

HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE

MEETING MINUTES

November 4-5, 2009

Radisson Reagan National, Arlington, VA

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November 4-5, 2009

1. Call to Order, Agenda Review, Subcommittee Reports, and Public Comments

Chairman Walker called the November 4-5 meeting of the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC or Committee) to order at 8:32 a.m. and briefly reviewed the meeting agenda.

Chairman Walker began a discussion about the HTAC meeting schedule for the upcoming year. The members agreed to the following dates for HTAC meetings in 2010:

- February 10-11 (Washington, DC)
- June 3-4 (Washington, DC)
- October 14-15 (consider San Antonio, with a site visit; Fuel Cell Seminar is the following week in San Antonio)

The Committee then briefly discussed news updates from Washington. Bob Rose mentioned the pending National Academy of Science report and the EPA’s new guidance regarding real-world vehicle performance.

1.1 Subcommittee Reports

There were no subcommittee reports to deliver.

1.2 Public Comments

Chairman Walker opened up the discussion for public comment. There were no public comments.

2. Remarks from Deputy Assistant Secretary for Renewable Energy

Mr. Jacques Beaudry-Losique, EERE

>> *see full presentation at http://www.hydrogen.energy.gov/htac_meeting_nov09.html*

Chairman Walker introduced Mr. Jacques Beaudry-Losique, the Deputy Assistant Secretary for Renewable Energy at DOE, for an update on the DOE hydrogen program's direction.

Deputy Assistant Secretary Beaudry-Losique began by noting the positive developments that have occurred since the last HTAC meeting, including a meeting between Under Secretary Kristina Johnson and HTAC members. He applauded the Committee for its commitment to educating DOE management, asserted that their efforts have made an impact, and assured the HTAC members that their input is valued, and DOE will continue to seek their advice. Though the DOE 2010 budget request reduced funding for hydrogen technologies, nearly all the funding was restored by Congress. Secretary Chu has said that he will accept Congress' intentions to provide funding for fuel cell vehicles, and will work to ensure the funds are spent in the most effective way possible and in ways that balance near-term and long-term objectives. Deputy Assistant Secretary Beaudry-Losique agreed that hydrogen is not a "silver bullet," noting that there are no silver bullets for solving the energy and climate crises. What is needed, he said, is an understanding of how all the technology options can work together, in what sectors and in what proportions. Finding the best application and use for each technology depends on rigorous analysis, a broad base of input, unbiased science, and open minds. The administration must find a suitable balance between funding projects that will produce results swiftly, and funding for longer term projects that will contribute to meeting the ultimate energy and environmental goals, while not leaving us at a competitive disadvantage down the road.

Mr. Beaudry-Losique noted that the President's energy policies are in large part defined by the goal of reducing greenhouse gas emissions 80% by 2050, so the long-term nature of the problem is recognized. Support for basic research to achieve fundamental breakthroughs will continue. A diverse portfolio of alternative energy technology options will continue to be funded, since there is a lot of uncertainty around these technologies, and there is growing consensus that a portfolio of options will be needed to reach our energy goals.

Deputy Assistant Secretary Beaudry-Losique went on to review the many "exciting advances that have happened in the hydrogen and fuel cell field since the HTAC last met." R&D accomplishments included the following: (1) reports from 3M Company on a membrane electrode assembly with durability of more than 7,000 hours in single-cell testing in the lab, and (2) the 2009 DOE automotive fuel cell cost analysis projecting high-volume fuel cell production cost of \$61 per kilowatt (a 15- to 20-percent decrease from where we were last year), noting that hydrogen production costs are continuing to decrease. A recent independent assessment of DOE's electrolysis cost assessment confirmed the progress made in reducing

the cost of hydrogen from electrolysis, bringing both centralized and distributed costs substantially closer to the cost target for enabling commercial viability.

There is also good news, he said, from outside the DOE program and around the world. Germany and Japan have made strong commitments to building a hydrogen fuel infrastructure, and global automakers remain dedicated to commercializing fuel cell electric vehicles (FCEVs): eight of the world's largest automakers, Daimler, GM, Ford, Renault, Hyundai, Toyota, Honda, and Nissan recently signed a letter of understanding in support of FCEVs, anticipating widespread commercialization starting in 2015, and calling for increased investment in refueling infrastructure. Despite GM's financial situation, they have continued to be a real leader in fuel cell technology. Mr. Beaudry-Losique noted that there have also been advancements in non-automotive fuel cell markets. Over the past year American companies have reported plans for substantial exports of stationary fuel cell systems, which is a "great example of American industrial success."

Given the growing list of accomplishments and encouraging signals from key industrial partners from around the world, Deputy Assistant Secretary Beaudry-Losique expressed his confidence that hydrogen and fuel cell technologies will play an important role in the DOE's Energy Efficiency and Renewable Energy Portfolio, as well as in our world's energy future. He encouraged the HTAC to continue their efforts to provide input and feedback on the Administration's policies, and he thanked the HTAC for their work over the past year.

Questions, Answers, and Discussion

- Chairman Walker asked what Deputy Assistant Secretary Beaudry-Losique specifically meant by his use of "near-term, medium-term, and long-term" regarding hydrogen development and deployment. The Deputy Assistant Secretary said that, to him, long-term means 2050, because that is the date the President has set for reducing carbon emissions by 80%. In the long-term, it is clear that hydrogen vehicles will play a part in the commercial vehicle market. The short-term is generally defined by a four-year political cycle. The medium-term is broadly defined as somewhere between 2015 to 2020.
- Chairman Walker asked what HTAC has done that has been most effective in convincing the administration of the viability of hydrogen technologies. Deputy Assistant Secretary Beaudry-Losique said that the administration responds to scientific, logical explanations of the technology and the industry's approach for overcoming technical obstacles, as opposed to more aggressive, less technical arguments.
- Dr. Robert Shaw made the comment that, with any new technology, it typically takes 15-20 years for significant market penetration to occur, which means that efforts must start today in order to get where you want to be by 2050. He asked for the administration's view on how to justify acting today on technologies that will have great value in the long term but that that may not show big results in the 4-year political cycle. Deputy Assistant Secretary Beaudry-Losique said that, in his view, you can achieve both short-term and long-term goals by focusing on early markets in the short-term, which provides near-term support for the technology and boosts development in the long-term. Two good examples of recently successful early markets are fuel cell forklift and back-up power applications. The key, he said, is focusing on the early market applications that provide the biggest benefit toward the program's ultimate, long-term objectives.
- Mr. Maurice Kaya noted that the Administration has recognized that individual programs will need to rely a lot more on integrating with other programs in order to succeed. He asked what this emphasis

on “integration” means in terms of EERE’s renewable energy programs and hydrogen fuel cells development. Deputy Assistant Secretary Beaudry-Losique responded that EERE is beginning to examine transportation as a whole, and doing analysis of the kind of portfolio balance that is needed to achieve emissions reduction goals by 2050. This requires cross-agency planning and integration, which the DOE has begun to do, coordinating with the Department of Transportation (DOT) and Environmental Protection Agency (EPA), among others. The ultimate result of this process is likely to be a more integrated EERE strategic plan, which includes all transportation technologies, along with stationary and other applications. He expects this planning process to begin ramping up soon.

- Dr. Alan Lloyd then asked whether the DOE is working with the EPA as the agency moves ahead with the rulemaking process regarding greenhouse gas (GHG) emissions for vehicles. He noted that the rulemaking will specifically address electric vehicles, and wondered how the DOE will make EPA aware of the potential GHG reductions offered by FCEVs, even in the near-term. Deputy Assistant Secretary Beaudry-Losique said that experts from DOE and EPA will be meeting soon to discuss the assumptions and content of the rulemaking so that DOE can prepare more specific input and feedback.
- Mr. Jan van Dokkum asked whether DOE is keeping track of the investment tax credits that are being granted for fuel cells, the number of projects applying for and receiving the credit, and what applications are receiving them. Deputy Assistant Secretary Beaudry-Losique said that he was not aware of such a tracking effort, but agreed that it would be interesting to see the data. Dr. Satyapal said that DOE is tracking various aspects of the Recovery Act projects including job creation.
- Mr. Robert Rose noted that many companies and manufacturers cite the lack of infrastructure as the most pressing issue for the hydrogen industry, and asked whether the DOE has any plans to get more involved in the infrastructure side of hydrogen development. Deputy Assistant Secretary Beaudry-Losique acknowledged the importance of adequate infrastructure for hydrogen delivery and distribution, and announced that DOE plans to hold a workshop with industry leaders in early 2010 to identify barriers and opportunities in this field, and to form a strategic plan for addressing these issues.
- Mr. John Hofmeister mentioned that the major oil companies are moving toward a biofuel mix because of the potential for carbon credits they get as a result. He asked the Deputy Assistant Secretary whether there is any thought being given to a carbon credit approach as an incentive for private businesses to develop hydrogen infrastructure. The Deputy Assistant Secretary agreed that such a policy would provide industry with a strong incentive.

3. DOE Program Update

Dr. Sunita Satyapal, DOE EERE; Joe Graber, DOE BER

>> see full presentation at http://www.hydrogen.energy.gov/htac_meeting_nov09.html

3.1 Overview of Hydrogen and Fuel Cell Activities

Dr. Satyapal began by thanking the members of the Committee for their support and for their continuing interest in and commitment to the program. She described the current and future direction of the DOE Fuel Cell Technologies Program, including the fiscal year 2010 funding request and Congressional budget activities. Her remarks addressed the following topics:

- R&D progress and accomplishments in fuel cells, hydrogen production and delivery, hydrogen storage, technology validation, systems analysis, early markets, and market transformation
- FY03 to FY10 EERE hydrogen and fuel cells program budget appropriation, and overall DOE funding for hydrogen and fuel cells
- Recovery Act project kick-off, including 41 projects initiated between August 21 and October 1.
- Small Business Innovative Research Program (SBIR) project kick-off and review
- Upcoming workshops on production and delivery, storage, fuel cells, market transformation, and safety, codes and standards
- DOE Request for Information (RFI) focusing on performance and cost requirements of fuel storage subsystems for early market fuel cell applications
- SBIR Funding Opportunity Announcement (FOA) for energy storage for intermittent renewable energy, fuel cell balance-of-plant, advanced hydrogen storage, and low-cost dispensing for materials handling and specialty vehicles
- 2007 market report, discussing world-wide trends in units shipped and financing, to be released in December 2009
- Program priorities and next steps
- Key program documents

3.2 Biological Hydrogen Production: Fundamental Research on Systems Biology

Dr. Joe Graber of the DOE Office of Science's Biological and Environmental Research (BER) program presented on BER's research into systems biology and hydrogen production. The research will help provide an understanding of hydrogen production by photosynthetic and fermentative microbes. Dr. Graber's presentation included the following points:

- The Office of Science's basic research on biological production of hydrogen, which received approximately \$15 million in funding in FY09.
- Specific pathways for biological production of hydrogen, including photobiological production of hydrogen by algae, fermentative synthesis by bacteria, and photosynthetic bacteria that produce hydrogen through anoxic conditions.
- Activities of the DOE Joint Genome Institute, overseen by BER, which supports genome sequencing of plants and microbes that are relevant to hydrogen production.

Questions, Answers, and Discussion

- Dr. Shaw asked Dr. Satyapal whether the slight reduction in the budget for safety codes and standards signifies that the problem has been solved, or whether it simply is not a priority. Dr. Satyapal said that continued efforts on safety, codes and standards are absolutely essential, but the reduced budget required a small reduction in funding for codes and standards.
- Chairman Walker asked whether the elimination of funding for nuclear hydrogen R&D was a Congressional decision or an agency decision. Dr. Satyapal said that the decision to zero the budget for nuclear was in the original DOE budget request.
- Dr. Lloyd asked why the budget for fuel processing R&D was cut to almost nothing. Dr. Satyapal answered that the budget line item for fuel processing over the past several years has

been a result of a congressional appropriation for on-board fuel processing. DOE had requested a zero budget for this line item because it was originally for on-board fuel processing and DOE had made a no-go decision, terminating on-board gasoline reforming R&D a number of years ago. DOE has requested a consolidated distributed fuel processing, transportation, and stack components line item key activity called “Fuel Cell Systems R&D.” This would provide more flexibility for applying funds towards distributed fuel reforming or fuel processing, versus on-board fuel reforming. This year, the legislative language says that DOE needs to fund all its existing competitive agreements, so there are no funds to start new activities in the fuel processing area.

- Mr. Rose asked why the \$11 million in hydrogen earmarks were not included in Dr. Satyapal’s budget charts. She replied that Congress appropriated additional funds for the congressionally-directed projects, so their funding does not affect the actual Fuel Cell Technology Program budget. Some of these are crosscutting (e.g. include solar or other technologies) and it is not yet clear how much of the funds apply to hydrogen and fuel cells.
- Mr. van Dokkum asked how the reduced funding for hydrogen storage will impact transportation technologies, and whether the automakers have decided that on-board compressed hydrogen storage is the way to move forward. Dr. Satyapal said that the automakers have demonstrated significant driving range with high-pressure tanks, and though cost is an issue, tanks will be available in the near-term for early market penetration. R&D is still required for advanced materials that may allow low pressure storage in the long term.
- Dr. Kathleen Taylor asked how much of the \$32 million budget for the Storage Centers of Excellence represents activities that go beyond 2010. Dr. Satyapal replied that she could follow up with the exact number and that each of the Centers of Excellence (CoEs) has received between \$5 million and \$8 million per year. Dr. Carol Reade, a member of DOE’s Hydrogen Storage Team, noted that the activities for the three materials CoEs (which began in FY 2005) were completed this year; the Engineering CoE (which began in FY 2008) is the major effort going forward beyond 2010. No new project starts are planned for any of the CoEs in FY 2010.
- Mr. Hofmeister asked whether anyone has tabulated the funding that is being applied towards hydrogen and fuel cell development across the Federal government (e.g., DOT, EPA, DOD, etc.) and what activities are being funded. Dr. Satyapal said that the Interagency Hydrogen and Fuel Cell Working Group, which meets monthly, is compiling that information. In the past, the total Federal funding has been approximately \$400 million, and the group is currently compiling the most recent data.
- Dr. Mike Ramage asked whether the budgets for hydrogen and fuel cell work being conducted in the various DOE programs—Science, Fossil, etc.—have been sorted into focus areas (rather than program areas), in order to give a more accurate picture of the total amount being spent on different critical issues. Dr. Satyapal said that this has been done for the applied research programs, but it is difficult to do this for the basic research because the research is often highly crosscutting in nature and is focused on fundamental knowledge and scientific discovery versus meeting the Fuel Cell Technology program’s particular R&D targets. She noted that there is a lot of coordination between the applied and basic research programs at DOE, including joint workshops.
- Dr. Shaw commented that the National Science Foundation (NSF) recently released a substantial amount of money for hydrogen storage R&D under the Recovery Act. He asked Dr. Janice Hicks whether they coordinate with other agencies on funding. Dr. Hicks said that they do some

collaboration and are planning a joint workshop in January. NSF spends about \$10-\$15 million on hydrogen, mostly in the storage materials and biological areas.

- Mr. Hofmeister asked Dr. Satyapal what the affect would be if, in the 2011-2013 timeframe, gasoline prices rose to the \$4-6/gallon level—whether this would accelerate fuel cell vehicle (FCV) adoption. Dr. Satyapal said that the DOE System Analysis Team, led by Fred Joseck, is performing sensitivity analyses to examine the rates of adoption, given varying levels of gasoline prices. The program will use this analysis to assess what the cost targets for hydrogen would need to be to be competitive. Mr. Hofmeister commented that he believes that oil prices in the coming months and years will rise to peak levels, and are unlikely to decline, especially if a carbon price is attached. Dr. Satyapal agreed, but warned the group that the hydrogen production and fuel cell cost projections developed by DOE are for high-volume production levels. At low volumes, the costs of hydrogen and fuel cells will be much higher.
- Dr. Rose asked Dr. Satyapal to explain why one of her graphs shows a very dramatic decline in the delivered price of hydrogen via tube trailer, which appears to drop to almost zero. Dr. Monterey Gardiner, the DOE Delivery Team Leader, responded that the price reduction is largely due to the increased capacity of tube trailers, which have more than tripled in capacity. The state-of-the-art tube technology has moved from steel, to carbon fiber, to glass fiber, which enables higher pressures, lower costs and lighter weight. The costs are projected for high-volume as well. Dr. Shaw suggested that DOE add the current cost of gasoline delivery to the chart as a frame of reference.
- Dr. Ramage asked Dr. Satyapal whether DOE has examined the possibility of a more significant role for distributed natural gas reforming, and what this might do to the price and supply of natural gas. Dr. Satyapal said that most of the analyses conducted by DOE, Oak Ridge National Lab, the National Academy of Sciences (NAS), UC-Davis and others, has considered natural gas reforming as a transition technology. DOE's hydrogen production R&D program takes a portfolio approach, and the primary focus is lowering the cost of renewables and all the different hydrogen production options. Dr. Ramage made the comment that, in his opinion, hydrogen infrastructure development will not take a “miracle,” especially using distributed natural gas reforming. Dr. Satyapal, referring to results of analyses conducted over the last several years, noted that even distributed natural gas reforming can lower CO₂ emissions from vehicles by 50-60%. Dr. Alan Lloyd commented, saying that most environmental advocates believe that hydrogen is only worth pursuing if it can be produced from renewable sources, “which is a misnomer.”
- Dr. Shaw commented that, due to recent rule changes, it is now virtually impossible for a venture capital-backed company to get Small Business Innovative Research (SBIR) program funding, because more than 50% of the company must be owned by individuals. Since many venture capital firms get their funding from pension or other investment funds, this can limit a company's SBIR eligibility. Dr. Satyapal suggested that HTAC members bring this to the attention of Under Secretary Kristina Johnson, who has been supportive of small businesses. Mr. Rose asked Dr. Satyapal if DOE could monitor this and let HTAC know of any businesses that fall victim to this new SBIR requirement.
- Chairman Walker asked Dr. Satyapal if HTAC members could be invited to DOE's technical workshops. Dr. Satyapal said that the meetings are typically open to the public and the dates and topics are listed on the DOE hydrogen program website. Dr. Satyapal said DOE would provide that information to HTAC.

- Mr. Kaya observed that the HTAC has not heard much to date about the activities of the Department of Defense (DOD) and noted that DOD is both acquiring commercial fuel cells for operational use as well as developing hydrogen and fuel cell technologies for their particular needs. Mr. Kaya suggested that DOD will play an important role in market transformation and hoped that they are actively cooperating in the Hydrogen and Fuel Cells Interagency Action Plan. Dr. Satyapal said that DOE has a very strong relationship with DOD and collaborates with them on R&D and deployment, and that DOD activities are being included in the Interagency Action Plan. Chairman Walker suggested that someone from DOD be invited to speak at the February HTAC meeting about DOD hydrogen and fuel cell initiatives. Asked about the Hydrogen and Fuel Cell Interagency Task Force, Dr. Satyapal responded that it has not yet been reformulated under the new administration. The Task Force is comprised of political appointees from the various participating agencies, and it has taken some time for those appointments to be made and to brief them on the Task Force.
- Dr. Shaw asked whether HTAC has a formal obligation to review the new Fuel Cell Technology Program Plan that is being prepared to update the Hydrogen Posture Plan, since review of the Posture Plan was part of the HTAC's initial charge under the Energy Policy Act of 2005. The HTAC Designated Federal Officer, Mr. Michael Mills, will check into this and report back to the HTAC.
- Mr. Rose suggested that DOE reexamine the dates for its next infrastructure workshop so the results of the workshop can be used to influence the 2012 budget. Concerns about hydrogen vehicles center around the "Valley of Death" issue, and the existence of adequate infrastructure is central to the debate. Mr. Rose also noted that, in his view, the reality is that government will have to get involved in building and funding hydrogen infrastructure. Mr. Frank Novachek suggested that gas and electric utilities representatives should be included as invitees to the infrastructure workshop.
- Dr. Ramage updated the HTAC on the progress of the NAS study that is underway, which adds plug-in hybrid electric vehicles (PHEVs) to the alternative vehicles that are compared in its 2008 report "Transitions to Alternative Transportation Technologies: A Focus on Hydrogen." The update is currently in review and he expects the report to be released within the next month or so, and will be happy to brief HTAC and DOE once it is released. The report will compare plug-ins to hydrogen FCVs, biofuel vehicles, battery electric vehicles (BEVs), and advanced hybrid vehicles at both a maximum practical and probable market penetration rate. He noted that the report includes analysis based on numerous interviews with the national and international automotive and battery industry, and will offer very important perspectives on the comparisons of these technologies. Mr. Rose requested a webinar briefing on the report soon after it is released, since the HTAC will not get together again until February 2010.
- Dr. Shaw asked Dr. Satyapal to give HTAC an overview of her recent trip to Europe, specifically, whether she thinks the Europeans and Japanese are serious about the recent commitments made to building infrastructure by 2015. Dr. Satyapal said that there is more emphasis on a portfolio approach than there has been in the past. The emphasis on biofuels and PHEVs seems to vary by country, but there is strong consensus around moving towards electric vehicle platforms, including PHEVs, BEVs, and FCEVs. She could not comment on whether the timetables announced by Germany and Japan for infrastructure build-out are generally perceived as realistic, but noted that many people expressed skepticism about Germany's ability to build 1,000 stations by 2017.

- Mr. van Dokkum asked Dr. Satyapal for her advice about how HTAC can best support the DOE hydrogen program. Dr. Satyapal said that HTAC has done a good job educating the administration and politicians, and should continue to do so; the diversity and expertise of the HTAC has been helpful. She also said that it is important to use scientific, rational arguments that express the pros and cons of the technologies. HTAC can also help inform DOE on the role it can/should play in market development or technology deployment, and help inform the policy debate, and how hydrogen and fuel cell technology can be influenced outside DOE's R&D programs.
- Mr. Rose asked about the IPHE meeting in December, and what the U.S. position is on continuing in IPHE. Dr. Satyapal said that the U.S. will host an IPHE meeting in December and will continue to be an active and participating member of IPHE. She reported that Germany will take over the role of Secretariat from Canada, and that the December meeting will largely focus on the status of IPHE and how it should be structured going forward. DOE will provide information about the meeting to HTAC members so they can attend the public portions of the meeting if they would like to.
- Dr. Shaw asked Dr. Graber for his opinion on which of the technologies his office is considering seems the most promising, and how long it might take for it to reach commercial viability. Dr. Graber said BER's projects are typically oriented towards producing fundamental knowledge and they try to avoid "picking winners," but that some promising results are being reported by several projects examining hydrogen-producing cyanobacteria, which use the same photosynthetic mechanisms as algae for hydrogen production, but are much more tolerant to oxygen.
- Dr. Lloyd asked Dr. Graber about the criteria BER uses to determine whether to stop research that fails to meet expectations. He also asked how, since this is long-term research, the funding and programmatic consistency is maintained over multiple administrations. Dr. Graber answered that BER coordinates with EERE to ensure they understand what the needs are for biological hydrogen production. He noted that many of BER's projects address multiple interests, since the fundamental knowledge gained can be applied to many different areas, e.g., the use of microorganisms for carbon fixation. He explained that BER's projects are grants that typically have a three-year duration. If BER is still funding research in this area after the three years, the project can apply for a new grant, at which time BER would conduct a project review to determine whether to continue funding.

4. Global Auto Industry Update

Todd Suckow, Hyundai; Steve Ellis, Honda; Bob Wimmer, Toyota; Mike Schweizer, Daimler; Barbara Nocera, Mazda; Keith Cole, GM

>> *see full presentations at http://www.hydrogen.energy.gov/htac_meeting_nov09.html*

Chairman Walker introduced the next session on the status of FCV work and expectations in the global automotive industry, which featured six speakers from different automotive companies. Summaries of the presentations are offered below, followed by highlights from the question and answer session.

4.1 Hyundai—Sustainable Mobility: Fuel Cell Vehicles

Since 2000, Hyundai has developed a series of FCVs, including the 2008 Borrego FCV, a 115 kW vehicle with a 471-mile range and a 60.47 mile per kilogram efficiency. Cold start capability has improved to -20 degrees Celsius, and durability is rising. In South Korea, the early commercialization period has begun, with ten refueling stations, 30 FCVs, and 10 fuel cell buses. On Hyundai's roadmap for fuel cell development, small-scale production (100-1000 vehicles) will begin in 2012. This "4th generation" FCV will have a 100 kW PEMFC with metallic bipolar plate, a lithium polymer battery, greater than 60% system efficiency, and -20 degrees Celsius cold startup capability.

4.2 Honda Fuel Cell Vehicle Activities

Due to the innovation of compact, distributed components, Honda's newest fuel cell stack is one-fifth the size and weight per kW compared to its fuel cell vehicles of 10 years ago. Honda has identified three Southern California cities with the most consumer interest in fuel cells: Santa Monica, Torrance, and Costa Mesa. Honda's vehicles have a 240-mile "real-world" range, and recharge in less than five minutes. Honda has identified infrastructure and vehicle cost as the primary barriers to the marketability of fuel cell vehicles.

4.3 An Update of Toyota's Fuel Cell Vehicle Activities

Toyota's newest Highlander fuel cell vehicle (the 2008 FCHV-adv) has a cruising range of 455 miles and fuel economy of 72.4 miles/kg of hydrogen. FCVs are more efficient than any other type of vehicle, including all-electric vehicles. The key technical challenges are:

1. Cruising range,
2. Freeze start capability,
3. Stack durability, and
4. Cost and power density.

According to Toyota, for FCVs to succeed, the deployment of refueling infrastructure must increase.

4.4 Daimler—On the Road to Sustainable Mobility: Fuel Cell Electric Vehicles

Of all vehicle technologies, only fuel cells are equally-suited for both short- and long-term mobility. Daimler is pursuing commercialization of FCVs with its B-Class F-Cell, which has a higher stack lifetime, range, freeze start ability, and increased power. Daimler envisions preliminary deployment in three California regions: Sacramento, the Bay Area, and Los Angeles, but a sufficient number of fueling stations is essential. In Germany, fueling infrastructure build-out will begin nationwide in 2010.

4.5 An Overview of Mazda Hydrogen Vehicles

Mazda's approach to hydrogen vehicles is to develop vehicles powered by a hydrogen combustion engine with dual fuel systems, rather than a fuel cell vehicle. Hydrogen internal combustion engine vehicles cost less and are more reliable than fuel cell vehicles. Another benefit of these vehicles is that they can run on gasoline in addition to hydrogen, making them more flexible and, perhaps, more consumer-friendly. The Mazda 5 hydrogen vehicle has a 124-mile all-hydrogen range. Mazda currently has about 20 vehicles, mostly in use by the governments of Japan and Norway.

4.6 GM: Automotive Fuel Cells

The most appropriate vehicle technology depends on the drive cycle and the duty cycle of the application, with battery-electric vehicles being appropriate for light-load, stop-and-go driving, and with fuel cells more appropriate for continuous driving with either high or light loads. The cost of fuel cells has decreased 75% since 2002, and is approaching the DOE cost target of \$45/kW by 2010. Automotive fuel cell technology will likely be in the marketplace by 2015, with the first large-scale commercialization in Germany or Japan, both of which have coordinated infrastructure and FCV commercialization plans. If early commercialization begins in 2015, FCVs could be competitive head-to-head in the 2020-2022 timeframe. The U.S. must get serious about hydrogen infrastructure development, and make commitments similar to what is going on in Germany and Japan, for FCVs to be viable in the U.S. market. The Department of Defense may offer some unique and valuable opportunities to be early adopters, given their high level of interest in increasing the energy security of military bases.

Questions, Answers, and Discussion

- Mr. Bob Rose noted that it seems like Hyundai is becoming more open about its progress and plans for the future, and he asked whether there is a strategic reason for this openness. He also asked how invested the government of Korea is in the FCV pathway. Mr. Suckow responded that the recent openness of Hyundai about its fuel cell vehicle programs is largely due to the recent shift in the U.S. political environment away from hydrogen and fuel cells. Hyundai wants to reiterate its commitment to developing and commercializing FCVs and to communicate that commitment to the U.S. government. He also said that the Korean government is committed to commercializing these vehicles and establishing infrastructure, but they are also—like the U.S.—trying to diversify and develop a portfolio of electric vehicles.
- Dr. Alan Lloyd asked whether Hyundai plans to export its fuel cell buses. Mr. Suckow said that, though Hyundai is open to the idea, there are not yet plans to export fuel cell buses.
- Mr. van Dokkum asked Mr. Suckow which, out of the competing advanced vehicle technologies, Hyundai believes is the most promising. Mr. Suckow said that though Hyundai is pursuing a portfolio approach to vehicles, he believes the company views FCVs as the most promising of the competing technologies.
- Mr. van Dokkum asked the group of auto company representatives for their take on what is needed—and what HTAC can do—to help spur the needed hydrogen infrastructure development in the U.S. Mr. Ellis said that the energy companies simply will not invest in infrastructure until the point where sufficient customer demand exists to generate a profit. Thus, government support for fueling stations—via public-private partnership, including innovative partnerships that might include non-traditional players—will be needed. He also stressed the need for customer-friendly fueling stations with enough locations and dispensers (more than one dispenser per station, with multiple hoses per dispenser) to make fueling fast and convenient. Ms. Nocera suggested that federal incentives for hydrogen stations would be extremely helpful. Mr. Ellis commented that a low-carbon fuel standard like the one in California, or credits for energy companies to meet their standards, are other options that might provide incentives. Mr. Cole said that starting with a smaller, more concentrated market, such as Southern California, is a good strategy, because the number of stations needed would be smaller, and the marginal cost would be lower. He also mentioned California's requirement that existing fuel stations provide alternative fuel pumps once the number of vehicles in the market exceeds 20,000, and noted that they are considering requiring hydrogen fuel pumps for a lower

number of vehicles. He added that military bases, are an important potential early market opportunity, because DOD has a strong interest in security of energy supply. Military bases are also essentially “mini-cities” with much of the infrastructure of a typical city (wastewater treatment plants, building heat and power needs, vehicle fleets and fueling stations, etc.) and offer unique opportunities to demonstrate system-level approaches for energy that incorporate renewable energy, hydrogen, and fuel cells.

- Mr. John Hofmeister noted that none of the presentations included information about the jobs impact of the transition to hydrogen vehicles, and asked whether any of the representatives could give any quantified data on that subject. Dr. Satyapal commented that the DOE report to Congress on the subject (*Effects of a Transition to a Hydrogen Economy on Employment in the United States Report to Congress*) found that a transition to hydrogen vehicles would generate as many as 675,000 net new jobs nationwide by 2050.
- Dr. Lloyd asked whether DOE could go ahead and start funding some infrastructure investments now, in a proactive fashion. Dr. Satyapal explained that the 2010 Congressional appropriations language required DOE to fulfill its commitments to its existing 190 projects so there was less flexibility for new starts. She noted that DOE is continuing to fund the Technology Validation projects, including the fueling demonstrations, and that the program initiated a new “trigeneration” project to generate combined heat, hydrogen and power (CHHP) at a California fueling station. The upcoming DOE infrastructure workshop will take a strategic and systematic look at what is needed and where is it needed, to provide better guidance for DOE activities in the future.
- Mr. Rose asked the auto company representatives for what their funding priorities would be for DOE’s fuel cell vehicle program, and suggested that support for fueling infrastructure would probably be near the top. Hearing agreement from those present, he also agreed that the major oil companies may have a different answer to that question. Mr. Hofmeister explained that for the oil companies, hydrogen is “well down the hierarchy of what hits the bottom line.” He also explained that most of the oil companies are not in the fuel retailing business: 95% of the retail gas stations are owned by private businesspeople, and the oil companies simply license the sale of a particular brand of fuel. Because of the “chicken and egg” problem (what comes first – the fueling stations or enough vehicles to make them profitable?), he thinks there is a need for government intervention and support in the early years.
- Mr. van Dokkum emphasized the criticality of the infrastructure problem, and urged industry and HTAC members to be very vocal about what is needed. He asserted that without an adequate commitment to and development of infrastructure in this country, the technology, and all the investment in it, could be lost. He expressed confidence that the technology will deploy in Europe and Japan, however.
- Congressman Walker asked whether Honda is still pursuing a home refueler concept. Mr. Ellis replied that Honda is working on two versions of a home energy station, which are both still in the R&D stage. One produces hydrogen via reforming natural gas and also provides heat and power for the home. The second one uses a photovoltaic array to electrolyze water for hydrogen.

5. International Status of Fuel Cells and Hydrogen Technology

Lisa Callaghan Jerram, Fuel Cell Today

>> see full presentation at http://www.hydrogen.energy.gov/htac_meeting_nov09.html

Fuel Cell Today provides research and market intelligence in the fuel cell industry. Lisa Callaghan Jerram presented the results of Fuel Cell Today's 2008 Annual Review. Highlights of the presentation include:

- Shipments of fuel cells increased to 18,000 units in 2008.
- Europe saw the biggest increase in shipments, while North America experienced a slight decline.
- Shipments of portable fuel cell applications are growing, driven largely by the Asian market.
 - Toshiba launched its Dynario DMFC charger, with an initial production volume of 3,000 units.
 - The annual output value of fuel cells in Taiwan is expected to reach \$130 million by 2011, and \$424 million by 2016.
- North America leads in shipments of stationary fuel cells, followed by Asia.
- India will be a key early market for mobile telecoms backup power, with over 500,000 new telecoms backup sites required before 2011, many in remote rural areas.
- Japan is leading the residential CHP market, with 3,000 residential fuel cells installed and tested at the end of 2008.
- The majority of niche market shipments are auxiliary power units (APUs), with the materials handling share growing.

Questions, Answers, and Discussion

- Dr. Schultz asked Ms. Jerram whether the overall fuel cell industry is improving from year to year. She responded that 2008 experienced a 50% increase in shipments over 2007, and there was similar growth in 2007 over 2006. Though she expects to see growth in 2009, that growth is probably not as high as in previous years. Mr. Rose noted that the 50% growth in shipments does not necessarily mean a 50% in size, because the measuring is done in units shipped, not megawatts. Ms. Jerram commented that the 2009 Fuel Cell Today Market Report, still in draft, will track megawatts in addition to shipments.
- Dr. Shaw asked whether companies are profiting from their shipments of fuel cell applications. Ms. Jerram said that a number of companies are shipping thousands of units and are on their way to profitability, but are not quite there yet. Revenues are growing, and the industry is moving in the right direction.
- Mr. Rose asked what the number of fuel cell shipments would be if fuel cell toys were excluded from the 18,000 units shipped. Ms. Jerram said she did not know for certain, but the number would be considerably lower, possibly thousands lower. Mr. Rose commented that the 18,000 unit number is somewhat misleading, then, because so many of the units shipped were very small applications.

6. Discussion on Recommendations to the Secretary and Report on Meeting with DOE Under Secretary for Energy

Chairman Walker began a discussion about the August 30, 2009 HTAC meeting with Dr. Kristina Johnson, DOE Under Secretary for Energy. Though the Committee would have preferred a meeting with Secretary Chu, as originally requested, the Committee agreed that an initial meeting with Under Secretary Johnson was a good start on communicating with the new administration's upper management at DOE. Chairman Walker reported that the meeting went well, and established the groundwork for a continuing honest, open dialogue with HTAC.

- Dr. Shaw suggested that HTAC try to set up regular meetings with the Under Secretary—for example, every six months or at least annually (perhaps after the release of the HTAC's Annual Report on the State of the Industry).
- Dr. Satyapal agreed that it was a positive meeting, saying that the Under Secretary was impressed by the level of expertise and diversity represented by the HTAC members.
- Mr. van Dokkum asked Chairman Walker whether any concrete action items resulted from the meeting. Chairman Walker said that Under Secretary Johnson had hoped to attend the November 2009 HTAC meeting, but a scheduling conflict prevented it. He added that the major concrete accomplishment of the meeting was a working relationship with her and her team.
- Dr. Ramage noted that DOE Under Secretary for Science, Steven Koonin, also has a major role to play in energy policy and suggested that Chairman Walker try to arrange an HTAC meeting with him. Chairman Walker agreed, and remarked that it would also be good to follow up with Assistant Secretary for Energy Efficiency and Renewable Energy Cathy Zoi, who expressed her interest in meeting with the HTAC in a letter following the meeting with Under Secretary Johnson.
- Chairman Walker asked Mr. Rose to give his impression of the meeting with Under Secretary Johnson. Mr. Rose said that Under Secretary Johnson seemed most concerned with issues surrounding developing the infrastructure – especially the cost and the government's role in the process.
- Mr. Kaya noted that the Administration is emphasizing the need to stimulate the economy, create green jobs, and be competitive in the global economy. He asserted that DOE can't do that strictly from an R&D agenda, so he thinks DOE will be actively examining what role DOE should play in deployment, given the reality of the Federal budget situation. He thinks it's important for external advisors such as HTAC to provide input into that discussion, and is supportive of HTAC efforts to meet with DOE senior managers, including Dr. Koonin, Dr. Johnson, and Ms. Zoi.
- Mr. Hofmeister suggested that HTAC should be more aggressive in communicating the potential for hydrogen and fuel cells to completely transform the energy system, while biofuels and batteries are more of a near to medium-term transitional solution that won't lead to a major shift in the way we make and use energy. Especially considering the activity in Europe and Asia, the U.S. stands to lose competitiveness if action is not taken by this administration. Mr. Hofmeister added that the statutory role of HTAC is to advise the Secretary on matters related to hydrogen and fuel cells, and the Committee should be persistent and insistent in its efforts to serve in this capacity.
- Dr. Mike Ramage noted that the primary concern of Under Secretary Johnson, along with Secretary Chu, seems to be the hydrogen infrastructure issue, so he suggested HTAC adopt infrastructure as an issue on which to focus, explain, and develop a plan for moving forward. He

further suggested putting the estimated costs for hydrogen infrastructure in context of costs for the ethanol subsidy, for operating and maintaining petroleum refining and distribution infrastructure, etc. Chairman Walker agreed that the infrastructure issue could be a major theme in the HTAC annual report. Dr. Geri Richmond argued for a more balanced dialogue that includes fundamental science rather than focusing on a single issue to the exclusion of others, especially when those other issues—hydrogen production, storage, and fuel cell costs—deserve focus as well. She suggested that the HTAC recommend an even greater connection between the basic and applied research programs at DOE, to help strengthen the work and stimulate university and other researchers towards pursuing goal-oriented science. Dr. Ramage agreed that there are multiple issues that deserve HTAC's focus, but that many of the HTAC reports are too general and broad, and don't have a clear, succinct message. Dr. Richmond suggested that the Committee focus on two or three pertinent issues and present them in a way that balances both the market needs and the science needs. Mr. van Dokkum added that it is important for the HTAC to bring value-added products to the Secretary, and suggested that the Committee think about how to do this going forward.

- Dr. Shaw said that, if he were to pick one issue for HTAC to address, it would be the ability of hydrogen to enable the entire renewable energy system. This topic, he said, is broad enough to encompass every sector of hydrogen, but focused enough to make a targeted argument. Mr. van Dokkum said this approach is the one European countries have taken, and they have developed successful programs.
- Dr. Satyapal noted that DOE has had a Technology Validation effort, planned at \$390 million over the last several years, which supported the demonstration of 20 hydrogen fueling stations and 140 hydrogen fuel cell vehicles. She added that progress in the hydrogen and fuel cells arena has been fast-paced over the past couple of years, but more work remains to be done to address cost and performance. Chairman Walker agreed, but noted that if the U.S. is going to be competitive in a global environment that is pushing towards a 2015 commercialization date for FCVs, then it needs to start getting serious about the hydrogen infrastructure issue now. He noted that there are creative ways to stimulate private sector funding for these stations (such as favorable capital depreciation allowances), which should be considered.

7. Update on Status of Battery Technology

Jim Miller, Argonne National Laboratory (representing Tien Duong, DOE Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Program)

>> see full presentation at http://www.hydrogen.energy.gov/htac_meeting_nov09.html

The DOE Office of Vehicle Technologies (OVT) Program, in partnership with the United States Advanced Battery Consortium (USABC) seeks to advance the development of batteries to enable a large market penetration of hybrid and electric vehicles. The target applications for the Program are power-assist hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery-electric vehicles (BEVs). The primary goals for the program are:

1. To develop a 25 kW power-assist HEV battery that costs \$500 in 2010.
2. To develop a PHEV battery that enables a 40-mile all-electric range and costs \$3400.

Since 2007, the battery R&D program has increased calendar life of the battery by 2-5 years and has improved cold cranking power, though costs have increased slightly. The key challenges for OVT are:

- Reducing cost,
- Extending battery life, and
- Weight and volume.

Mr. Miller's presentation identified notable accomplishments from some of the USABC partners, including Johnson Controls-Saft, A123 Systems, and Compact Power/LG Chem; other USABC battery developers include EnerDel, 3M, Celgard, and Entek. DOE cost sharing for USABC projects is \$12.5 million per year.

Questions, Answers, and Discussion

- Chairman Walker asked Mr. Miller about the difference between GM's proposed battery coming out in 2010 in the Volt versus the DOE's work in the same area. Mr. Miller responded by saying the basic difference would be the cost (roughly \$8,000 for the GM system, versus DOE's goal – a \$3,400 unit).
- Mr. van Dokkum raised a concern about the feasibility of actually meeting the DOE goals, because it appears not a lot of progress is being made. Mr. Miller said he is optimistic about reaching or coming close to those targets. Mr. van Dokkum also brought up the large amount of money being put into batteries, but Mr. Miller reminded everyone of two points: 1) funding provided under the Recovery Act is specifically for battery manufacturing facilities, not for R&D or technology development, and 2) it takes time before new developments make their way into the full-pack level, especially when demonstrating life.
- Dr. Shaw asked about the data on slide 8, which showed the overall progress of the DOE/USABC HEV programs. He asked why some of the technologies shown appear to be moving backwards rather than forward. Mr. Miller said that this is a result of trying to optimize several parameters at once, and that sometimes you have to give up performance in one area to gain performance in another.
- Dr. Shaw also asked about the PHEV battery status table on slide 13, and questioned why data on the state of charge swing was not presented. He noted that this data is important since it will increase the actual nameplate size of the battery needed for a particular job, which affects the cost per kilowatt-hour (kWh). He suggested that data for batteries always be presented on a cost-per-kWh-nameplate basis, so that the costs reported are realistic and comparisons between technologies can be made. Mr. van Dokkum agreed and encouraged the DOE to really look at the different engine technologies (internal combustion engines, diesels, various HEVs, fuel cells, etc.) on an apple-to-apple basis to see where the best investment would be. Dr. Shaw also made the point that fuel cells and batteries will most likely be working together in the same system in the future.
- Dr. Lloyd asked if operating temperature range is a challenge for battery systems. Mr. Miller said it is a challenge and current batteries will operate, but will lose significant power capability, at minus 20-30°C. Dr. Shaw asked if it would be necessary to provide temperature control for the battery packs and Mr. Miller said it would. Later in the discussion, Dr. Shaw commented that battery performance drops off much faster at higher temperatures as well (45-55°C range).
- Chairman Walker commented that as a policymaker, his concern is that electric vehicle battery technology does not appear to be as "near term" as many people think it is. For example, some people see the battery-powered Tesla as proof the technology is already available and the only problem is building up manufacturing capacity. However, the information discussed today shows that vehicle battery systems (including the lithium-ion battery packs used in the Tesla) still have safety

issues (especially related to the potential for overcharging) cost, and performance issues. Policymakers need to understand these issues so they can make sure priorities and policies are in-sync with reality.

- Mr. Rose asked what happens when a battery degrades—does it slowly lose power capability or does it have a catastrophic failure, and how long before this degradation happens. Mr. Miller responded by saying it depends on the type of battery and chemistry used, but the important thing to look at is degradation in energy capacity and power capacity – power (acceleration) capacity being the limiting factor for battery use in many cases. When Mr. Rose asked specifically about vehicle performance over time and near the end of the battery’s life, Dr. Shaw said that manufacturers will size the battery somewhat larger than required for the vehicle’s size to account for degradation over time, so that the vehicle will have the same driving range at the beginning and end of the battery’s life.
- Dr. Lloyd asked Mr. Miller what he felt were the main challenges for batteries, as opposed to fuel cells. Mr. Miller responded by saying the biggest factor for both technologies is cost. He added that the technologies are complementary, rather than competitive, and advances in one area will help the other area. For example, better battery technology can reduce the size of the fuel cell needed in an FCV.
- Dr. Schultz asked what fraction of battery cost is for raw materials, and whether this puts a fundamental limit on the potential for cost reduction. Mr. Miller replied that there are still a lot of things that can be done to reduce materials cost, and the material cost varies from battery to battery.

8. Role of Fuel Cells in Smart Grid Programs

Dan Ton, DOE Office of Electricity Delivery and Energy Reliability; Susan Schoenung, Longitude 122 West, Inc.

>> see full presentations at http://www.hydrogen.energy.gov/htac_meeting_nov09.html

8.1 Smart Grid R&D at the U.S. Department of Energy

Dan Ton, Program Manager for Smart Grid R&D at the Department of Energy, gave an overview of the program and its planned activities for 2010. Dr. Ton defined “Smart Grid” and explained its various applications throughout the economy. Smart Grid applications help reduce energy use by engaging customers and enabling them to reduce peak load. Smart Grid also minimizes system losses and disturbances, thus enhancing grid reliability.

Dr. Ton’s presentation included:

- A discussion of the Smart Grid R&D budget and spending.
- Methodology for setting standards for interoperability of smart grid devices and systems.
- Overview of renewable and distributed systems integration demonstrations.
- Discussion of the Smart Grid Maturity Model, which helps utilities develop and communicate a smart grid vision and plan, prioritize options and support decision making, and measure progress.
- Discussion of the 2009-2010 Smart Grid R&D focus areas and FY10-14 Multi-year Program Plan development.

8.2 International Experience in Fuel Cells and Hydrogen for Electric Power Applications

Dr. Susan Schoenung of Longitude 122 West, Inc. presented on the International Energy Agency's Task 18, which evaluates hydrogen systems performance, cost, safety, and codes and standards permitting policies. Task 18 focuses on hydrogen vehicles and refueling stations, as well as stationary hydrogen and fuel cell systems. The program has a number of renewable hydrogen projects around the world, which convert renewable energy to hydrogen. In addition to the environmental benefit of zero-emissions, these renewable hydrogen projects are advantageous because hydrogen storage balances intermittent renewable energy sources, which do not match load. The Task 18 team has found hydrogen storage to be competitive with other large-scale storage technologies, including compressed air and pumped hydro.

Dr. Schoenung's conclusions for HTAC were:

- Stationary hydrogen and fuel cell applications complement the electric system across a spectrum of sizes.
- Hydrogen is an ideal match for renewable energy of all scales.
- Hydrogen storage can have a major impact on hydrogen supply for both transportation and power distribution schemes.
- Geologic formations offer opportunities to store hydrogen.
- Innovative analysis of system-optimized hydrogen storage installations is needed to fully appreciate the synergies between applications.

Questions, Answers, and Discussion

- Chairman Walker asked if any of the DOE funding for Smart Grid demonstrations and projects is aimed at utilizing hydrogen or fuel cells. Dr. Ton said that there are still a number of projects under consideration for awards, and he did not know if any of them include hydrogen or fuel cells. In response to a follow-up question from Chairman Walker, Dr. Ton said that the findings from the international demonstrations and analyses described by Dr. Schoenung are having an impact on the decision-making process for Smart Grid project investments and demonstrations in the U.S.
- Dr. Shaw asked Dr. Schoenung whether cost information was available for the IEA demonstration projects, particularly whether they have any estimates of what it might cost for a commercial project. She replied that the IEA cost data represents funding for the demonstration, and is not representative of commercial cost. The IEA Task 18 plans to initiate a project in early 2010 to look at the learnings from the demonstrations and evaluate alternative turnkey systems. Dr. Schoenung also noted that Japan will be reporting on costs of its residential fuel cell system demonstrations in 2010.
- Mr. Novachek noted that energy storage will be very important to address the wide voltage fluctuations that could be expected from high penetrations of solar power. He explained that when clouds pass over, voltages can drop suddenly from 100% to 20%. Some of the questions that Xcel Energy's new Solar Technology Acceleration Center will address are how to deal with this voltage fluctuation, how to best regulate voltage on distribution feeders, and where to put storage on a feeder to provide the best benefit for integrating renewable power.
- Mr. Rose asked if any of DOE's money was being invested in renewable hydrogen or more efficient electrolyzers. Dr. Satyapal replied that while the largest part of the EERE Fuel Cell Technologies Program R&D budget is directed at fuel cells, the budget does include a Hydrogen Production line item (\$10 million in FY 2009 and \$15 million in FY 2010) that includes renewable hydrogen production. The Program also funds electrolyzer R&D projects; participates in an interagency

collaboration in Hawaii that includes hydrogen storage of intermittent renewable power; and funds a project with Xcel and NREL on an integrated wind-hydrogen-fuel cell system.

9. Presentation from Rocky Mountain Institute: A Practical and Profitable Hydrogen Transition

Amory Lovins, Rocky Mountain Institute

>> see full presentation at http://www.hydrogen.energy.gov/htac_meeting_nov09.html

Amory Lovins described his vision of the transition to a hydrogen economy, which includes:

- Begin the transition by installing fuel cells in buildings for tri-generation (combined heat, hydrogen and power generation) fueled by natural gas reformers or off-peak electrolyzers.
- Introduce high-efficiency, lightweight hydrogen-ready cars, beginning with fleets that return nightly to the depot for refueling and consumer who live or work in/near buildings equipped with fuel cells for tri-generation. While parked, the vehicles could produce power for sale back to the grid.
- As hydrogen fueling appliances decrease in cost, begin to install them at outdoor refueling stations, starting with natural gas reformers. As hydrogen vehicle sales go up, central production and bulk distribution of hydrogen becomes justified and economical.
- Use mature technology available today to reform natural gas at the wellhead and reinject CO₂. Where feasible, use electrolyzers with low-cost renewable electricity, and use hydrogen as an energy storage medium for off-peak renewable power production and to improve the dispatchability of intermittent renewable power.
- Recognize and reward the strong business case for hydrogen that is utilized by existing businesses (automotive companies, utilities, oil companies, and coal companies) as well as new and emerging businesses.

In his view, the five steps to a hydrogen transition are:

1. Make the cars hydrogen-ready.
2. Integrate fuel cell deployment in stationary and mobile applications so they reinforce each other.
3. Reward utilities for using natural gas efficiently.
4. Embrace decentralized electricity and gas systems.
5. Evolve hydrogen towards renewables, but meanwhile use natural gas reforming.

Five ways the government can enable the transition are:

1. Stimulate demand for very efficient vehicles using incentives and rebates.
2. Build vibrant 21st century industries by sharing R&D risk and deploying faster than the private market.
3. Lower the risk of investment for new manufacturing through loan guarantees to automakers.
4. Support the development of domestic energy supply infrastructure.
5. Remove barriers to efficiency through implementing coherent policies and purging perverse incentives.

Questions, Answers, and Discussion

- Dr. Shaw asked Mr. Lovins his view of what needs to happen “to move the ball forward” and where the main holdbacks are. Mr. Lovins noted that the automakers seem to be generally moving in the direction of vehicle lightweighting and are developing new platform design strategies. However, he recognized that there is still a large cultural barrier to “ultralight” vehicle

designs that employ advanced composite materials instead of metal. He believes the DOE programs focus too much on drive trains—he thinks the first priority should be the platform itself. Once you have the most efficient vehicle shell that you can get, then you can design a drive train with the power you need to move it around. A smaller drive train will also be less expensive and use less energy. He alluded to rapid, transformational innovations occurring at some companies that will leave other companies, as well as regulators, “playing catch-up” for many years. Dr. Satyapal pointed out that the EERE Vehicle Technologies Program funds lightweight materials R&D (currently at about \$32 million), and the automotive members of the FreedomCAR & Fuel Partnership provide DOE with input on the overall R&D strategy and budget allocations for various vehicle technologies and components.

- Dr. Lloyd asked Mr. Lovins if today’s technology for gaseous hydrogen storage on board a vehicle is adequate for the consumer, or if there should be a continuing emphasis on better storage technology. Mr. Lovins responded by saying hydrogen storage for vehicles “has been adequate for over a decade, especially if the vehicle is efficient.” He does not see hydrogen storage as an obstacle, and thinks consumers will be satisfied and safe with properly designed fueling systems.
- Mr. Rose observed that it would be discouraging to conclude that we have to wait for an industry-wide cultural shift to ultralight vehicles before fuel cell engines can be cost-competitive. Mr. Lovins explained that the shift could happen with just one significant company leading a “game-changing” transformation that will force the rest to follow.
- Dr. Shaw asked Mr. Lovins how he would allocate the DOE EERE funding resources among the alternative vehicle fuel programs (ethanol, batteries, etc.). Mr. Lovins suggested putting several times more money into the hydrogen program and making sure that all parts of the Department are working together towards a coordinated mobility and electricity strategy.

10. ZEVs for California—Building an Ultra-Low Carbon Transportation System

Catherine Dunwoody, Executive Director, California Fuel Cell Partnership (CaFCP)

>> see full presentation at http://www.hydrogen.energy.gov/htac_meeting_nov09.html

Ms. Dunwoody made a brief presentation to the HTAC on current and upcoming events in California. She reported on the publication of an action plan that details a strategy for deploying hydrogen fueling stations and fuel cell vehicles in California [entitled *Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A Strategy for Meeting the Challenge Ahead*]. The action plan specifies the steps needed to meet the fuel needs of 4,300 passenger vehicles and 60 fuel cell buses by 2014, and prepares for even more growth through 2017. The plan calls for 46 retail hydrogen fueling stations in six key California communities at a cost of about \$180 million over four years; \$60 million from industry and \$120 million from government.

She reported that four new stations have been approved by the Air Resources Board in California since the action plan was adopted. These stations, which are expected to come on line next year and provide about 460 kg of hydrogen per day, are sufficient to get California through about 2011, when they expect to have 700 FCVs on the road. However, soon after this, the state will need more stations to accommodate the industry’s projections for FCV deployment in California (which could be as high as 4,300 FCVs by 2014, 50,000 by 2017). She emphasized a near-term need to figure out how to encourage

companies to start building stations, or incorporating hydrogen dispensers into their gasoline stations, in the early years when demand is somewhat uncertain and the vehicle numbers are still low. There is also the issue of creating a level playing field, not only with gasoline, but with other alternative fuels. As an example, she noted that in California hydrogen is the only alternative fuel that is required to be 33% renewable today. Electricity has until 2020 to meet that goal.

Ms. Dunwoody also noted that the California Public Utilities Commission held a proceeding on the impacts of electric vehicles on the state's electric infrastructure deployment and what regulations or incentives might be needed to ensure that California is ready for PHEVs. She noted that the proceeding generated interesting information on the cost of that infrastructure development relative to hydrogen infrastructure. Other issues addressed in her presentation included:

- A listing of California policies that affect hydrogen vehicles.
- An informational report due out to the Air Resources Board in December on the technical status of implementing a zero-emission vehicle (ZEV) infrastructure, and what complimentary policies might be needed to ensure success.
- Supporting regulations for hydrogen infrastructure, including the Low Carbon Fuel Standard, the Clean Fuels Outlet requirements, and the Alternative Fuel Funding Program (AB118).
- A new technology demonstration to showcase the synergies between stationary and mobile applications, in which an Orange County energy station will use wastewater treatment plant biogas to produce hydrogen for vehicles and heat and power for the treatment plant.
- The importance of conveying to people how, where and why hydrogen can be used in their daily life, in order to make it real to them. The CaFCP focuses a lot of attention on social communications and social media, not just the technical side of things.

Questions, Answers, and Discussion

- Chairman Walker asked for the rationale behind the decision to disadvantage hydrogen with the requirement that it meet a 33% renewable target long before anybody else. Ms. Dunwoody explained that the California legislature required that it meet that standard to be assured that hydrogen wouldn't be any "dirtier" than the fuels we use today. She noted that this law was passed several years ago, when we didn't have the well-to-wheels analysis information that shows the environmental advantages of fuel cell vehicles using hydrogen from natural gas. There is also a very strong battery constituency in California, which changes the dynamics for battery acceptance from a consumer standpoint.
- Dr. Lloyd asked if there was anything the HTAC could do to contribute to the Air Resources Board meeting in December. Ms. Dunwoody said that the staff report is due out one month prior to the meeting, and said she would be happy to provide the link to HTAC members when it is available. She encouraged HTAC members to review and provide comments on the report.

11. HTAC 2009 Annual Report on the State of the Hydrogen and Fuel Cell Industry

Mr. Frank Novachek led a discussion of the HTAC annual report for 2009. Before the November meeting, Mr. Novachek sent an email to all HTAC members requesting their input for the report. He received over 60 comments from eight members, and all inputs were incorporated in a spreadsheet that is organized based on last year's annual report. Additionally, Mr. Novachek identified some key themes that emerged from the HTAC inputs and summarized the inputs from the HTAC members.

- Mr. Novachek asked HTAC members for suggestions on any additional key 2009 reports or studies to reference in the annual report. Dr. Shaw suggested engaging with FERC or someone in Germany or Japan to find a recent analysis on the potential for hydrogen as storage for renewable energy. Mr. Kaya suggested looking to the Department of Defense (DOD) and their work on evaluating electricity production and storage options on the island of Oahu, where DOD energy use represents 20% of the island's demand. Mr. van Dokkum suggested the NREL report highlighting the opportunity for bulk energy storage using hydrogen. Dr. Satyapal suggested the recently released reports of two independent review panels commissioned by DOE ["Fuel Cell System Cost for Transportation—2008 Cost Estimate: Independent Review" and "Current (2009) State-of-the-Art Hydrogen Production Cost Estimate Using Water Electrolysis: Independent Review"], and a PNNL report on commercial or near-commercial products that benefited from support of the DOE R&D program ["Pathways to Commercial Success: Technologies and Products Supported by the Hydrogen, Fuel Cells and Infrastructure Technologies Program"].
- With regard to commercial installations and demonstrations, Mr. van Dokkum said a key point to emphasize is the success of the Investment Tax Credits in spurring market development and commercial installations. Dr. Shaw volunteered to examine past issues of *Fuel Cell Today* to identify additional relevant events in this category. Dr. Satyapal noted that in FY 2010 the DOE Fuel Cell Technologies Program budget included, for the first time, a line item especially for Market Transformation and the program also received \$42 million in Recovery Act funds, which mostly went to fuel cell deployments. Mr. Novachek summarized several additional points to highlight, including: 1) real-world testing of current-generation Toyota and Hyundai FCVs shows driving ranges in excess of 400 miles; 2) successful cold starts continue to be demonstrated in FCVs; and 3) nearly all the major automakers see FCVs as the end-game.
- The Committee began discussing the key themes for the report. Dr. Shaw said that the most important thing that happened in the U.S. hydrogen and fuel cell industry in 2009 was the DOE's decision to zero the R&D budget for hydrogen production, storage and delivery and the resulting efforts on the part of the industry to communicate the value of hydrogen. Chairman Walker said that the most important thing that happened was the Secretary's public comments on "four miracles" that he thinks need to occur for hydrogen fuel cell vehicles to succeed ["Q&A with Steven Chu," *MIT Technology Review*, May 14, 2009] and the resulting impact worldwide, as countries took a second look at their hydrogen programs.
- The Committee members went on to discuss the organization of the annual report, with some suggesting that the report be organized around Secretary Chu's four "miracles," in order to convey that overcoming the technical challenges will not take miracles, but rather are achievable goals. Others thought the report should focus on the technical progress that has been made over the last several years and the implications of the massive activity occurring in the rest of the world—particularly in Europe, Asia, northern Africa and the Middle East—regarding hydrogen and fuel cells development and deployment, and the comparative disadvantage the U.S. faces if it

does not act as well. In the end, the Committee agreed to organize the report in a way that addresses Secretary Chu's concerns about automotive fuel cell cost and hydrogen production, storage, and distribution infrastructure in a natural, logical way, with the aim of educating readers on real commercial achievements and technical advances in these areas.

- The Committee discussed next steps for drafting the report, as follows:
 - Mr. Novacheck will provide compiled input for the report, including today's discussion of key themes, out to the entire HTAC for review and any additional comments.
 - Mr. Novacheck will incorporate these comments and provide a draft report to the HTAC Policy and Planning Committee (PPC) for review, incorporate comments, and provide a revised draft out to the full HTAC ahead of the February 2010 meeting for review and editorial comment. Mr. Novacheck will address editorial and substantive comments received from the members, and produce a revised, final report.
 - At the February HTAC meeting, the final report will be submitted for a brief final review (as edited) and vote of approval, and published as soon as possible following the meeting.
- Dr. Shaw said the HTAC should plan to brief Secretary Chu on the Annual Report soon after its release. Mr. Katsaros and others stressed the importance of engaging in an ongoing dialogue with the Secretary to better understand the basis for his concerns and what the HTAC can do to help DOE with program implementation. Mr. Rose pointed out that March 2010 is too late to affect the 2011 budget, so there should be an additional action to engage the Secretary on key opportunities and recommended priorities before then. Chairman Walker noted that the recent letter to HTAC from Assistant Secretary Zoi expressed interest in meeting with Committee members, and suggested that as one pathway for engaging with the administration. The members also discussed the statutory requirement for the Secretary to respond to the Committee's recommendations on a biannual basis, and noted that the last biannual report from the Secretary was released in 2008. While there is no particular schedule required from the HTAC for recommendations to the Secretary, members agreed that it will be important to put something together soon to have any impact on budget decisions. After some discussion, several follow-up actions emerged, as follows:
 - Chairman Walker will draft a letter to Secretary Chu reporting on the November 4-5 HTAC meeting, which will emphasize what was presented by the global automotive industry and others about technical progress and international commitments towards fuel cell vehicle and infrastructure commercialization, and seek another meeting with him. Once reviewed by the HTAC members who attended the November meeting, he will send the letter to the Secretary.
 - Dr. Satyapal will assist in getting a meeting with HTAC members on Assistant Secretary Zoi's calendar.
 - Mr. Rose and Mr. van Dokkum will draft a set of strawmen recommendations for presentation and consideration at the February 2010 HTAC meeting. Time will be devoted on the February agenda to allow for an initial presentation on day one, discussion in small groups over dinner (perhaps organized by transportation, stationary, and infrastructure), and a follow-up discussion on day 2 to work towards final recommendations that can be provided to Secretary Chu as soon as possible following the February meeting.

- Dr. Satyapal noted that the 2008 HTAC Annual Report was received very favorably and is posted on the Fuel Cell Technologies Program website. She thinks the 2009 report will be similarly valuable and urged the HTAC to publish it as soon as possible. She also reported that Assistant Secretary Zoi and Principal Deputy Assistant Secretary Kelly have been briefed by a number of industry representatives and stakeholder groups, and they have been positively impressed.
- Mr. Rose asked whether the HTAC would be able to be briefed on the 2011 budget request in February, even if it had not yet been made public. Dr. Satyapal explained that they cannot release any budget information, even to the HTAC members, until it is made public. She said that the 2011 budget is expected to be announced prior to the February 10 meeting date.

12. Discussion of 2010 HTAC Meeting Schedule and Other Business

- Mr. Rose asked whether the draft Fuel Cell Technology Program Plan would be available for the HTAC to review before the February meeting. Dr. Satyapal thought that it would be, and offered to provide a pre-decisional draft (if permissible) to the HTAC for review, as the report would still be in DOE concurrence.
- After some discussion of the protocol for reviewing HTAC meeting minutes, the members in attendance agreed that the draft should be sent to the entire Committee prior to the subsequent meeting. Comments will be incorporated and a final set of minutes presented to the HTAC Chairman for approval and public release. Mr. Rose asked whether the minutes could be shortened to a much briefer format. Dr. Satyapal noted that the Biomass R&D Board's minutes are typically only four pages long for a one-and-a-half day meeting. Dr. Shaw argued for the longer format, which provides a very good record that helps remind Committee members who attended the meeting, as well as those who could not, and provides detailed information about what was said in the discussion among HTAC members. Dr. Satyapal said DOE is happy to continue supporting production of the minutes in whatever format the Committee thinks is most valuable.
- Chairman Walker opened the discussion up to any public comments, but none were made.

Chairman Walker adjourned the HTAC meeting at 2:00 p.m., November 5, 2009.

**TWELFTH MEETING OF THE
HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE (HTAC)
PARTICIPANT LIST
NOVEMBER 4-5, 2009**

HTAC Members Present

- Janice Hicks
- John Hofmeister
- Art Katsaros
- Maurice Kaya
- Alan Lloyd
- Frank Novachek
- Michael Ramage
- Geraldine Richmond
- Bob Rose
- Ken Schultz
- Robert Shaw
- Kathleen Taylor
- Jan van Dokkum
- Robert Walker

HTAC Members Not Present

- Mark Chernoby
- Anthony Eggert
- David Friedman
- Jim Narva
- Joan Ogden
- Philip Ross

U.S. Department of Energy Staff

Office of Energy Efficiency and Renewable Energy

- Jacques Beaudry-Losique
- Kathi Epping Martin
- Richard Farmer
- John Garbak
- Monterey Gardiner
- Fred Joseck
- Michael Mills

- Grace Ordaz
- Dimitrios Papageorgopoulos
- Carole Read
- Antonio Ruiz
- Sunita Satyapal
- Dan Ton

Office of Fossil Energy

- Mark Ackiewicz
- Lowell Miller

Office of Science

- Joseph Graber

Members of the Public in Attendance

- Sjoerd Bakker – Utrecht University
- Lisa Callaghan Jerram – Fuel Cell Today
- Ed Cohen – Honda
- Keith Cole – General Motors
- P.J. Dougherty – Strategic Marketing Innovations
- Catherine Dunwoody – California Fuel Cell Partnership
- Steve Ellis – Honda
- Robert S. Glass – Lawrence Livermore National Laboratory
- Leo Grassilli – U.S. Navy
- Dennis Kountz – DuPont
- Walter Lee
- Amory Lovins – Rocky Mountain Institute
- Bill MacLeod – Hyundai
- Monica Mallini – Northern Virginia Community College Manassas Campus
- Kim McGrath – QuantumSphere, Inc.
- James Miller – Argonne National Laboratory
- Greg Moreland – Sentech, Inc.
- Barbara Nocera – Mazda
- Pinakin Patel – FuelCell Energy
- Dan Ryan – Mazda
- Susan Schoenung – International Energy Agency
- Mike Schweizer – Daimler
- Joseph Stanford – Sentech, Inc.
- Todd Suckow – Hyundai

- George Sverdrup – National Renewable Energy Laboratory
- Sandy Thomas – H2Gen
- Michael Thompson – New West Technologies, LLC
- Sean Todd – FPR LLC
- Steven Weiner – Pacific Northwest National Laboratory
- Mark Williams – URS Corporation
- Bob Wimmer – Toyota

Support Staff

- Judi Abraham – Conference Management Associates, Inc.
- Kristin Deason – Sentech, Inc.
- Samantha Jacoby – Energetics Incorporated
- Melissa Laffen – Alliance Technical Services, Inc.
- Shawna McQueen – Energetics Incorporated
- Mark Ruth – National Renewable Energy Laboratory