional barriers. The Posture Plan reflects this approach by laying out an integrated plan for research, development, and demonstration needed

[2] Oak Ridge National Laboratory, Transportation Energy Data Book: Edition 25, (2006)

to address key cost and performance targets. The goal is “technology readiness” by 2015 to enable industry to make commercialization decisions.

The Posture Plan acknowledges that numerous market and institutional factors will influence industry commercialization decisions. As mentioned on page *iii* of the Plan, “technology that meets consumer requirements is necessary, but not sufficient, for industry to move forward with commercialization plans.” DOE agrees that it is important to assess and understand all the risks, in an effort to manage expectations about when hydrogen may become available as a commercial energy carrier. The Hydrogen Program recently initiated scenario analyses to investigate the emergence of hydrogen and fuel cell vehicles. The analysis will explore the impacts of various market risks, including different production volumes, hydrogen and fuel cell vehicle cost, and fuel availability and station proximity to vehicle users.

The DOE responses to HTAC recommendations I.3, III.2, and III.11 provide more discussion of market barriers and consider the government role in overcoming these barriers.

HTAC Recommendation III.2

The Posture Plan needs to better define the government role in commercialization.

The Posture Plan does a very good job of describing the research and development plan for reaching the 2015 goal of "technology readiness." It is the Committee’s opinion that a strong government role is needed beyond this point, to foster public acceptance and market entry of hydrogen and fuel cell technologies. Because the risks are high and the benefits are large, there is justification for a government role in helping industry move from technology development to market acceptance (known as the "valley of death" or "crossing the chasm" created by lengthy lead time between significant investment outlays, manufacturing and fueling infrastructure and the recovery of that investment). Increasing the level of R&D on portable and stationary power systems in the Plan would reduce the technical and market risks associated with longer-term applications in the transportation sector. The Posture Plan should include a discussion of DOE’s role in overcoming market barriers. This role should be complementary to research and development, and synchronous with industry’s efforts to move technologies into end-use applications and the consumer marketplace; this role should go beyond support for demonstrations and include needed policy initiatives. The DOE should initiate a market transformation program that allows federal agencies to apply for cost shared dollars to pay the incremental cost of fuel cell technologies as a transition strategy. The DOE should support fuel cell and appropriate financial and regulatory incentives (inclusive of current tax credits) for fuel cells and hydrogen systems.

DOE Response III.2

While the Program is focused primarily on RD&D, we are also conducting analyses to assess the non-technical barriers to hydrogen and fuel cell commercialization, and promoting deployment

in early markets. The Hydrogen Program commissioned Battelle Memorial Institute[3] to study the economic, technological, and marketplace drivers needed for commercialization of stationary and pre-automotive PEM fuel cell systems. Through this study, Battelle identified three promising near-term markets:

1. Emergency power for state and local emergency response agencies
2. Forklifts in warehousing and distribution centers
3. Airport ground support equipment

Power for data centers has also been identified as a potential early market for fuel cells.

The Hydrogen Program is working with Federal agencies individually and through the Interagency Task Force to identify opportunities for agencies to deploy fuel cells in the identified early markets including micro, portable, and stationary fuel cells. Coordination through the ITF has resulted in several interagency agreements between DOE and other Federal agencies in support of market transformation.

Additional market transformation activities are linked to education and include cost-shared projects through two DOE funding opportunity announcements. Two topics from the FY2008 DOE Hydrogen Education Development funding opportunity, "State and Local Government Outreach" and "End User Outreach" seek to facilitate early market adoption through education and outreach in conjunction with practical, real-world use. Awards will be announced in spring 2008. A recent FY 2008 DOE Hydrogen Fuel Cell funding opportunity includes a topic encompassing projects that will provide DOE with real-world operations data to support market introduction.

The Program has also organized a number of informational events and developed resources on early adoption. A series of workshops and meetings brought together Federal and National Laboratory facilities managers with fuel cell companies to exchange information on power needs and the fuel cell products available to meet them. A set of tools developed for the Interagency Task Force provides project financing information and templates for Federal agencies to deploy fuel cell systems.

HTAC Recommendation III.3

The Posture Plan needs to present a broader vision of how hydrogen fits into the overall energy strategy for the United States, and convey the message that hydrogen will be a key part of the energy mix, which will include an array of advanced technologies using energy derived from fossil, nuclear, and the various renewable resources.

The Committee strongly believes that achieving the goal of energy security in a carbon constrained world while maintaining economic competitiveness will require that we draw on

[3] Battelle Memorial Institute, *Identification and Characterization of Near-Term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets*, April 2007, http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pemfc_econ_2006_report_final_0407.pdf.

multiple energy resources and technologies. Conventional hydrocarbons will remain important energy resources for traditional end uses and for the production of hydrogen for at least two or three more decades. Nuclear energy will also have a role in providing stationary power and, potentially, in producing hydrogen. A long-term goal is to increase the use of renewable resources to produce hydrogen in the future. The Committee believes that hydrogen and fuel cells can play a very important role in reducing oil consumption and "de-carbonizing" the transportation sector, since hydrogen can be produced from any primary energy source and fuel cells are one of the few technologies that offer the potential for zero-emissions vehicles. The Posture Plan should present a balanced R&D program that focuses on near-term technologies for the transition, development of renewable resources and other long-term technologies for maximum impact; this will ensure that the "pipeline" is charged to work towards the ultimate goals of eliminating dependence on oil imports, diversifying energy sources, improving environmental quality, and greatly reducing carbon emissions.

DOE Response III.3

The posture plan does discuss how hydrogen fits into the overall energy strategy for the United States. The foreword of the Posture Plan states that the President's National Energy Policy, the Energy Policy Act of 2005, and the U.S. Department of Energy Strategic Plan all call for expanding the development of diverse domestic energy supplies, which include hydrogen as well as other energy sources and carriers. The Plan also notes that the Advanced Energy Initiative (AEI), while reinforcing the President's Hydrogen Fuel Initiative to reduce oil use in the longer term, also accelerates research on technologies having the potential to reduce near-term oil use in the transportation sector, e.g., advanced batteries for hybrid vehicles and cellulosic ethanol. In addition, the AEI supports research to reduce the costs of advanced electricity generation technologies in the stationary sector such as clean coal, nuclear energy, solar photovoltaics, and wind energy.

In 2007, the Hydrogen Program completed development of a number of analytical tools and models to better understand how the various options and pathways for hydrogen production and delivery might evolve over time. In 2009 and beyond, Systems Analysis will take the lead in development and improvement to the H2A Delivery model, similar to the role that it has played with the H2A Production model. These models include estimates of costs, resource use, resource availability, well to wheel (WTW) emissions and energy use, as well as other factors. The HyTrans model developed at Oak Ridge National Laboratory (ORNL) examines the transportation sector across all of the current and alternative fuels and vehicle platforms, including hybrids, biofuels, and hydrogen fuel cell vehicles. The DOE Office of Energy Efficiency and Renewable Energy (EE) is using the National Energy Modeling System (NEMS) to examine possible energy futures across market segments. Both NEMS and HyTrans include the capability to examine how government policy can impact the outcome.

HTAC Recommendation III.4

The Posture Plan needs to expand its scope beyond the current focus on transportation to include stationary and portable fuel cell power applications.

The Committee understands that the Posture Plan was directed toward the DOE goal of reducing oil consumption, which is strongly linked to the transportation sector and well aligned with section 802 Purposes three and four. DOE has established five strategic themes including "promoting America's energy security through reliable, clean, and affordable energy," consistent with the Purpose five. Commercialization of stationary and portable fuel cells supports this objective and can play a key role in ensuring reliable, high quality power, especially for critical infrastructure which is vital to our nation's energy security. The Committee therefore recommends that the Plan provide more emphasis on portable and stationary power applications and the role that these technologies can play in enhancing electric grid reliability, addressing air quality and climate change concerns, developing early markets, consumer acceptance, component manufacturing capabilities, codes and standards, and early hydrogen production infrastructure. This recommendation is consistent with section 805, which directs the program to "demonstrate and commercialize the use of hydrogen for transportation (in light duty and heavy duty vehicles), utility, industrial, commercial, and residential applications."

DOE Response III.4

DOE agrees that early market fuel cells in stationary and portable power can play a role in developing consumer acceptance, component manufacturing capabilities, and codes and standards. These applications could also contribute to development of early hydrogen production and delivery infrastructure and to enhancing electric reliability, as well as to helping address climate change concerns. Future Hydrogen Program plans will address the role of these applications. However, it is important that the program stay focused on achieving the stated critical path goals.

As described previously (see DOE responses II.1 and III.2), the Program has several stationary PEM fuel cell demonstrations in place and supports activities that are focused on early markets for stationary and portable power fuel cells. In addition, the fuel cell stack components key activity supports the development of materials and components for all fuel cell applications – transportation, stationary, and portable power.

HTAC Recommendation III.5

The Posture Plan should articulate a plan for a DOE leadership role through the Interagency Task Force in coordinating the multiple branches of government and rulemaking organizations in order to harmonize and expedite efforts to develop consistent codes and standards, which are needed to commercialize hydrogen and fuel cell technologies.

The Committee believes that the pathway to commercialization of hydrogen and fuel cells would be greatly accelerated by uniform and rapid adoption by all governmental jurisdictions of consistent requirements for portable devices and hydrogen installations, including stationary power and fueling stations. Initial provisions for hydrogen in existing Codes and associated

product Standards have been developed, but they have not yet been drawn into State and local regulations nor into training programs for permitting authorities; and they are not consistently applied. High priority should be given to educational programs for permitting officials and emergency responders who are not yet familiar with these new hydrogen provisions. In addition, revision of those provisions must be supported to accommodate new hydrogen technologies and high priority must be given to programs focused on the evaluation of their safety and demonstration of their safe operation to support revision of the existing requirements. For many portable hydrogen-fueled devices, the constraint of federal regulations limits the ability to transport them or travel with them (especially air travel) and presents a clear barrier to market acceptance. Internationally, the harmonization of requirements for both stationary and mobile applications should be a high priority, so that companies in the United States are able to move forward with commercialization plans and are not hindered in their efforts to compete globally by non-tariff trade barriers.

DOE Response III.5

The Department recognizes the importance of consistent harmonized codes and standards, the need for coordination across government and regulatory organizations, and the need for education of permitting officials and emergency responders. Over the past several years, a coordinated, national agenda for hydrogen and fuel cell codes and standards has emerged through DOE leadership and the support and collaboration of state, local, and federal government, industry, and key standards and model code development organizations (SDOs and CDOs)[4]. DOE works to harmonize national and international standards, codes, and regulations that are essential for the safe use of hydrogen by consumers in the U.S. and throughout the world.

DOE and the major SDOs and CDOs created national templates to coordinate the prepare standards and codes for hydrogen and fuel cell technologies and applications. All of the relevant major SDOs and CDOs in the U.S. are part of this national effort. Accomplishments to date include the following:

- Hydrogen is now recognized as a fuel gas, and hydrogen applications are incorporated in the 2003 and 2006 editions of the International Code Council (ICC) model codes.
- Provisions for the use of hydrogen are included in ICC's International Building, Residential, Fire, Mechanical, and Fuel Gas Codes.
- The National Fire Protection Agency (NFPA) has also updated and incorporated additional hydrogen safety requirements into its family of codes and standards.

To educate permitting officials, the Program conducted three national workshops in 2007 and 2008 on station permitting and developed a web-based compendium as a one-stop source of information that includes a database of key standards and codes that presently govern permitting. In addition to outreach efforts to permitting and code officials, DOE is raising awareness about hydrogen to facilitate its adoption and use as a fuel. To this end, DOE has launched an "Introduction to Hydrogen Safety for First Responders" web-based course that provides an "awareness level" overview of hydrogen for fire, law enforcement, and emergency medical personnel.

[4] See http://www1.eere.energy.gov/hydrogenandfuelcells/codes/pdfs/cs_templates.pdf

Recognizing that a key aspect of international harmonization is a sound scientific and technical foundation for hydrogen safety, the Program collaborates with organizations in Europe and Japan to share information on hydrogen behavior and codes and standards. For example, DOE is participating in HyPER (Installation Permitting Guidance for Hydrogen and Fuel Cell Stationary Applications), a European Commission (EC) effort to develop fast-track approval for small, stationary hydrogen and fuel cell systems and safe procedures to enable a comprehensive installation process for developers, design engineers, manufacturers, and installers across the European Union. DOE is also actively participating in two other EC efforts: HyApproval that focuses on harmonizing permitting requirements for hydrogen fueling stations, and HySafe to coordinate hydrogen safety RD&D and to widely promote and share hydrogen safety information.

In summary, the Program is facilitating the timely dissemination of technical data required for further development and refinement of hydrogen codes and standards; consolidating domestic hydrogen codes and harmonizing codes and standards internationally; and engaging with key stakeholders to promulgate, adopt, and judiciously apply the most current codes and standards for hydrogen applications.

HTAC Recommendation III.6

The challenges and costs associated with off-board storage and hydrogen delivery should be more fully described, and the budget for the Delivery sub-program should be shown separately from the Production sub-program.

The importance of off-board storage and hydrogen delivery is under-emphasized in the Posture Plan. For centralized production facilities, the costs associated with transporting hydrogen from its point of production to its point of use can contribute heavily to the delivered cost of hydrogen and can have a big impact on how the infrastructure could evolve. Similarly, both for central and distributed production, the cost of storage at the fueling station and the hardware for dispensing the hydrogen to vehicles must be addressed. The Committee believes it is important to more fully describe the challenges that need to be addressed, the plan for addressing the challenges, and the budget that is provided for hydrogen delivery.

DOE Response III.6

The delivery portion of the hydrogen production and delivery subprogram currently focuses on lowering the costs, improving the energy efficiency, and ensuring reliable performance of the key delivery technologies: compression, liquefaction, off-board bulk hydrogen storage and pipelines. The potential use of novel carriers is also being explored. The near-term emphasis is on technologies that support early, lower-demand markets for hydrogen as an energy carrier (distributed hydrogen production at refueling stations and stationary power sites). Improved technologies for hydrogen transport from higher-volume, central production facilities are being researched in parallel, but will be given more emphasis later in the program. Examples of

progress to date include development of two delivery infrastructure analysis tools – the H2A Delivery Components Model and the H2A Delivery Scenario Model.

In the FY 2004-2008 Budgets, hydrogen delivery was combined with hydrogen production, reflecting the need for hydrogen to be cost-competitive with delivered conventional fuels, such as gasoline. While the FY 2009 Budget does not include funds for Hydrogen Production and Delivery in EERE, funding for hydrogen production R&D is requested in the Offices of Fossil Energy, Nuclear Energy, and Science. As progress is made in these programs, the Department will evaluate whether to request funds for applied research in renewable hydrogen production and hydrogen delivery in light of competing priorities to keep the Program on schedule for critical path technology readiness in 2015.

HTAC Recommendation III.7

The next version of the Posture Plan should reflect improved "well-to-wheels" analyses that depict the impact of each of the hydrogen pathways on the goals to reduce oil imports and our carbon footprint. The assumptions and results of these analyses should be corroborated with other, similar independent analyses. The carbon analyses should be expanded to include biofuels pathways and stationary power applications.

The "well-to-wheels" analyses included in Appendix B of the Posture Plan are very good. However, the Committee notes some discrepancies between the costs and assumptions used in the DOE analyses and those used in similar analyses conducted by the National Academy of Science and DOE's Fossil Energy Program, and the assumptions that led to the results should be clarified. The Committee would also like to see well-to-wheels analyses for all hydrogen pathways receiving funding from DOE (including biofuels pathways and stationary power applications). To the extent possible, the analyses should include synergies among the different pathways that would improve the efficiency or reduce the cost of the pathways. A similar analysis also should be done for stationary systems. We need to always do this in order to both reduce carbon emissions and to increase efficiency. Such an analysis in the stationary power sector will lead to a more distributed energy system in which waste heat allows for significant efficient improvements.

DOE Response III.7

DOE agrees and has already begun to implement this recommendation. New case studies based on transparent and consistent assumptions will be conducted for hydrogen pathways from renewable, fossil and nuclear energy. The latest project information for these pathways will be included in the case studies, which will be posted on the Program's website.

The Program has made an effort to corroborate the assumptions and results of the DOE analyses with similar, independent analyses. The Program's H2A production model, which includes renewable, fossil and nuclear hydrogen pathways, is being updated to incorporate recent developments and data from the hydrogen production technologies of key industrial

collaborators, academia and the national laboratories. For example, DOE compared its well-to-wheel analyses to those conducted by the National Academy of Science, and enumerated the differences between these two studies in a presentation to HTAC on July 31, 2007.

Emissions analysis is being conducted with the GREET model to examine and benchmark the potential reduction the carbon footprint for various stationary power generation options, including hydrogen. To analyze the cost of stationary generation systems, DOE is developing an H2A-type cost model to ensure consistency of results and transparency or assumptions.

HTAC Recommendation III.8

The Posture Plan should include analysis of strategies that evaluate the potential for reducing carbon emissions and oil imports through the development of a hydrogen economy.

The Committee recommends analyses that use dynamic transition models, coupled with macroeconomic models for the United States and the world, that enable assessments of the relative benefits of these strategies to guide the program. The Committee would be pleased to provide guidance on strategy development. Such analyses should be presented in a way that clarifies the magnitude and timing of environmental impacts and oil imports through the development and implementation of a hydrogen economy under different pathways.

DOE Response III.8

A number of analyses have been completed, and several are underway, that evaluate the energy and environmental impacts of different hydrogen pathways. One example is the Hydrogen Scenario Analysis recently published by ORNL. The analysis utilizes a number of analytical tools, including the H2A, HyTrans, and GREET (well-to-wheels analysis) models, to generate projections about the costs and benefits (including impacts on petroleum use and carbon dioxide emissions) of different fuel cell vehicle market penetration and fueling scenarios. The Scenario Analysis employs an integrated market simulation model (HyTrans) to represent the economic decisions of vehicle manufacturers, energy suppliers and consumers to estimate market outcomes through 2050, both with and without policy incentives. The Hydrogen Program's modeling tools will be incorporated with the national-scale models (NEMS and MARKAL) to evaluate the macroeconomic impacts of hydrogen on oil imports and carbon emissions. This analysis will be conducted with the updated versions of the H2A production and delivery models and will consider regional issues and resource requirements to determine the optimum portfolio of technologies available for hydrogen production.

DOE also is actively engaged in an analysis being conducted through the International Partnership for a Hydrogen Economy and the International Energy Agency analysis. The IPHE and IEA are coordinating a worldwide analysis (North America, Europe/Africa, and Asia/Pacific) on "Building the Hydrogen Economy: Enabling Infrastructure Development." The main objective of this activity is to convene public and private sector officials in an international

strategic process to evaluate transition planning scenarios for the expansion of infrastructure and to inform policymakers on opportunities to accelerate these transition plans through both public policy instruments and market mechanisms. Information about these and other analysis efforts will be summarized in future Program planning documents.

HTAC Recommendation III.9

The Posture Plan should articulate a process for down-selecting pathways or for directing applied research efforts back to exploratory research efforts when these pathways encounter roadblocks that require major breakthroughs to resolve. This process should include go/no-go decision points and be consistent with the techno-economic progress of the pathways and the potential for the pathways to contribute to reducing oil consumption and carbon emissions in a cost-effective manner.

The Committee suggests the use of "net-present-value" analysis, among other financial assessment techniques, especially for near-term technologies, to help guide research and select priorities in times of budget shortfalls.

DOE Response III.9

DOE agrees that a disciplined approach to directing research and down-selecting pathways should continue to be an integral part of the Program. Future updates of the Program plan will articulate the process that is used. The Program employs go/no-go decision points based on performance based technical milestones and quantitative metrics at the project-, task area- and subprogram-level. DOE will consider using “net-present-value” analysis as an additional factor in evaluating research priorities. The Department will consider ways to apply this methodology without prematurely screening out high-risk, high-payoff technology candidates.

The Department employs a rigorous approach to RD&D planning and management that enables both top-down (program and subprogram-level) and bottom-up (task area- and project-level) priority setting:

- Program and subprogram strategies and approaches are developed through extensive planning and analysis, meetings with stakeholders, discussions with the FreedomCAR and Fuel Partnership, the NAS, and HTAC as appropriate.

- Projects are selected through competitive solicitations that include rigorous merit review recommendations by an expert panel.

- All projects have a well defined project plan that includes go/no-go decision points with well defined criteria. All projects are reviewed internally several times during the year, once a year by the FreedomCAR and Fuel Partnership Tech Teams and annually by outside reviewers at the Annual Program and Merit Review.

- Technical review panels of peer experts are convened to provide an independent assessment and recommendation to DOE for major go/no-go decisions or when an assessment of progress toward one of the key technical targets of the Program is warranted.

- The applied research programs work closely with the DOE Office of Science (SC) to provide input on basic research needs. The Offices of Science, Fossil Energy, Nuclear Energy and EE actively collaborate on project reviews and solicitation planning to properly balance efforts between basic and applied research for the different technology areas within the Program.

Based on all of the above:

- Specific projects are terminated when they do not meet contracted milestones or performance criteria.

- The balance between basic and applied research on a particular technology effort is adjusted as technical progress or roadblocks are encountered.

Examples of major go/no-go decision points and down-selects are outlined both in the Posture Plan and in the multi-year RD&D plans prepared by individual DOE and DOT offices.

HTAC Recommendation III.10

The Posture Plan should give stronger emphasis to the importance of general human aspects—including developing a sufficient knowledge-base—that will be needed to sustain the growth, use, and maintenance of hydrogen and fuel cell technologies and infrastructure.

While the Plan does address the need for education and outreach activities, this discussion should be given greater emphasis. It should reflect the large magnitude of the task of educating all parties involved in the widespread adoption of new technologies. This discussion should address the following critical areas: (1) developing the necessary level of understanding among government officials (including safety, code, and zoning officials); (2) establishing a sufficient talent-base to supply the necessary technical workforce; (3) conducting education programs at all levels (K-12, trade schools, and universities); (4) developing the knowledge-base needed for a supply-chain infrastructure; and (5) and providing sufficient, broad-based education to allow for consumer understanding and acceptance.

DOE Response III.10

DOE agrees that education is important and is cognizant of the economic, institutional and societal barriers to the widespread adoption of hydrogen and fuel cell technologies. The Hydrogen Education subprogram seeks to facilitate hydrogen and fuel cell demonstrations and support future commercialization by providing technically accurate and objective information to

key target audiences who are both directly and indirectly involved in the use of hydrogen and fuel cells today. These audiences include safety and code officials, state and local government representatives, local communities and the public, as well as potential end users. Undergraduate and graduate students, professors, and middle and high school teachers and students comprise another important audience, as they are our Nation's future researchers, scientists, engineers, technicians, and technology users. For more information about the subprogram activities, please refer to the Education sections of the Multi-Year Research, Development and Demonstration Plan: Planned Program Activities for 2004-2015 (http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/) and the Annual Progress Report (http://www1.eere.energy.gov/hydrogenandfuelcells/annual_reports.html).

The Program's education efforts must assume a phased and focused approach that considers technology readiness and the Hydrogen Program's overall market transformation strategy. In the near term, a national education effort or campaign risks overselling hydrogen and fuel cells before they are widely available. Instead, the Education activity will "follow the technology" and concentrate on areas where hydrogen and fuel cells are (or soon will be) publicly visible through demonstration projects or early niche market commercialization efforts. As the Hydrogen Program's market transformation strategy develops, the Education activity must develop and evolve as well, to align with plans for hydrogen and fuel cell technology introduction. Accordingly, target audiences have been prioritized according to their near-term relevance and effect on the use of hydrogen and fuel cell technologies today. While activities to educate all key target audiences are important, the subprogram must focus its limited resources on those with the greatest near-term need.

The Education activity includes the development and dissemination of information resources as well as training and relies on partnerships to leverage limited resources and extend the reach of its efforts.

HTAC Recommendation III.11

The Posture Plan recognizes that manufacturing challenges are a significant problem for the commercialization of fuel cells, since high manufacturing yields at affordable costs are needed to make the economics viable. The Program's manufacturing activity was only recently begun and should receive significant and continuous support.

Members also recognize that work in this area will be quite costly and a challenge to conduct in parallel with technology R&D.

DOE Response III.11

The Program recently selected new projects addressing R&D of manufacturing processes and technologies for membrane electrode assemblies, fuel cell stacks, and compressed hydrogen storage tanks. The objective of these projects is to reduce manufacturing costs and to help develop a domestic supplier base for hydrogen and fuel cell components and systems. However,

considerable work is needed to reduce material costs and improve the durability of fuel cells, and to increase the capacity of storage materials before a manufacturing infrastructure will be viable. Therefore, substantial increases have been requested for these areas in the FY 2009 budget and no funds have been requested for the Manufacturing R&D activity.