HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE

MEETING MINUTES

May 13 – 14, 2008
Courtyard by Marriott Pentagon South, Arlington, VA

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MAY 13, 2008

1. *Call to Order, Agenda Review*

Congressman Walker, Vice Chair of the Hydrogen and Fuel Cells Technical Advisory Committee (herein called either *HTAC* or *Committee*), called the meeting to order at 9:10 am. Dr. Alan Lloyd (HTAC Chairman) was not able to attend the May 13–14 meeting due to a conflicting engagement. Congressman Walker welcomed the two new members of the Committee, Dr. Gerhard Schmidt and Dr. Philip Ross, and asked them to introduce themselves. Dr. Schmidt remarked that he is honored to be a member of the HTAC team. He is the Chief Technical Officer and Vice President of Research and Advanced Engineering at Ford Motor Company. He noted that fuel cell technology within Ford is his responsibility and that he is very much engaged in what the Committee will be talking about for the next two days. He has been with Ford for seven years, and his responsibilities include advanced technologies for new vehicles, including advanced power trains, materials, and electronics. Before joining Ford, he was with a German company for 21 years, responsible mainly for developing power trains.

Dr. Ross stated that he recently retired from Lawrence Berkeley National Laboratory (LBNL) but is still active in advising scientific staff there. Prior to starting at LBNL in 1978, he worked at the United Technologies Research Center. He has worked on fuel cells his entire scientific career and has published

at least one paper on every kind of fuel cell, even molten carbonate. He has also done research on lithium batteries and is very interested in the complementarities of fuel cells and batteries.

2. ***Update on DOE Program and 2009 Budget Request for Hydrogen Activities***
Dr. JoAnn Milliken, Program Manager, DOE Hydrogen, Fuel Cells and Infrastructure Technologies Program

>> see full presentation at http://www.hydrogen.energy.gov/advisory_htac.html

Dr. Milliken provided an update on the DOE Hydrogen Program activities since the Committee's last meeting in December 2007, including a report on the fiscal year (FY) 2009 DOE budget request. She reviewed the key aspects of the FY 2009 budget request, which:

- Increases funding for hydrogen storage R&D, fuel cell stack component R&D (focused on the cost and durability barriers), distributed energy fuel cell systems (including early market activities), and basic science (focused on hydrogen production, storage, and fuel cell-related topics)
- Moves funding for the technology validation; safety, codes, and standards; and education activities to DOE's Vehicle Technologies Program budget in order to take advantage of the synergies that those activities have with other alternative fuel vehicle programs (biofueled, plug-in hybrid, and so on)
- Reduces funding for technology validation by 50%
- Defers (zeroes) funding in the Office of Energy Efficiency and Renewable Energy's (EE's) budget for renewable hydrogen production, hydrogen delivery, and manufacturing R&D
- Reduces the EE portion of the DOE hydrogen budget from $211 million in FY 2008 to $178 in FY 2009 (but reduces the total budget for DOE hydrogen activities by only five percent)

Dr. Milliken noted that EE's Hydrogen, Fuel Cells and Infrastructure Technologies Program (HFCIT) will continue to be closely involved with the technology validation; safety, codes, and standards; and education activities, and the same staff will manage these efforts. The move will increase coordination on these crosscutting areas and provide a "one-stop shop" for alternative fuel vehicles.

The DOE decision to defer funding in the FY 2009 HFCIT budget for R&D on renewable hydrogen production, hydrogen delivery, and manufacturing was made to (1) increase the focus on critical path technologies for achieving the DOE goal for technology readiness in 2015, and (2) provide a more balanced overall EE portfolio of near-, mid-, and long-term solutions. The remaining critical path technologies are: (1) reducing the cost and improving the durability of fuel cells, and (2) identifying new materials that can increase hydrogen storage capacity. Dr. Milliken reported that significant increases in funding for fuel cells and hydrogen storage is required in order to stay on track for 2015, so funding for areas that are not considered to be on the critical path has been delayed. In the hydrogen production area, research has enabled a near-term hydrogen production pathway from distributed (on-site) natural gas reforming. While natural gas is not the optimal pathway, it does provide a low-carbon pathway compared to conventional fuels. The FY 2009 budget defers funding for many longer-term hydrogen production technologies and improves the portfolio balance—with continuing escalation of fuel prices and the increasing urgency of climate change, there is a need for nearer-term solutions.

Dr. Milliken went on to present details on the budget appropriated for President Bush's five-year Hydrogen Fuel Initiative (FY 2004-2008) for all the DOE offices involved and for the Department of

Transportation (DOT). As shown in Dr. Milliken's presentation, the total appropriation over this period of $1.6 billion was very close to the President's commitment of $1.2 billion. The FY 2009 budget request for the DOE hydrogen program is $266 million, down from $279 million in FY 2008, which includes reductions in funding for the offices of EE and Fossil Energy (FE), an increase for Nuclear Energy (NE), and a substantial increase for Science (SC).

Dr. Milliken presented several slides showing further breakdowns of the budget, including the FY 2004–2009 EE hydrogen budget by activity area, the FY 2009 DOE request by office (EE, FE, NE, and SC), and the FY 2009 DOE request for all of EE's programs (including Vehicle Technologies, Biomass, Wind, and Solar). She pointed out some additional highlights of the FY 2009 EE hydrogen budget request compared to the FY 2008 budget:

- Includes a $16 million increase for Hydrogen Storage R&D and almost a $20 million increase for Fuel Cell Stack Components R&D
- Increases funding for Distributed Energy Fuel Cell Systems for stationary fuel cells and early markets
- Zeroes funding for Fuel Processing R&D
- Includes decreases for Safety, Codes, and Standards (by about 20%) and Systems Analysis (by about 30%); funding for Education remains close to the same

She pointed out that although R&D for hydrogen production is zeroed in the 2009 budget request for EE, hydrogen production research will continue in DOE's Fossil, Nuclear, and Science programs. She reported a total 2009 budget request of $60.4 million for hydrogen-related basic research in DOE's Office of Science. Although the breakdown shown in the presentation arbitrarily divides this equally among hydrogen production, storage, and fuel cells, the actual amount applied to each activity will depend on the final appropriation and on the proposals selected in these areas for funding under the Office of Science's Energy Frontier Research Centers.

Dr. Milliken described some highlights of the 2009 budget request for DOE's Office of Energy Efficiency and Renewable Energy (EE):

- The budget requests for the Vehicles Technology and Hydrogen Technology programs are among the top 4 of the 11 EE programs.
- The Biomass Program requested a budget increase in 2009, to focus more resources on ethanol as a near-term approach.
- The Vehicle Technologies Program also requested a budget increase, primarily to increase R&D on batteries and plug-in hybrids.
- The Building Technologies Program requested a budget increase to focus more resources on energy efficiency.
- The Solar Energy Program was slightly reduced compared to the 2008 appropriations.

Dr. Milliken reviewed key milestones and activities for hydrogen production, storage, fuel cells, and systems analysis planned for 2009. She noted that a go/no-go decision will be made in 2009 on certain carbon-based materials for hydrogen storage. She pointed out that DOE determined that there was a gap in addressing small-scale, distributed applications for solid oxide fuel cells (SOFCs), because FE mostly addresses *large-scale* SOFC systems, and EE mostly addresses polymer electrolyte fuel cells (PEMFCs). In FY 2009, EE will initiate some projects on *small-scale,* distributed SOFCs operating on natural gas.

At this point, Dr. Milliken took questions from the HTAC members, as summarized below.

- Dr. Milliken clarified that the Codes & Standards and Education activities and their associated budgets will not move to the Vehicle Technologies Program until the passage of the FY2009 budget (as proposed). She noted that when this move occurs, the budget for these programs will fall under the Vehicle Technologies Program; however, the two programs (Vehicle Technologies and Hydrogen Technologies) will continue to work closely together on managing and administering these activities.
- Mr. Rose asked about the interaction between SC and EE, and whether SC could pick up any of the renewable energy research projects not funded in the proposed FY 2009 EE budget. Dr. Milliken replied that the Science budget will include funding for projects in the area of Renewable Hydrogen Production, with a focus on longer-term approaches, such as photoelectrochemical and biological systems. Therefore, although SC will not be picking up projects funded by EE's applied program, SC will be supporting activities at universities and at national labs that have applicability to renewable hydrogen production. Dr. Milliken noted that the existing hydrogen production projects in EE will be canceled, delayed, or re-scoped. Some projects, however, will be able to continue work into 2009 using carry-over funding from FY 2008.
- Dr. Shaw wanted to know why DOE zeroed out the budget for manufacturing R&D, especially since he has heard many discussions about how critical manufacturing technology is in this phase of technology development. Dr. Milliken replied that manufacturing is not perceived to be on the critical path. DOE views manufacturing as an important area of R&D down the road, once problems relating to the cost and durability of fuel cell stacks and hydrogen storage are solved. She added that the EE program did run a manufacturing R&D solicitation in FY 2008, and Congress appropriated funding for this activity in 2008. DOE awarded six projects to start in late 2008, and DOE expects those projects to continue into 2009. If a couple of them look promising, then it is possible that the Program will be able to continue to fund relevant manufacturing projects in FY 2009 under the Fuel Cell subprogram.
- Dr. Schmidt asked about the consequences of the proposed budget reduction to the Technology Validation subprogram. Dr. Milliken said that she was not sure. DOE plans to hold discussions with the organizations involved in the learning demonstrations to determine how to address validation and demonstrations with a reduced budget, perhaps by reducing the scope or by spreading the program out so that it ends later than originally planned.
- Mr. Friedman asked about the budget cuts in the Systems Analysis subprogram. HTAC considers system analysis very important for communicating and better understanding the impacts. Dr. Milliken responded that DOE substantially increased the budget for Systems Analysis in FY 2005–2008 (adding that the DOE requests for Systems Analysis were larger than what was ultimately appropriated, due to funding for congressionally directed projects in the early years). This level of funding allowed DOE to complete a large amount of analysis and develop some very useful modeling tools. She noted that these tools will continue to serve the program and that the program can afford to reduce the budget here in FY 2009 in order to place a greater emphasis on the critical path technologies.
- Mr. Friedman asked whether the "near-term versus long-term" logic for whether to fund hydrogen production research was also applied to nuclear hydrogen funding. Dr. Milliken replied that the budget process for nuclear hydrogen production is handled by DOE's Office of Nuclear Energy and does not factor into EE's budgeting decisions.

- Mr. Rose commented on the magnitude of the funding reduction for hydrogen production research, remarking that the dramatic drop, from $40 million in FY 2008 to zero in FY 2009, is not something that he ever likes to see. He asked Dr. Milliken what she thinks will be the impact of this dramatic change, and whether she is comfortable with the decision.
- Dr. Milliken started off by saying that when the Hydrogen Program began back in 2003–2004, the only production pathway on the critical path to the 2015 technology readiness goal was natural gas. Currently the most economical way to produce hydrogen is from natural gas, and most of the hydrogen today is made from natural gas. The critical path requires the availability of one pathway for hydrogen production that is technically and economically feasible; work on other pathways can then be continued, and other pathways to hydrogen production can come on-line, piggybacking on the infrastructure, as the market develops. She noted that DOE funded a lot of work on small-scale natural gas reformers for distributed production of hydrogen, and DOE's recent analysis shows that this technology can meet DOE's cost goal of $3 per gallon of gasoline equivalent or $3 per kilogram. Therefore, distributed hydrogen production from natural gas, while not the ultimate pathway for hydrogen, provides a reasonable pathway for hydrogen production in the transition. Due to the remaining difficult challenges to meeting the near-term goals for fuel cells and storage, DOE decided to back off its R&D in production and focus more resources on addressing these challenges. The Office of Science will continue to pursue breakthroughs in renewable hydrogen production pathways and, as they make progress, DOE expects to transition some of that work into the applied research programs.
- Dr. Milliken agreed that the production budget cut will have serious impacts on some projects, but that hard decisions needed to be made about what to fund with the existing budget. She noted that the actual impact on individual projects will vary depending on the project. Some projects, nearing their end, will be closed out naturally. Projects that are mid-way or three-quarters of the way through will be delayed; though some will be able to continue through FY 2009 (perhaps with reduced scope) using carry-over funds from 2008. DOE has also had to make fewer awards than originally planned from the recent hydrogen production solicitation, and those projects generally have been required to shorten their performance periods and reduce their scopes.
- Dr. Taylor asked about the interaction between DOT and DOE, and why the budget shown for DOT is so small, considering the magnitude of the barriers relating to addressing safety, codes, and standards. Dr. Milliken replied that DOE works with DOT quite a bit. There is a Hydrogen Coordination Group that meets regularly, which includes representatives from all the involved DOE offices and from DOT. There is also a senior-level Interagency Hydrogen and Fuel Cells Task Force and a staff-level Interagency Hydrogen and Fuel Cells Working Group, in which DOE and DOT are involved, among other agencies. These groups share information on safety, codes, and standards development, as well as on activities outside of the Hydrogen Fuel Initiative budget, such as DOT's fuel cell bus demonstration program. EE collects data from the fuel cell buses, monitors the data, and determines the status of the technology. Dr. Milliken added that the budget for DOT's hydrogen-related activities is something that DOT is working on expanding, and that DOE encourages and supports its efforts.
- Congressman Walker questioned the underlying philosophy behind the budget. He observed that hydrogen is referred to as a "long-term solution," and biofuels, particularly ethanol, are referred to as "short-term." However, he noted that most of the talk is focused on cellulosic ethanol, which has an R&D timeline that is very close to hydrogen. He wondered how we arrived at a conclusion that

hydrogen is way out in the distance while some of these other alternatives are much nearer-term solutions to the energy problem. Dr. Milliken replied that she does not know the timeline for cellulosic ethanol, but that she believes biorefineries are being built now. From what she understands, plug-in hybrid electric vehicles are expected in 2010. For the hydrogen program, the timeline is aimed at meeting targets in 2015 that will enable widespread market penetration in the 2018–2020 timeframe. She suggested that one thing DOE could do is to arrange for representatives of these programs to provide briefings to the HTAC on technology status and timelines.

- Congressman Walker agreed that plug-in hybrid vehicle platforms provide an opportunity for fuel cells, but he expressed concern that the pathway is not being adequately prepared to make this a realistic possibility for companies. Dr. Milliken disagreed and stated that she believes the pathway is being prepared, but that hard decisions had to be made in light of the limits placed on the budget request. She noted that codes and standards are now in place that have enabled industry to build stations; workshops are being held to train permitting officials; the time required to permit a station is being reduced; and issues such as the size of the station footprint, setback distances, and others are being addressed.
- Dr. McCormick described his difficulty understanding what DOE expects to deliver in 2015 how this reconciles with what the auto companies expect to deliver in 2015, and what they need to get there, noting that designs for a car company's 2015 offerings will be locked down by early 2011. He asked Dr. Milliken to describe, when she speaks of a "critical path," what it's a critical path *to*. He further explained that omitting manufacturing from the critical path was questionable because a large portion of the cost of a fuel cell stack will be in the manufacturing, not in the materials or components.
- Dr. Milliken answered that the 2015 deliverables are technologies that meet DOE's targets, as published in the multi-year RD&D plans, and as developed in collaboration with industry. She also noted that one of the contributing factors to EE's decision to delay funding for manufacturing R&D in the face of the budget constraints was the fact that the materials of construction are changing. Because the materials are not set, it is hard to address manufacturing. Dr. McCormick conveyed his belief that DOE should focus on areas that industry is not involved in—that is, longer-term, high-risk research aimed at developing breakthrough solutions that will enable next-generation technologies for hydrogen and fuel cells. Dr. Milliken argued that DOE's current portfolio is looking at breakthrough solutions. She pointed out that the storage activity, in both EE's applied program and in SC's basic research program, is looking at breakthrough materials and making tremendous progress, which will be reported at the upcoming Hydrogen Program Annual Merit Review in June 2008. She concluded that DOE is eager to meet the 2015 targets (which the industry helped develop on the basis of consumer requirements and system requirements), to help enable industry to make a commercialization decision if the market conditions are appropriate and the technology is ready. She agreed with Dr. McCormick that DOE will not make the commercialization decisions: "DOE's role is to fund R&D to get the technologies to where we think they should be, based on our work with the industry."
- Mr. Rose expressed his concern that the FY 2009 budget decision implies that sustainability is not a significant aspect of the program. He asked Dr. Milliken if she considers sustainability to be a major motivator for the program. He worried that if not, the case for hydrogen is weakened. Dr. Milliken responded that the program is motivated by sustainability. She re-emphasized the basis for DOE's decision: that if the targets for on-board hydrogen storage capacity and fuel cell cost and durability

are not met, there will not be sufficient demand to justify a hydrogen infrastructure. So, while sustainability is the ultimate goal, it is not on the critical path for the near term.

Dr. Milliken continued with her presentation, moving on to recent activities and programmatic progress, as highlighted below.

- Hydrogen Production
  - Eight new projects were awarded in FY 2008 (focused on distributed electrolysis, hydrogen compression, tube trailers, and liquefaction).
- Hydrogen Storage
  - DOE issued a solicitation for a Hydrogen Storage Engineering Center of Excellence, which will complement the materials R&D by focusing on systems engineering issues, with funding of $35 to $40 million over 6 years.
  - Progress is being made on selecting promising potential storage materials, and the field of possibilities has been narrowed through down-select decisions.
- Fuel Cells
  - The updated fuel cell cost analysis reported a high-volume cost of $94 per kilowatt.
  - DOE issued a solicitation addressing stack components, materials, research, market transformation, and other areas, for awards expected to total to $130 million over three years.
- Manufacturing
  - Six new projects were awarded in 2008, focused on membrane electrode assemblies, gas diffusion layers, stack assembly, stack conditioning, leak testing, and compressed tanks.
- Technology Validation
  - Testing is underway and data are being collected on 92 first-generation fuel cell vehicles and 15 fueling stations.
  - Second generation vehicles are coming on-line now, and DOE is beginning to plan for Phase II of the learning demonstration, which is anticipated to include third-generation vehicles.
- Safety, Codes, and Standards
  - Progress has been made on streamlining the permitting process, and a permitting compendium has been published; it is currently being updated to include permitting for stationary power as well as transportation applications.
  - Progress has been made towards a hydrogen fuel quality standard.
  - DOE will continue to coordinate with more than nine active codes and standards organizations to develop and publish codes and standards.
- Education
  - A solicitation closed in January 2008 and awards are expected to be made soon (focused on partnerships with state and local governments, early deployment and education activities, and university programs)
  - New education products include training materials for first responders and code officials; radio spots, podcasts, and web-based information to educate local communities; materials for end users (particularly in early markets); and workshops and competitions for students

- The radio spot has been played during broadcasts of Orlando Magic games

- Systems Analysis
  - Hydrogen Transition Scenario Analysis published *Analysis of the Transition to Hydrogen Fuel Cell Vehicles and the Potential Hydrogen Energy Infrastructure Requirements*
    - Oak Ridge National Laboratory (ORNL) published the report in collaboration with other labs.
    - National Academies of Sciences requested a report to evaluate how a transition to hydrogen might occur.
    - While not a strategy or a plan, the report presents potential market penetration scenarios and what infrastructure and policy would be needed to execute them.
    - Results will be presented at the Hydrogen Program Annual Merit Review meeting on June 9–13 in Washington, D.C.
    - A report is available online at http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_30.pdf (copies of the report were provided to HTAC members on May 14).
  - National Renewable Energy Laboratory is evaluating the opportunity for using hydrogen as energy storage for intermittent renewables.
  - ORNL conducted a study of the impacts of early markets, which concluded that early adoption of stationary fuel cells by the Federal government can bring costs down and have a positive effect on the industry.
  - Analysis on carbon dioxide emissions will be presented to the HTAC on May 14.

- Market Transformation
  - The Hydrogen and Fuel Cells Interagency Task Force (ITF) has held three meetings
    - April 15, 2008, meeting focused on finance tools and contract templates, impacts of federal deployment, and growing need for power reliability in Federal agencies (see briefing by Christy Cooper).
    - The focus of ITF is market deployment and working with a number of federal agencies to purchase hydrogen and fuel cell technologies.

- International Activities
  - International Partnership for the Hydrogen Economy (IPHE) has narrowed down to four priorities. The top priority is accelerating market penetration and early adoption; related to this priority is raising the profile with policymakers and helping to influence policy and public education. The IPHE is focused more on high-level strategic coordination and collaboration.
  - International Energy Agency (IEA) focuses more on collaborative R&D, and has ongoing work in two Implementing Agreements and a number of task areas.
  - Joint IPHE-IEA analysis is focused on vision and pathways for building hydrogen infrastructure worldwide.

- External Program Review/Strategic Input
  - In January 2008, the U.S. Government Accountability Office released a report on the Hydrogen Fuel Initiative (see presentation by Robert Sanchez).

- National Academies/National Research Council review of the Freedom CAR & Fuel Partnership released April 2008 (see presentation by Kathy Taylor).
- Both reports are generally favorable but offer valuable recommendations for how the program should proceed.

At this point, Congressman Walker took questions from the HTAC, as summarized below.

- Dr. Dresselhaus asked which countries are doing the best research—which countries are ahead of the United States, by how much, and in what way. Dr. Milliken responded that she could not fully answer the question, but that Japan and Germany are very active. Japan is doing a lot of research in both fuel cells and storage and Germany is doing R&D in the area of storage. She noted that Los Alamos National Lab recently signed a memorandum of understanding to work with researchers in Japan, and there is ongoing information exchange. Dr. Milliken offered to provide more information in the subject of international R&D and the collaborative research being pursued through IEA or other organizations at a future meeting. Dr. McCormick noted that GM is pursuing commercialization activities in China, Korea, and Germany, some of which will be covered in the GM presentation on Project Driveway.
- Dr. Dresselhaus stated her perception that many other countries seem generally ahead of the U.S. in numerous areas relating to science, technology, and innovation, as well as in making political commitments to renewable fuels. She said that it is very important for the U.S. to keep an eye on the nature and pace of activities in other countries because once they get established with the technologies and business relations, it makes it more difficult for the U.S. to catch up. Dr. Saillant responded that both Japan and Germany are working toward goals that have not been made explicit in the United States: (1) a zero net carbon energy system, and (2) a system of extraction, manufacturing, design, development, use, and so forth, that is zero landfill. He stated that if DOE had those sorts of long-range goals and a foundational basic vision and timeline driving it, the hydrogen and other activities would fall in line. Dr. Dresselhaus agreed and recalled that Germany has cited 2020 as a timeframe for achieving 18% renewable energy in the electricity sector, while France committed to 20%. She expressed her disappointment that the U.S. has not defined a clear vision for where the country is heading.
- Mr. Rose asked about the International Standards Organization (ISO) standard for fuel quality. He stated that the scientific basis for establishing impurity levels in hydrogen was not clearly established prior to adopting the ISO standards. He is particularly concerned about the levels specified for carbon monoxide (CO), ammonia, sulfur, and chlorine. He noted that natural gas reforming and cleaning can be done in many ways, and that different types of fuel cells can handle different levels of impurities. He is concerned about adopting standards without full input from the scientific community. Dr. Milliken responded that DOE is aware of this issue and shares the concern about prematurely establishing a fuel standard. She noted that currently there is only a hydrogen fuel "specification," not a standard. The target date for the standard is 2010, and DOE is working with the various standards organizations to provide information on the response of a fuel stack to impurity levels.
- Dr. Shaw reported that he recently saw an announcement that the renewables community was very frustrated with the pace and politics of IEA activities, and was considering setting up a new organization outside of the IEA arena. He wondered whether the hydrogen community shared this sentiment. Dr. Milliken replied that she had not heard that about the IEA. She offered her suspicion that the frustration may be with higher-level groups within the IEA, but that the working-level groups

in which the hydrogen program participates seem to function well. She noted that the IPHE includes 16 member countries and the European Commission, and the point of view varies. She believes that the primary frustration within IPHE is not so much that things are moving slowly but that they want to have more impact. They are trying to determine how they can be more proactive through, for example, a global demonstration project or other more tangible, public activities.

Dr. Milliken concluded her presentation with a brief review of technical accomplishments and R&D progress towards DOE's critical path targets, including progress towards: (1) hydrogen cost production targets; (2) hydrogen storage targets for system capacity; and (3) fuel cell targets for cost, efficiency, and durability. Highlights of the presentation are summarized below.

- Based on a gasoline price of $3.25/gallon (untaxed), hydrogen is cost-competitive, on a cents-per-mile-driven basis, with conventional internal combustion engines at $7.80/gge and with gasoline-fueled hybrid-electric vehicles at $5.40/gge, so some hydrogen production technologies are already competitive with gasoline.
- The current cost of hydrogen from distributed natural gas is about $3.55/gge (untaxed), with assumptions of $7.75/million Btu natural gas, 1,500 kg/day stations, and 500 reforming units manufactured per year.
- Costs are coming down slightly for distributed electrolysis: Recent data indicate that the 2012 targets for both electrolyzer system capital cost and efficiency will be met.
- Work on distributed bio-derived liquids reforming has only been recently started; no progress to report.
- Central production pathways are not on the critical path but show promise for meeting targets in out years, with biomass and coal as the current low-cost options for centralized hydrogen production (and within the range of cost competitiveness with gasoline today on a cents-per-mile basis).
- Storage remains the most significant technical challenge, and no material has yet been identified that simultaneously meets the system targets.
  - R&D on hydrogen storage is relatively new, so the program is not discouraged by these results.
  - Many potential materials have been identified, and R&D is ongoing.
- The 2007 automotive fuel cell cost status is projected at $94/kW—it will be very challenging to reach the 2009 target of $60/kW and the 2015 target of $30/kW.
- Recent data indicate that the 2015 automotive fuel cell durability target of 5,000 hours will be met.
- For stationary fuel cells, the 2005 durability status was 20,000 hours, and the 2011 target is 40,000.
- The Hydrogen Program Annual Merit Review will be held June 9–13, 2008, in Crystal City, VA, and is open to the public. The plenary session will provide an overview of the program and progress, and technical sessions the following days will present project results.

Questions and answers about this portion of the briefing are summarized below.

- Dr. McCormick asked what the target dates (years) mean. Dr. Milliken responded that the date is the year in which DOE has demonstrated, either in the laboratory (e.g., for storage targets) or in a prototype component or system (e.g., for production and fuel cell targets) a technology that is

projected to meet the targets at high volume. Dr. McCormick asked if the cost analysis for status and targets includes the cost of capital, and she replied that it includes a 10 percent return on investment. Dr. Milliken emphasized that these are DOE targets and are independent of what industry does, though the targets are developed with industry input. The hardware "deliverables" from the projects are provided to DOE's test facilities, and the results are independently verified by experts.

- Mr. van Dokkum asked whether the DOE's calculations on the cost competitiveness of hydrogen compared to gasoline includes any kind of carbon tax or cap and trade schemes. Dr. Milliken replied that a cost for carbon is not included. Mr. van Dokkum asked about targets for other types of fuel cells, and Dr. Milliken replied that DOE is currently working on developing targets for solid oxide fuel cells for distributed energy generation and the reporting the status of the technology. She noted that while DOE is not doing any research on molten carbonate or phosphoric acid fuel cells, DOE is working hard to develop opportunities to deploy those technologies in federal facilities such as federal data centers.
- Dr. Saillant asked if it would be difficult to normalize the cost of delivered hydrogen to a standard CO_2 basis. Mr. Fred Joseck of DOE replied that he could update the costs accordingly.
- Mr. Friedman asked whether, given the rapidly rising cost of gasoline, changing fuel economy standards, and pressure to place a value on carbon, there is an opening to re-evaluate the DOE targets. He agreed that "moving the goal posts is tricky," but asserted that sticking with the current goals could be dangerous for the future of the program. He stated that revised targets would likely show that the Hydrogen Program is a lot closer to where it needs to be in a real competitive environment as opposed to a past competitive environment. Dr. Milliken replied that DOE has been debating this issue internally. She noted that DOE needs to use Energy Information Administration (EIA) data and forecasts in developing its targets, but the $2.00–$3.00 production cost target was based on data that has since been revised by EIA. She stated that the program could, then, revise the target based on the most recent EIA projections, but that would still not reflect current prices. She added that gasoline prices fluctuate a lot and it would not be useful for the program to revise its targets every three months. Therefore, the approach adopted by the program is to produce a sensitivity analysis and communicate that the actual targets will depend on a number of variables. Mr. Friedman agreed and added that perhaps more of that would be useful. He asked whether DOE is required to use EIA data, and Dr. Milliken replied that it is standard operating practice for the entire Department, but she is not sure if it is a regulatory or legislative requirement.
- Dr. McCormick observed that the Department of Defense uses a hierarchy of research targets, starting with very aggressive research targets right on the edge of achievable, and moving towards more commercial. He advocates for a system that assigns "different colors of money to different phases of the program." He believes there is a problem in communicating (among the HTAC members and to the larger group) the difference between a research target and a commercialization target, and that these should be clearly separate. He would like to see DOE set very aggressive research targets but does not want those to carry over into decisions regarding what may or may not be commercialized. Mr. Friedman added that this gets to another point often raised by the HTAC: The magnitude and urgency of the problem is not matched with resources, which forces us to continually shuffle around "pieces of a pie" that is either the same size or shrinking. In reply to Dr. McCormick's point, Dr. Milliken noted that DOE does divide its research among "basic" and "applied" research and has set aggressive research targets, particularly for hydrogen storage. The target of 9 weight percent capacity exceeds the storage capacity for liquid hydrogen and will be extremely challenging to achieve. She

stated that the program has been considering establishing more relaxed targets for early market technologies and applications (e.g., for 100 kg/day hydrogen production rather than 1,500 kilograms per day hydrogen).

- Mr. Mudd asked whether the capital cost estimates presented for fuel cell systems and electrolyzers were in 2003 dollars. Dr. Milliken responded that the fuel cell costs were revised more recently and are in 2006 dollars, and the electrolyzer targets are in 2003 dollars. Mr. Mudd said that the electrolyzer costs are misleading, because costs have gone up significantly for everything since 2003. Dr. Milliken replied that the program is aware of this problem and is working on addressing this issue.

3. *Briefing on Activities of the HTAC Policy and Planning Subcommittee*

Dr. Robert Shaw

>> see full presentation at http://www.hydrogen.energy.gov/advisory_htac.html

Dr. Shaw, Chair of the HTAC Policy and Planning Subcommittee, reported on activities of the Subcommittee since the December 2007 HTAC meeting (see presentation for full list of members). The Subcommittee met via teleconference on March 19, 2008. The main agenda items for the call were:

- HTAC vision statement
  - Discuss and refine
- HTAC annual report
  - Discuss concept
  - Consider categories of information to be gathered
  - Define information-gathering process
- Hydrogen Progress Index
  - Discuss concept
  - Consider potential index components and structure

Dr. Shaw briefly reviewed the *vision statement*, as revised and agreed upon by the Subcommittee members. He pointed out that the HTAC agenda includes time on the morning of May 14 to discuss the vision statement, and he suggested that the members review the vision overnight and provide any comments during that session.

The Subcommittee endorsed the idea of HTAC preparing an *annual report*, with the following characteristics:

- Brief, no more than five pages, very pithy and focused
- Focus on the major accomplishments in the hydrogen world during the past year
- Produce a report this year and circulate widely, both inside and outside Washington
- Continue in subsequent years if the report appears to have value

The Subcommittee prepared a draft outline of the type of information that could potentially be included in the annual report (including key reports issued, product events, technology events, major policy decisions and initiatives, and new entrants into the hydrogen space). HTAC members were asked to assist in gathering input for the annual report by sending information to Dr. Shaw (aretecorp@roadrunner.com) and to Shawna McQueen (HTAC support staff) at smcqueen@energetics.com. He urged the Committee

members to send information for the annual report as it comes to their attention, rather than trying to rush to put this together at the end of the year.

On the idea of a *hydrogen progress index*, the Subcommittee members agreed that it is a good idea, but were concerned about making it too quantitative. The consensus was to try to work towards a qualitative index, similar to the "Minutes to Midnight Doomsday Clock" used by the *Bulletin of Atomic Scientists*. This type of index would be useful in quickly communicating the Committee's assessment of how we are doing. Dr. Shaw reported that after the March 19 teleconference, he drafted a concept for a Hydrogen Progress Index that he did not have a chance to fully vet among all the Subcommittee members. He presented the draft index concept (shown on slide 9 of his briefing)—an "elevator scale" that ranges from zero ("very disappointing progress") to 10 ("unusually exciting progress"). The middle of the scale (5) is termed "solid progress," indicating that we are moving ahead but nothing really great or very disturbing has happened. Dr. Shaw noted that the briefing shows the indicator arrow at "6," but that this is arbitrary and would be set by the Committee at the end of the year.

Dr. Shaw presented a list of metrics (or variables/factors), developed by the Policy and Planning Subcommittee, which could be considered by the HTAC in determining the progress for the year (e.g., number of fuel cell vehicles on the road, number of hydrogen fueling stations, etc.). The proposed process for developing the index is that the Committee would, in the early calendar year, consider the important events highlighted in the HTAC Annual Report and any metrics that can be gathered and develop a qualitative judgment on what the progress rating should be for that year.

Dr. Shaw asked for comments and invited any Committee members to join the Policy and Planning Subcommittee. He added that the Subcommittee will meet again in the late summer or early fall to prepare for the annual report, and he reminded Committee members to send their inputs to him and Shawna McQueen.

Questions, Answers, and Discussion

- Congressman Walker advised that the biggest question of the public will be "why should I care?" He recommended that the annual report include price point data that would be attractive to the public. If the public sees technologies that are more efficient at prices that are reasonable, they will ask for it. Dr. Shaw agreed that economic data will be an important input to the annual report.
- Mr. Friedman agreed that it is useful to address progress and important events/activities in the annual report, but he argued that the report should also address gaps. He suggested that part of the role of the HTAC is to continually point out what is missing and what is needed to reach the vision.
- Dr. Dresselhaus suggested another metric for reporting in the annual report and for measuring the progress index is to report: the amount of hydrogen that is produced from renewable resources (or progress in this direction).
- Dr. Ross noted that the California Fuel Cell Partnership (CaFCP) gathers some of the information called out for the HTAC annual report and progress index, including information on fueling station installations and data on usage of stationary fuel cells and fuel cell vehicles. Mr. van Dokkum stated that the CaFCP data are available on-line and that the CaFCP will collaborate with HTAC.

- Dr. Ross commented that it will take considerable staff support to develop and accurately maintain the HTAC annual report and asked whether the Committee has that level of support. Dr. Shaw reported that Shawna McQueen has been designated by DOE to work with the Subcommittee; it is unclear whether this level of support will be sufficient.
- Mr. van Dokkum stated that there is information overload on hydrogen and fuel cells and that the report can serve to distill the information. He suggested that one important outcome of the report should be to provide an indicator of whether we are on the right track: "Are we meeting our goals as a society to get hydrogen embedded into our energy portfolio or not? Where is more effort needed to actually advance on this pathway?"
- Mr. Mudd congratulated the Subcommittee on crafting a vision statement that is devoid of agendas. He asked who the intended audience is for the annual report. Dr. Shaw responded that the target audience is Congress (members and their staff), the business community, and the general public. Mr. Mudd expressed concern with using the term "index" for the hydrogen progress indicator, because many people equate an index with numbers and, therefore, something that is quantitative rather then qualitative. He wondered whether this term would create confusion or false expectations, and he suggested calling it something other than an index. Dr. Shaw noted his point and asked for specific ideas on an alternative term for the index. He noted that all suggestions are welcome, because this is still a work in progress and the objective is to communicate clearly.
- Mr. Rose reported that the Subcommittee began their deliberations by considering a numerical index, but concluded that a quantitative index would be very difficult to do well and credibly and would be too much of an administrative burden. He agreed that the term index is probably a misnomer, now that the decision has been made to move to a qualitative rating scheme.
- Dr. Ross asked to see a copy of the HTAC's legislative authorization. He wondered whether there was anything in that authorization that would prevent the HTAC from promulgating a vision statement, or whether there was anything that the Committee is supposed to be doing that it has not yet done.
- Dr. Ross expressed concern about including "new entrants into the hydrogen space" as a topic area/tracking metric for the annual report. He stated that if new start-ups are included, then companies exiting the marketplace should also be included. He wondered about the value of that information because the major corporate initiatives would likely be captured in the other topic areas.
- Dr. Dresselhaus suggested that international comparisons be included as a topic/tracking metric for the annual report and index. She noted that this is very important because Congress is concerned about international competitiveness, losing jobs, and so on. Congressman Walker agreed that the U.S. leadership position is important.
- Dr. Shaw asked Dr. Milliken whether she thought any of the topics under discussion (the HTAC vision statement, annual report, or progress index) would be problematic for DOE. She responded that she did not see any problems with what is currently proposed. Dr. Shaw noted that Kathi Epping Martin is part of the Subcommittee and DOE is welcome to contribute to the drafts.
- Mr. van Dokkum stated that he has difficulty seeing how the progress indicator can be boiled down to one single point. He suggested that the Committee consider a "dashboard" approach that has the different elements that need to addressed, each with a gauge that measures progress for that element. Dr. Shaw agreed that the dashboard approach is fairly commonly used in the business world to

measure progress. However, he argued that a dashboard can be visually overwhelming and hard to understand what it all means without a lot of explanation. He proposed that the Committee think about developing a dashboard using the agreed-upon metric areas for the progress index, and then synthesize this into a single measure of performance. Congressman Walker added that if the dashboard approach is pursued, then perhaps the single indicator of progress could be represented by a speedometer—the speed at which we have moved in the past year toward the goals.

- Dr. Shaw thanked the Committee for their comments and asked for any additional input via telephone call or email. He conveyed his impression that the Committee is supportive of taking on the tasks to produce an annual report and an index of some sort and will proceed with these tasks in the Policy and Planning Subcommittee.

4. *Briefing on GAO Report on DOE's Hydrogen R&D Program*
Robert Sanchez, U.S. Government Accountability Office
>> see full presentation at http://www.hydrogen.energy.gov/advisory_htac.html

Mr. Sanchez briefed the HTAC on a recent study of the Hydrogen Fuel Initiative released by the U.S. Government Accountability Office (GAO), which can be found at http://www.gao.gov/new.items/d08305.pdf. The study objectives were to examine the extent to which DOE has (1) made progress in meeting the Hydrogen Fuel Initiative (HFI) R&D targets, (2) worked with industry to set and meet targets, and (3) worked with other federal agencies to develop and demonstrate hydrogen technologies. The main conclusion of the report is that "DOE has made important progress and involved stakeholders but needs to update what it expects to achieve by its 2015 target." Mr. Sanchez specially thanked Dr. Milliken and her staff at DOE for the assistance they provided GAO as they were working on the report, and he said that he found the "DOE staff to be extremely dedicated, extremely helpful, and very well organized." He went on to describe some of the report's key findings:

- DOE has made important progress in meeting targets.
- DOE's targets are very ambitious.
- Some target dates have been pushed back due to budget constraints and technical challenges.
- Some targets require significant advances or breakthroughs to achieve.
- DOE has a good planning process and involves industry, university experts, and other stakeholders.
- DOE effectively coordinates with other federal agencies.
- DOE has a good mix of fundamental and applied science.
- DOE focuses resources on high priority areas.
- Developing physical infrastructure for hydrogen is challenging and will likely take decades and cost billions of dollars and require sustained commitment of federal and industry resources.
- The 2006 Hydrogen Posture Plan does not accurately reflect the impact of budget constraints and technical challenges on targets and should be updated.

Questions, Answers, and Discussion

- Dr. Shaw asked Mr. Sanchez whether he thought the industry was moving faster or more slowly than what the targets in the Posture Plan would indicate. Mr. Sanchez replied that the major automobile companies are not waiting for the hydrogen storage problem to be solved and are going forward with vehicle production schedules on their own individual timelines. Likewise, the GAO heard feedback

from the stationary fuel cell industry that they need to go ahead with current technology. He noted that the development of markets and infrastructure would take time as well as commitment from the federal government and industry. Many companies are interested in making limited investments only in niche markets until they see a clear path forward for larger investments. He added that the GAO wanted the Congress to understand that this technology is high risk, and it will take a sustained commitment and investment on the part of the government to make it happen.

- In response to a comment from Dr. Saillant about the level of investment required for hydrogen infrastructure, Mr. Sanchez replied that the GAO report confined itself to what kind of investment might be required during the transition years (a couple of decades and tens of billions of dollars). Dr. Shaw reported that modeling he is aware of concludes that the size of the infrastructure investment is relatively insignificant when compared to "the cost of the vehicle buy down that may be required in the early days." Until an economy of scale emerges on the order of millions of vehicles, hydrogen cars will not be cost-competitive with current vehicles. He is concerned that so much discussion focuses on how difficult and costly the infrastructure problem is, when he has become convinced that it is a relatively "small piece of the puzzle." He urged GAO not to overstress the cost or present it as insurmountable, because a phased roll-out of infrastructure, from distributed generation to pipelines, can lower the societal costs until such time that unsubsidized investments become economically attractive. Mr. Sanchez replied that GAO does not consider infrastructure cost to be an insurmountable barrier, but it will cost money to overcome; whether that is the taxpayer or someone else is left to Congress to decide. Mr. van Dokkum and Mr. Katsaros agreed with Dr. Shaw and stressed that the most difficult period will be the technology transition, and getting policies into place that will make the transition possible.
- Dr. Dresselhaus communicated to Mr. Sanchez that the research community is very frustrated and discouraged by the recent difficult funding cycles: solicitations that are not ultimately awarded and cuts in appropriated funding. She noted that this sort of uncertainty and variability in funding hurts R&D efforts, and that this problem should be addressed in the GAO reports. She stressed that researchers can work on other projects, causing a loss of good contributors due to frustration in the system. Dr. Taylor agreed with these comments. Dr. Dresselhaus suggested establishing more fellowships for graduate and postgraduate students to maintain adequate education levels for the hydrogen future.
- In attending worldwide conferences, Dr. Dresselhaus has learned about many renewable fuel systems that will be potential competitors with hydrogen. "So we have to consider all of these things that may play out in a totally different way than we anticipate now."
- Mr. van Dokkum agreed with the GAO's opinion that the Posture Plan needs to be updated. He suggested that this update consider international progress towards the DOE targets. He noted that he spends as much as three-quarters of his time overseas, mainly in Korea, Japan and China, where they are more active in hydrogen and fuel cells than in the United States.
- Dr. Taylor noted that variable research funding also affects the in-flow of students that choose to study hydrogen and fuel cells. She asked whether the GAO report addressed future workforce issues. Mr. Sanchez replied that the report did not address workforce issues, but he noted that GAO published a report several years ago that addressed workforce issues at the national laboratories. That report found that some of the labs were having recruiting problems because many of the qualified graduate students were international and cannot receive security clearances.

- Dr. McCormick communicated that one of the key problems is the issue of time. He noted that industry has to run on a particular timeline, which happens to be in a one-year to four-year timeframe. However, the problem that we are trying tackle is a long-term problem. Resolving the differences between these two time horizons requires vision and leadership at the government level. He recommended two recent speeches that shed light on this subject—the talks by Jeffrey Immelt and Thomas Freidman at the winter 2008 meeting of the National Governor's Association (see: http://www.nga.org/portal/site/nga/menuitem.6c9a8a9ebc6ae07eee28aca9501010a0/?vgnextoid=5b83315eff9e7110VgnVCM1000001a01010aRCRD&vgnextchannel=530f749a71302010VgnVCM1000001a01010aRCRD). Dr. McCormick stressed that the scope of what needs to be accomplished requires us to set steady goals that drive us towards creating viable options for the endpoint. The market will determine which options are good.
- In response to a question from Mr. Katsaros about continuing GAO involvement in the Hydrogen Program, Mr. Sanchez explained that the current GAO review is over. They conduct studies mainly at the request of Congress; revisiting the Hydrogen Program will depend on the level of interest of the Congress. He added that copies of the report and a briefing on the results were provided to the requesting group, the Committee on Science, as well as several other Congress members who expressed interest along the way. The GAO also performs annual budget reviews during which it updates its information, and the interested members of Congress were updated more recently.
- Mr. Paul Brubaker (DOT) asked whether there was any plan at GAO for looking into some potential incentives that could jumpstart or compress the time frame for infrastructure or alternative vehicle deployment. Mr. Sanchez replied that GAO is currently conducting a review of ethanol that includes the infrastructure development. He stated that GAO has not been asked to look at hydrogen infrastructure by itself and that if they did this any time soon it would probably be part of a larger body of work. He pointed out that GAO did issue a report about a two years ago addressing incentives provided for alternative energy technologies at the state and federal government levels. One of the findings was that the states are far ahead of the federal government in terms of providing incentives for alternative technologies and there are a variety of different mechanisms in use.
- Dr. Saillant asked which governmental organization is responsible for end-game, strategic thinking about scenarios for the future. Mr. Sanchez replied that the GAO tends to focus on technical issues; the bigger picture questions are addressed by industry organizations, think tanks, the White House Office of Science and Technology Policy, or congressional legislation or appointment of congressional bodies that would provide oversight or advice. Dr. Shaw pointed out that the National Academies is currently working on a report (in which Dr. Mike Ramage, an HTAC member, is involved) that will likely address some of these issues.
- Dr. Shaw pointed out that the targets are set based on current competition. He questioned whether it is fair to say that gasoline at $3 or $5 a gallon is the real effective societal price because it does not include the carbon impact. He noted that a fair analysis would include the externalities and compare technologies on that basis. Mr. Sanchez replied that other GAO studies have reported on the externalities associated with carbon-based energy resources, but that this subject was not considered to be in the scope of the hydrogen program review.
- Congressman Walker commented that the single-year appropriation cycle for Congress makes it difficult for programs to plan over a long term and creates continuity problems, especially for big programs.

- Congressman Walker asked whether the GAO recommended a funding level for the Hydrogen Program. Mr. Sanchez replied that that GAO did not do an independent analysis but "parroted" what they heard from the majority of industry, which was that the Hydrogen Program needed more funding. The GAO also found the level of participation in the Hydrogen and Fuel Cells Interagency Task Force to be acceptable.

Dr. McCormick stressed that hydrogen is not "the" answer, but one of the potential options that the market will pick from. He surmised that if the nation were to declare the "moral equivalent of war," this would stimulate more aggressive actions for industry to create these options and to pursue them all until the winners emerge. He noted that the tendency is for policymakers to change courses frequently on the basis of the latest analysis results rather than pursuing a slate of options.

5. ***Report on the NAS Review of the Research Program of the FreedomCAR and Fuel Partnership***
Kathy Taylor
>> see full presentation at http://www.hydrogen.energy.gov/advisory_htac.html

Dr. Taylor spoke on her participation in and the findings of Phase II of the National Academy of Sciences' 2007 review of the research program of the FreedomCAR and Fuel Partnership. NAS issued the Phase I review report in 2005. Dr. Taylor described the background of the Partnership, the scope of the NAS review, review committee members and organization, and highlights of the findings and recommendations for the program as a whole and in each key R&D area. She listed some of the report's general observations and noted that the NAS review committee found that significant progress had been made since the first review and that DOE was generally receptive and responsive to the Phase I NAS recommendations. The NAS also found the DOE R&D programs to be well managed, focused on appropriate barriers and research activities, and well-served by the "huge benefits" from strong auto and energy company input on critical issues and goals. She stressed the need for additional studies (e.g., on timing and availability of carbon sequestration and biomass-to-hydrogen) and for more continued focus on safety; technical validation; fuel cells; storage; and production, delivery, and dispensing (including fueling station footprint). She closed by presenting the report's overall assessment, as shown below.

- The FreedomCAR and Fuels Partnership has developed an extremely effective way to conceive, fund, and execute programs that can enable beneficial, long-term, transformational change in the automotive transportation system.
- Significant progress has been made in all of the key research areas that could make the transportation system sustainable in a resource-constrained and environmentally responsible world.
- The expertise, experience, and judgment of the leadership of this Partnership constitute a resource uniquely qualified to help define the overall energy transportation policy of this country. Achievements in this program provide the credentials for this role.
- All of the diverse technical activities addressed by the Program have made significant progress.
- Management has set appropriate goals, provided excellent oversight, and, within the constraints imposed by the funding process, adjusted priorities appropriately.
- The potential societal value of achieving the very difficult goals of the Program justifies current expenditures, and successes to date may justify expansion of the program in the future.

Questions, Answers, and Discussion

- Dr. Shaw asked why the foreign automakers were not involved in the Partnership, since the U.S. subsidiaries of some foreign energy companies are involved (BP and Shell). Dr. Milliken explained that the FreedomCAR and Fuel Partnership is with USCAR, which includes only the U.S. automakers (Ford, GM, and Chrysler). She noted that DOE works formally (through agreements with the national labs) and informally with all of the major worldwide automakers.
- Dr. Schmidt, as a member of the USCAR Council, stressed that the FreedomCAR and Fuel Partnership and USCAR pursue pre-competitive R&D. He pointed out that the automotive business has become increasingly international, because many U.S. auto companies own foreign subsidiaries. He remarked on the importance of the demonstration programs and the amount of progress that has been made in developing fuel cell vehicles.
- Mr. Rose asked Dr. Taylor to comment on the bullet point shown on page 17 of her briefing (related to on-board hydrogen storage) that says "meeting program goals will require a storage technology as yet undiscovered." He noted that this statement could be taken the wrong way, especially because other reports (and perhaps even the NAS report itself) have pointed out that meeting all targets may not be necessary for fuel cell vehicle commercialization. Dr. Taylor responded that the NAS was trying to communicate that the ultimate goals for solid-state storage are far from being met, and that the targets were created so a hydrogen vehicle could meet ultimate range and weight requirements. However, in the near term, automakers are satisfied with compressed hydrogen gas or hydrogen liquid as an option and are moving forward on that basis. The point is that even though these options are "good enough for now," the program should continue to aggressively pursue breakthroughs in these other storage materials; research into these materials is relatively new, so the rate of progress should not be discouraging.
- Dr. Shaw followed on with a question about the cost of the on-board hydrogen tank, assuming mass production. Dr. McCormick replied that the auto companies have done this analysis, based on different designs and manufacturing technologies. Dr. Schmidt responded that the tank was about double the cost of a four cylinder engine today. Dr. McCormick estimated a cost of approximately $2,000 for a tank offering a 300 to 400 mile range, possibly as low as $1,200 with some advanced tank designs.
- Dr. Dresselhaus asked whether the report commented on the importance of hydrogen production from renewables. Dr. Milliken explained that the NAS report was issued before the FY09 budget request was released and therefore did not comment on the reduction in the applied renewable hydrogen production budget. She pointed out that one of the report's key recommendations was to increase the work on reducing the capital costs of electrolysis, which goes directly to renewable hydrogen production technologies.
- Dr. Ross remarked that "DOE and the FreedomCAR and Fuel Partnership under-serve the country and society by not engaging more in the regulatory process." He noted that he was surprised when listening into a recent California Air Resources Board workshop at the limited information provided by the industry; he argued that this information is critical input to good policy decisions. Dr. Taylor explained that companies are limited in what they can talk about with one another, not only to protect intellectual property but also to adhere to the requirements of anti-trust laws and to avoid the appearance of colluding. Dr. Ross noted the need for legislative bodies to really understand

technology when writing policy. He cited the California Clean Air Act of 1992 and its zero-emission vehicle mandate, which actually hurt efforts to develop hybrid vehicles.

- Mr. Brubaker informed the HTAC that the Secretary of Transportation has asked for a review of all the safety evaluation and approval processes within DOT in order to make them "more agile and responsive to developments in technology in the Information Age."
- Dr. Schmidt stressed that companies invest in research and technology development that is both risky and long-term. They will not see a return on much of their work in fuel cells and related technologies for 10 years or more. Dr. McCormick confirmed that remark, and stated that his company has put billions into fuel cell vehicles and will not see a profit from them for close to a decade.
- Mr. Keuter stressed that nuclear hydrogen needs not only basic research, as pointed out in Dr. Taylor's presentation, but also technology development and demonstration. Dr. Taylor agreed and stated that she did not mean "just" basic research, but this area needs continuing efforts in basic research, because sometimes that gets forgotten.
- Dr. Dresselhaus noted that many foreign auto makers are relying on U.S. universities for research and not the universities in their own countries.
- Congressman Walker asked whether the NAS review committee viewed the two sets of companies—energy and automobile—as forward thinking or as hesitant in terms of hydrogen. Dr. Taylor replied that the people with whom the NAS review committee worked are generally enthusiastic and optimistic about the work they do. She also related her feeling that the energy companies are newer players in this sort of partnership. She saw a marked improvement in the involvement of the energy companies since the Phase I review and hoped that this engagement would continue into the next administration.

6. ***The U.S. DOT Hydrogen Plan***
Paul R. Brubaker, Administrator, Research and Innovative Technology Administration, Department of Transportation
>> see full presentation at http://www.hydrogen.energy.gov/advisory_htac.html

Mr. Brubaker briefed the HTAC on the activities of the Department of Transportation (DOT) related to hydrogen vehicles and envisioned infrastructures. DOT is currently updating its 2005 Hydrogen Roadmap. The updated DOT plan for hydrogen will be included as part of the DOT Alternative Fuels Roadmap, scheduled to be released on September 30, 2008. A group created within DOT, the "Alternative Fuels Board," is developing this roadmap to look across all modes of transportation and consider what DOT needs to do to support the nation's goals to reduce energy consumption and costs in the transportation sector. The Roadmap will support an increased budget request for DOT's hydrogen activities, especially in the areas of development and deployment. He noted that a few initiatives are being considered as part of the reauthorization proposal for the Surface Transportation Act. While these initiatives are not yet "vetted policy," the ideas include: (1) creating energy independence bonds to help fund infrastructure deployment; (2) allowing the Transportation Infrastructure and Loan Guaranty (TILG) the authority to build infrastructure; and (3) use of alternative energy sources for airplane taxiing. Mr. Brubaker went on to describe DOT's role in hydrogen and fuel cell development for the transportation sector and efforts to update its hydrogen roadmap as a guide for future programs and activities. Highlights of the presentation are summarized below.

- DOT considers its support of the Hydrogen Fuel Initiative a top priority, with three principal areas of authority: (1) safety of (and regulations for) transporting and using hydrogen as a fuel, (2) RDD&D (research, development, demonstration, and deployment) of medium- and heavy-duty vehicles and their infrastructures, and (3) guiding the RDD&D of a hydrogen infrastructure (including stationary power) and its integration into DOT-regulated systems.
- The DOT Hydrogen Working Group was created in 2003 to coordinate DOT hydrogen activities across administrations.
- The 2005 U.S. DOT Hydrogen Roadmap serves as a guide for DOT hydrogen efforts and describes key activities in four topic areas: (1) Safety Codes, Standards, and Regulations; (2) Infrastructure Development and Deployment; (3) Safety Education, Outreach, and Training; and (4) Medium- and Heavy-Duty Vehicle Development, Demonstration, and Deployment. The updated DOT alternative fuels roadmap, to be released in September 2008, will provide next steps for DOT in each of these four topic areas.
- The DOT has created a website (http://hydrogen.gov/interactive_map.html) to provide users with simplified access to the regulatory authorities and existing regulations that affect hydrogen and fuel cell vehicles
- Recent reports have pointed to the need for an increased level of effort from DOT on R&D and analysis related to hydrogen and fuel cells. DOT recognizes the program deficiencies with respect to funding for support for hydrogen codes and standards (among other) work and is working to address them.

Questions, Answers, and Discussion

- In response to questions from Dr. Shaw, Mr. Brubaker explained that DOT has approximately 500 employees in its Research and Innovative Technology Administration (RITA), most at the Volpe National Transportation Center in Cambridge, MA. Until last year, RITA had one full-time person working on hydrogen with a $500,000 budget. Mr. Brubaker is trying to leverage this funding and has provided additional staff resources for the hydrogen activities. He estimated that DOT-wide, the funding for hydrogen-related activities is about $3 million. Mr. Brubaker noted that he is a political appointee; his goal is to have a strategic plan in place for moving forward by the time he leaves the Department in January 2009.
- Mr. Friedman asked why DOT is conducting RD&D on buses and heavy duty vehicles; he thought that the vehicle RD&D was more in the missions of DOE and EPA. Mr. Brubaker replied that DOT is leveraging DOE's work. He believes that the bus demonstrations will be useful to provide real-world experiences to state and local officials with whom DOT works, and efforts to reduce bus costs will benefit public transit agencies. Mr. Rose added that the hydrogen fuel cell bus program moved from DOE to DOT about nine years ago at the direction of Congress.
- Dr. Ross asked why the DOT codes and standards effort was criticized by the NRC as being underfunded and behind schedule: What is needed in terms of codes and standards that is not available now? Mr. Brubaker replied that his understanding for the criticism is the lack of sufficient model codes and standards and related outreach efforts to state and local officials, as well as not enough efforts focused on "training the trainers" at the DOT's state-based University Transportation

Centers and so on. Congressman Walker noted that issues, such as bans that prohibit driving hydrogen-fueled vehicles through the Hudson Tunnel in New York City, that still must be addressed.

- Dr. Dresselhaus brought up how differently hydrogen behaves compared to other fuels and therefore advised more research before implementing regulations. Mr. Brubaker agreed but added that apples-to-apples comparisons should be conducted. He has received a lot of feedback from industry and others that hydrogen and ethanol are being held to higher safety standards than gasoline. Dr. Shaw referenced a study conducted some time ago by Arthur D. Little, which evaluated the safety of gasoline, hydrogen, and natural gas as a vehicle fuel. The study concluded that hydrogen was safest. He suggested tracking down this study as a reference.
- Dr. McCormick thanked Mr. Brubaker and DOT for attending a recent crash test of a GM fuel cell vehicle that included a 50-mile-per-hour head-on collision. He is encouraged by DOT's participation and its increased level of involvement, and he reported that the crash test went very well.

7. *Discussion of California Air and Resources Board Zero Emission Vehicle Action with Responses from Auto Representatives*

Mr. Jan van Dokkum, Dr. Gerhard Schmidt and Mr. Keith Cole

Fuel Cell Vehicles in California: On the Road to Commercial

Jan van Dokkum

>> see full presentation at http://www.hydrogen.energy.gov/advisory_htac.html

Mr. van Dokkum, who serves as the Steering Team Chair for the California Fuel Cell Partnership (CaFCP), provided a briefing on CaFCP activities. He noted that the Partnership is a unique institution because it has no formal legal structure; rather, it is a collaboration between automotive companies, energy companies, technology companies, and government. The Partnership is tackling, in a very collaborative way, issues of all kinds that can prevent introduction of fuel cell cars into California. While Mr. van Dokkum noted that a Steering Team drives the agenda, numerous working groups underneath that steering group actually conduct the work. The Partnership is helping to meet a mandate to introduce zero-emissions vehicles to California's market. The drivers for the Partnership are improving air quality, reducing global warming, and reducing dependency on petroleum. The Partnership guides deployment of both fuel cell vehicles and fueling infrastructure. Highlights of Mr. van Dokkum's presentation are summarized below.

- Collaboration is the key to making sure that implementation of fuel cell cars is possible—removing obstacles that can prevent the introduction of fuel cell cars into California.
- The Partnership focuses on introducing not just passenger cars but also transit vehicles, which will help get the hydrogen economy going within California.
- Much of the Partnership's focus over the past year and a half has been on synchronizing the roll-out passenger vehicles and buses with the infrastructure needed to support them, as well as on working with the automotive, transit agencies, and energy companies on this kind of long-term strategic planning.
- One of the Partnership's guiding principles is to preserve the pleasure of driving and to focus on developing collaborative approaches for solving any problems that could negatively affect the consumer experience.

- Stations will be focused in the San Fernando Valley: West Los Angeles, downtown Los Angeles, and Orange County.
- The California Air Resource Board (CARB) issued a mandate for the top six market share leaders in the automotive field to start introducing zero emission vehicles (ZEVs) by 2009, with ramp-ups in 2012 and 2015. The CARB ZEV regulations, as revised on March 27, 2008, are outlined in the full presentation.
- The CARB Zero Emission Vehicle Regulation for buses beginning in 2011–2012 requires transit agencies operating more than 200 buses to make 15% of new bus purchases zero emission buses (seven fuel cell buses are now operating in California, with hydrogen usage of about 30 kg per bus per day, with eight more already planned over the next few years).
- The California legislature allocated $19 million to the construction of the Hydrogen Highway Network (2005 through 2008), and the Partnership has a current RFP for $7.7 million for three retail-like stations and two upgrades of stations (both 350 and 700 bar, with hydrogen produced from 33% renewable resources).

Questions, Answers, and Discussion

- Mr. van Dokkum explained to Dr. Shaw that Honda did not drop from the Partnership, but moved into its own facility in Southern California. He noted that as more companies develop their own operational and support facilities in Southern California, there is less of a need for that function to be provided by the Partnership. The Partnership's facility provides more of a demonstration function now than it did in the past.
- Mr. Brubaker made the Committee aware that DOT is organizing an upcoming "Innovation Tour" that will include 14 to 16 congressional staffers and a few members of Congress. The tour will include a visit to the CaFCP and some other California laboratories.
- In response to a question from Dr. Ross, Mr. van Dokkum explained that the CaFCP does not have a plan in place to meet the requirement for 33% renewable-sourced hydrogen in the distributed hydrogen stations, and he agreed that this would be challenging. He added that CARB is expected to come out with a new ruling; it is hoped there will be some relaxation of the targets that would allow, for example, an aggregate goal so that every station does not need to meet the 33% requirement.
- Mr. Mudd asked how much hydrogen a typical fuel cell vehicle will consume per day. Mr. van Dokkum replied that a typical vehicle with a typical commute (20 to 30 minutes each way) will consume 2 to 3 kg per day.

Discussion of Recent Changes to ZEV Mandate
Gerhard Schmidt,
>> see full presentation at http://www.hydrogen.energy.gov/advisory_htac.html

Dr. Schmidt spoke on recent changes to the Zero Emission Vehicle (ZEV) Mandate issued by the California Air Resources Board. The revised regulation will allow automakers to reach the mandate using a mixture of fuel cell, plug-in hybrid electric vehicles (PHEV), hydrogen internal combustion engines, biomass electric vehicles, and fuel cell electric vehicles. This flexibility, Dr. Schmidt observed, will allow the market forces to choose which vehicle technology will be the majority. CARB continues to "set

technology forcing targets," which may need to be adjusted if the technology or market cannot bear the restrictions. CARB also stressed the need for infrastructure to complement any advanced vehicle design. Dr. Schmidt's summary of the changes in the ZEV Mandate is presented below.

- CARB's goal for sustainable ZEV transportation is laudable.
    - OEMs are doing extensive work to make these technologies viable.
- Industry recognizes that customer demand for green vehicles is undergoing unprecedented change.
- Technological and commercial challenges for zero emission vehicles still exist.
    - Must be monitored to make appropriate adjustments to the ZEV regulations, as necessary.
- A collaborative approach that includes all the stakeholders is needed, similar to FreedomCAR and Fuel Partnership.
- Automotive manufacturers cannot do this alone.

Questions, Answers, and Discussion

- Responding to a question from Dr. Saillant about lightweighting, Dr. Schmidt told the Committee that Ford is working on a Focus concept car, with a weight reduction of 300–600 lbs, at a cost he expects to be reasonable [Dr. Schmidt later clarified that the cost is to be evaluated].
- Dr. Ross asked about other states and remarked that the number of states with ZEV regulations could impact the number of ZEV-qualified vehicles required. Dr. Schmidt stated that the same ZEV regulations apply to at least 16 other states [Dr. Schmidt later clarified that the regulations apply to 14 states], but a travel provision allows ZEV's placed in other states that have adopted the ZEV program to count towards the volume requirement in California (and vice versa).
- Dr. Ross hoped the CARB realized that each separate requirement of the automakers would be expensive (meeting increased CAFE requirements, meeting flex fuel or ZEV mandates, and so on). He remarked that some priority-setting would be beneficial, as informed by science. Dr. Schmidt stated that he cannot speak in behalf of Air Resources Board, but his interpretation is that CARB intends to bring about a carbon-free transportation system, by giving incentives to develop technologies which are really in the true sense zero emission both with regard to carbon emissions and with regard to hydrocarbon, carbon monoxide, oxides of nitrogen, and particulate matter. Dr. Schmidt went on to say that "introducing fuel cell vehicles starting in 2012–2014 will not significantly reduce the carbon emissions because the volume at the beginning is so small, that we have to do something in addition and this is addressed by different standards."
- Dr. Shaw asked whether there was a possibility for the Federal government to take a "preemptive right to tell California, just as they are trying to do on global warming initiatives, that they cannot regulate ZEVs if the Federal government has established new CAFE standards?" Dr. Schmidt did not want to speculate, but he said that he thinks the auto companies are "committed to proceed" but that some of the demonstration programs could slow down as a consequence. Mr. van Dokkum continued, "Clearly we make a lot of investments in this technology and the only reason we do that is not because of regulation [but] because we truly believe this is the real end game and there is actually money at the end of the rainbow here." He noted that products being introduced in the U.S. are also being introduced in other overseas markets, so this is a global market. Dr. Schmidt noted that one of the key drivers is the need to reduce the use of fossil fuels, which are, ultimately, in limited supply.

- Dr. Shaw pointed to the difficulty of meeting various states' standards, to which Mr. van Dokkum agreed but pointed out the collaboration between many of the states.
- Mr. Rose offered a historical perspective on California's regulations, noting that California's air-quality regulations for motor vehicle emissions predate the federal regulations. He stated that it is "quite a rational system right now... it has been adjudicated and gone through Congressional review at rather exhaustive levels." He added the ZEV regulations are only approved by EPA through 2010 or so, so there will be another round of EPA review.
- Mr. Friedman stated that the U.S. as a whole does not set enough sense of urgency on solving the energy problem. He stated that a variety of different tools and solution sets could be debated, but the first order of priority must be to set the tone for urgent action. He argued that "we are not shooting high enough yet when it comes to getting the fuel cell vehicles out there and getting the infrastructure out there, and I think that's the bigger problem that I want us to keep our eyes on as the prize."

Project Driveway: HTAC Review
Keith Cole, Director of Legislative and Regulatory Affairs, General Motors
>> see full presentation at http://www.hydrogen.energy.gov/advisory_htac.html

Mr. Cole spoke about GM's Project Driveway: a "worldwide market test" that will deploy 100 hydrogen fuel cell vehicles (Chevy Equinoxes) to mainstream individual drivers and government and private fleets. This demonstration will be the largest test of fuel cell vehicles (FCVs) with real drivers in the world. A variety of U.S. drivers, in differing driving environments, will operate these vehicles and refuel with hydrogen in three geographic areas: California, the New York metropolitan area, and Washington D.C. The vehicles represent GM's fourth-generation fuel cell technology. Service centers are operational in the New York City, Washington, DC, and Los Angeles areas, as well as Shanghai, Tokyo, Berlin, and Seoul. Fleet vehicles will be operated by a number of organizations, including Virgin America, Disney, the United States Postal Service, the U.S. Army, and University of California-Irvine. Mr. Cole described progress and status of the Project Driveway program, including location of service centers and fueling stations. Accomplishments include:

- Over 1,500 first responders have been trained in Washington, D.C., New York, and Southern California, with additional information available on the Internet.
- Vehicles operated in cold weather conditions in New York and Washington, D.C.
- The project conducted high-profile public relations events (e.g., the Oscars, Super Bowl) involving celebrities (e.g., Fergie, Jay Leno, Jonas Brothers, etc.), some of whom have driven the vehicles.
- Six stations are on-line (available to Project Driveway drivers) to date and fourteen 700 bar stations and five 350 bar stations are planned to be available in the three U.S. cities by end of 2008.

Mr. Cole also outlined a number of observations:

- Fueling station quality (in terms of user friendliness and accessibility) varies; many stations do not look like typical retail fueling stations. The geographic distribution of stations is also not optimal.

- Though there are a number of existing fueling stations in southern California, it has been difficult to gain access to many of these facilities, due to logistical and/or liability issues; the plan is to gain access and certify 30 current and planned 350 bar stations.

In addition, Mr. Cole discussed the international effort

- GM is also testing fuel cell vehicles in overseas markets, including Germany, China, South Korea, and Japan.
- Fueling station efforts overseas include
  - Three stations in Berlin, which are very much like normal retail stations, with more planned under Germany's Green Plan
  - Up to 15 stations planned in Shanghai to support FCVs for the 2010 World Expo
  - Japan has launched a plan to build 11 fueling stations, well-spaced around Tokyo, using different types of resources for hydrogen production (including industrial waste streams) and engaging different, "unconventional" types of companies in producing hydrogen. The Japanese government has set a target of 2015 for FCV commercialization and has a plan to build hydrogen station capacity in advance of vehicles to support the roll-out.
  - Three fueling stations available in Seoul, Korea, with promise for more, given interest in FCVs by the Korean automakers and government

Questions, Answers, and Discussion

- In response to a question from Dr. Shaw, Mr. Cole noted that about two thirds of the 100 Project Driveway vehicles are going to individuals, with the remainder going to business fleets. The majority of the 100 vehicles are in southern California; 30 are in New York; about 6 are in Washington, DC; and the rest are at military installations. People who apply for vehicles are selected partly on the basis of their proximity to available fueling stations. Each private individual will have the vehicle for only two or three months, then they will be cycled to the next customer; the business customers will have them for longer, about two years.
- Mr. Rose asked whether the Federal government could have a role in opening some of the fueling stations that are "behind the fence" and currently inaccessible to public users. Mr. Cole noted that the Federal government may have direct leverage for stations that received federal funding, but that many of the stations are privately owned or funded by state government. Mr. Cole believes that DOE could use its "bully pulpit" to encourage the opening of private stations to all owners of hydrogen vehicles. He stated that GM's focus is getting public access to at least 100 stations. Larry Burns spoke at the NHA meeting about how 40 stations in Los Angeles and 40 stations in New York City would open the hydrogen vehicle market to tens of millions of potential customers.
- Mr. Cole mentioned a bill recently introduced by Congressman Knollenberg, ranking member on the Department of Transportation Appropriations Committee. The bill would provide funding (authorized at $250 million) for a DOT demonstration of initial hydrogen infrastructure with the goal of funding 100 hydrogen stations in at least two geographically diverse regions over the next five years.

- Mr. Rose asked whether a federal risk-sharing program would help open the private stations to the public. Mr. Cole portrayed this as a future problem, to be addressed in the 2015 to 2020 timeframe. For the first 100 stations, what is needed is federal funding: "Changing liability isn't going to make the stations happen. Funding them will." Congressman Walker considered whether locating stations at dealerships and allowing for a one year depreciation schedule would adequately incentivize station building. Mr. Cole explained that the limited numbers of vehicles to consume hydrogen fuel means stations will not be economically viable. Therefore something more like grant funding is needed. He characterized Congressman Walker's idea as another potential policy option for the 2015–2020 timeframe, once more vehicles are on the road.
- Mr. Mudd questioned Mr. Cole on the repair infrastructure for the fuel cell vehicles. Mr. Cole stated that building the maintenance facilities is not a major challenge; the design just requires attention to different building codes that account for hydrogen storage. The GM service centers can perform on-site maintenance on most parts of the fuel cell vehicle except the fuel cell power module. The vehicles are engineered with GM diagnostics and maintenance procedures so that eventually dealerships can perform all maintenance procedures.
- Mr. Friedman was intrigued by the fact that almost no oil companies are involved in building the fueling stations shown for the Tokyo, Japan area. He asked how Japan got involvement from such a diverse group of companies and how Japan is structuring its infrastructure ramp-up phase because many of the companies currently involved are not in the energy business. Mr. Cole explained that METI did a thorough analysis of potential sources of hydrogen, including where hydrogen could be produced as a co-product or from an industrial waste stream. The Japanese government then worked with the identified industries and convinced them to "go along with the program." Mr. Cole agreed that it is not clear how many of these industries would be interested in making a business case out of producing hydrogen and move to larger-scale production. In his view, the Japanese are casting a broad net to see if they can find unlikely market entrants, where someone can make a business case that you might not be aware of today. Dr. McCormick noted that GM participated on the Steering Committee that is helping to inform the Japanese program, and that there is a commitment to build out stations in advance of vehicles.
- Responding to a question from Mr. Rose about how much it will cost to build the first 100 hydrogen fueling stations, Mr. Cole stated that the cost of stations will go down as more are built. He estimated that the first 10 could cost as much as $4 to $6 million apiece, depending on the location. He reported that the input to Congressman Knollenberg envisioned early, retail-like stations in the $4 million range with the 100th station at less than one million dollars, and an average cost of $2.5 million a station. Mr. van Dokkum noted that in California the cost of real estate is a big cost factor, so they are working with energy companies to try to add hydrogen islands to existing gasoline fueling stations to bring the cost of hydrogen fueling facilities down.

8. *HTAC Open Discussion*

Congressman Walker opened the floor for the Committee members to discuss what was presented today or anything relating to the present status of the Hydrogen Program and where it should go from here. The discussion is summarized below.

- The minutes of the December 18–19, 2007, HTAC meeting were formally approved by the Committee.
- Dr. Shaw offered his opinion that higher-visibility demonstration programs are needed. He suggested a dealership-based demonstration located at an upscale shopping mall, including a fueling station and 30 to 50 vehicles. The vehicles could be driven by local people doing their normal errands and family activities and attract a lot of attention in one area. He worried that the current demonstrations seem to be "spread all over the place" and do not allow enough people to see the vehicles in daily, routine operation. Dr. McCormick replied that the demonstrations in Burbank, California do offer this level of concentration and visibility. He also noted that one key objective of Project Driveway is to get customer feedback on vehicle operation and fueling station availability, convenience, and use. The Project is trying to get very broad experience in different operating environments and different drive cycles.
- Mr. van Dokkum stated that station underutilization is a big problem— energy companies are reluctant to build stations that receive very limited traffic, or their demonstration stations have very limited hours and then eventually close up once the "experiment" is over. He noted that the CaFCP has been trying to encourage new market entrants and to explore new paradigms based on different business models. As an example, he envisioned a grocery store-based fueling station, in which hydrogen powers a stationary fuel cell that provides power to the store, and which takes advantage of combined heat and power generation. He asserted that we need to start thinking out of the box on how to get the infrastructure going—making combinations of new technologies creates real opportunities for the future. Congressman Walker agreed and added that non-traditional fueling locations, such as automobile dealerships, would put pressure on the energy companies. Dr. McCormick agreed with Mr. van Dokkum and stated that it makes sense to maximize the uses for stations and to combine applications and technologies. He noted that GM is considering partnerships with a variety of different companies to produce hydrogen at a variety of different scales and asked the Committee to "stay tuned" for further developments. He also pointed to the success of the German model, which is following the energy and auto industry's advice to focus on one city for deployments.
- Mr. Rose questioned whether the July HTAC meeting would be the last before the Committee's next report to the Secretary of Energy is drafted, and he wondered whether ideas for content of the report should be the focus of the July meeting. He also suggested that the HTAC agree to a regular reporting timeline (e.g., an annual report and semi-annual update). Congressman Walker asked about the Committee's statutory reporting requirements. Dr. Milliken and Ms. Epping responded that EPACT requires the Secretary of Energy to issue a biennial report to Congress on the HTAC's recommendations over the reporting period. Ms. Epping clarified that while the Secretary is required to produce a biennial report, HTAC can submit recommendations to the Secretary at any time, but an annual report would be a good idea. The Committee's next report will likely be submitted to a new Secretary after the beginning of the next administration. Dr. Shaw suggested that the Committee also take action on the idea to prepare talking points to brief the next administration. He suggested that HTAC should begin discussing this topic the next day (May 14) and can continue this discussion at the July meeting.
- Dr. Saillant asked whether the technology development area has adequate standardization and whether these actions are being adequately coordinated with codes and standards development. Dr. McCormick noted that virtually every actively engaged company has been involved in discussions

and round robin meetings on national and international codes and standards. He feels confident that proper coordination on things like common sizes of fittings and tanks is taking place (among both vehicle developers and fueling station equipment developers). He stated that part of HTAC's role should be confirming that hydrogen is deployed in a way that will support the "collective best interests" and that takes the global market into consideration.

- Mr. van Dokkum summarized five issues discussed by the Committee, which he views as key factors that are hampering the hydrogen economy's advancement: (1) maintaining adequate, long-term funding commitments to R&D at universities so they can develop "the right scientists and the right solutions;" (2) infrastructure deployment; (3) codes and standards; (4) international competition in the marketplace; (5) crossing the "valley of death"; and (6) liability. He suggested that the Committee keep track of these issues as they report out and mark areas where progress has or has not been made and make recommendations where more efforts are needed.

The May 13, 2008 HTAC meeting was adjourned at 5:50 pm.

MAY 14, 2008

Congressman Walker called the meeting to order at 8:35am.

1. *Discussion of HTAC Vision Statement*

Dr. Robert Shaw, chair of the HTAC Subcommittee on Policy and Planning, opened the floor for comments on the HTAC vision statement, the text of which had had been revised following the December HTAC meeting. After extensive discussion, the Committee revised the HTAC Vision Statement as shown below:

Our vision of the future is that hydrogen will become a [universal and] [widely used and] economically competitive ~~a ubiquitous~~ energy carrier, progressively substituting for carbon-based fuels over time, to meet the needs of the planet. Hydrogen will be produced from a number of sources, increasingly with the lowest possible carbon impact. ~~In time, hydrogen will become the most economically competitive carrier to meet the needs of the planet.~~ To realize this vision, the nation must aggressively introduce to the market the hydrogen-based technologies that are available now and those that will be developed in the future. HTAC's role is to ~~develop a framework for the nation's hydrogen conversion business plan, taking into~~ aid the nation in developing a policy framework that takes into account the technical, political, social, cultural, environmental and commercial requirements of the transition to hydrogen.

Highlights of the HTAC discussion on the vision statement are summarized below.

- Dr. Dresselhaus questioned whether the statement "hydrogen will become the most economically competitive energy carrier to meet the needs of the planet" was too strong. The Committee agreed that strong statements are expected in vision statements, but noted that it needs to make clear that this statement is presented as part of a vision, not a statement of fact. The Committee revised the vision statement as shown above to address this concern.
- Dr. Dresselhaus, Dr. Taylor, Mr. Friedman, and others stressed the need to portray hydrogen as an important energy carrier but not as the *only* energy carrier.
- The Committee agreed to strike the word ubiquitous and find a different word that conveyed their meaning. Two proposed options included "widely used" and "universal." Some members felt the term universal was too ambiguous and implied that hydrogen would be used everywhere. Others felt that widely used was clearer in its meaning, which is that hydrogen will be one of a number of different energy sources. Others argued that universal was the stronger, more poetic term and conveyed the sense of the vision that hydrogen would be used in all applications to "meet the needs of the planet." Mr. Hofmeister amplified on this discussion, saying that he preferred the term universal because of the carbon constraint of the future. He stated that we cannot get to the 80 percent below the 1990 level by 2050 if we continue to intensively use hydrocarbon fuels, and hydrogen is an opportunity to move beyond the hydrocarbon fuel source. He argued that hydrogen would have to be universal—it would have to be in essentially all forms of vehicular traffic and other uses. He pointed out that diesel fuel is widely used, but you cannot buy it everywhere; the vision should be that hydrogen can be bought everywhere. Mr. Friedman disagreed, saying that there would probably be areas of the economy that hydrogen would not touch (e.g., aviation). Mr. Mudd suggested deleting the terms altogether, and just state it as "…hydrogen will become an economically competitive energy carrier…" Since consensus on the terms was not achieved, Dr. Shaw agreed that the Subcommittee on Policy and Planning would consider the two terms further in developing the final draft vision statement for approval by the HTAC.

- The Committee agreed to describe the need for "aggressive" action to stress the speed at which the world must change in order to avoid major climate change.
- Mr. Mudd asked whether the goal was to introduce hydrogen technologies to market, or to actually put the technologies into use. Congressman Walker noted that consumers will define the market: "all we can do is be a force for seeing to it that they have that choice." Dr. Shaw explained that the intention was to convey the sense that we cannot wait until the perfect, and ultimate, technologies are developed. We need to start introducing the best available technologies now (e.g., hydrogen production from natural gas). Dr. McCormick pointed out that "the nation doesn't develop products, companies do." He suggested that what the nation needs to do is develop policies to support an aggressive introduction of hydrogen technologies.
- The HTAC decided, through discussion, that their ultimate "customer" was the nation at large. The Committee members directly work for the Secretary of Energy but in doing so they attempt to influence energy policy for the nation as a whole.
- Dr. Shaw stated that the HTAC Subcommittee on Policy and Planning would consider the revised vision statement again and make any last revisions before submitting another version for approval by the full Committee.

2. ***Potential Role of Hydrogen in the U.S. Energy Mix***
Fred Joseck, Hydrogen, Fuel Cells and Infrastructure Technologies Program, U.S. DOE
>> see full presentation at http://www.hydrogen.energy.gov/advisory_htac.html

Mr. Joseck spoke on the results of a recent effort to model the future utilization of hydrogen as an energy source, its integration with all U.S. energy sources, how the modeling was performed, what that model's assumptions were, and the effects of hydrogen on U.S. CO_2 emissions. This work stemmed from an HTAC recommendation for DOE to present a broader vision of how hydrogen fits into the nation's overall energy strategy and convey the message that hydrogen will be a key part of the energy mix.

Mr. Joseck noted that hydrogen is one component of DOE/EE's portfolio of technologies because it can potentially reduce our dependency on oil, lower CO_2 emissions, be produced from diverse domestic resources, and be used in highly efficient fuel cells. To address the HTAC recommendation, DOE analyzed various market penetration scenarios for vehicles and for stationary fuel cells, as well as the potential energy and carbon reduction benefits. He stressed that the results are not meant to be predictions, but simply the results of potential scenarios.

Mr. Joseck described the modeling approach, which used Argonne National Laboratory's VISION model to analyze alternative fuel cell vehicle (FCV) and stationary fuel cell penetration scenarios, as compared with the Energy Information Administration's (EIA's) Reference Case, which assumes negligible fuel cell vehicle penetration (*Annual Energy Outlook 2008*). The stationary power scenario considers hydrogen-powered polymer electrolyte membrane (PEM) fuel cells for combined heat and power (CHP) and distributed electricity generation. The fuel cell vehicle penetration scenarios included a "moderate" penetration rate (which assumes the penetration of multiple vehicle platforms, including plug-in hybrids) and an "aggressive" penetration rate (based on the penetration scenario in the National Academies 2004 hydrogen report which yields a light-duty vehicle fleet in 2040 that is 80 percent FCVs). In both the moderate and negligible penetration cases, fuel cell vehicles saw market entrance in 2015 followed by

faster ramp up after 2025. The more aggressive NRC scenario sees 100 percent fuel cell vehicle penetration by 2050 compared with 66 percent in the moderate case. The sources for hydrogen production included a mix of natural gas, coal, biomass, and electricity (water electrolysis), with the mix changing over time. (The analysis determined that nuclear hydrogen production will not to be cost effective during the study's timeframe). The analysis reached the following conclusions:

Transportation Sector

- Relative to the transportation sector of the EIA Reference Case, aggressive deployment of FCVs can reduce gasoline use by 30 percent in 2030 and by over 90 percent in 2050.
  - The moderate scenario predicts 18 percent gasoline reduction in 2030 and 50 percent in 2050.
- The aggressive scenario shows overall transportation oil demand, including diesel and jet fuel, reduced by 17 percent in 2030 and 45 percent in 2050.
  - The moderate scenario projects oil reduction of 10 percent in 2030 and 24 percent in 2050.

Stationary Sector

- Stationary fuel cells can potentially expand to over 10 percent of projected U.S. grid capacity by 2050 and account for a 2 percent reduction in CO_2 in 2030 and 8 percent reduction in CO_2 by 2050, relative to the EIA Reference Case for the two most impacted sectors (commercial and industrial).

Overall Energy Mix (Transportation, Commercial, Residential and Industrial Sectors)

- For the overall energy mix (transportation, commercial, residential and industrial sectors), fuel cell vehicles and stationary fuel cells would reduce CO_2 emissions by 7 percent in 2030 and 18 percent in 2050 for the aggressive scenario relative to the EIA Reference Case.
- The moderate scenario, projects CO_2 reduction of 5 percent in 2030 and 10 percent in 2050.
- For the overall energy mix, stationary fuel cells would cause a 1 percent reduction in CO_2 emissions for both scenarios in 2030 and 3 percent in 2050.

Questions, Answers, and Discussion

- In response to a question from Dr. Saillant on whether reducing energy consumption is part of DOE's overall strategy, Dr. Milliken explained that DOE/EE has a broad portfolio that includes energy efficiency. She pointed out two examples: the Industrial Technologies Program performs efficiency assessments to help industrial facilities lower their energy use and the Building Technologies Program, which includes an effort aimed at zero-energy buildings and activities to encourage consumers to reduce energy consumption. Dr. Saillant does not like how "the force of [the DOE] messaging just seems to focus on how we address this growing demand rather than how we can accelerate reduction in the demand." Dr. Milliken conceded that message, while out there, may not be as visible as some others.

- Mr. Hofmeister expressed his view that energy demand reduction is an outcome rather than an objective. He pointed out that energy companies exist to supply energy—we will continue to create more opportunities for use of energy—the target should be efficient use of clean, affordable energy. He added that other constraints, such as carbon constraints and efficiency requirements, can help lead to that outcome. Mr. van Dokkum stressed the need for increased energy productivity, with energy serving multiple productive purposes, and agreed with Dr. Saillant on the importance of a decrease in the growth of energy demand. Mr. Friedman agreed, and asserted that meeting carbon reduction goals will require slowing the growth of demand. He raised the broader, often-debated question of whether energy is an unlimited resource. He agreed that sunlight and some other energy sources are effectively unlimited. However, "the rate at which you can get [energy] and the effects of how quickly it is extracted are not trivial." He stated that "we run the risk of repeating past mistakes if we approach this from a perspective, that it's just a question of using energy efficiently. It doesn't matter how much we demand and how much demand grows both because there are real constraints on the system." Dr. Shaw suggested that HTAC consider this topic as a discussion item for a future meeting. Congressman Walker agreed, and asked that this suggestion be considered in developing the next HTAC meeting agenda.
- Responding to a question from Dr. Shaw, Mr. Joseck explained that the study assumed the biofuels mandates specified in the Energy Independence and Security Act of 2007 (EISA) are met and CAFE standards for vehicle fuel economy are met.
- Beyond 2030, the end of the EIA forecast, the study used a linear extrapolation to forecast energy consumption, based on 5 percent growth.
- Congressman Walker asked about the use of PEM fuel cells for stationary power in residential applications. Mr. van Dokkum explained that the penetration of PEM fuel cells for residential power generation will be limited, due to their lower efficiencies (60 percent maximum) and expectations for very high durability (about 80,000 hours). He noted that a lot of technology development is needed to get PEM fuel cells to that point.
- Dr. Shaw found the results of the analysis to be very discouraging, insofar as they show that even with an aggressive FCV penetration rate, the overall effect on the nation's greenhouse gas emission reductions is small. He noted that the decision to confine the analysis to only light duty passenger vehicles and to PEM fuel cells for power generation influenced these disappointing results. He pointed out that diesel and jet fuel account for a large portion of the energy consumed in the transportation sector. He stated that a paradigm shift will be needed for the nation to make real progress on carbon emissions reductions.
- Congressman Walker noted that the study's key message to policymakers is that real change in the transportation sector's CO_2 or energy consumption profile will only be possible through an aggressive move to fuel cells. Mr. Rose pointed out that the results show that even a 100 percent penetration of hybrid electric vehicles will not have a significant impact on carbon emissions or gasoline use. In contrast, fuel cell vehicles can virtually eliminate gasoline use in the light-duty vehicle sector.
- Dr. Shaw asked whether DOE had considered including more uses for hydrogen in its analysis, in line with HTAC's vision to have hydrogen be a "universal" energy carrier (e.g., substituting hydrogen for oil and natural gas use in industry, for diesel in heavy duty trucks, and for aviation fuel). He added that "in a lot of places where you've got a flame or a turbine it's not all that tough." Mr. Joseck explained the DOE is conducting R&D to improve the fuel efficiencies of heavy trucks, and that

adequate hydrogen storage and driving range would be an issue in these vehicles. Dr. McCormick noted that some of the heavy truck problem could be dealt with through strategies like mode switching, where truck trailers are carried on rail cars for the interstate portions of the haul, and the tractor cabs are used only for the in-city part of the trip. Mr. Joseck noted that DOE is considering another opportunity: the use of fuel cell-powered auxiliary power units (APUs) on trucks and ships, so that they do not burn fuel when idle or when sitting at truck stops or in ports. Mr. van Dokkum added that fuel cell buses offer additional opportunities.

- Responding to a question from Mr. Friedman, Mr. Joseck explained that the data in the chart dividing U.S. CO_2 emissions among the economic sectors (showing transportation at 33 percent) does not include upstream emissions. Mr. Friedman noted that this method of accounting would result in zero carbon emissions for electric vehicles, which is not accurate. Mr. Joseck replied that this is the way EIA does it; EIA includes the emissions from generating the electricity for the vehicles in the power generation sector. Mr. Friedman encouraged Mr. Joseck and the Committee not to think about emissions in this way, but to think about the whole system, including upstream and downstream impacts. He noted that showing the transportation sector as representing only 33 percent of U.S. CO_2 emissions not only underestimates how big the issue is, but also underestimates the large opportunities some of the zero carbon approaches have. Dr. Milliken agreed, and stated that he made an excellent point.
- Mr. Friedman thanked DOE for the modeling effort and for presenting the results. He reiterated his message that while hydrogen is really important, especially in the light duty vehicle sector, it is not the "be all and end all." We still need to deal with many other emissions sources. He urged DOE to consider the entire energy system and to present analysis that shows how all the different solutions can fit together and "paint a very positive vision of all the work that DOE is doing." Mr. Joseck agreed and stated that his Systems Analysis group is working with other groups in DOE to investigate integration opportunities and look at issues such as the best uses for biomass (e.g., for gasoline vs. diesel).
- In response to a question from Mr. Rose, Mr. Hofmeister explained that the rise in the cost of crude oil was not being caused by rising gasoline demand, but by rising global demand for diesel and jet fuel. He replied that only a portion (currently close to one-third) of a barrel of oil can be refined into "middle distillates" (diesel and aviation fuel). After checking with his Chief Scientist, Mr. Hofmeister reported that improved chemistry could increase the yield of diesel and aviation fuel to about 50 percent of a barrel, but that was probably the practical limit. "So, as you look out into the future, you're going to continue to see upstream crude oil production grow to meet global demand for the middle distillates requirements." This evolution could lead to a point "where we have an extraordinary surplus of gasoline" which could be reformed into hydrogen or other chemical or fuel products.
- Asked by Dr. Richmond whether gasoline users were "subsidizing" the cost of jet fuel by paying higher prices at the pump, Mr. Hofmeister replied that jet fuel prices have risen at a much higher rate than have gasoline prices. He added that refineries have been able to pass through less than 40 percent of the crude cost increase in gasoline, so consumers are actually "getting an extraordinary bargain on the gasoline [price] relative to the crude cost increase." Dr. Milliken wondered why gasoline prices would not be lower if we have, as Mr. Hofmeister said, more gasoline supply than demand. Mr. Hofmeister replied that currently demand is large enough to enable refineries to capture some (about 40 percent) of the increased cost of crude. "If there was a total collapse [in demand], you could

actually see crude costs go up and gasoline prices come down. It hasn't totally collapsed yet." He further clarified that "there is a very serious issue in refining right now with not making money because we're eating the crude price increase, which we have to, but not making enough off of diesel and aviation fuel to cover the cost of making the gasoline with a slowing gasoline demand."

- Mr. van Dokkum complimented DOE on the analysis and agreed that it points to the real benefits of fuel cells in the transportation sector. He pointed out that the "elephant in the room" is residential and commercial electricity use, which accounts for a large portion of the nation's total energy consumption and carbon emissions. He pointed to the need to improve the efficiency of electricity production. He noted that "the way electric utilities are organized and incentivized and the way that they are operating is really not the most optimal for our energy portfolio of the future." Mr. van Dokkum agreed that PEM fuel cells would not be significant players in electricity use, but asserted that solid oxide, molten carbonate, and phosphoric acid fuel cells could be, since they have higher efficiencies, are closer to commercialization, and are easier to implement. He suggested that DOE take a look at CHP with fuel cells and what that could mean to improving the energy productivity of commercial and residential buildings. Mr. Joseck noted that DOE's Office of Fossil Energy supports work on higher-end (one-megawatt and higher) fuel cells for power generation. Mr. van Dokkum agreed on the importance of efforts on high capacity fuel cells, but encouraged DOE to look at mid-scale fuel cell systems that can utilize the waste heat for nearby heating, cooling, hot water, and refrigeration systems. Dr. McCormick agreed on the importance of combining applications and making the most of energy, and noted that Honda's home hydrogen refueler "does hot water, electricity, and hydrogen for fueling cars." Honda's analysis, which GM is working to validate, shows that a 2-car (FCV) family can reduce its carbon footprint by 30 percent with the combination of benefits offered by the system.
- Mr. Katsaros asked Mr. Joseck's team to develop a chart that shows the nation's oil import bill and how the balance would change as a result of fuel cell penetration predicted in the DOE analysis. This type of chart could provide a striking depiction of the increased economic power and energy security created by utilizing alternative technologies, and could have a "wow effect." Mr. Joseck replied that he could easily to generate this chart and will prepare it for the July HTAC meeting.
- Mr. Hofmeister asked whether the DOE analysis considered the effects of a carbon constraint. He suggested that a policy designed to meet the "80 percent below 1990 by 2050" emissions levels could significantly alter the forecasts for energy consumption. Mr. Joseck replied that DOE is conducting analysis to explore the impacts and costs of carbon policies and would report on these results in the near future.
- Dr. Shaw asked whether DOE had looked into what system-wide changes would need to be made to meet the 550 ppm CO_2 maximum set by the International Panel on Climate Change. He believes the U.S. should set an example and lead this endeavor given our substantially higher CO_2 releases. He finds the EIA's business-as-usual forecast alarming, and noted the entire energy system must change to meet carbon reduction goals, and quickly. He stressed the need for carbon-free hydrogen however the world can get it (coal with sequestration, nuclear, and renewable), and for use of hydrogen (and other clean energy sources) in as many applications as possible, not just the light-duty vehicle sector. He suggested that the HTAC consider the numbers for "what it would really take in terms of big coal sequestration, in terms of big nuclear, in terms of electrolysis using renewables to solve this problem." Mr. Ross suggested the presentations made by Dr. Nathan Lewis (California Institute of

Technology) as a source for this information (see http://nsl.caltech.edu/energy.html), and Dr. Shaw agreed that Dr. Lewis's data was very enlightening.

3. *Open Discussion on the Energy Strategy and Climate Change*

Congressman Walker started the session by recognizing Mr. Mudd, who gave a short presentation to the HTAC on the size of a "gigaton of carbon" and what that means in terms of the size of the challenge for reducing CO_2 emissions. He noted that achieving stabilization at the goal of 550ppm by 2100 means that we need to avoid emitting 500 gigatons of carbon (cumulative). A gigaton of carbon is equivalent to "250,000 Capitol domes, 500 new nuclear plants, or one billion cars doubling their efficiency." He concluded that the challenge is very large, though not unsolvable, and will take a "moon shot" approach and a combination of options to solve.

Congressman Walker opened the floor to a discussion of possible "talking points" that the HTAC could use in trying to educate the next United States President, the next DOE transition team, and the broader policy community. He asked the HTAC to offer comments on hydrogen and fuel cell talking points that would have relevance in the debate as it relates to climate change and energy needs, and how hydrogen plays a role going forward. Ms. Epping recorded a list of the HTAC's rough talking points during the discussion period, as shown as Exhibit 1.

Exhibit 1. Rough Draft of Ideas for HTAC Talking Points for Policymakers

STRUCTURE:
- Problem
- Solution (vision and barriers)
- What are we asking for?

- New Administration will be concerned with climate, jobs, and anger over energy prices.
- We need a commitment that is on the scale of the problem.
- How do renewables and hydrogen fit into the existing infrastructure?
- Hydrogen is technically and economically feasible.
- Hydrogen is "change you can believe in."
- Decarbonization.
- Hydrogen R&D and commercialization is ongoing—the next administration needs to provide public policy leadership.
  - We have a big challenge before us, but that means we also have a great opportunity to continue this evolution toward cleaner, low carbon energy. Hydrogen will be a safe and essential part of this opportunity. Moving towards hydrogen will help our economy grow, create jobs, and improve the global competitiveness of the nation (and address the cost of energy and climate change).
- Environmentally sound and clean energy source.
- U.S. technology and innovation.
- Hydrogen is an energy resource available to us in unlimited quantities (do not have to

depend on other nations, i.e., energy independence). If you build the infrastructure, you can always have it.

- Address timing and what impact can be made during their tenure. Need to find a balance between "it is here now" and "there are opportunities to expand the use of hydrogen and fuel cells now."
- What can be accomplished in 8 years.
  - List of obstacles or barriers, e.g. capital, fear, infrastructure, etc.
  - What impact their administration can make on carbon in 2050 (as a metric).
  - Pie showing spending now vs. what we need to spend on R&D, implementation, etc. (addressing short (8-10yrs), medium (10-20yrs), and long term (20+yrs)).
- Implement EPACT 2005.
- Address safety – hydrogen is being demonstrated to be safe.
- Getting emerging technologies and incumbent technologies on an even footing. Contribution margin penalty. The policies made by the politicians affect the inventory that the manufacturers can offer. Incremental change vs. taking the larger step toward a larger solution. How many infrastructures are we willing to pay for?
- No plan today; it's every state and every nation for themselves. Therefore, we need a blueprint —cooperation at an international level—and the time is now.
- How do you create global demand for new technologies?
  - You can if another force is at work, e.g. fear. How do you turn something that is amorphous and looming to a clear and present danger?
  - But we should be able to do this without fear—with a stimulus.

For the ultimate presentation of the talking points, the HTAC agreed to assume the audience has only "hearsay" knowledge about hydrogen, its uses, relative benefits, or safety. Congressman Walker noted that many members of Congress and their staff would have at least a "cursory knowledge" of hydrogen, but that some have misconceptions. Additional highlights of the discussion are summarized in the bullets below.

- *Dr. Shaw:* Start with the thought that hydrogen is an energy carrier that can be burned or used in an electrochemical reaction without creating any pollution. Hydrogen is substitutable in most applications for a currently used fossil fuel.
- *Mr. Friedman*: Do not over-sell—hydrogen only produces no pollution if it is produced from clean, low-carbon energy sources.
- *Mr. Katsaros:* This should be an "elevator speech" that makes a big impression in a short period of time. The most important message we can get across is that hydrogen is really here and it can really happen—it's technically feasible, it's economically feasible, and there are real cars on the road doing real things. He added that he is always struck by the reaction of most people, which is, "Oh, that's a pipe dream. Yeah, I understand it's pollution-free, but it's a pipe dream."
- *Dr. McCormick:* We tend to present this as something new, when in fact mankind has been "de-carbonizing" its energy sources over time, as a "natural, evolutionary" process. Thus, rather than presenting hydrogen as this great "utopia" that requires an "intellectual leap," we should present it as the logical next step in our path towards decarbonization. The combination of hydrogen and

electricity is happening and will continue to happen. It is not something that will require us to stop everything we have been doing and reboot – there is a graceful path forward.

- *Mr. Hofmeister*: Hydrogen research, development, and commercialization are already ongoing. What the next President needs to do is provide continuous public policy leadership.
- *Mr. Friedman*: The messages of the "elevator speech" are:
  - The scale of the problem
  - The need for multiple solutions
  - It can be done safely and can generate jobs, economic growth, and competitiveness.
  - Dr. Dresselhaus added a fourth point: What happens if we do nothing?
- *Mr. Friedman*: The broad statement is that we have a big challenge before us. We are addicted to oil. We are facing a serious crisis in climate change. We are facing world-wide economic growth and increasing numbers of consumers. But that also means we have a great opportunity. That opportunity is to continue the evolution towards cleaner, lower carbon alternatives, and hydrogen can be an essential and safe part of that. If you do that, we can create new jobs, we can grow our economy, and we can improve international competitiveness. If we sell hydrogen as a silver bullet, we will be ignored. But hydrogen is potentially a huge and important part of that evolution.
- *Congressman Walker:* The "grabber" needs to be something that the politician knows is being discussed at the dinner table in multiple households in his/her district or across the country. Right now, these topics include the price of gasoline and the price of energy generally (and how they affect food prices, etc.). Therefore, price is one thing that needs to be included in the HTAC message. American competitiveness in a global environment (jobs and the economy) is another big issue that resonates. These two facets of the hydrogen story will help to convince policymakers and the public that hydrogen is something they really need to take a look at.
- *Mr. Hofmeister*: Without meaning to be facetious, "hydrogen is change you can believe in." If America does not grab the fuel cell initiative, Japan will, or has. This is about American technology and innovation for next generation fuel, or energy, efforts. Getting the word "American" in there, and "technology" and "innovation" together are very important for a new administration.
- *Mr. van Dokkum*: One other subject that the households in America are starting to talk about is climate change. This has changed over the last five years, and climate change is now a real concern to American families. So, cost of energy, climate change, and international competition are the three drivers that a politician will gravitate to right now. If we can tie those three together with a solution set that speaks to each of these issues, the message would be ideal to get a candidate's attention.
- *Mr. Mudd*: The key message is that hydrogen can be an important part of the solution for global climate change. The sub-bullets to this statement are: it's a domestic fuel source, it's safe, it can create domestic jobs, and with R&D can be cost-competitive with imported gasoline very rapidly.
- *Dr. Taylor*: Another message needs to be energy security, since national security is also important to the public.
- *Dr. McCormick:* State the problem and then propose the solution. Do not try to build the problem into the explanation of the solution. The story becomes convoluted, and people have trouble tracking

it. As Mr. van Dokkum said, state that "the issues facing us are 'A, B, C'…" followed by "this approach allows us to simultaneously do 'X, Y, Z' to address the problem."

- *Congressman Walker*: The concept that hydrogen is an energy resource that is available to us in unlimited quantities will also be appealing. One of the reasons why hydrogen plays globally is because every nation has a supply of hydrogen, and will not need to depend on other nations for fuel. The hydrogen source may be different and hydrogen might be more expensive in some places than others, but it is available in virtually unlimited quantities to any nation that builds the infrastructure to utilize it. Few other resources provide that advantage.
- *Mr. van Dokkum:* The first thing a UTC customer asks about this new technology is "What is the return on investment? What will I pay for energy?" The second thing they ask is "How does this fit with reducing my environmental impact and my carbon footprint?" And, in political circles, people are asking what this technology can do for the country's employment base and technology base. Just like Microsoft has a lock on computer technology, can we establish America as a leader in renewable technologies or environmentally friendly technologies?
- *Congressman Walker*: While the climate change message is important, it is not without controversy. The really central issue, and one that has buy-in across the board, is that the nation needs an environmentally sound, or clean, energy resource. Tying HTAC's message about hydrogen's environmental benefits only to its impact on climate change is "not necessarily a ubiquitous message that fits across the board inside the political community at the present time."
- *Mr. Friedman*: We agree that we've geared the talking points toward a broader audience than just the presidential candidates. However, climate change and energy security are indeed very powerful messages for the candidates.
- *Mr. Rose*: It would be useful for the members of HTAC who have already developed talking points on hydrogen and fuel cells to share them with one another, and use them as input for the HTAC talking points.
- *Mr. Rose:* Make the case for investment in hydrogen fuel cells as a strategic investment. It is not about what is happening today or in the next couple years—think of this investment in a larger context. The Defense Department has identified hydrogen fuel cells as a strategic technology, as have other countries. The Department of Energy will soon publish a jobs study that will show positive numbers on how hydrogen technology can contribute to U.S. employment.
- *Congressman Walker*: The first question a Congressperson or staffer will ask about hydrogen fuel cells is "where are we going to get the hydrogen?" Most people on Capitol Hill think that getting the hydrogen is a big problem. They are surprised to find out that there are vast supplies of hydrogen available.
- *Mr. Rose*: HTAC cannot shy away from the hydrogen supply issue. We should communicate that hydrogen is just like electricity. In the future, hydrogen will be produced from locally available sources, depending on what is the most economically advantageous.
- *Dr. Milliken*: Timing is an issue on the minds of many people, including politicians. It may be important for the HTAC to communicate what can be achieved with hydrogen and fuel cells in the near term, i.e., during a presidential term.
- *Congressman Walker*: Hydrogen is real; it is here now. HTAC needs to communicate this key point. Part of the problem is that the political community has basically accepted the idea that hydrogen fuel

cells are a distant solution—that hydrogen is a wonderful thing if we could ever get there, but in the meantime we have to do something else. The investments the policymakers want to make are for things they believe are just over the horizon (even though many of those things may in fact be further away than hydrogen).

- *Mr. Friedman:* On the issue of timing, the Committee needs to be careful that we find a balance in our message that does not oversell. There is a difference between "there are opportunities now" and "hydrogen and fuel cells are here now." We do not want to imply that if we invest in hydrogen today, it will be the solution for tomorrow. Similar to what is conveyed in the HTAC vision, we might send the message that there are opportunities to expand the use of hydrogen and fuel cells now, and that is part of building a future where hydrogen could be a widespread technology.
- *Congressman Walker:* Consider the politician meeting with his or her constituents at a town meeting. These constituents are looking for near-term solutions. Talking about where the opportunities lie may be a nice discussion point, but it will not carry the kind of message that the politician is looking for.
- *Mr. Friedman*: The issue of safety is something that we know is on people's minds, and we should address it proactively, e.g., by including a talking point that makes a simple statement such as "hydrogen is being demonstrated to be safe" or something along these lines.
- *Dr. Saillant*: Create a pie that shows how much we are spending on R&D in hydrogen today and how much we really need to spend, as well as how much we spend on demonstration or deployment programs and how much we really need to spend. This illustration would show what is happening in contrast to what needs to happen. The talking points should address both what can be done in the near-term, within one or two presidential administrations, but also explain what is being done to address the future for America's children and grandchildren.
- *Mr. Rose*: One simple answer could be that all the next President needs to do is implement the Energy Policy Act of 2005 (EPACT). EPACT authorizes an RD&D investment that is twice the amount President Bush requested, and includes a lot of very attractive provisions (such as requiring the purchase of fuel cell vehicles in federal fleets by 2010). It also requires the purchase of fuel cells for other applications, but these provisions have not been implemented to any significant degree. EPACT provides a roadmap; what is needed is the leadership to implement what already exists in legislation.
- *Mr. van Dokkum*: One question policymakers frequently ask is "if fuel cells are so great, how come they're not here yet?" Part of the answer is that incumbent technologies are being mass produced and fuel cells and fuel cell vehicles are not. Volume makes the price points different. Crossing this "valley of death" is not trivial. The implementation of policies and incentives that provide even footing for new technologies versus incumbent technologies can have an immediate impact. Things like tax incentives can help in multiple ways, by getting the new technologies into the market, gaining experience in using them, getting codes and standards in place, and getting the domestic supply chain developed. We can start with technologies that we have today (stationary fuel cells) and move through the spectrum to the more challenging applications (fleet or automotive applications).
- *Dr. McCormick*: We should keep in mind that every time there is a policy that impacts automobile design (e.g., increasing CAFE standards), it requires vehicle redesigns that are quite costly and difficult to recover in the profit margin. This need to provide "one vehicle from every part of the Chinese menu…forfeits the ability for automotive companies to do the longer-term thing." The companies have limited dollars, people and manufacturing capability—choices need to be made.

- *Congressman Walker:* The current Congress and administration has bought into the concept of incremental change (versus dramatic change). There has not been enough discussion about the differences between these two approaches and the consequences of buying incremental change rather than investing in the larger solution.
- *Mr. Hofmeister*: Businesses ask the strategic question, "Is there a market pull or is there a technology push?" Like the automotive industry, the oil industry also deals with this question often, such as, "How many different fuels and fuel infrastructures we can afford to pay for?"
- *Mr. Hofmeister:* The thing that will appeal most to the next President will be what can realistically be achieved in an eight-year time horizon. Can we identify some concrete, meaningful steps that could be proposed and accomplished over that eight-year period? It will also be important to identify for the next President the likely obstacles or barriers, such as lack of confidence in the capital markets. Not much capital market money will flow toward hydrogen businesses in the short term without some major government push. With regard to public education, it will be important to address safety and the general layperson's fear of hydrogen. Infrastructure development is critical to making hydrogen available to consumers and the barriers to infrastructure development are large. These sorts of things are barriers that opponents of hydrogen will bring up, and we need to be straightforward about the challenges and timeline for addressing them.
- *Mr. Friedman:* The structure for the talking points should be "problem, solution, ask." The *problem* is the big picture, the *solution* is both vision and (maybe) barriers, and the *ask* is what we want. The Committee should not just talk about the problem and why hydrogen is great; we should also ask for something. Part of the "ask" should be that the nation needs a commitment that is on the scale of the problem. It is likely that both evolutionary and revolutionary changes will be needed to address the problem; regardless, the scale of commitment is going to be huge. The message needs to be "What, as President, are you going to do in four to eight years?" There is a critical need for a comprehensive national energy investment strategy that takes into account jobs, energy security, environmental quality, climate change, etc.
- *Dr. McCormick:* The notion of working together on this, as a partnership between government, industry, and the public, is crucial. Government cannot simply pass a law to regulate a particular technology change and expect the capital to be there to make it happen. There is definitely a need for a larger, national scale commitment that unifies the nation in addressing the energy problem and provides a framework for coordinated, focused national policy.
- *Dr. Shaw*: People often see further than their leaders—the cities, the states, and the "average Joe" are way ahead of most politicians on the issue of climate change. These constituents also understand that America gets a lot of our fuel from places that are not very reliable. The "beat out there" is that change is happening and bigger changes are needed. The next eight years is perhaps the most critical presidential cycle of all time, because in this eight-year period we will either decide to act aggressively or we will not. Many climate scientists have asserted the need to act quickly, within this next eight years, on reducing carbon emissions. The message for the Congress, and especially for the next President, might be that "this is the time for creating a *legacy* for how you are remembered by history." The next President has an opportunity over the next eight years to take a leadership position that will move people faster than they think they want to move, require taking bigger risks, and launch a change effort that is needed to "turn the ship in the direction it needs to go for our children and grandchildren." This huge issue will take a lot of capital and resources to address, but it also has a huge upside. The upside is not only in addressing climate change, but also in creating huge

numbers of "green jobs" for our population. One example of legacy building is the Eisenhower Interstate System. Only 10 percent of it was finished in President Eisenhower's term, but everybody refers to it as the Eisenhower Interstate System. The next President is not going to get us to the endgame but can create the initiative that will carry us to the end.

- *Dr. Shaw:* It is not widely understood that hydrogen can be used in almost any application in which we now use fossil fuels. We need to let people know the synergies between hydrogen (as an energy carrier and energy storage medium), electricity (which can be produced from stored hydrogen), and intermittent renewable energy supplies. The integrated picture of how renewables and hydrogen fit in the existing infrastructure is important. Hydrogen can be used in existing burners, turbines and engines—we do not have to change radically to begin introducing hydrogen into our economy.
- *Dr. Saillant*: One potential metric for measuring an administration's performance is its future impact on carbon emissions, e.g., parts per million CO_2 in 2050. This type of performance metric would raise the visibility and begin to ingrain into the "social consciousness of the country" an expectation for influencing the nation's carbon impact by the year 2050.
- *Congressman Walker*: The fact is that today the government is essentially dysfunctional and may not be capable of a creating a policy-driven approach such as what was crafted in Eisenhower's term to build the interstate highway system. The President and Congress are influenced by a number of constituencies and interest groups, some of which are very tightly bound to maintaining the status quo. Technology and industrial innovation can move at a much faster pace than government. For example, if you had suggested in 1995 that in 2008 cell phones would be ubiquitous in the economy or that 20 percent of U.S. households would not have a landline telephone, most of the political world would never have believed it. That change came about through a technologically driven, investment-driven revolution that took place over a period of a decade. Part of the question for HTAC is whether or not the government will really drive an energy transition and offer someone the potential to define their legacy, or whether the political system is too governed by competing special interests to allow this to happen. In thinking about the HTAC's "ask," should we ask the government to take a leadership role or should we assume that the leadership will to come from elsewhere, e.g., the investment community, and should government's role be something other than leadership?
- *Dr. Shaw*: Inertia indeed exists in the political system, but we need to move our thinking beyond that problem or we will not get any where. If the right thought-influencers get involved, we can overcome the inertia that is built into the system.
- *Mr. Friedman*: Congressman Walker's point about the way government works is well taken. The HTAC needs to make an "ask" but we need to make a smart and realistic "ask." At the same time, the "ask" does have to be at an appropriate scale. Can we frame the role of government in a way that gets away from the debate over "technology push versus market pull?" "Leadership" does not have to be "I have a blueprint, and you must follow my blueprint, and I force everything to happen." It is important to break the habit of assuming that this is what government leadership means. We need to frame the vision in a way that supports the role of the market. But government does need to provide a vision. How big and how "intrusive" that government vision is, is a separate debate, but it is essential that the nation have a vision and leadership. What leadership and vision translates to on a day-to-day basis can be endlessly debated; HTAC will not be able to resolve what this means.
- *Dr. Richmond*: It is very important to get the message out to the new administration quickly, and that the message is something that can be handed out very easily. Also, as the new Secretary of Energy

comes in, HTAC needs to say, "We are here; we report to you and are ready to help you any way we can." The Committee should strive to get the talking points prepared soon.

- *Dr. McCormick*: One of the big problems that companies like GM and Shell (and their suppliers) deal with is the difference in time scale. We are asking companies to invest people, who are productive, and capital, which can be productive, to develop and manufacture technologies that will not generate returns for 10 years. For example, getting the cost of membrane material where we need it is not a fundamental chemical problem—it is an economy of scale problem. GM and others have done reverse engineering studies that indicate it will take manufacturing volumes of about a million fuel cell vehicles a year for a membrane manufacturing plant to recover the capital and make returns at the targeted membrane material cost. Likewise, with hydrogen fueling stations built to support only a few vehicles, there is stranded capital. It will be important to use tax policy, or other means, to reduce the investment risk—so that a return 10 years from now does not cost too much right now.
- *Dr. Shaw*: Dr. Shaw noted that he is working with major corporations around the world to develop a large, multi-billion dollar fund to finance large-scale manufacturing plants for alternative energy technologies that can get us to the economies of scale needed to lower costs. This type of fund can provide investors with an opportunity to invest in new, emerging industries and provide the technology suppliers with a lower-risk way to invest their capital.
- *Mr. Hofmeister*: It is important to consider what organizations will be "competing" for the attention of the new administration. Whether it is the oil industry, the natural gas industry, or whoever, all the associations will be crafting their messages for the new administration, and it will be important that HTAC gets a share of the administration's attention. HTAC should craft two or three "big grabbers" that play to what both candidates will want to talk about in a general election. One will clearly be climate, one will clearly be jobs, and one will be current energy costs. The sooner we can start a dialogue with the administration, the better, since other associations will also be talking about these three issues.
- *Dr. Richmond*: With respect to Mr. Hofmeister's comment about getting our share of attention, it will be important to couch the HTAC message in a way that says "We, as a committee, are committed to helping develop an energy policy that will get us to a sustainable future, and part of that is hydrogen." If the Committee's message focuses solely on hydrogen, we will be viewed as just another interest group promoting our "fiefdom."
- *Dr. McCormick:* Responding to a question from Dr. Richmond about whether GM is concerned that more "nimble" start-up companies could "come in and compete and do something that you can't do right now," Dr. McCormick explained that the scale and the capital required is too large. No market exists that will pay the price of the cost of capital in the transition. In mature markets, when you have lots of hydrogen and lots of cars, plants running at full bore, and a robust supply base, it works. It is a "Valley of Death" problem. The automakers do not have the logical stepping stones that the Internet had through the Advanced Research Projects Agency or that the semiconductor industry had through the Defense programs. We are being asked to go from laboratory scale to millions covering huge territories.
- *Dr. Saillant*: Right now, somewhere in the range of $1 to $3 billion is being spent by industry to develop fuel cell technology. Companies spend this money because they see an opportunity for close to a trillion dollar a year market. However, the survival rate of the small companies trying to develop fuel cell technologies is bad; a number of different companies are going under. One thing that makes

this business risk unique is what Dr. McCormick already referred to—the scale of time between the investment and when you can get a reasonable return. The problems that we are trying to solve are on long, multi-generational time scales. The investment will also need to be, indeed has been, multi-generational. People who think in terms of "I need a return by next quarter, or in my next term in office" cannot fathom this order of time scale. However, when we communicate about this issue, we must portray the positive side—that demonstrations are underway, progress has been made, changes are occurring.

- *Dr. Saillant*: What may be needed is more of a unilateral action by the U.S. government. A perspective that approaches this problem in a way that is "less democratic than any other thing we have ever engaged." The democratic process has not worked in this area and has "put us at a disadvantage to countries that make unilateral decisions."
- *Dr. Ross*: If the Committee is satisfied with the provisions of the Energy Policy Act of 2005, then perhaps one thing we can ask for is to extend EPACT beyond its current expiration date of 2010. Or, if we are not satisfied with the provisions of EPACT, we should persuade the administration to pass a new law.
- *Mr. Friedman*: The risk of general economic crisis is very real if we do not do something. If we do not start to do these evolutionary things, if we do not make these investments, then we will see businesses failing because people are not going to be able to afford to buy cars. Irrespective of whether people are willing to pay more for a car with higher fuel economy, they just will not have the money to buy as many cars as they do today. This is already happening now. One thing the Committee seems to agree on is that there has to be help for the transition; and there has to be a vision for the transition. We will need more resources to do this—"R&D and government purchasing ain't [*sic*] going to be enough." The provisions of EPACT are nowhere near enough to get hydrogen where it needs to go. One of the great opportunities of something like a cap-and-trade bill is that you create a funding reservoir that can be used to get over some of the valley of death issues. We need smarter policies that guide the capital to where it needs to go and that acquire the capital. We hit roadblocks in Washington because we are talking big dollars, and big dollars get really, really scary, especially when you are competing against a lot of other entrenched interests.
- *Dr. Shaw*: Consider including a time dimension in the talking points, perhaps structuring them by what is achievable, what the issues are, etc., in the short term, medium term, and long term. The short term is 8 to 10 years, the medium term is 10 to 20 years, and the long term is 25-plus years.
- *Mr. Hofmeister*: Shell has published a scenario analysis that describes what is or could be happening in the world as we look out ahead (see www.shell.com/scenarios). The scenarios are not a prediction of the future, but a way of structuring thinking about the future. In one scenario, called the "Scramble Scenario," every nation, every company, every community looks out for itself because there is no plan. There is no larger framework in which we all operate. That is largely what is happening today. Every state is looking at its own climate change policy. Every nation is looking for its own energy resources and "the devil to the hindmost." In another scenario, called "Blueprint," there is increasingly comprehensive, coherent cooperation on principles and policies, which over time leads to international solutions for the issues that we face. In this scenario, government has a role, corporations have a role, and citizens have a role. This report may be useful in informing the Committee's thinking. Shell has been doing these scenarios for decades, but has never supported one scenario over another. For the first time in the company's history, Shell has expressed its support for a particular scenario—the Blueprint Scenario—and said it would "sign up for 'Blueprint' as a

company because 'Scramble' is ultimately a trip to international disaster." Crossing the valley of death is not unique to the automotive companies. Many valleys of death will need to be traversed if we get serious about climate change and carbon constraints in a meaningful way or get serious about transitioning work forces and transitioning developing economies into developed economies, etc. The point of the Blueprint Scenario is that "the time is now to get on with it."

- *Congressman Walker*: The fact is that the political establishment will respond to a demand by the public to make certain things happen, and the markets will respond if there is a demand for a product. We often try to create this demand by having the government buy product. We are much better off if we figure out a way to create a broad-based demand for the product, and there are a variety of ways to do that. One of the things the Committee should think about, which fits in with the "Blueprint Scenario," is how you create global demand for new and different technologies and new and different solutions to problems.
- *Dr. Shaw*: Fear (responding to a real or perceived crisis), unfortunately, has been the major motivator for rapid change in human history. The problem now is that people have a "looming sense that something big and bad is about to happen but we do not have a 'clear and present danger'." Is there a way to turn something that is "amorphous and looming" into something that is "clear and present?"
- *Congressman Walker:* It is possible to create demand without fear. For example, by providing people with free hydrogen. The government could, in the early stages, provide tens of thousands of people with free hydrogen at a cost of about 10 percent of what the taxpayers are now spending for ethanol subsidies.

Congressman Walker summarized next steps for the Committee in pulling together a set of draft HTAC talking points. He asked Mr. Friedman to join the Policy and Planning Subcommittee, and Mr. Friedman agreed. Mr. Friedman also agreed to develop a first draft of the talking points from the list of items captured by Ms. Epping (see Exhibit 1) and from the Committee's discussion. He will provide the draft to Dr. Shaw for distribution to the Subcommittee. Dr. Shaw will organize a Subcommittee meeting (teleconference) some time before the July 22-23 HTAC meeting to refine the talking points. They will distribute the product to the full Committee for discussion and further synthesis and revision at the meeting in July. Mr. Rose again suggested that the Committee members share with each other any talking points that they have already developed.

4. *Closing Comments*

Ms. Epping informed the HTAC that DOE General Counsel determined that it would be a violation of the Hatch Act for the Committee to invite staff of the presidential candidates to an HTAC meeting. Many of the Committee members are "special government employees," and as such are acting as federal employees. It may be possible to arrange another type of meeting with the candidates' energy advisors or their staff, particularly one that involves Congressman Walker, or other HTAC members who are not special government employees.

Ms. Epping asked the Committee members to confirm the date for the fall HTAC meeting: November 6-7, 2008. Mr. Friedman questioned whether it would be better to move the meeting to late November or early December, so that the HTAC could invite members of the transition team to the meeting. Congressman Walker suggested an approach in which the Committee as a whole develops the material

and talking points and a delegation from the Committee meets with the transition team to communicate the HTAC message. The early November meeting date would enable the Committee to tweak its message immediately following the election, and appoint a delegation to meet with the transition team as soon as possible. The members agreed to this approach and confirmed the date for November 6-7. They also decided to take up the subject of the 2009 meeting calendar at the July 22-23 HTAC meeting.

Because nobody expressed a desire to speak during the public comment period, no public remarks were made.

5. ***Adjourn***

The May 13-14, 2008 HTAC meeting was adjourned at 12:43 p.m.

SEVENTH MEETING OF THE
HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE (HTAC)
PARTICIPANT LIST
MAY 13 – 14, 2008

HTAC Members Present

- Mildred Dresselhaus
- David Friedman
- John Hofmeister
- Arthur Katsaros
- Dan Keuter
- Byron McCormick
- Michael Mudd
- Geraldine Richmond
- Robert Rose
- Philip Ross
- Roger Saillant
- Gerhard Schmidt
- Robert Shaw
- Kathy Taylor
- Jan van Dokkum
- Robert Walker

HTAC Members Not Present

- Larry Bawden
- John Bresland
- Mark Chernoby
- Alan Lloyd
- Rand Napoli
- Ian Purtle
- Michael Ramage
- Greg Vesey
- John Wootten

U.S. Department of Energy Staff

Office of Energy Efficiency and Renewable Energy

- Christy Cooper
- Peter Devlin

- Kathi Epping
- Rick Farmer
- John Garbak
- Monterey Gardiner
- Fred Joseck
- Jason Marcinkoski
- JoAnn Milliken
- Mike Mills
- Antonio Ruiz
- Ned Stetson

Office of Fossil Energy

- Mark Ackiewicz

Office of Nuclear Energy

- Carl Sink

Office of Science

- Harriet Kung
- Stephen Kung

U.S. Department of Transportation Staff

- Aviva Brecher
- Paul Brubaker

Members of the Public in Attendance

- Judith Bayer – UTC Power
- Andrea Chew – Sentech, Inc.
- Keith Cole – General Motors
- Mike Duffy – National Renewable Energy Laboratory
- Jessica Friedman – American Honda
- Robert Garris – U.S. Postal Service
- Leo Grassilli – U.S. Navy
- Tom Gross – IF, LLC
- Karl Jonietz – Lawrence Livermore National Laboratory
- Ed Kiczek – Air Products and Chemicals, Inc.
- Erin Lane – Plug Power
- Jonathan Munetz – Sentech, Inc.
- Jennifer Schafer – Plug Power Inc.
- Tom Sheahen – National Renewable Energy Laboratory
- Neil Snyder – National Renewable Energy Laboratory

- Joe Stanford – Sentech, Inc.
- George Sverdrup – National Renewable Energy Laboratory
- Kuppusamy Thirumalai – STI-Transportation Analysis Center
- Thomas Timbario – Alliance Technical Services, Inc.
- Steve Tomisek – U.S. Marine Corp (retired)
- Allison Trepod – SRI
- Puneet Verma – Chevron Technology Ventures

Support Staff

- Judi Abraham – Conference Management Associates, Inc.
- Anna Domask – Energetics Incorporated
- Melissa Lott – Alliance Technical Services, Inc.
- Kevin McMurphy – Sentech, Inc.
- Shawna McQueen – Energetics Incorporated