HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE

MEETING MINUTES

October 14 – 15, 2010

Radisson Hotel, 2020 Jefferson Davis Highway, Arlington, VA

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October 14, 2010

1. Call to order, new member introductions, agenda review, comments on minutes, and public comment period

1.1. New HTAC members

The following new Committee members were introduced:

- Dr. Richard T. Carlin
- Mr. Charles E. Freese, V
- Dr. Levi Thompson

Biographical information for all current members can be found at the following link: http://www.hydrogen.energy.gov/advisory_htac.html.

1.2. Public comments

Ms. Anna Stukas, Director of Intellectual Property and Regulatory Affairs, Angstrom Power, Incorporated

Ms. Stukas spoke about the fact that the U.S. Department of Transportation (DOT) has proposed not to fully harmonize with an international rulemaking, scheduled to take effect in January of 2011, concerning the transport of fuel cell cartridges for micro fuel cell devices aboard passenger planes.

>> *see full presentation at* http://hydrogen.energy.gov/pdfs/htac_oct1410_implications.pdf

2. U.S. Department of Energy program presentations

2.1. Dr. Sunita Satyapal, Program Manager, DOE Hydrogen and Fuel Cell Program and EERE Fuel Cell Technologies Program, U.S. Department of Energy

- Dr. Satyapal provided an update on DOE hydrogen and fuel cell activities, including changes to program organizational structure; research, development, and demonstration (RD&D) progress; new analysis and publications; fiscal year (FY) 2011 DOE budget request and congressional actions; upcoming workshops; and development of a new (draft) Hydrogen and Fuel Cell Program Plan for review.

>> *see full presentation at* http://www.hydrogen.energy.gov/pdfs/htac_oct1410_overview.pdf

Questions, answers, and discussion

- In response to a question about the source of funding for the hydrogen and fuel cell projects in the Small Business Innovative Research program (SBIR), Dr. Satyapal explained that the SBIR is an independently managed statutory program funded through set-asides (currently about 2.7% of each budget line item) from R&D programs in eleven different federal departments, including the DOE. Therefore the projects funded by SBIR do not necessarily match up with the program's budget structure; often, SBIR technical topics are offered in areas with low or zero budgets in the programs.
- Mr. Koyama asked when the $30/kW target for fuel cells was established, and what analysis has been done to compare it to current hybrid electric and battery-powered vehicles.
    - Dr. Satyapal responded that the target was established around early 2000, as the cost at which hydrogen fuel cell system could be cost-competitive with gasoline internal combustion engines (ICE) vehicles. There has been discussion about updating this target to reflect new vehicle technologies and the costs of more stringent fuel economy standards, but for now the program has decided to stay with the $30/kW target. The automotive companies are currently working with DOE to do a "clean room collection of sensitive cost data" to get a better idea of what the costs of advanced hybrid and other vehicles might be. A complete cents per mile analysis is also underway, which will help guide the target setting.
- Mr. van Dokkum asked if the Fuel Cell Technologies Program (FCTP) provided any of the funding for the Advanced Research Projects Agency-Energy (ARPA-E) and how much coordination exists between the two programs.
    - Dr. Satyapal replied that ARPA-E is a completely separate office that reports directly to the Secretary of Energy, has its own budget, and receives no funding from the FCTP. She also said that even though the ARPA-E program is new, there has already been good coordination with FCTP, and the two programs are looking at ways to further work together.

2.2. Dr. Brenda Haendler, Advanced Research Projects Agency-Energy

Dr. Haendler provided an overview of ARPA-E, which was created in 2007 under the America COMPETES Act. ARPA-E was created with a vision to bridge gaps in the energy innovation pipeline, by funding high-impact, high-risk, innovative R&D and now funds 121 projects in seven program areas. As such, ARPA-E falls in between the basic and applied research programs at DOE, focusing on "first prototype" type projects that last no more than 2 or 3 years and have average funding levels of $3-4 million per project. The program was funded in 2009, with $400 million appropriated under the American Recovery and Reinvestment Act. Dr. Haendler highlighted two projects of interest that were funded from the initial ARPA-E funding opportunity announcement: 1) New Membranes Enabling Non-Platinum Catalysts at UC Riverside and 2) Affordable Water from Energy and Sunlight from Sun Catalytix. The six other ARPE-E program focus areas include electrofuels (biofuels), batteries, carbon capture, power electronics, building energy efficiency, and grid scale energy storage.

>> see full presentation at http://hydrogen.energy.gov/pdfs/htac_oct1410_arpae.pdf

Questions, answers, and discussion

- Dr. Carlin asked for clarification on the general philosophy of ARPA-E in terms of the stage of R&D and how the projects move forward to market applications.
    - Dr. Haendler replied that while it varies from program to program, one of the goals is to bring together "communities" around the projects, such as DARPA, DOE applied research programs, and non-government funding sources such as venture capitalists in the hope that they will pick up on funding promising projects going forward. ARPA-E intends to only fund projects for a maximum of three years.
- Vice Chairman Novachek asked how ARPA-E arrived at the $250/kilowatt hour cost target for battery systems.
    - Dr. Haendler responded that she was not sure how the target had been developed, but she would look into it and provide more information to HTAC.
- Vice Chairman Novachek asked for clarification on why ARPA-E is including underground compressed air as a viable renewable energy storage option when its stated goal is to only consider technologies with at least an 80% round trip efficiency. The best round trip efficiency he has seen for underground compressed air is 74%.
    - Dr. Haendler said she would look into it and respond with more information.
- Mr. Freese asked whether or not there was a volumetric target for energy storage density.
    - Dr. Haendler stated she believes it is 300 watt hour per liter.
- Mr. Freese noted that with hydrogen as an energy storage option, there is the possibility that the round trip can be cut in half by using the hydrogen directly as a fuel for fuel cell vehicles or other applications. He asked whether ARPA-E has considered this scenario.
    - Dr. Haendler responded that she thought this scenario was considered, but is not sure whether hydrogen storage is a topic that's currently being pursued or funded.
- Dr. Thompson asked what metrics will be used to determine if ARPA-E sponsored programs are successful.
    - Dr. Haendler responded that one of the metrics used to determine success is follow-on-funding. The $363 million of funding for its R&D projects has already created $160 million in follow-on funding from other sources. Another metric is looking at how many of the projects continue once ARPA-E support expires.
- Dr. Thompson asked if the creation of ARPA-E had any adverse effects on other programs in DOE that may seem to have overlapping interests.
    - Dr. Haendler responded that there have been no adverse effects on other programs. The ARPA-E budget is not derived from any other program's budget. The hope is that APRA-E fills a gap and does not fund anything that other DOE R&D programs would want to fund.
- Dr. Ogden asked how the group will navigate technology transfer issues, especially given that it is funding projects by people who don't necessarily have a background in energy.
    - Dr. Haendler stated that ARPA-E has a commercialization team of five individuals who are focused on this issue.

3. HTAC subcommittee discussions—working group updates

Dr. Kathy Taylor and Mr. Frank Novachek provided updates on two working groups formed after the June 2010 HTAC meeting to offer insight or recommendations to DOE in two key areas:

1) stimulating hydrogen infrastructure development; and 2) the potential for hydrogen to serve as an enabler for renewable energy. Chairman Shaw encouraged new HTAC members to join either or both of the working groups.

3.1 Dr. Kathy Taylor, chair of the Stimulating the Hydrogen Infrastructure Working Group

The working group held a conference call on September 13, which was attended by members Shaw, Walker, Bond, Richmond, Kaya, Koyama, and Friedman (not on the call were working group members Hofmeister, Ogden, Lloyd, Eggert, and Cardillo). During the call, the group discussed and collected comments on the following topics:

- Current hydrogen infrastructure – what do we have now?
    - Most activity is coming from the automotive sector. For example, the SunHydro-Proton Energy fueling stations, the Honda home fueling stations, GM Project Driveway, and the Gas Company/GM project in Hawaii.
    - However, there are also ongoing infrastructure development needs and activities in the non-automotive sector (stationary and portable power), and those also need to be captured.
- Potential demand – what kind of demand can we expect and when?
    - At the suggestion of several HTAC members, Catherine Dunwoody, Executive Director of the California Fuel Cell Partnership, participated in the call and will provide input to the group from their state surveys and focus groups.
    - Will there be backlash if hydrogen is produced from non-renewable sources?
    - What can we learn from other markets, e.g., on location of stations and cost?
    - What kind of roll-out strategy is needed and are the necessary technologies available?
- Current and future policies – what policies are in place and working and what more is needed?
    - Codes and standards are very important.
    - Stable, durable support is essential.
- Scope and topics
    - The working group needs to ensure that its work stays within the scope of the HTAC charter.
- The international scene
    - What can we learn from activities going on outside of the United States?
    - The working group would like input from Mike Mills on the international partnerships.
    - The working group would like updates on the activities being undertaken in active countries like Japan and Germany.
    - Where is harmonization of codes and standards needed, or where are the gaps in development of standards?

Questions, answers, and discussion

- Mr. Rose asked for clarity on the product of the working group and cited that the Germans are doing the same work with a two-year timeline and a $1 million budget.
    - Dr. Taylor responded that the group does not intend to do any new research, but will explore existing information to see if it can develop insights or recommendations for DOE. She agreed with Mr. Rose and Dr. Shaw that perhaps one useful output could be a gap analysis, which summarizes accomplishments and status to date and what is

missing or needed, including policies. This could help to address misunderstandings about how difficult or costly it would be to build out hydrogen infrastructure.

- Mr. Rose asked how the group anticipates reaching out to industry.
  - Dr. Taylor responded that the group will reach out by providing information, but anything more than that is beyond the scope of the HTAC.
- Mr. Rose asked if the role of the working group is to track current global strategies and analyze the gaps.
  - Dr. Taylor agreed that this is the role of the working group. Chairman Shaw agreed and went on to say that the role of the working group, like the HTAC as a whole, is to summarize information and disseminate it to the DOE and others. He noted that it is not the role of the HTAC to directly make policy recommendations.
- Chairman Shaw encouraged every HTAC member to volunteer for one of the working groups if he or she hasn't already done so. The working groups should meet in person as needed. Each member should have clear take-away assignments and should then assemble a report based on his or her findings.
- Mr. Freese volunteered to join the working group, citing his involvement in GM projects such as the Hawaii infrastructure project. He noted that there seems to be a lack of consensus on what the business model looks like for infrastructure, and what the growth path could be. He recommended getting industry stakeholders together to examine the growth path of hydrogen infrastructure and develop metrics to measure progress.
- Dr. Carlin volunteered to join the working group, citing his experience doing surveys in Europe on hydrogen and fuel cells. He also recommended the group examine grid integration, which is an area that DOD is actively exploring.
- Mr. van Dokkum recommended bringing in members of the California Fuel Cell Partnership (CaFCP) to advise the working group, and offered to forward a list of names to Dr. Taylor. These are industry representatives (mostly retired) who have served as technical experts to the CaFCP for the last several years examining the hydrogen infrastructure potential around Los Angeles.
- Mr. Hofmeister suggested the group keep track of what major (global) auto, supply, and oil companies are doing with regard to hydrogen infrastructure. He also suggested examining Germany's work with hydrogen.
- Chairman Shaw suggested inviting Jeremy Rifkin to an HTAC meeting. Mr. Hofmeister offered to introduce Mr. Rifkin, who is working with Germany on its "four-pillar energy strategy," to Dr. Taylor so she could extend the invitation. Mr. van Dokkum suggested reaching out to Byron McCormick because he is leading the infrastructure piece for Mr. Rifkin.
- Dr. Ogden touched upon some of the work being done in California and around the world and offered to help the group.
- Mr. Eggert noted that recent analysis shows that only a modest investment is needed in the early years of hydrogen infrastructure to keep the option viable.
- Dr. Satyapal offered to provide information on other governments' programs, for example the funding that Germany is devoting to hydrogen. She also stated that the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) is preparing a "state of the nation" brochure that provides a collection of highlights of hydrogen and fuel cell commercialization, policy, and R&D activities in member countries. The brochure will be published in November. The McKinsey Group is also publishing a report in November that includes information from 30 stakeholders and 10,000 data points. It will address cost and impact of a variety of technologies including hydrogen and fuel cells.
- Chairman Shaw would like to have a report from the working group by the June meeting; he will check into whether there are any issues with the group making policy recommendations in their report.

- Chairman Shaw asked all the HTAC members to let Dr. Taylor know what information they'd be providing to her and when.

3.2 Frank Novachek, chair of the Hydrogen as Enabler for Renewables Working Group

Vice Chairman Novachek stated that the working group includes HTAC members Novachek, Bond, Friedman, Kaya, Koyama, and Shaw, as well as outside experts from the National Renewable Energy Lab, Proton Energy, and Hydrogenics. The group's purpose is to summarize the opportunities and challenges for using hydrogen as an enabler for high-penetrations of variable renewable energy in the United States. Some of the group's deliverables include summaries of conclusions from relevant publications, a summary of the most promising roles that hydrogen can play in enabling large-scale penetrations of renewable energy, and prioritizing key advances. The group has developed a work plan with recommendations for moving forward. It plans to present its findings to DOE in the form of a white paper.

Mr. Novachek also briefly reviewed the scope of the working group:
- Energy storage
- Energy transmission and distribution
- Improved renewable resource utilization via vehicle fuel production
- Supplement to natural gas system

>> See presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct1410_htacupdate.pdf

Questions, answers, and discussion

- Vice Chair Novachek asked the committee members if they had any ideas regarding where the working group members might find relevant studies.
    - Dr. Ogden responded that there are several important studies coming out of northern Europe that address hydrogen as a storage medium for wind energy. There are also papers out of UC Davis' Institute for Transportation Studies (e.g., Ryan McCarthy), which examine the impacts of renewable intensive grids and growth in electric vehicles.
- Mr. Freese volunteered to join the working group, noting that GM is working with a few other partners to explore the use of hydrogen as a buffer in the overall energy system, including their work on the Hawaii infrastructure project. He noted that hydrogen can also provide a buffer for battery energy storage.
- Mr. Rose commented on the working group's choice to only focus on hydrogen as an enabler for large-scale deployment of renewable, noting that there is a lot of activity on the small-scale side as well (e.g., home refueling). He suggested that the working group might also want to consider ongoing work in Europe, the Middle East and Africa on hydrogen integrated into large scale systems for supply of industrial gases.
- Mr. Hofmeister suggested a possible resource for the group -- The Wind Alliance, a multi-state organization of wind practitioners, with members from more than 55 companies. Mr. Hofmeister offered to introduce Vice Chair Novachek to the organization's managing director, Mr. John White.
- Dr. Thompson volunteered to join the working group. He also suggested that Mr. Novachek contact Larry Burns, a faculty member at the University of Michigan, as a potential outside expert.

- Dr. Satyapal offered to provide a summary from the upcoming Transatlantic Workshop, as it will address issues surrounding energy storage. Dr. Satyapal said she will find out and advise Vice Chair Novachek whether the meeting is open to the public.
- Dr. Carlin suggested looking into the upcoming International Renewable Energy Systems meeting sponsored by Eurosolar, held in Berlin just before Thanksgiving.
- Chairman Shaw suggested writing a report about the state-of-the-art projects happening around the world and the gaps that have yet to be addressed.

4. Industry Presentations

4.1 Dr. Thomas Jarvi, Chief Technology Officer, Sun Catalytix

Dr. Jarvi, former Research and Development Director at UTC and now CTO of Sun Catalytix, noted that the company's technology is a spin-off from a 2008 discovery by Professor Daniel Nocera (founder of Sun Catalytix). Dr. Jarvi described the basic idea of the technology as "something that turns sunlight into hydrogen through water." The company is developing photoelectrochemical cells for hydrogen production and electrolysis, based on a new catalyst material that can split water under benign conditions with inexpensive materials. The key applications are on-site industrial hydrogen production, energy storage, and fuels production. Dr. Jarvi explained that the project is 9 months into its two-year ARPA-E project and is already close to hitting its current density target, so will likely establish higher targets for the remainder of the project.

>> See presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct1410_sun_catalystix.pdf

Questions, answers, and discussion

- Chairman Shaw asked what the company will need in order to get its technology into a product available on the market.
  - Dr. Jarvi responded that he currently considers the company in a technology development state. It is beyond the science state but still has a lot of work to do. It hopes to have a product ready for demonstration in three to four years.
- Dr. Thompson asked why someone would use a photoelectrochemical cell as opposed to a solar cell or electrolyzer.
  - Dr. Jarvi stated that while there is still a lot of research to be done in the area, the use of either technology depends on the scale of the device and cost of hydrogen.
- Dr. Thompson asked why the company used iron oxide for the photoanode when it is not very stable.
  - Dr. Jarvi explained that the use of iron oxide was mostly for demonstration purposes. The company is concerned about the total efficiency of an iron-oxide-based device and may make changes. However it was quick and made sense at the time. Because Sun Catalytix is a small company, it may turn to collaborating with other groups on photoanode development.

4.2 Dr. Andrew Creeth, Chief Technology Officer, ACAL Energy

Dr. Andrew Creeth presented an overview of the proton exchange membrane (PEM) fuel cell technology that ACAL Energy is currently developing. The company is developing integrated fuel cell systems utilizing a proprietary liquid catalyst system instead of platinum. Because the fuel cell engine unit includes the fuel cell stack, regenerator, liquid circulation system, air

blower, and basic control system, no other major balance-of-plant components are needed. The engine can be tightly integrated to save space, offering a large degree of packaging flexibility and easy integration into system applications. The company hopes to deliver products for stationary and automotive applications that offer lower cost and higher reliability than current PEM fuel cells. The targeted launch date for its first product offering, a stationary power system, is early 2012.

>> *See presentation at* http://www.hydrogen.energy.gov/pdfs/htac_oct1410_acal.pdf

Questions, answers, and discussions

- Dr. Ogden asked Dr. Creeth about their consideration of methanol as a fuel, and asked whether the ACAL fuel cell could be run as a direct methanol fuel cell.
    - Dr. Creeth explained that direct methanol fueling has been explored by ACAL and that it works well. The only information they have published on this is in their patents.
- Dr. Thompson asked for more information on the mediator solution that ACAL uses.
    - Dr. Creeth clarified that the use of the mediator does make the system work like a flow battery and that ACAL is indeed working to resolve similar issues arising from controlling concentrations of soluble species, but noted that material crossover is much less of an issue in their system. He also noted that the materials used are not exotic and are relatively inexpensive (compared to platinum).
- Mr. van Dokkum asked about the ability of the liquid cathode system to operate at freezing temperatures, noting that car companies are targeting -40 degrees Celsius for automotive applications.
    - Dr. Creeth stated that the ACAL team is working on this challenge.
- Dr. Carlin asked about the potential for air contamination over time.
    - Dr. Creeth responded that the because the catalyst offers so many binding sites, the ACAL system is less sensitive to air contamination than standard PEM fuel cells.
- Dr. Thompson asked about the stability of the mediator given that it has to reversibly oxidize and reduce continually.
    - Dr. Creeth explained that the ACAL system is thermodynamically stable, so it is an association complex that self-assembles. The system will therefore adjust to a stable position as temperature or chemistry changes.
- Mr. Friedman asked for clarification on the size of the system.
    - Dr. Creeth stated that the system is not going to be too large and no heavier than a standard PEM system.

4.3 Mr. Hal Koyama, Chief Executive Officer, IdaTech

Mr. Koyama presented information about IdaTech, a company that designs, develops, and manufactures low-temperature PEM fuel cell products for small-scale (less than 15kW output) distributed power and stationary power applications. Its current market focus is off-grid and back-up power applications for telecommunications and other critical power needs, particularly in developing countries where grids are unreliable. The IdaTech systems are marketed as alternatives for battery systems or diesel generators, and offer benefits including increased reliability, lower maintenance costs, and clean, quiet operation. Ongoing R&D at IdaTech has led to cost reductions that have in some cases made the first cost equal to or

better than a diesel generator. Dr. Koyama noted that there are still issues with siting systems with gaseous hydrogen tanks (lack of local codes or unfamiliarity with codes that leads to restrictive set-back distances), so the company currently provides methanol reformers for the fueling system.

See full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct1410_koyama.pdf

Questions, answers, and discussion

- Dr. Carlin asked about the status of IdaTech's R&D on using heavy equipment fuels like JP8 or diesel in their reformers.
    - Mr. Koyama responded that the key challenge is producing a reasonable sized, cost-competitive reformer that will 1) deal with the high sulfur content in JP8 and diesel, and 2) catalyze the breakdown of all the different heavy hydrocarbons.
- Dr. Carlin asked if IdaTech was involved in biofuel reforming and suggested that the technology described by Mr. Koyama would be a good application of biofuels.
    - Mr. Koyama responded that IdaTech has used a number of different types of biofuels, including ethanol and canola oil. Ethanol was not difficult to use; canola was more difficult.
- Mr. Rose noted that most of the cost comparisons presented by IdaTech were to diesel generators, and wondered if this was the real competition as opposed to battery backup systems.
    - Mr. Koyama confirmed that currently, the best markets for its fuel cell systems are those that have higher back-up or off-grid power requirements, so it is targeting applications that would require a diesel gen set or a large battery pack.
- Mr. Rose asked what IdaTech is offering as a commercial guarantee for its systems.
    - Mr. Koyama responded that the guarantee depends on the market. In the traditional market, IdaTech guarantees a specific number of operating hours for a certain number of years. However there are emerging markets where the guarantees focus more on providing a certain level of power service.
- Mr. Rose asked for more information about the cost reduction IdaTech has achieved on its newest systems, specifically the data presented on a 50% manufacturing cost reduction.
    - Mr. Koyama stated that the level of cost reduction actually varies —in some subsystems the cost has been reduced by a factor of five, in others a factor of two. The specifics on how and where this reduction was achieved are not publically available, but he could look into how they might be able to publish some of the information.
- Mr. Eggert asked for clarification on the cost curves shown in Mr. Koyama's presentation, and whether the numbers include developmental (e.g., non-recurring engineering) costs. He followed up with a question on whether IdaTech is selling products at a profit on a variable basis.
    - Mr. Koyama stated that the new generation technology cost curves showing variable costs are based on current technology (not higher volume projections), and they do include development costs as well as a profit margin.

Questions posed to Dr. Jarvi, Dr. Creeth, and Mr. Koyama

- Chairman Shaw asked the group what issues keep them awake at night.
    - Dr. Jarvi responded that he is excited by the technical challenges. His biggest worries are the market challenges associated with bringing a new technology to market, and maintaining sufficient investment to sustain the R&D needed to develop the technology.
    - Dr. Creeth stated that he was initially concerned with whether the technology would work at all; now the concerns revolve around engineering solutions to produce a robust and high-performing product.
    - Mr. Koyama stated that time to market is critical. It is important to keep the momentum going and get the systems into the market as quickly as possible so that experience and familiarity builds.
- Dr. Odgen asked, in reference to IdaTech's use of methanol as a fuel, if methanol use could take off in the United States. Most small fuel cell systems in the United States are based on natural gas or biofuels. She also asked whether the system could be adapted to provide combined heat, hydrogen and power.
    - Mr. Koyama responded the best fuel source depends on the application—whether on- or off-grid, continuous or back-up power, and whether there is a ready supply of natural gas or biofuels at the site. He replied that the system could be adapted to provide a slipstream of hydrogen for vehicle refueling, but the economics of doing so would have to be evaluated.
- Mr. Kaya stated that he really liked having companies in various stages of technology development give presentations. He asked the presenters how the public sector could best assist with transitioning these products to market.
    - Mr. Koyama noted that the FY11 DOE budget request for Market Transformation (MT) is zero, but now is the time when MT is critical. As the country moves out of recession and companies are more willing or able to spend capital, MT activities will have the biggest bang for the buck in these emerging markets.
    - Dr. Jarvi suggested that the DOE place more emphasis on ensuring that each project has a valid business plan, as well as integrating the total program from technology development, to product development, to market transformation type activities, with appropriate metrics for each stage of development..
    - Dr. Creeth added that help is important at every stage in the process. He noted that both venture capital and government funding have supported technology development at ACAL.
- Mr. Walker asked if the government had done anything that was harmful to the presenters' efforts to enter the market.
    - Mr. Koyama responded that uncertainty is harmful. For example, right now it is not known if the U.S. government will offer a tax credit or rebate incentive next year, and this makes capital expenditure budgeting for a project difficult, and is delaying project decisions.

5. HTAC Annual Report discussion, Mr. Anthony Eggert

Mr. Eggert led a discussion about the Committee's annual report. Prior to the meeting, HTAC members submitted what they felt were important developments in the use of hydrogen and fuel cells

over the last year. This input was then reviewed at the meeting for the purpose of identifying elements to include in the 2010 report.

- **Potential key messages**:
    - Reports that have recently been published further confirm the need to sustain a portfolio strategy to meet energy and environmental goals; outputs of the International Energy Agency (IEA) and other scenario analysis reports show a major role for hydrogen and therefore it should be kept in the portfolio.
    - Highlight demonstrated, real-world performance results and customer satisfaction with commercial deployments and field demonstrations.
    - Maturing and consolidation of the industry
        - The industry is starting to focus more on core competency among some of the players, and others are being consolidated to take advantage of their products and expertise.
    - Fragile state of the industry and the need for consistent and durable support.
    - U.S. leadership versus the rest of the world and trends in number of shipments.

- **Next Steps**
    - Mr. Eggert will send another call to HTAC members for specific inputs and broader themes
    - Incorporate feedback from meeting
    - Produce a draft report for review by Policy and Planning Subcommittee (and discuss and reconcile comments in a conference call)
    - Produce and distribute the draft for full HTAC review by end of January/early February
    - Final review at February HTAC meeting
    - Finalize report in early March 2011

October 15, 2010

6. Call to order, 2011 HTAC meeting dates, and review of draft DOE Hydrogen and Fuel Cells Program Plan

6.1. HTAC meeting dates in 2011

- Feb 17-18 (coordinate venue with the National Hydrogen Association's annual conference)
- June 15 tentative (Rochester, NY) – optional, unofficial tour of GM facility will be offered by GM on the 14th
- Nov 3-4 (Washington, DC)

6.2. Process for HTAC review of draft DOE Hydrogen and Fuel Cells Program Plan

Dr. Satyapal stated that DOE will create an e-mail address to collect comments from the broader public and stakeholders, with comments due by November 30th. HTAC members are welcome to use it as well. Chairman Shaw suggested that the HTAC's Planning and Policy Committee (PPC) be the focal point for gathering and compiling HTAC comments on the Program Plan, and the following process was agreed to:

- DOE will email an electronic copy of the draft plan to all HTAC members
- All HTAC members will provide their comments electronically to HTAC Chairman Shaw or PPC Chair Rose – either as a marked up version of the draft (using track changes) or in comments via email.
- The PPC will compile the comments and send to DOE by November 30.

7. Hydrogen threshold cost analysis update -- Mr. Fred Joseck, DOE Office of Energy Efficiency and Renewable Energy, Fuel Cell Technologies Program and Mr. Mark Ruth, National Renewable Energy Laboratory (NREL)

Mr. Joseck and Mr. Ruth provided a review of the DOE cost threshold analysis, which was first presented to the HTAC in June 2010. Some HTAC members participated in a detailed review in July 2010 of the assumptions and process used for the analysis, and their inputs were incorporated into the revised analysis. The cost threshold at which hydrogen is projected to become competitive with gasoline in hybrid electric vehicles (HEVs) in 2020 is $2–$4 per gasoline gallon equivalent (gge).

>> *see full presentation at* http://www.hydrogen.energy.gov/pdfs/htac_oct1410_costanalysis.pdf

Questions, answers, and discussion

- Mr. Eggert commented that the work was excellent, and noted that this program stands out as one of the best for use of consumer focused metrics that are used in developing clear targets to guide R&D. He asked if DOE will be considering carbon price factors in their analysis.
    - Mr. Joseck responded that the methodology is able to include such costs if they come into effect; currently these costs are set at zero.
- Dr. Carlin noted that the gasoline costs used in the analysis are the Energy Information Administration's costs used in its *Annual Energy Outlook*, which is the price at the pump (delivered, with taxes). He said that for the DOD, the delivered costs of fuel at forward operating bases (FOBs) can range from $40 - $600 per gallon. He asked if the analysis had considered these sorts of scenarios.

    - Mr. Ruth responded that the current cost analysis does not consider a non-retail situation for gasoline or hydrogen, but could do so if requested. Dr. Carlin noted that there is a team that has been working on developing the full cost of fuel to DoD, and it would be good to bring the hydrogen cost analysis into that effort.
- Mr. Rose asked whether, as a rule of thumb, we could say that hydrogen can be one-third more expensive than gasoline and still be competitive.
    - Mr. Ruth replied that the rule of thumb is generally accurate, as long as we assume the vehicle costs are equivalent, which they may not be.
- Mr. Koyama commented that the hydrogen cost analysis is very good and rigorous and would like to see the same level of rigor and detail applied to the fuel cell cost target, which was set some time ago at $30/kW. He also asked about the fuel economy used in the analysis.
    - Dr. Satyapal responded that the $30/kW target is just for the fuel cell power plant. The DOE is now launching a much more rigorous total vehicle cents-per-mile analysis that includes all the vehicle costs (including battery, fuel cell, fuel, etc.).
    - Mr. Ruth responded that the analysis uses an average fuel economy for city and highway driving, which comes to 42 miles per gge.
- Mr. Hofmeister noted that vehicle cost analyses should consider the actual cost to supply the product and vehicle ownership costs over the life of the vehicle. He asked whether a fuel cell is expected to last the life of the vehicle.
    - Mr. Freese stated that the fuel cell will last the life of the vehicle (considered to be fifteen years).
- Mr. Freese stated that all of the cost breakpoint scenarios are dependent on the size of the vehicle. The breakpoint for big vehicles is very different from small vehicles. DOE's analysis is based on a compact sedan, which may not be the best place to differentiate the technologies. He urged that this issue be addressed in future work.
- Chairman Shaw encouraged DOE to produce and publish a paper describing the hydrogen threshold cost analysis methodology, assumptions, and results.

8. DOE Safety, Codes and Standards R&D overview

Mr. Antonio Ruiz, DOE Fuel Cell Technologies Program, and Dr. Daniel Dedrick, Sandia National Laboratories (SNL)

8.1. U.S. DOE hydrogen and fuel cell activities, Mr. Antonio Ruiz

- Mr. Ruiz presented information about the key objectives of the FCT Program's Safety, Codes and Standards (SC&S) subprogram. The SC&S subprogram is responsible for developing and implementing safety practices and procedures to ensure the safe operation, handling, and use of hydrogen and fuel cell technologies, while at the same time supporting critical R&D for the development of scientifically and technically sound codes and standards that enable the safe use of hydrogen.

>> *see full presentation at* http://www.hydrogen.energy.gov/pdfs/htac_oct1410_fuelcell.pdf

Questions, answers, and discussion

- Chairman Shaw asked what Mr. Ruiz considered to be the most difficult remaining problems in developing codes and standards.
    - Mr. Ruiz stated that though a lot of progress has been made, there is still a lot of work to be done. Among the near-term priorities is developing the information and tools needed to site indoor hydrogen refueling, which directly affects the deployment of forklifts in material handling facilities. Though indoor hydrogen dispensers have been successfully installed and operated at a few locations, the DOD has thus far prohibited indoor hydrogen dispensers at their facilities. More training and best practices are needed to overcome this barrier. Another near-term challenge is ongoing certification and testing of Type-4 hydrogen storage tanks, which are being considered by automakers for high-pressure (10,000 psi) hydrogen fueling. Type-4 tanks manufactured in the U.S. have been tested and certified for use in vehicles; however, some Chinese-made Type-4 tanks failed their certification testing, and more needs to be understood about why this happened. There are also gaps with regard to development of standards for specific components. For example, valves that are being used now for 5,000 psi fueling may not yet be fully qualified for 10,000 psi fueling.

8.2. Research and development in the Safety, Codes, and Standards Program element, Dr. Daniel Dedrick, Sandia National Laboratory

The SC&S subprogram has taken a multifaceted approach to establishing the technical basis for codes and standards. Each R&D element—including hydrogen behavior, risk analysis, and hydrogen-compatible materials and components—is constructed to impact technology deployment. The program works with outside stakeholders to identify R&D needs, and uses a science-based, risk analysis approach to perform R&D to support codes and standards development. R&D results are published, and communicated through participation in technical committees of codes and standards development organizations. Researchers also participate in international groups working to harmonize codes and standards. Dr. Dedrick described a number of examples where DOE-funded research and modeling has supported the development of hydrogen codes and standards, including bulk hydrogen storage set-back distances, forklift tanks, stationary pressure vessels, fuel cell vehicle system components, and material certification. Future efforts will continue to address R&D gaps in codes and standards development.

>> see full presentation at http://hydrogen.energy.gov/pdfs/htac_oct1410_rd.pdf

Questions, answers, and discussion

- Chairman Shaw commented that there are still common misperceptions among laypeople about hydrogen safety, with many thinking that it is very dangerous. He asked whether any of the research results have been directed at understanding the risk of hydrogen relative to other fuels, in order to help the average person understand that hydrogen is no more dangerous than any other fuel.
    - Dr. Dedrick acknowledged this is a good point, and stated that risk data is a significant input into the specification of requirements for hydrogen infrastructure and components. The risk of established technologies, such as refueling a gasoline car, is used as a benchmark for the maximum level of risk acceptable for the new technology.

- Mr. Eggert commented that the work is excellent and has contributed to significant and rapid progress over the last ten years, which should serve as a model to others. He noted that in working with the California Fuel Cell Partnership, he learned that the best way to convince people that hydrogen is safe is through first-hand experience, like having people actually drive the vehicles or use the products.
- Mr. Rose asked whether SNL was the designated lab for SC&S research, and how much of the budget is committed to R&D-level activity.
    - Dr. Satyapal responded that many of the labs play a role, but traditionally Sandia has been the leader in conducting combustion-related research. She added that budgets for SC&S activities have in the past been somewhat higher than the current DOE request of $9 million, at around $12.5 million to $15 million. She said she could get back with details on exactly how much of the SC&S budget is devoted specifically to R&D activities, but noted that each year priorities are set based on ongoing and emerging needs.
- Mr. Koyama asked whether the setback distances in the bulk hydrogen storage separation distances table that was recently adopted as part of the NFPA-55 code had changed much from those that were formerly used.
    - Dr. Dedrick responded first that the separation distance table changed across the board because the numbers were generated based on a scientific process. Some of the distances increased somewhat and others decreased by as much as half, depending on the system parameters.
- Dr. Taylor asked if any new materials issues have arisen from the concept of blending hydrogen into existing natural gas lines.
    - Dr. Dedrick answered that blends have not yet been a high priority in the United States, except for a handful of demonstration projects. Not much systematic research has been done at this point, so it is largely unknown what the long-term effects would be. There is some anecdotal evidence that embrittlement can be an issue with hydrogen-natural gas blends, but it is still not fully understood.
- Dr. Odgen commented that she believes the work is very important and is glad to see research supporting the standards.

9. Codes and Standards Development

Dr. James Ohi, Chair of Codes and Standards Working Group; Mr. Martin Gresho, National Fire Prevention Association - 2; and Mr. Nha Nguyen, U.S. Department of Transportation (DOT)

9.1. Overview of codes and standards development, James Ohi, DOE consultant

Dr. Ohi presented an overview of the regulations, codes and standards (RCS) development process, both domestic and international. He reviewed the national codes and standards templates for hydrogen and fuel cells, and noted that, in the U.S. alone, there are as many as 44,000 federal, state and local "authorities having jurisdiction" (AHJs) over RCS development, adoption and implementation. Coordinating and harmonizing activities among the various codes and standards development organizations (CDOs and SDOs) and the AHJs is a key need, and the national template helps provide a roadmap for collaborative work. In the international arena, key standards are under development or revision through the International Organization for Standardization (ISO) and the International Electrochemical Commission (IEC). Harmonization of testing and certification procedures in key market countries around the world is underway. The United Nations Economic Commission for Europe (UN/ECE)

Global Technical Regulations (GTR) for hydrogen fueled vehicle systems is also nearing completion.

>> see full presentation at http://hydrogen.energy.gov/pdfs/htac_oct1410_codes.pdf

Questions were reserved for after Mr. Nguyen's presentation.

9.2. Domestic activities: DOE-enabled code development, Martin Gresho, FP2FIRE, Inc.

Mr. Gresho, a code developer, former Fire Marshal, and licensed fire protection engineer, presented information about the National Fire Prevention Association's (NFPA) code development process and how DOE helped to develop a research-informed code. He noted that the full cycle for code development (from initial proposal through drafting, technical and public review, and consensus approval generally takes from 3-5 years (sometimes longer). The majority of codes are written using an "experience-based" process, where code is developed based upon the collected experience of the technical committee and loss or accident histories. Where this experience isn't available (as with hydrogen vehicle fueling), research-informed processes are needed. Research-informed code development uses published and peer-reviewed data to inform targeted and specific codes. The research findings are needed at the initial proposal stage and into the code development stage, so the research must begin years before the code is proposed. Mr. Gresho discussed the process involved in revising the bulk hydrogen storage separation distances table, which was originally written in 1950 for NASA's use of hydrogen in space applications. He credited DOE support for the research and modeling that informed the technical committees, enabling an update in the table as codified in the most recent (2010) edition of NFPA 55.

>> see full presentation at *http://hydrogen.energy.gov/pdfs/htac_oct1410_nfpa55.pdf*

Questions were reserved for after Mr. Nguyen's presentation.

9.3. International activities: International Organization for Standardization and UN/ECE Global Technical Regulations, Mr. Nha Nguyen, Department of Transportation (DOT) National Highway Traffic Safety Administration (NHTSA)

DOT/NHTSA is one of the key domestic regulatory bodies involved in the World Forum for Harmonization of Vehicle Regulations, a permanent working party (WP.29) operating under the framework of the United Nations to develop Global Technical Regulations (GTR) for vehicles, including hydrogen fueled vehicles. Thirty one contracting parties are under the 1998 Agreement including Canada, China, the European Commission, India, Japan, Korea, and South Africa. The effort is cosponsored by Japan, Germany, and the United States. GTR objectives state that hydrogen fueled vehicle standards must 1) attain identical levels of safety as conventional gasoline powered vehicles, 2) be performance based (not design specific), 3) be data driven and science-based, and 4) achieve objectively measurable compliance. Mr. Nguyen described the various GTR technical and testing requirements for hydrogen fueled vehicles and discussed the timeline for development of the draft and final regulations. The final GTR is expected to come to a vote by the entire WP.29 in November 2011. Upon approval, the contracting parties under the 1998 agreement will be obligated to start the adoption of the GTR into their own laws or regulations, which means that DOT will initiate a public rulemaking process to adopt the requirements in the GTR in the United States.

>> see full presentation at http://hydrogen.energy.gov/pdfs/htac_oct1410_gtrvehicle.pdf

Questions, answers, and discussion

- Mr. Walker asked if hydrogen vehicles are going to be as safe as vehicles currently on the road.
    - Mr. Nguyen responded that the goal of the codes is to ensure that hydrogen vehicles are just as safe as conventional gasoline vehicles.
- Mr. Rose asked for more information about whether testing performed by non-U.S. entities is accepted and integrated into the GTR.
    - Mr. Nguyen responded that the working group has used a large amount of data from Japan (including JARI and METI) to help inform its development of the GTR. It has also gathered data from Europe, HySafe, industry, and others.
- Dr. Carlin asked how much work has been done on modeling the dynamic loading of tank cylinders in order to develop predictive capability.
    - Mr. Ohi responded that Sandia has been doing some of this type of modeling, particularly with regard to fast-fill procedures and the effects of various fast-fill scenarios on temperature and pressure within cylinders. Dr. Carlin noted that DOD has also been doing some work in this area and could collaborate with DOE.
- Mr. van Dokkum extended a thank you to the presenters as a representative of industry, noting that this kind of work is essential for successfully introducing new technologies to market.

10. Codes and standards implementation

Mr. Carter Marantette, Director of Federal Sales, ReliOn, and Mr. Aaron Harris, Environmental Health and Safety Coordinator, Nuvera Fuel Cells

10.1. ReliOn, Mr. Carter Marantette

Mr. Marantette began his presentation by stating that as a manufacturer of fuel cells for stationary back-up power applications, his business is dictated by codes and standards regulation. He gave several examples of the types of codes and standards ReliOn adheres to on a regular basis, including design, installation, and various permitting standards. He described a number of C&S-related issues that have hindered ReliOn's deployment of fuel cells, including misinterpretation of code language by AHJs; AHJ use of outdated or different code references; code officials (and, in some cases, potential end users) being generally inexperienced with hydrogen and often adopting overly conservative approaches (e.g., very large setback distances); and, finally, the amount of on-site hydrogen storage allowed in current regulations is overly restrictive, especially for ReliOn's telecomm applications.

>> see full presentation at http://hydrogen.energy.gov/pdfs/htac_oct1410_relion.pdf

Questions were reserved for after Mr. Harris' presentation.

10.2. Nuvera Fuel Cells, Mr. Aaron Harris

Mr. Harris discussed the status of codes and standards development efforts to date for industrial truck (forklift) applications. He pointed out that in terms of actual real-world experience, the worldwide hydrogen powered industrial truck fleet is much larger than the hydrogen fuel cell vehicle (FCV) fleet, uses much more hydrogen than the current automotive and bus FCV fleet, and mostly operate almost 24 hours per day 7 days per week. There are many similarities that can be built upon for code and standards development and for building a history of operating and fueling experience. He described the various components of a typical Nuvera fuel cell forklift system (including the lift trucks, on-site reformer, and indoor

or outdoor refueling dispensers), the existing codes and standards that have been written, and what more are needed for forklift-specific applications.

>> see full presentation at http://hydrogen.energy.gov/pdfs/htac_oct1410_trucks.pdf

Questions, answers, and discussion

- Mr. Hofmeister noted that education will be a key factor going forward and questioned whether the DOE budget request of $1 million for education was going to be enough to meet the needs.
    - Mr. Ruiz responded that the safety, codes and standards group works closely with the education group to leverage expertise, including communicating directly with code officials.
- Chairman Shaw summarized the presentations by remarking that it looks as though the process of getting codes and standards in place for companies like Nuvera and ReliOn is coming along nicely, and gaps are being quickly filled.
- Mr. Harris stated that he thinks the creation of the Hydrogen Safety Panel has been very valuable.

11. Nuclear Energy Hydrogen Program overview, Dr. Carl Stoots, Idaho National Laboratory, and Dr. James O'Brien, Idaho National Laboratory

Dr. Stoots presented his team's work on nuclear powered high-temperature electrolysis for large-scale central hydrogen production. He pointed out that high-temperature electrolysis is more efficient than conventional electrolysis, with an overall thermal-to-hydrogen efficiency of greater than 50% (higher heating value basis). Idaho National Lab served as the lead lab for High-Temperature Electrolysis (HTE) research and development from 2003–2009, and during that time built and operated a 15 kW Integrated Lab Scale HTE unit with more than 1,080 hours of operating time. It is now continuing to improve its existing designs, promote the development of larger format cells, and demonstrate high pressure HTE operation. The team envisions a large-scale, centralized nuclear hydrogen production facility directly coupled with an advanced high-temperature reactor with a 600 MW reactor. Such a plant could produce up to 85 million standard cubic feet of hydrogen per day, with potential applications such as large scale hydrogen production as a direct vehicle fuel, biomass- or coal-to-liquids, petroleum refining, and ammonia production. They are also exploring opportunities for smaller scale, distributed hydrogen production using HTE powered by grid electricity, with a supplemental heat requirement

>> see full presentation at http://hydrogen.energy.gov/pdfs/htac_oct1410_nuclear.pdf

Questions, answers, and discussion

- Chairman Shaw asked if Idaho National Lab is measuring output degradation from the initial startup of its fuel cells, and if so, what it is.
    - Dr. O'Brien responded that the target is 0.5% cell performance degradation per 1,000 hours; right now it is just above 0.9%.
- Chairman Shaw asked whether the system described by Dr. Stoots could be integrated into an existing nuclear station.
    - Dr. Stoots replied in the affirmative, however he noted the existence of an efficiency penalty if a low temperature reactor were used. HTE could also be integrated with concentrated solar power systems.

- Dr. Ogden suggested that Dr. O'Brien and Dr. Stoots extend the system cost analysis from the point of production all the way to the dispenser (i.e., including delivery and storage costs) and then compare the results. She also suggested that they compare conventional electrolysis at scale with high-temperature electrolysis, and that they include a pure battery electric vehicle in their analysis of power requirements for the light duty vehicle sector.
- Mr. Hofmeister asked how many reactors would need to be constructed if the country were to achieve a completely carbon-free energy economy.
    - Dr. O'Brien responded that each large plant can produce about 1 gigawatt of power, so it would depend on how much is generated from nuclear and how much from renewables like wind and solar.

Chairman Shaw adjourned the meeting at 2:55 p.m.

THIRTEENTH MEETING OF THE
HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE (HTAC)
PARTICIPANT LIST

HTAC Members Present

- Peter Bond
- Mark Cardillo
- Richard Carlin
- Anthony Eggert
- Charles Freese
- David Friedman
- John Hofmeister
- Maurice Kaya
- Harol Koyama
- Frank Novachek
- Joan Ogden
- Bob Rose
- Bob Shaw
- Kathleen Taylor
- Levi Thompson
- Jan van Dokkum
- Robert Walker
- Bill Wyalm

HTAC Members Not Present

- Alan Lloyd
- Geraldine Richmond

U.S. Department of Energy Staff

Office of Energy Efficiency and Renewable Energy

- Peter Devlin
- Kathi Epping Martin
- Richard Farmer
- John Garbak
- Nancy Garland
- Fred Joseck
- Michael Mills
- Antonio Ruiz
- Sunita Satyapal
- Ned Stetson

Office of Fossil Energy

- Guido Dehoratiis

Office of Science

- John Vetrano

Advanced Research Projects Agency—Energy (ARPA-E)
- Brenda Haendler

U.S. Department of Transportation Staff
- Martin Koubek
- Nha Nguyen

Members of the Public in Attendance
- Anthony Androskya
- Robert Burgess – National Renewable Energy Laboratory
- Andrew Creeth – ACAL Energy
- Daniel Dedrick – Sandia National Laboratories
- Travis Doom – Arizona State University
- Matthew Erwin – Mazda North American Operations
- Marty Gresho – National Fire Protection Association
- Thomas Gross – Independent Consultant
- Aaron Harris – Nuvera Fuel Cells
- Thomas Jarvi – Sun Catalytix Corporation
- Wayne Lundberg – Leonardo Technologies, Inc.
- Carter Marantette – ReliOn, Inc.
- James O'Brien – Idaho National Laboratory
- Jim Ohi – Consultant
- Kathleen O'Malley – Sentech, Inc.
- Catherine Gregoire Padro – Los Alamos National Laboratory
- Mark Ruth – National Renewable Energy Laboratory
- Jeff Serfass – Technology Transition Corporation
- Dan Shumaker – Sentech, Inc.
- Carl Stoots – Idaho National Laboratory
- Anna Stukas – Angstrom Power
- George Sverdrup – National Renewable Energy Laboratory
- Steve Weiner – Pacific Northwest National Laboratory
- Brittany Westlake – American Chemical Society

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