

**HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE
MEETING MINUTES**

October 29-30, 2013

NREL Research Support Facility; Golden, Colorado

TABLE OF CONTENTS

DAY 1 – OCTOBER 29, 2013	1
1. HTAC Business	1
1.1. Renewal of Existing Members	1
1.2. Approval of Prior Meeting’s Minutes	1
1.3. Discussion on 2014 Meeting Schedule.....	1
1.4. Approval of the Meeting Agenda	1
2. U.S. Department of Energy Updates: Dr. Sunita Satyapal, Director, Fuel Cell Technologies Office, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy	1
2.1. Scope and Membership of HTAC	1
2.2. DOE Leadership Updates	2
2.3. DOE Hydrogen Program and Budget Updates.....	2
3. Presentation on EERE’s Strategic Plan: Jason Walsh, Senior Advisor to the Assistant Secretary, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy	4
4. Overview of the National Renewable Energy Laboratory and the NREL Fuel Cell and Hydrogen Technologies Program	5
4.1. Dr. Dana Christensen, Deputy Laboratory Director, Science & Technology, National Renewable Energy Laboratory	5
4.2. Keith Wipke, Program Manager, Fuel Cell and Hydrogen Technologies Program, National Renewable Energy Laboratory	6
5. NREL’s National Fuel Cell Technology Evaluation Center: Jen Kurtz, Group Manager, National Renewable Energy Laboratory.....	7
6. EERE’s Work on Grid Integration: Kevin Lynn, Director, Energy Systems Integration, U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy	7
7. H ₂ USA Partnership Overview: Morry Markowitz, President & Executive Director, Fuel Cell and Hydrogen Energy Association	9
8. Subcommittee Updates	10
8.1. Hydrogen Infrastructure Subcommittee Report, Robert Rose, HTAC Member	10

8.2.	Hydrogen Enabling Renewables Subcommittee Report, Frank Novachek, HTAC Member	12
8.3.	Manufacturing Subcommittee Report, Hal Koyama, HTAC Member.....	12
DAY 2 – OCTOBER 30, 2013.....		12
9.	Hydrogen Production: Overview, Dr. John Turner, Research Fellow, National Renewable Energy Laboratory	12
10.	Current Hydrogen Cost, Brian Bonner and Ed Kiczek, Air Products.....	13
11.	Hydrogen Production Potential Impacts to Utilities, Frank Novachek, Director of Corporate Planning, Xcel Energy	15
12.	Techno-Economic Analysis of Hydrogen Production Pathways, Brian D. James, Strategic Analysis Inc.	16
13.	JCAP Research Overview for HTAC, Dr. Carl Koval, Director, California Institute of Technology, Joint Center for Artificial Photosynthesis.....	17
14.	Other HTAC Business	17
PARTICIPANT LIST.....		19

DAY 1 – OCTOBER 29, 2013

The Hydrogen and Fuel Cell Technical Advisory Committee (HTAC or the Committee) meeting began at 8:06 a.m. (MDT).

HTAC Chairman John Hofmeister welcomed all attendees and staff. He called roll of HTAC members, both present and on the phone. Mr. Hofmeister also invited members of the public in attendance to introduce themselves.

1. HTAC Business

1.1. Renewal of Existing Members

There were no renewals of existing members or introductions of new members. Dr. Satyapal introduced the new Designated Federal Official (DFO) for HTAC, Mr. Jim Alkire from the U.S. Department of Energy (DOE) Golden Field Office, who replaces Mr. Joseph Stanford.

1.2. Approval of Prior Meeting's Minutes

The minutes from the April 23-24, 2013, HTAC meeting were unanimously approved.

1.3. Discussion on 2014 Meeting Schedule

Chairman Hofmeister presented the results of a survey of HTAC members that showed that April 1st and 2nd would be the best dates for the next in-person meeting. He also noted that a subcommittee would have to be formed to help Levi Thompson produce the annual report before the next in-person meeting. Mr. Hofmeister asked for volunteers to join this subcommittee. The following members volunteered: Anthony Eggert, Charlie Freese, Bob Shaw, Richard Carlin, and Peter Bond.

1.4. Approval of the Meeting Agenda

Chairman Hofmeister asked if any members had amendments, questions, or concerns about the day's agenda. Alan Lloyd recommended that the time for subcommittee updates be changed from half an hour to a full hour. Mr. Hofmeister replied that the session could be extended if necessary, since it is at the end of the day.

2. U.S. Department of Energy Updates: Dr. Sunita Satyapal, Director, Fuel Cell Technologies Office, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy

2.1. Scope and Membership of HTAC

Dr. Sunita Satyapal reminded new members that HTAC's charter focuses on the implementation of programs and activities under Title 8 of the Energy Policy Act of 2005, which directs the Secretary of Energy, "in consultation with other Federal agencies and the private sector, to conduct a research and development program on technologies relating to the production, purification, distribution, storage and use of hydrogen energy, fuel cells, and related infrastructure." It also directs HTAC to review the safety, economical, and environmental consequences of these technology areas, as well as the Hydrogen and Fuel Cells Program Plan. Dr. Satyapal noted that her presentation will touch upon DOE's recent work in these areas. She explained that the Committee has already completed its obligation to review the Program Plan, through its review and comment on the original "Hydrogen Posture Plan," and its subsequent review of the revised Hydrogen and Fuel Cells Program Plan in 2011.

As called for in Title 8, the Committee is made up of members from diverse backgrounds, including industry, academia, nonprofits, professional societies, government, national laboratories, federal, and financial and environmental organizations. Dr. Satyapal asked HTAC members to provide her or the DFO with any input on gaps in the Committee's expertise they foresee in addressing the Committee's scope.

2.2. DOE Leadership Updates

Dr. Satyapal continued with an overview of recent changes within DOE leadership. She noted that the new Secretary of Energy, Dr. Ernest Moniz, created the Office of the Under Secretary for Management and Performance to promote effective and efficient management operations. The second change mentioned was consolidating management of the DOE's Office of Science and its various energy programs, creating the new Office of the Under Secretary for Science and Energy. She noted that the Under Secretary has not yet been named, but that her office has briefed Deputy Under Secretary Michael Knotek. The third change was the creation of new Secretarial Councils by the Secretary: the Energy Council, the National Laboratory Policy Council, the Credit Review Board, and the Cyber Security Council. In addition, the Office of Policy and International Affairs has been split into two separate entities: the Office of International Affairs and the Office of Energy Policy and Systems Analysis (EPSA), both of which will be headed by Assistant Secretaries. Another change was the creation of the National Laboratory Operations Board, an additional indicator of the Secretary's strong interest in management and organizational improvement efforts.

Questions, answers, and discussion

- Mr. Hofmeister asked whether the new Secretarial councils will be made up of individuals from the public or the government.
 - Dr. Satyapal replied that announcements to date speak of just beginning to establish the councils, so she does not yet know what organizations they will include. She noted that Secretary Moniz has indicated an interest in restructuring the Secretary of Energy Advisory Board (SEAB), which does include external stakeholders, including four standing subcommittees that address each of DOE's major mission areas. She committed to pass along information on the councils to HTAC members as it becomes available.

2.3. DOE Hydrogen Program and Budget Updates

Dr. Satyapal described the Fuel Cell Technologies Office's (FCTO's) mission to enable widespread commercialization of hydrogen and fuel cells. She described the Hydrogen and Fuel Cells Program's research and development (R&D), demonstration, and deployment activities and discussed DOE's hydrogen production strategies. She reviewed DOE's new automotive fuel cell cost target of \$40/kW by 2020. She introduced the launch of H₂USA and reviewed the H2incidents database, and several global safety collaborations. She previewed FCTO's fiscal year (FY) 2014 budget request for key program activities. She described recent R&D fuel cell activities that are part of the Advanced Research Projects Agency-Energy (known as ARPA-E), including a new program—intermediate temperature fuel cells. She also discussed two National Renewable Energy Laboratory (NREL) studies: one on hydrogen production pathways and one (not yet published) on the hydrogen production resource requirements associated with future market success of fuel cell electric vehicles. She described FCTO's efforts to

track the impacts of DOE funding, including an upcoming report on the number of patents attributed directly to DOE funding (now at 455 patents in fuel cells and hydrogen technologies), a report by Pacific Northwest National Laboratory that tracks fuels and hydrogen technologies directly attributable to DOE funding that have been commercialized and are actually available in the market (now at 41), and efforts to track additional private funding (e.g., installation of a new manufacturing line) and revenues versus DOE investment at companies where there has been significant DOE funding (currently at a ratio of 6:1).

Dr. Satyapal discussed national meetings and partnerships, including the mission and first regional summit of the Clean Energy Manufacturing Initiative (CEMI), a three-year effort with the American Energy & Manufacturing Competitiveness Partnership, plans for a workshop on quality control/assurance and metrology in manufacturing processes, results from the HTAC Hydrogen Production Expert Panel Workshop, and the establishment of a DOE-wide Fuel Cells Tech Team. She provided an overview of international partnerships, such as collaborations with the International Partnership for Hydrogen and Fuel Cells in the Economy and implementing agreements with the International Energy Agency. She also described the recent audit by DOE's Office of the Inspector General (IG). She expressed her appreciation for the valuable inputs of HTAC to date, including the annual reports; input on the DOE hydrogen cost target, H-Prize topics, and Hydrogen Program Plan; the reports of the Energy Storage, Hydrogen Production, and Hydrogen Infrastructure subcommittees; and the ongoing work of the Manufacturing and Hydrogen Retailing subcommittees. She described the proposed Hydrogen Refueler H-Prize criteria (focused on two topics—a home refueler and community-level refueler) and asked for continued HTAC feedback on this, as well as a number of upcoming DOE Requests for Information (RFIs), including (1) an interim (near-term) hydrogen cost target and (2) development of an “hGallon” cost metric, similar to the eGallon cost used for electric vehicles.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_1_satyapal.pdf

Questions, answers, and discussion

- Dr. Shaw stated that the eGallon cost should include all of the relevant pieces, not just the cost of electricity. As with hydrogen, gasoline, diesel, or biofuel, the cost should represent the effective cost per mile on average, including the whole drive-train.
- Mr. Eggert surmised that DOE has done a lot of total-cost-of-ownership analysis, but guessed that it would be difficult to roll all of those data into a single term, given the diversity of the vehicles.
- Mr. Hofmeister pointed out that consumers are most interested in their out-of-pocket costs when they fill up, so a comparable metric to the cost of gasoline per gallon would be useful. He also suggested that a second metric on total cost of ownership would be useful for comparisons over the life cycle (e.g., the ENERGY STAR ratings for appliances).
- Dr. Satyapal replied that DOE does have data on total cost of ownership and could present this at a future HTAC meeting if there is interest. She noted that people often do not understand that the cost of hydrogen includes the infrastructure cost, and making that clear is critical.
- Dr. Lloyd asked if the Hydrogen and Fuel Cells program was singled out during the IG audit for potentially unallowable costs. Dr. Satyapal clarified that this was not the case and that other programs have also been referenced in this regard. She also clarified that the costs cited from several years ago were cited as potentially

unallowable and that the contracting office was still retrieving receipts such as for researcher meals, travel and subcontracts to determine if the costs were actually unallowable.

- Mr. Kaya agreed with Dr. Satyapal's suggestions on topics that HTAC could provide input and noted that there are a number of crosscutting stakeholder initiatives, particularly in the deployment area, that could support the Office of Energy Efficiency and Renewable Energy (EERE) strategic plan and help better tie activities of the Hydrogen and Fuel Cells Program to the Secretary's strategic growth areas.
- Dr. Satyapal agreed and asked Mr. Kaya to bring this up in the next session when Mr. Walsh will be speaking on the status of the EERE Strategic Planning process.

3. Presentation on EERE's Strategic Plan: Jason Walsh, Senior Advisor to the Assistant Secretary, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy

Mr. Walsh presented an overview of EERE's Strategic Plan, beginning with an overview of some of the background and motivations leading up to the creation of the Strategic Plan. The Plan set out to define EERE's vision for the future, provide a framework for the Multi-Year Program Plans developed by EERE offices, and clearly describe the analytical basis for the strategies pursued by EERE. Mr. Walsh's presentation outlined top-level EERE strategic goals. These goals have been consolidated into a set of principles that Mr. Walsh summarized as goals to: "support energy solutions that will make our country more prosperous, make our energy more affordable and clean, make us more secure and independent, and give our consumers access to more options." He concluded by outlining the seven strategic goals as listed in the EERE Strategic Plan.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_2_walsh.pdf

Questions, answers, and discussion

- Mr. Lloyd asked what was meant by the term "government-leading speed" in the EERE strategic goal "Execute our work with government-leading speed, quality, and accountability."
 - Mr. Walsh responded that, since the federal government is the largest employer in the country, this term means that the organization wants to be fast and agile.
- Mr. Lloyd asked about the phrasing used in the EERE strategic context statement for "Environmental Responsibility." He asked why, given the aggressive greenhouse gas reduction targets, the statement used "*minimize* adverse environmental impacts from our energy system..." rather than "*reduce*."
 - Mr. Walsh agreed this was a fair point on choice of words and noted that the Strategic Plan will communicate the urgency of reducing greenhouse gases and the fact that this will animate much of EERE's activities.
- Mr. Kaya asked how HTAC and other DOE advisory committees, which comprise a broad representation of stakeholder groups and expertise, can be effective in helping EERE with its strategic planning process.
 - Mr. Walsh replied that DOE valued this opportunity to engage HTAC. He noted that several workshops have been held to engage stakeholders in transportation, renewable power, and energy efficiency, but there is a time constraint how on much of this can be done. He also noted that a section of the Plan will focus on EERE partnerships, which are at the core of most of EERE's activities.
- Dr. Shaw noted that the current Strategic Plan does not seem to address a key barrier he sees in the energy sector: overcoming institutional barriers in the incumbent energy industries and

convincing consumers and makers of products that alternative energy is the way to go and the business case will work.

- Mr. Walsh agreed that there is no obvious place for addressing market barriers in the EERE strategic goals that he presented, but that addressing these barriers will be included in various sections of the Plan, since it is embedded in how EERE works with its partners to bring technologies to market. He noted that EERE does produce communication and training products to help build a skilled workforce and provide clear information on the value, and money-saving nature, of renewable and energy efficient technologies.
- Mr. Rose noted that DOE and EERE have a transformational role to play and encouraged Mr. Walsh not to shy away from passionate, mission-oriented statements in the Plan.
- Mr. Hofmeister made the recommendation that Mr. Walsh do everything he can to emphasize the aspect of affordability in the Plan.

4. Overview of the National Renewable Energy Laboratory and the NREL Fuel Cell and Hydrogen Technologies Program

4.1. Dr. Dana Christensen, Deputy Laboratory Director, Science & Technology, National Renewable Energy Laboratory

Dr. Christensen provided a snapshot of NREL's physical assets (including the new Energy Systems Integration Facility, or ESIF), mission, and program funding sources for FY 2012 (totaling \$352 million). He noted that funding sources for NREL's Fuel Cell and Hydrogen Technologies (FCHT) Program continue to grow through diversification of funding sources by broadening the program's R&D focus. He concluded with an overview of FCHT Program objectives, budget from 1999–2014, and office structure.

>> *see full presentation*

at http://www.hydrogen.energy.gov/pdfs/htac_oct13_3_christensen_wipke.pdf

Questions, answers, and discussion

- Mr. Hofmeister asked what international activities are being conducted at the laboratory.
 - Dr. Christensen responded that there is more international work in the renewable energy area than the energy efficiency area, particularly solar work with Germany and wind work with Ireland. NREL is currently working on the US-Indo partnership with India on solar deployment. NREL is also starting up a new research program with Saudi Arabia on both renewables and solar, primarily with solar. NREL also has staff stationed in China and Guam and works in collaboration with Japan, including with the National Institute of Advanced Industrial Science and Technology (AIST), and also with the Fraunhofer Institute in Germany.
- Dr. Shaw noted that the energy efficiency and cost to build the ESIF building at NREL (\$260/ft²) is very impressive and should be used as an educational tool for architects, university facility managers, city planners, and others. He noted that universities, in particular, could benefit because they build many buildings. He cited Cornell, where he serves on the Engineering College Council, as one example.
 - Dr. Christensen said he would be happy to meet with the Cornell Engineering College or others. He noted that NREL hosts numerous tours of the facility and has in fact built in “tour paths” and viewing windows so that visitors can see key ongoing work in research laboratories and renewable and energy efficiency aspects of the facility. NREL also produces seminars for the building community to show that this can be done.

4.2. **Keith Wipke, Program Manager, Fuel Cell and Hydrogen Technologies Program, National Renewable Energy Laboratory**

Mr. Wipke presented NREL's unique approach to photoelectrolysis that utilizes state-of-the-art III-V semiconductor materials. He noted that NREL is also developing photobiological systems for large-scale hydrogen production from water that photoproduce hydrogen in the presence of higher oxygen concentrations. He described NREL's research on improving fuel cells that focuses on catalysis, polymer electrolytes, electrodes/contaminants, and manufacturing. He discussed NREL's efforts in technology validation in real-world settings; market transformation; and guidance on safety, codes, and standards. He concluded with a description of NREL's hydrogen and fuel cell partnerships across the United States, in Japan, and in the United Kingdom as NREL's first-class laboratory facilities, highlighting the ESIF and the recently launched National Fuel Cell Technology Evaluation Center (NFCTEC) designed for the secure management, storage, and processing of fuel cell technologies data.

>> *see full presentation*

at http://www.hydrogen.energy.gov/pdfs/htac_oct13_3_christensen_wipke.pdf

Questions, answers, and discussion

- Dr. Lloyd asked, given all of the opportunities at NREL, does it see the organization growing, and if so, to what size?
 - Mr. Wipke responded that increasing the number of staff at NREL is not a goal; rather, NREL is seeking to help increase connectivity with the marketplace and will work to increase partnerships with universities and industry to help move technology more quickly into the marketplace.
- Mr. Kaya asked why NREL's Market Transformation program showed several years of lower (or no) funding, despite this being cited as an important area of emphasis for the laboratory. He elaborated, asking what is being done for outreach in this area to enable industry or government partnerships to address the needs of systems integration, an area that is becoming increasingly important in many states and regions.
 - Mr. Wipke noted that the ESIF is a designated user facility, and as such, NREL can issue solicitations and provide funding to awardees that use the facility. He also stated that DOE helps underwrite the base cost of the laboratory, which helps to defray the cost of companies or individuals that want to do work at the facility. NREL is also being proactive by hiring staff with industry experience to bring more skills into project areas and reinforce market connectivity. Mr. Wipke noted that technology transfer and industrial deployment is a key goal of Secretary Moniz, so he expects this type of activity to be included in the laboratory's future Annual Operating Plans.
- Dr. Lipman asked if there are plans to continue the DOE Learning Demonstration for vehicle technologies.
 - Mr. Wipke stated that NREL is working with DOE on a follow-on project. The first project was a seven-year effort that coupled the vehicles to infrastructure and required an automotive company to be teamed with an infrastructure provider. The second project does not require this teaming, but it is collecting data and disseminating composite results in the same way from participating fueling stations and vehicles, many of which are providing NREL with data on a voluntary (unpaid) basis.

5. NREL’s National Fuel Cell Technology Evaluation Center (NFCTEC): Jen Kurtz, Group Manager, National Renewable Energy Laboratory

Ms. Kurtz described the launch of the NFCTEC, which is a national resource for hydrogen and fuel cell stakeholders, enabling the independent and secure analysis of fuel cell electric vehicle and hydrogen fueling station technologies data. She noted that the center provides industry with data to confirm component and system technical targets; validate technology; and evaluate, optimize, and demonstrate integrated energy systems and real-world operation. NFCTEC receives bundled data and internally analyzes the data quarterly, providing results in the form of both detailed data products (shared only with the partner who supplied the data) and composite (aggregated) data products without revealing proprietary data. She described how data process and analysis capabilities are being leveraged across technology validation projects, including buses, cars, infrastructure, forklifts, stack, and backup and prime power as well as the status of these technologies in progressing toward targets and market needs. This real-world data provides status, trends, and gaps to key stakeholders.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_4_kurtz.pdf

Questions, answers, and discussion

- Mr. Eggert noted that the metric presented for fuel cell durability, which DOE sometimes uses for “current status,” is based on older technology and may not represent the true current status of technology.
 - Ms. Kurtz agreed that gathering data from technology in the field means that the technology has already been in development for at least four or five years, creating a lag in the reporting that is possible. To address this issue, DOE is also collecting data on laboratory-scale, single-stack testing, and DOE reports this durability data as well as the historical data.
- Dr. Shaw asked how NFCTEC keeps track of the users of its data and how it evaluates that users are getting what they need from the data. Would users be willing to support this without DOE funding?
 - Ms. Kurtz responded that there is a lot of value in this data, but it is difficult to track because only the composite data products are published. Most of the Center’s analysis results are never published because the data from individual companies are proprietary and the analyses are provided directly back to the data providers. She noted that several companies provide NREL with more data than contractually obligated, because they see value in NREL’s analysis and insights. She also noted that NREL has a team dedicated to data analysis and tools to process data very quickly to track and report on standard statistics every month. She clarified that before starting with this next generation of fuel cell vehicle analysis, the team reviewed past results to see what users found most useful in the past. Ms. Kurtz reiterated her belief that users would continue to support this level of activity, though some of the reasons may not be visible through published works.

6. EERE’s Work on Grid Integration: Kevin Lynn, Director, Energy Systems Integration, U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy

Mr. Lynn presented the objectives of the DOE Grid Tech Team (GTT), which is responsible for leading a holistic approach to grid modernization through strategic thinking; improved communication, coordination, and collaboration; and understanding the integration of solar, wind, vehicles, and buildings on the grid. He noted that GTT has wide representation within DOE to achieve a more resilient and capable grid system. He explained that for EERE to fulfill its mission, it must address integration of energy efficiency and renewable energy technologies into the grid at scale. He explained that as hardware prices for technologies fall, it is increasingly

important to address deployment challenges. He described EERE's goal of 80% renewable energy by 2050, with more than 50% from wind and solar, and reduced oil imports by 33% by 2025. Mr. Lynn explained the Energy Systems Integration (ESI) concept, which is to utilize clean energy sources while maintaining reliability at an affordable cost. He discussed the technical and institutional challenges associated with integrating EERE technologies into the grid at scale and how transaction-based controls, being developed by the Building Technologies Office and Office of Electricity, are control solutions that will allow operational decisions to be based on market signals. He outlined specific ESI activities by technology office within EERE. He concluded with a summary of several renewable energy projects: Solar Energy Grid Integration Systems—Advanced Concepts, Solar Resource Forecasting, Wind Forecast Improvement Project, and Western Wind and Solar Integration Study Phase 2.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_5_lynn.pdf

Questions, answers, and discussion

- Mr. Kaya noted that Mr. Lynn's work is extremely urgent and important and pointed out that the Big Island of Hawaii is generating up to about 50% of its power from solar and wind alone (mostly wind), and that the island of Maui is at about 35% (with the majority through distributed solar). He agreed that the business aspects of increasing renewable energy on the grid are important, and that sending the right signals and helping the market adjust to new demands is really significant. He asked Mr. Lynn about his team's thoughts on what is necessary in this regard. He added that there may be no one-size-fits-all answer, because the responses and solutions could be very site- or situation-specific. He noted the example of companies today that are developing technologies for energy storage and the smart grid integration that is necessary; this will not make sense unless there is a rate structure that makes this advantageous for the entire system and for the business of running the utility. He stated that solving these issues will require leadership and convening of disparate interests.
 - Mr. Lynn noted that many people have asked for DOE's vision on what a future electric system would look like, and a lot of that would depend on what one's answer is for energy storage. And while it is necessary to have a vision of what the future energy system is going to be in order to make decisions today to get to that vision, DOE needs to be very careful about creating that vision, because there are so many different players in the field, and they all have their own different vision of what the future looks like. For example, Hawaii's vision is very different than the Southeast's vision. Therefore, DOE's role is to be able to inform and create tools that help people understand the impacts of different decisions, or help people choose the actions or technologies that will help them to meet their particular goals.
- Mr. Eggert applauded DOE for taking up the issue of grid systems integration, because he believes these factors will largely determine the ultimate success of renewables and efficiency. Noting that Mr. Lynn included institutional factors as a component of his team's work, Mr. Eggert asked if he anticipates looking into potential low-cost futures and specific policies that could achieve those.
 - Mr. Lynn spoke to the specific example of distributed generation and the policy issues surrounding how a Public Utility Commission or other authority can enable the existing utility infrastructure to be paid for while these new technologies are taking away their existing revenue streams. This is a big issue in Germany, where the largest utility is looking at a new business model of just owning the wires and distribution system. In the United States, states such as California, Hawaii, Colorado, Arizona, and Minnesota are developing their own regulations based on their assumptions around value, cost, and acceptable price of energy today. Again, DOE seeks to play an informational role by

developing tools that can be used for decision making, taking into account different regional aspects.

- Dr. Shaw questioned why utilities do not include these new technologies as part of their business models rather than in opposition to or competition with them. He recognizes that there are some regulatory challenges to doing this, but he argued that these could be addressed if the different stakeholders worked together. He noted that there is a business opportunity in large-scale storage of renewable energy, which he assumes could be done by the utility under the current regulatory environment, but he has not heard utilities talking about this. He suggested that establishing a dialogue on these topics would be a useful role for DOE.
 - Mr. Lynn noted that many utilities have conducted business the same way for many years, and to adopt a new business model or new business area is risky. Many utilities are very risk averse. But others are looking into pulling together different power generation resources such as solar, combined heat and power, and natural gas to provide energy services.
- Mr. Novachek commented on a recent paper by the Edison Electric Institute that focused on issues surrounding net metering, noting that it delved into a question of equity and whether some utility customers are subsidizing others (those with distributed solar power). He commented on Mr. Lynn's slide 13 (titled "Challenges to Integrating EERE Technologies into the Grid at Scale"), saying that it misses two key aspects: (1) the degree of distributiveness and (2) affordability. He pointed out that it will be more expensive to mitigate the effects of solar photovoltaics at the end of a utility's feeders than dealing with them within the grid at larger nodes, where the utility can get some economies of scale for the solar. He added that large-scale solar at the end of a feeder will create problems upstream. He suggested that it would be very valuable if Mr. Lynn's team could work toward addressing the challenges by optimizing on the four dimensions. This could help utilities to identify the scale of things that need to be looked at to provide the best value for society.
- Chairman Hofmeister recognized that the motivation for this work starts with the DOE goal of 80% renewable energy by 2050. He noted that 2050 is only 37 years from now, less than the life of one power plant being built today. From an outsider's business perspective, meeting this 80% goal does not seem realistic. He suggested that DOE look at this from three perspectives: (1) regulatory, (2) geographic (metropolis/city/suburban/urban/rural; state; and regional), and (3) commercial (because utilities will want to get full payment for their investments in infrastructure).
 - Mr. Lynn agreed that all of these perspectives are important and that the decisions adopted by different cities, states, or regions can be very diverse.

7. H₂USA Partnership Overview: Morry Markowitz, President & Executive Director, Fuel Cell and Hydrogen Energy Association

Mr. Markowitz presented the mission and goals of H₂USA, which is to promote the commercial introduction and widespread adoption of fuel cell electric vehicles by establishing a hydrogen infrastructure. He provided an organizational chart outlining the steering committees and the responsibilities of the committee's four working groups. He detailed how the collaboration needs a broad spectrum of participants to be successful, including pure retail organizations that have no stake in the products themselves. He listed the 26 signatories on the Letter of Understanding, which include automotive companies, industrial gas producers, trade associations, nonprofit industry-government partnership organizations, fuel cell suppliers, financial companies, and federal and state government agencies. He concluded with a description of the group's key action areas: financing infrastructure, hydrogen fueling capability, market support and acceleration, and locations roadmap.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_6_markowitz.pdf

Questions, answers, and discussion

- Dr. Thompson asked how an organization becomes an H₂USA member.
 - Mr. Markowitz explained that the steering committee is working on formal criteria now, but that this is an organization established to conduct work, and participating organizations have committed to contribute both financially and with manpower toward the goal of meeting the H₂USA mission and goals.
- Chairman Hofmeister suggested that H₂USA target participation of the big fuel retail organizations, such as Wawa, Costco, Wal-Mart, and Safeway. He suggested that the name-brand oil companies are likely not good candidates, since they are focused on protecting their refinery investments and they have no interest in paying for infrastructure at privately owned fueling stations.
- Chairman Hofmeister also noted that the National Petroleum Council serves the Secretary of Energy, and if he is interested in pulsing the large oil companies about hydrogen he could ask them to answer a specific question.
- Mr. Eggert commented that even with the passage of AB-8 by the California legislature (which will make \$100 million available for hydrogen infrastructure and \$2.2 billion for across-the-board advanced vehicle technologies and low-carbon fuels), there is still a lot of skepticism about the viability of a transition to hydrogen fuel cells within the state. He asked whether one of H₂USA's roles is to provide information; for example, by having members meet with California legislators to answer questions. He also asked how H₂USA collaborates with the California Fuel Cell Partnership (CaFCP).
 - Mr. Markowitz responded that CaFCP is part of H₂USA's Operational Steering Committee. If asked by CaFCP or a coalition of the group's members, H₂USA would send representatives to California to speak with legislators or others. Because H₂USA is a new organization, it is just getting started on activities such as creating a website, fact sheets, questions and answers, and other outreach products, but there are teams working on this. He noted that H₂USA will need to target its direct outreach to high-priority groups, such as first responders and state and local government associations, especially in the areas targeted by automakers for initial fuel cell electric vehicle rollout.
- Dr. Shaw commented that the group should actively engage representatives from the financial industry.
 - Mr. Markowitz agreed and said they are seeking to recruit a consultant from the financial community to serve as the Chairman of the Financing Infrastructure Working Group. He added that Jay Keller is chairing the Market Support and Acceleration Working Group, Karen Hall is chairing the Hydrogen Fueling Station Working Group, and Joel Rinebold is Chair of the Locations Roadmap Working Group. He noted that H₂USA is also trying to recruit a member from the American Gas Association.
- Chairman Hofmeister noted that one issue with the franchises of the big-name oil companies is that their franchise agreement prohibits the sale of any fuels not sanctioned by the franchisor under the canopy.

8. Subcommittee Updates

8.1. Hydrogen Infrastructure Subcommittee Report, Robert Rose, HTAC Member

Mr. Rose reported on the status of the report from the retired ad hoc HTAC Subcommittee on Hydrogen Infrastructure. He noted that the report was approved for publication at the last HTAC meeting, with some recommended revisions. Because there has been so much progress in 2013, in both the understanding of hydrogen's benefits as a

fuel and in infrastructure development activities around the world, he feels that the report has been overtaken by events and does not accurately convey the progress and momentum that exists now. He suggested three options for publishing the report: (1) reconvene the subcommittee and start over again; (2) task Mr. Rose with revising the report as written to reflect recent progress; or (3) send the recommendations in the report to the Secretary, along with a letter describing progress on hydrogen infrastructure.

He reported that he had made some minor revisions to the report's recommendations to make them stronger, which are shown in slide 5 of his presentation. The main change he suggested was to delete the 5th recommendation calling for a National Energy Policy, because that does not seem likely.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_7_rose.pdf

Questions, answers, and discussion

- Mr. Freese objected to deleting the 5th recommendation regarding a National Energy Policy, saying that a constancy of purpose is lacking in the United States. He argued that the recommendation should be made, even if it is not likely to be adopted. Mr. Rose suggested that if the recommendation is kept, the language should be strengthened to make it clearer.
- Dr. Satyapal expressed concern about submitting an outdated report on infrastructure to the Secretary, but supported the transmittal of the Committee's recommendations on infrastructure along with a letter conveying recent progress, including H₂USA. She noted that because the landscape is quickly changing, it would be good to get the information quickly to the Secretary.
- Chairman Hofmeister noted that HTAC has commissioned a new subcommittee on Retail Fueling Infrastructure, so the Committee will be continuing to look into infrastructure. There are also the recently completed reports of the Renewable Subcommittee, and the work that is just getting underway in the Manufacturing Subcommittee. He suggested that key findings from these subcommittees could be presented in the next HTAC annual report.
- After discussion from members about how and to whom (Secretary Moniz or Assistant Secretary Danielson) to submit the recommendations on infrastructure, the Committee decided on the following:
 - HTAC approved the recommendations as re-drafted by Mr. Rose. Mr. Rose will strengthen the language and replace the recommendation to include hydrogen infrastructure as part of a National Energy Policy.
 - HTAC authorized a subcommittee led by Mr. Rose, Dr. Taylor, and Chairman Hofmeister to produce a letter (no more than three pages) transmitting the recommendations to Secretary Moniz, and suggested that the letter be drafted in three weeks.
 - The draft letter will be reviewed for substantive issues by Mr. Eggert, Dr. Shaw, and Dr. Lloyd, after which it will be delivered to DOE.
 - The letter will be informational in nature and include updates on progress in the United States and internationally, lowering of costs, synergies with natural gas, and establishment of H₂USA. It should convey that while progress has been rapid and substantial, this is still a fragile time period in the evolution of markets, and this is a key opportunity for DOE to engage and make a real difference.

8.2. Hydrogen Enabling Renewables Subcommittee Report, Frank Novachek, HTAC Member

Mr. Novachek reported that he had distributed the final draft report of the Subcommittee on Hydrogen Enabling Renewables to all of the HTAC members for final review prior to this meeting. Some comments were received and incorporated, but none were significant material comments that need to be reviewed by the full Committee. Therefore, Mr. Novachek considers the report to be final and ready for publication.

- HTAC moved to accept the report as final and to deliver it to the Secretary.
- Chairman Hofmeister will produce the transmittal letter for the report using the cover letter that Mr. Novachek wrote to transmit the final draft to HTAC.
- Dr. Satyapal will check into whether the report can be distributed publicly or posted to the HTAC website before the Committee receives a response from the Secretary. Until then, the report should not be distributed outside of HTAC.

8.3. Manufacturing Subcommittee Report, Hal Koyama, HTAC Member

Mr. Koyama reported on the Subcommittee on Manufacturing, whose mission is to investigate potential opportunities for advanced manufacturing to benefit hydrogen and fuel cell production and commercialization. He listed the 16 members of the subcommittee, which include non-HTAC subject matter experts from industry and national laboratories. He described the subcommittee's focus and process and some of the activities undertaken since it was formed, including an initial survey of the hydrogen and fuel cells industry and some literature reviews. He presented a summary of the initial feedback received from industry (see slide 6 of his presentation) and described the subcommittee's next steps: (1) present a webinar for the members on the status of additive manufacturing; (2) launch a broader questionnaire process and conduct follow-up interviews (targeting hydrogen producers, fuel cell stack suppliers and integrators, and other key fuel cell or hydrogen fueling system component suppliers); (3) prepare and present a presentation on advanced manufacturing at the next HTAC meeting; and (4) prepare a report summarizing key findings and recommendations.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_8_koyama.pdf

DAY 2 – OCTOBER 30, 2013

The second day of the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) meeting began at 8:04 a.m. (MDT).

9. Hydrogen Production: Overview, Dr. John Turner, Research Fellow, National Renewable Energy Laboratory

Dr. Turner presented on sustainable paths to a hydrogen economy. He discussed today's primary routes for producing hydrogen (primarily steam methane reforming) and consuming hydrogen (primarily petroleum recovery and refining and ammonia production). He overviewed the various sustainable hydrogen pathways currently in research and development (R&D), including solar-thermal water splitting, electrolysis with renewable (wind/solar/geothermal/hydro/nuclear) power, reforming of biomass-derived liquids or gases, photoelectrochemical (PEC) and photobiological water-splitting, and direct-fermentation hydrogen production. He also recognized the recent work of the HTAC subcommittee on hydrogen production, noting that the Hydrogen Production Expert Panel's report includes a number of recommendations on R&D priorities for hydrogen

production, as well as opportunities for coordination among Federal agencies and offices to optimize effectiveness of the R&D portfolio.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_9_turner.pdf

Questions, answers, and discussion

- Mr. Eggert noted that the hydrogen production cost models presented to HTAC indicate that biomass could be one of the lowest cost pathways to renewable hydrogen. He asked whether enough R&D is being done on different biomass-to-hydrogen pathways to realize this potential.
 - Dr. Turner replied that, in his opinion, there is currently not enough investment in any of the hydrogen production pathways to realize their full benefits.
 - Mr. Eggert asked a follow-up question: which is the more promising pathway for investment?
 - Dr. Turner responded that in the near-term, the lowest cost options are electrolysis and bio-derived hydrogen. He added that a vision of the ultimate application(s) for hydrogen would be needed in answering this question, since the scale of production helps determine the best pathway to choose.
- Dr. Lipman asked if NREL is actively investigating high-temperature electrolysis.
 - Dr. Turner responded that NREL is not currently working in that area, and added that the solar-thermal program is currently investigating chemical cycles.
- Dr. Lipman asked about the use of heat sources such as a geothermal source or a nuclear cycle.
 - Dr. Turner replied that nuclear cycles may work, but geothermal sources may not be hot enough.
- Mr. Chalk asked how close the PEC efficiency target of 25% is to the theoretical limit and whether there was a pathway from the current 12.5% efficiency to 25%.
 - Dr. Turner replied that the theoretical efficiency limit is “in the thirties.” He cited a recent paper from the Joint Center for Artificial Photosynthesis (JCAP) that modeled various types of resistive and kinetic losses. The paper presented realizable efficiencies in the 25% range; however, current designs require the use of expensive materials, so research is needed to lower costs.

10. Current Hydrogen Cost, Brian Bonner and Ed Kiczek, Air Products

Mr. Kiczek gave an overview of Air Products’ current hydrogen production costs. Air Products is a global provider of atmospheric, process and specialty gases, performance materials, equipment and services, with over 50 years of hydrogen experience and is the world’s largest producer of merchant hydrogen. The company’s 160 hydrogen fueling stations now provide over 850,000 fuelings/year, and they expect to reach 1,000,000 by the end of 2013. He outlined the company’s lessons learned with hydrogen fueling infrastructure including the need to improve hydrogen delivery technologies; reduce fueling station maintenance costs; make station technologies simple, modular, and expandable; piggyback on existing assets; and work towards high variable, low fixed cost options. He explained Air Products’ preference for station design options that enable elimination of on-site compression, which add significantly to both fixed and operating costs. Mr. Kiczek presented data on feedstock costs for hydrogen production today (electricity and natural gas), and Air Products’ conclusion that electrolysis is cost-prohibitive at on-site fueling stations due to the high cost of electricity. However, he added that gaseous hydrogen (GH₂) production from steam methane reforming (SMR) using the latest technology advancements is competitive with gasoline, especially if the hydrogen is produced at a large plant with co-production of steam and power and delivered to the fueling station at high pressure. He

stated that while composite tube trailer delivery pressures are currently limited to 7,500 psi (due to Department of Transportation regulations), Air Products has technology that can deliver at 10,000 psi and is working on technology that can deliver at 14,000 psi. He reviewed the various components of hydrogen cost (feedstock, production, distribution, station equipment, and operations). He stated that today, Air Products' dispensed cost of hydrogen is \$8/kg (at a 150-200 kg/day GH2 station, hydrogen produced by central SMR and delivered to the station by tube trailer truck). This is equivalent to \$3.50/gallon of gasoline in a 30 mile-per-gallon car. He noted that the lowest-cost production option is a large-scale natural gas/biogas refinery that can supply hydrogen via pipeline to multiple customers, as well as power and steam. He stated that biogas conversion is the lowest cost renewable option for producing hydrogen today; it adds about \$1 to the price of dispensed hydrogen. He presented data on U.S. biogas resources that showed the potential for biogas to fuel 210 million cars.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_10_bonner.pdf

Questions, answers, and discussion

- Mr. Freese asked about Mr. Kiczek's chart comparing natural gas and electricity costs. He asked why electrolysis was ruled out by Air Products, and how his analysis would be modified for areas with a lot of wind or solar energy generation, or an unreliable electric grid.
 - Mr. Kiczek replied that there are niche applications for electrolysis, but Air Products is looking at mass market applications in California and, more broadly, the United States.
- Dr. Lipman asked how the SMR plant shown would support both electricity and steam production as well as hydrogen production.
 - Mr. Kiczek explained that multiple products are typically produced by large SMR systems to maximize system efficiency, and that steam turbines are used to generate electricity.
- Dr. Thompson noted that Air Products' conclusions on hydrogen production costs differed from those in the NREL presentation delivered to HTAC the previous day.
 - Mr. Kiczek stated that his presentation focused on today's costs, while NREL's presentation showed projected costs based on future larger volume hydrogen demand and larger scale manufacturing of the electrolyzers and other on-site equipment. Air Products believes it will take 15-20 years to reach that point.
- Mr. Eggert asked for ideas on shortening the current hydrogen fueling station construction schedule, noting that HTAC has been told that it typically takes two to three years to get a station permitted and built.
 - Mr. Kiczek replied that the primary issue with getting stations built in one to two years is permitting. The Authorities Having Jurisdiction (AHJs) are often uncomfortable with approving the permits since this is a new technology – any problems with a station will come back to them. He explained that in material handling applications, Air Products has built stations in as little as eight weeks. In California, Air Products plans to use the same exact station design for the ten stations in planning, which they hope will expedite the permitting process. Air Products has also already gone through the process of having all their station components third-party certified (through UL listings, etc.), so that will also help.
- Dr. Shaw asked about the accuracy of meters in monitoring the quantity of hydrogen dispensed to the vehicle.
 - Mr. Kiczek replied that current metering technologies are about +/- 2-4% accurate. He noted that California is deciding on an appropriate standard (likely in the +/- 3-5% range) for hydrogen dispensing until better metering technology is developed.

- Dr. Satyapal added that DOE is involved in follow-up discussions with California and the National Institute of Technology and Standards about metering and she will keep HTAC informed on any developments. Her office has also issued a Funding Opportunity Announcement for R&D on metering technology.
 - Mr. Wipke from NREL added that NREL has just started a project at the wind-to-hydrogen facility to measure the accuracy and repeatability of various hydrogen dispensing and metering systems.
- Mr. Chalk asked if Air Products' \$8/kg delivered cost estimate included all of the “soft costs,” such as station siting and permitting. He also asked about the maximum economical distance between the SMR production facility and a fueling station.
 - Mr. Kizcek replied that the \$8/kg is fully costed, that is, it includes all costs, including the typical profit margins for Air Products and the fuel retailer. The maximum distance for delivery of hydrogen to a station via high-pressure composite tube trailer is about 150 miles, but Air Products can place a dual-phase liquid trailer anywhere in the country, as a “mobile fueler” for smaller composite tube trailers, though this would make the hydrogen more expensive.

11. Hydrogen Production Potential Impacts to Utilities, Frank Novachek, Director of Corporate Planning, Xcel Energy

Mr. Novachek presented on the potential impacts of hydrogen production on utilities. He began with a discussion of the two most available hydrogen production methods today—electrolysis and natural gas reformation. He clarified that there are different types of utilities, e.g., electric generation, transmission, and distribution; gas transmission and distribution; and combined gas and electric, and each will view the production of hydrogen differently. He detailed the potential impacts of hydrogen production on the electric system, describing the impacts on systems operations, renewables integration, and electric loads (especially with electrolysis, which requires 43–63 kW/kg of hydrogen produced). He noted that increased loads for electrolysis systems are not a problem for most electric utilities. He explained other unique opportunities that hydrogen production can provide to electric utilities, including the ability of electrolysis systems to deliver regulation services since they are interruptible and dispatchable. Hydrogen production can also help integrate renewable power generation, by increasing off-peak demand for electricity, assisting with variability mitigation, and providing energy storage in situations where more than three weeks of storage is required for grid reliability or other reasons. He reported on the potential impacts of hydrogen production on the gas utility system, including the LDC fuel supply, gas system regulation, and gas infrastructure. Mr. Novachek described the unique opportunities hydrogen production could provide to gas utilities, including increased throughput and contributing to reserves or special pressure or gas quality requirements. He concluded by saying that utilities are well-positioned to be an enabler of the hydrogen economy.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_11_novachek.pdf

Questions, answers, and discussion

- Mr. Hofmeister asked how and when hydrogen is removed from the natural gas flow once added.
 - Mr. Kaya responded, saying that the methodology for separation is not finalized, but there are several possible methods depending on the hydrogen and natural gas mixture.
 - Dr. Satyapal referred to the findings of a DOE-sponsored report on hydrogen injection into the natural gas pipeline, which were previously presented to HTAC. The report found that up to 15% hydrogen can be safely injected into a natural gas pipeline. Several methods of hydrogen separation were explored; at low pressures, it is not economical.

However, it can be economical when the pipeline system is at higher pressures, such as at pressure-letdown stations.

- Dr. Flood noted that in Germany, hydrogen produced from excess wind power is being stored in former natural gas caverns and introduced into the natural gas system to enrich the gas stream; as long as the hydrogen content is under 15% it is alright to use it in conventional natural gas appliances.
- Dr. Lloyd asked whether there are criteria for whether and how much hydrogen can be injected based on the quality or age of a natural pipeline.
 - Mr. Novacheck stated that he is not aware of specific criteria established for this, and agreed that it might be a good area of study for NREL or another group. He added that all natural gas utilities have ongoing pipeline upgrade programs, but most probably do not consider the need to accommodate higher levels of hydrogen.
- Mr. Rose asked whether utilities would be willing to pay for any of the “unique opportunities” described by Mr. Novachek.
 - Mr. Novachek stated that there are prices for system regulation and ancillary services already, for example those set by the Midwest ISO and California ISO. Renewables integration has also been assigned a value (as a function of the penetration of renewables on the system). Xcel Energy has not yet filed reports on the value of energy storage. He mentioned that NREL has initiated a study on the value of an energy storage system as a function of the penetration of renewables on a system.

12. Techno-Economic Analysis of Hydrogen Production Pathways, Brian D. James, Strategic Analysis Inc.

Mr. James provided an overview of recent techno-economic analyses of hydrogen production and delivery pathways. He reviewed the overall purpose of the analyses—to determine the most economical and feasible production pathways, identify technical bottlenecks and key cost drivers, assess technical progress towards DOE cost goals, and identify R&D priorities. He reviewed the H2A Production Model, which is the primary analysis tool for projecting the cost/kg of hydrogen and cost sensitivities. He explained that the H2A model is a discounted cash flow analysis tool that computes the required price of hydrogen for a desired after-tax internal rate of return (nominally 10%). He described the various hydrogen production technologies that have been analyzed using H2A, and provided details on recent H2A proton exchange membrane (PEM) electrolysis case studies based on detailed information provided by four electrolyzer companies on current and projected future technology. He clarified that “current” means the technology is either available today but in limited use, or has been demonstrated and could be inserted into the next generation product, and the costs are projected to high-volume (1,500 kg/day stations and manufacturing rates of hundreds of electrolysis units/year). He reported that the latest H2A analyses of current electrolysis technology projects hydrogen costs in the range of \$4–\$5/kg, significantly lower than “existing” (best available off-the-shelf systems today) PEM electrolysis systems, which have costs of about \$11/kg. He presented sensitivity charts showing that electrolytic hydrogen costs are predominantly influenced by the cost of electricity, but are also significantly affected by electrolyzer efficiency and equipment capital costs. With regard to capital cost drivers, he reported that the stack, power electronics, and gas management systems make up 71% of the electrolyzer system cost.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_12_ramsden_james.pdf

Questions, answers, and discussion

- Mr. Lloyd asked if all four electrolyzer companies provided data used to develop the “existing” cost estimate of \$11/kg and Mr. James replied that they did.

13. JCAP Research Overview for HTAC, Carl Koval, Director, Joint Center for Artificial Photosynthesis

Dr. Koval reported on work being performed by the Joint Center for Artificial Photosynthesis (JCAP), the nation's largest research program dedicated to the development of an artificial solar-fuel generation technology established as a U.S. Department of Energy Innovation Hub. He described JCAP's goals to find a cost-effective method to produce fuels using only sunlight, water, and carbon dioxide inputs. He described JCAP's five-year goal to discover and assemble an artificial photosynthetic system. Dr. Koval highlighted JCAP's approach to artificial synthesis, providing an in-depth review of directed research, materials discovery (i.e., high-throughput experimentation and screening), material integration and engineering (i.e., molecular and nanoscale interfaces, and membranes and mesoscale assembly), and benchmarking project for the performance validation of electrocatalysts and photocatalysts. He described JCAP's scientific discovery of a new family of electrocatalysts for the oxygen evolution reaction (OER). He explained that, using a testbed system, solar-powered water splitting with the new OER catalyst was demonstrated for 100 hours. He shared JCAP's approach to system integration of solar-fuels generators and prototype designs for the solar-driven, water-splitting device. He also discussed highlights from the group's recent research: modeling of resistive losses, optimization of electrode geometries, solar-fuels generation using water vapor, and development and testing of a recirculating prototype.

>> see full presentation at http://www.hydrogen.energy.gov/pdfs/htac_oct13_13_koval.pdf

Questions, answers, and discussion

- Dr. Shaw asked if JCAP is open to others for testing new catalysts or other technologies.
 - Dr. Koval reported that JCAP will soon be publishing a paper on their benchmarking studies. He noted that JCAP will sign intellectual property protection agreements with others, and researchers have come to JCAP to test their materials or collaborate on innovative ideas. JCAP can also ship their “glassy carbon disk” testing substrate to outsiders so that they can deposit materials for JCAP to use or test.

14. Other HTAC Business

- Chairman Hofmeister asked members to think about the following questions, which he originally asked in the run-up to his accepting the role of HTAC Chairman.
 - Is HTAC getting sufficient visibility?
 - Is HTAC working on sufficient content for what it attempts to do?
 - Is HTAC having the impact it seeks in terms of accomplishing objectives and creating meaningful outcomes?
 - Is HTAC having a meaningful impact with the Secretary?
 - What is HTAC's role in education?
 - Are Committee members keeping each other sufficiently informed of information acquired through their work outside of HTAC?
 - Should HTAC consider the risk of over-analysis or over-education versus getting things done?
- Mr. Chalk reviewed the new EERE organizational structure, and noted that HTAC cuts across all three areas: Energy Efficiency, Renewable Energy, and Sustainable Transportation. While most of the budget for the Department's hydrogen and fuel cells R&D will fall under the new Deputy Assistant Secretary (DAS) for Transportation, Mr. Chalk will continue to be involved with HTAC in his role as the DAS for Renewable Energy. He expressed the Department's appreciation for HTAC's work and inputs, saying that DOE is interested in technical input, but also in input on how DOE can help address market barriers, which is an important and

- expanding role for DOE. He noted that DOE can play an important role in providing credible analysis, facilitating the acceleration of validation by providing open data, and so on. He asked whether developing a uniform template for AHJs would be a useful activity for DOE. He conveyed that one of Secretary Moniz's top priorities is the new Quadrennial Energy Review (QER), which will address the entire DOE energy portfolio, including EERE, Fossil, Nuclear, and Electricity. The QER will be an interagency effort led by DOE's Energy Policy and Systems Analysis (EPSA). He urged HTAC to get involved in the QER development process, as any new energy policy and budget will likely be informed by the QER going forward. He confirmed that the HTAC's reports have definitely been received by Assistant Secretary Danielson, and offered his assistance to the HTAC Chairman on developing additional avenues for communicating with the Secretary.
- Chairman Hofmeister noted that the last Annual Report and accompanying cover letter were submitted to the Secretary in June 2013, so the Secretary's feedback should be coming to HTAC soon.
 - Chairman Hofmeister asked members to offer opinions on any of the above questions or other issues.
 - Dr. Shaw noted that education is very important; a broad education program is needed, since he has observed that even well-educated people have not heard of hydrogen and fuel cells.
 - Mr. Eggert offered his opinion that there is a need for ongoing analytical work, noting that it is relatively cheap and provides additional insights before going to scale-up. With regard to education, he recommended targeting education towards key decisionmakers and policymakers across the state and Federal governments. He added that this needs to be done on an ongoing basis, since these are rotating positions.
 - Mr. Chalk agreed that targeted education is more important and cost-effective than a broad-based program. He recommended that communication activities start with an understanding of what you want the users to do with the information, because positive action is needed. He also urged HTAC members to "be a facilitator for information sharing" and provide people who need information on hydrogen or fuel cells with contacts at DOE.
 - Dr. Shaw suggested that more time be provided for discussion in HTAC meetings, with less time allocated for presentations.
 - Mr. Rose urged the Committee to consider the full breadth of the fuel cell technology family, and not just focus on PEM fuel cells or automotive technology. He noted that the budget for the DOE solid oxide fuel cell research program is in dire straits. He also suggested a survey of HTAC members to assess the "state of HTAC."
 - Dr. Taylor noted that HTAC previously had three in-person meetings annually, and suggested that a question on adding a third meeting be included in the HTAC survey.
 - Dr. Thompson noted that the HTAC has received conflicting information on the cost of hydrogen production from electrolysis, and asked how they could resolve the differences in these conclusions from credible sources.
 - Mr. Chalk replied that DOE would have its analytical team look into this. Dr. Satyapal agreed and noted that the assumptions for the studies need to be better clarified so that the context for the conclusions is understood.
 - Dr. Satyapal mentioned that the Fuel Cell Technologies Office is convening some independent panels, and DOE will be asking HTAC members for input on industry experts to serve on the panels. She also asked the members to provide DOE with input on hydrogen and fuel cell RD&D activities that could be undertaken at NREL's ESIF.

The HTAC meeting was adjourned at 11:48 a.m. , October 30, 2013.

**TWENTY-FIRST MEETING OF THE
HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE (HTAC)**

PARTICIPANT LIST

October 29-30, 2013

HTAC Members Present

- Peter Bond
- Mark Cardillo
- Richard Carlin
- Anthony Eggert
- Gary Flood
- Charles Freese
- John Hofmeister
- Maurice Kaya
- Harol Koyama
- Timothy Lipman
- Alan Lloyd
- Frank Novachek
- Robert Rose
- Robert Shaw
- David Taylor
- Kathleen Taylor
- Levi Thompson

HTAC Members Not Present

- Joan Ogden
- Joe Triompo
- Jan van Dokkum

U.S. Department of Energy Staff - Office of Energy Efficiency and Renewable Energy

- Jesse Adams
- Chris Ainscough
- Jim Alkire
- Steve Chalk
- Josh Eichman
- Rick Farmer
- Monterey Gardiner
- Reid Heffner
- Gregory Kleen
- John Lemmon
- Kevin Lynn
- David Peterson

- Katie Randolph
- Sunita Satyapal (speaker)
- Joseph Stanford
- Reg Tyler
- Jason Walsh (speaker)

Members of the Public in Attendance

- Andrew Bermingham—Montreux Energy, LLC
- Brian Bonner—Air Products and Chemicals, Inc.
- Dana Christensen—National Renewable Energy Laboratory (speaker)
- Adrian Corless, Plug Power Inc.
- Todd Deutch, National Renewable Energy Laboratory
- Brian James—Strategic Analysis, Inc. (speaker)
- Arianna Kalian, ClearEdge Power
- Edward Kiczek—Air Products and Chemicals, Inc. (speaker)
- Carl Koval—California Institute of Technology (speaker)
- Jennifer Kurtz—National Renewable Energy Laboratory (speaker)
- Morry Markowitz—Fuel Cell and Hydrogen Energy Association (speaker)
- Mark Melaina, National Renewable Energy Laboratory
- John A. Patterson, Denver City Council
- Susan Pullman—National Renewable Energy Laboratory
- Todd Ramsden—National Renewable Energy Laboratory
- Anne Shaw—Arete Venture Management
- Neil Snyder, National Renewable Energy Laboratory
- Robert Stokes, Consultant
- George Sverdrup—GMS Consulting, LLC
- John Turner—National Renewable Energy Laboratory (speaker)
- Max Wei—Lawrence Berkeley National Laboratory
- Keith Wipke—National Renewable Energy Laboratory (speaker)

Support Staff

- Dorothy Bunn—Bunn & Associates
- Rachel Davenport—Alliance Technical Services, Inc.
- Shawna McQueen—Energetics Incorporated
- Neil Popovich—National Renewable Energy Laboratory
- Dee Scheaffer—National Renewable Energy Laboratory