HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE MEETING MINUTES
May 4–5, 2017
National Renewable Energy Laboratory (NREL) Conference Room
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DAY 1 – May 4, 2017

Chairman Novachek commenced the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC or Committee) meeting at 9:00 a.m. Eastern Daylight Time (EDT). The meeting began with introductions of new and existing Committee members. The Committee reviewed the draft agenda and it was approved by the full Committee.

1. U.S. Department of Energy (DOE) Sustainable Transportation, Reuben Sarkar, Deputy Assistant Secretary for Sustainable Transportation, Office of Energy Efficiency and Renewable Energy (EERE), DOE

Mr. Sarkar thanked the Committee for their efforts, in particular the recent work by the Safety and Event Response subcommittee to produce a report with recommendations to DOE. He also commended the work of the External Communications subcommittee and their efforts to clarify the benefits of hydrogen and fuel cells and convey the message that battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) is not an "either/or" proposition; rather, both are needed to meet future consumer demands. He spoke about the White House's March 16, 2017, budget proposal and noted that it emphasizes early-stage research. Mr. Sarkar emphasized the need for market-driven goals focused on achieving direct, head-to-head cost competiveness with incumbent technologies, and technology solutions that scale. He noted this requires setting very aggressive technical goals that will require step-changes in technology – not just incremental improvements – upon which DOE will be focusing its efforts. He thanked Acting Assistant Secretary Simmons for attending and for sharing the Administration's perspectives.

Discussion Highlights

- Mr. Sarkar asked the Committee for suggestions on elements that are currently missing from DOE's fuel cell technology portfolio, and for ways to push disruptive technology advances (from both industry- and government-led efforts).

2. DOE Updates and Discussion, Sunita Satyapal, Director, Fuel Cell Technologies Office (FCTO), EERE, DOE

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_01_satyapal.pdf

Dr. Satyapal provided relevant program updates since the last HTAC meeting, including DOE hydrogen and fuel cell recent accomplishments, cost status and targets, and FCTO's efforts to leverage national labs through consortia focused on breakthrough developments in hydrogen production, platinum-free fuel cell catalysts, and hydrogen-at-scale to serve multiple energy sectors. She reviewed the White House's March 2017 budget blueprint language with regard to energy technology research, as well as the recently released FCTO FY17 Omnibus Budget. She also reviewed recent HTAC recommendations to DOE and DOE's responses and asked the Committee for input on strategies for leveraging program funding, especially for later stage research, development, and market acceleration efforts.

3. DOE EERE Welcome, Daniel Simmons, Acting Assistant Secretary, EERE, DOE

Dr. Satyapal introduced Daniel Simmons, recently appointed as the Principal Deputy Assistant Secretary for EERE and now serving as the Acting Assistant Secretary. Mr. Simmons thanked the Committee for their expertise and advice, as well as Chairman Frank Novachek and Vice Chairman Charlie Freese for

their leadership roles in the Committee. He commended the Committee for putting together the HTAC Annual Report, noting that it will be a valuable point of reference for him and for Secretary Perry. He spoke about his experience driving one of DOE's two FCEVs, the Toyota Mirai, noting that energy technology research makes exciting options like this possible. He provided a high-level overview of hydrogen and fuel cell market progress and the impact that DOE- and EERE-funded efforts have made on advancing these technologies and lowering their costs. He cited the language of the White House budget proposal, with its focus on early stage R&D, and noted that FCTO is well-positioned since the bulk of its program is already focused in this area. He assured the Committee that the administration is committed to ensuring access to affordable, reliable energy in order to promote economic growth and energy security and provide the American people with greater access to energy choices. He also expressed his interest in hydrogen and fuel cells regarding a role in continuing the downward trajectory of national criteria air pollutant levels.

Discussion Highlights

- Mr. Eggert noted that FCTO (and EERE in general) has historically done a good job of considering the full chain of lab-to-market, with a focus not just on early-stage R&D but also applied R&D that addresses issues like manufacturing challenges and in-field technology validation that feeds data back to early-stage R&D and the development of market-relevant technology cost and performance targets. He asked for Mr. Simmons' advice on the current direction for early-stage vs. later-stage research and development (R&D).
    - Mr. Simmons stated that, given budget constraints and the Administration's focus of the Federal role on 'early-stage applied R&D,' activities outside of this category will be difficult for DOE to fund.
- Ms. Gobin spoke about Connecticut's air pollution problems and the state's interest in new (and affordable) energy solutions that will help move the mobile source sector to zero emissions. She noted that there are new technologies, like FCEVs, available but their cost is an issue for state fleets. She suggested that DOE help facilitate making FCEV leases (that include fuel in the lease package) available as an option for government fleets.
- Ms. Dunwoody encouraged DOE to keep a focus on advanced heavy-duty vehicle technology (a significant source of particulate air pollution) as the Department moves toward early-stage research and to continue supporting light-duty technology advances. She asked how DOE can continue to partner with states to support their investments in new energy technologies and help bring technologies to market.
    - Mr. Simmons noted that the head of Toyota North America recently visited the Energy Secretary and spoke about Toyota's development and demonstration of a heavy-duty fuel cell truck to move freight inland from Long Beach, CA. Mr. Simmons expressed his interest in seeing ideas such as these flourishing.
- Dr. Powell asked Mr. Simmons about how the national manufacturing institutes (operated under the Manufacturing USA initiative) can interact with fundamental research efforts to accelerate deployment.
    - Dr. Satyapal noted that the morning's presentations by the DOE Advanced Manufacturing Office will provide relevant information on hydrogen- and fuel cell-relevant activities at the institutes, and noted that FCTO is already working closely with IACMI (Institute for Advanced Composites Manufacturing Innovation) and Power America on carbon fiber and semiconductor/power electronic applications, respectively.

- Mr. Markowitz noted the importance of open lines of communication and suggested that Mr. Simmons maintain an open door policy.
    - Mr. Simmons stated his intention to maintain open lines of communications and to meet with as many people as possible.
- Mr. Kodjak commented that, in many countries such as China, Brazil and India, heavy-duty vehicles and buses make up 50–60% of the energy consumed in the transportation sector; this factor is driving an increased focus on more efficient and cleaner heavy-duty technologies. He noted that U.S. policies for heavy-duty vehicles are some of the best in the world, and present a standard for the world to emulate. He also noted that DOE's SuperTruck program contributes technology innovation that will be of global interest in the "race to heavy-duty vehicle technologies of the future."
    - Dr. Satyapal replied that FCTO is participating in a workshop in California this week, focused on technical targets and R&D needs for heavy-duty fuel cell trucks, and the Sustainable Transportation offices are also funding a market segmentation study that will look at the opportunities for different powertrains and fuels in different market segments. She also pointed to recent market activity, such as Toyota's prototype hydrogen fuel cell Class-8 drayage truck with a 240-mile range, and Alstom's first hydrogen fuel cell passenger train, in Germany, with a 500-mile range.
- Mr. Freese noted that the greatest value from hydrogen and fuel cells comes from its cross-cutting capability to provide multiple services in multiple end-use applications. He emphasized the importance of collaboration and the role of DOE in helping to coordinate various stakeholders to enable further development of fuel cell technology and business models that capture these cross-cutting benefits. He noted that GM is working closely with the Department of Defense to capture some of these benefits for military applications.

4. HTAC Discussion

- Mr. Kodjak directed a question on the fuel cell cost target to Mr. Sarkar and Dr. Satyapal, and asked whether the target is set based on achieving parity with gasoline or diesel, or with other low-carbon technologies that are coming online. He suggested that comparison to other low-carbon technologies is more important than comparison to gasoline or diesel.
    - Mr. Sarkar replied that DOE's market segmentation analysis effort has been directed to compare the different advanced powertrains and combinations thereof to the next-best future alternative. He noted that different market segments will likely have different fuel cell cost and durability targets.
    - Dr. Satyapal added that DOE's target-setting approach has become more comprehensive since the fuel cell target was set initially for cost parity to an advanced gasoline engine. Now the cost analysis includes advanced hybrid/electric vehicles, assessment of total cost of ownership, sensitivity/trade-off analysis around various components and system features, and modeling based on different manufacturing volumes. The cost analysis also goes through a very rigorous review during the target setting process.
    - Dr. Azevedo noted that other factors that should be considered in the analysis are public benefits and how consumer choice and behavior would influence the targets, e.g., long-term customer behaviors with respect to fuel choices, energy-efficient technologies, and cost of ownership.
        - Mr. Sarkar agreed and stated that DOE is open to advice on approaches for including behavioral science in its analysis, but noted that the targets are focusing on

head-to-head cost parity so that issues like policies, incentives, and favorable consumer behavior aren't necessary to make the technologies profitable. He added the caveat that value is not equivalent to price, so features that add value for the consumer also need to be considered.

- Mr. Eggert agreed that technologies ultimately have to be profitable, so the cost target is important. However, he asserted that it is also important to understand how technologies compare against each other with respect to providing public benefits such as energy security and environmental benefits, and to consider these factors in setting targets.
- Chairman Novachek asked Mr. Sarkar whether it is appropriate for HTAC to make recommendations that go beyond early-stage R&D, as part of its broader function to serve all of DOE.
    - Mr. Sarkar replied that it is important for HTAC's purview to advise broadly, in alignment with its charter.
- Dr. Powell noted there are existing or proposed polices in many countries that could have a significant impact on vehicle and other energy technologies, and on the market opportunities for companies like Shell. He noted that these countries are considering the economic/competitiveness benefits of the policies as well as the environmental and health benefits.
- Mr. Markowitz noted that with technologies like flat screen televisions there was a market tipping point due to better consumer experience and more value provided. He suggested that looking at case studies of transformational technologies like these could offer lessons for FCEVs and hydrogen.
- Dr. Ayers noted that synergies and interactions among technologies should be taken into consideration in setting R&D targets and developing R&D plans. She noted, for example, that a focus on non-PGM catalysts could cause certain other pathways to be overlooked that might have nearer-term market success. She emphasized thinking about technologies that are building blocks to other technologies.

5. HTAC External Communications Subcommittee, Charlie Freese, HTAC Member

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_02_freese.pdf

Mr. Freese presented on the status of the external communications website, providing updates since the last meeting. He identified key focus areas for messaging in the communications materials, and showed the layout of the website, presenting how the organization and content will help tell the narrative. He highlighted the focus that the website would have on educating the public on fuel cell technologies and infrastructure.

Discussion Highlights

- Dr. Lipman asked about messaging and proposed a narrative of "what does the world look like without fuel cells or electric vehicles," with metrics on important issues like air pollution and public health impacts.
- Mr. Eggert asked about how Mr. Freese plans to drive traffic to the site.
    - Mr. Freese suggested a few ways of driving traffic: ensuring "wow factor" news releases are posted/linked to in a timely manner, using social media like LinkedIn and Twitter, or

hosting short "TED Talk"-type podcasts that provide engaging, routinely released educational videos and generate a regular audience.

- Chairman Novachek proposed adding a "10 Myths about Hydrogen" page.

6. Advanced Manufacturing Office Activities Related to Hydrogen and Fuel Cells, Rob Ivester (presenting for Mark Johnson), Advanced Manufacturing Office (AMO), EERE

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_03_ivester.pdf

Dr. Ivester discussed work being funded by the EERE's Advanced Manufacturing Office (AMO), including activities focused on using energy more efficiently in manufacturing, improving the manufacturability of low technology-readiness-level (TRL) technologies, and increasing the manufacturing-readiness-levels (MRLs) of advanced technologies. Dr. Ivester spoke about job creation with a focus on the "multiplier effect" in advanced manufacturing. He presented the AMO manufacturing bandwidth studies, highlighting the potential for energy savings in energy-intensive industries. He also presented on some of AMO's technology partnership programs, user facilities, and Manufacturing USA consortia (including the Manufacturing Demonstration Facility, Critical Materials Institute, Power America, Clean Energy Smart Manufacturing Innovation Institute, and the Institute for Advanced Composite Manufacturing Innovation) and highlighted several AMO R&D projects including advanced additive manufacturing techniques and materials research.

Discussion Highlights

- Dr. Ogden asked if multiplier effects have been tracked historically.
  - Dr. Ivester replied that data on multiplier effects has been collected for decades and that the Bureau of Economic Analysis (BEA) publishes extensive data and documentation of this information.
- Ms. Dunwoody asked whether multiplier effects have been compared between "clean" industries and "traditional" industries and whether multiplier effect estimates account for environmental impacts of production.
  - Dr. Ivester indicated that the BEA data are grouped and aligned with North American Industry Classification System (NAICS) codes, which makes this kind of analysis difficult.
- Dr. Ayers suggested that more education is needed to communicate that there are a lot of good manufacturing jobs and opportunities in the U.S., despite the "big news" stories about particular towns where large numbers of jobs have been lost due to plant closures.
- Dr. Ayers agreed that advanced manufacturing can help pull a low TRL technology up, but noted that there are also a lot of high TRL emerging technologies with low MRLs and advocated for R&D to better match those up.
- Dr. Ogden noted that there are many opportunities for high-precision manufacturing in the hydrogen and fuel cells space, and hoped that these would be explored.
  - Dr. Ivester noted that a number of opportunities have already been identified and are being pursued and he would be happy to help make additional connections among researchers and organizations.

7. Overview of H2@Scale, Bryan Pivovar, NREL

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_04_pivovar.pdf

Dr. Pivovar provided an overview of the H2@Scale concept. He illustrated the importance of "pace and scale" in implementing large-scale clean energy and presented the vision for H2@Scale in terms of key attributes and benefits. He highlighted the significance of natural gas as a path to large-scale hydrogen production and discussed other opportunities for cost reductions in hydrogen production, including the value proposition of renewable energy. He also discussed the importance of considering future impacts, presenting some examples of the environmental impacts from these technologies.

8. H2@Scale: Research Needs and Outreach, Neha Rustagi, DOE

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_05_rustagi.pdf

Ms. Rustagi presented on outreach activities for H2@Scale and results from the H2@Scale 2016 workshop. Topics included R&D needs for electrolyzer integration with energy transmission and nuclear generation, advanced technologies for wide-scale hydrogen infrastructure, and applications for hydrogen in the oil and chemicals industries. She also discussed the role and value of electrolyzers in the power grid in three areas: (1) matching power supply with demand; (2) managing perturbations and different frequencies on the grid; and (3) managing and responding to unplanned outages.

9. Analysis of H2@Scale Value Proposition, Mark Ruth, NREL

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_06_ruth.pdf

Mr. Ruth provided an overview of a multi-lab H2@Scale analysis project to evaluate and quantify potential hydrogen demand and hydrogen supply resources (including fossil, nuclear, and renewable sources), associated infrastructure issues, and potential impacts (resource use, emissions, and economic). He presented results of regional analysis showing opportunities and challenges related to hydrogen supply/demand, grid impacts, and initial hydrogen supply and demand curves. Mr. Ruth asked the Committee for thoughts on additional H2@Scale impacts, stakeholder perspectives that might not yet have been considered, and gaps in the analysis.

Discussion Highlights

- Dr. Powell suggested looking at how other carriers, such as ammonia, might impact the grid system.
- Chairman Novachek suggested that the cost of hydrogen might be considerably less than $2 for an electrolyzer with 40% capacity factor, especially if electrolyzers are allowed to directly access the market, rather than having to sell their energy into the distribution system.
- Dr. Ayers noted that a key factor driving electrolyzer costs today is the fact that electrolyzer manufacturers are small companies (100 employees or less), and the same goes for component manufacturers. She also noted there has not been a concerted effort in the R&D community to design materials (e.g., membranes, catalysts) specifically tailored towards the needs of electrolyzers. She described the two biggest opportunity areas as power electronics and stacks, including membrane and electrode assembly and transport layers. Chairman Novachek asked that

a list of membrane-based electrolysis technical challenges and R&D needs provided by Dr. Ayers be entered into the minutes; it is provided in the bullets below.

Technical challenges in membrane-based electrolysis:

- Highest cost stack elements are the membrane electrode assembly, porous transport layers, and anode flow fields
- All are still manufactured at relatively low volume (thousands of cells/year max)
- Based on these sales volumes, manufacturing methods are lower capacity, higher labor content methods and tend to be batch processes
- Membrane is a major efficiency limitation, both due to the mechanical requirements which increase thickness to far higher levels than fuel cells, and creep characteristics which limit higher temperature operation
- There is a very limited subset of materials that are stable in the oxygen side of PEM-based electrolysis cells, which drive higher cost
- Catalyst loadings are significantly higher than fuel cells, even on the hydrogen electrode which should be very much analogous to the fuel cell hydrogen electrode
- Porous transport materials tend to be rigid (partly due to the differential pressure requirements) and do not lend themselves well to roll to roll processes
- It has been difficult to develop accelerated testing conditions for electrolysis – the voltage is already higher than open circuit, and freeze-thaw/RH cycling are not really applicable like they are for fuel cells
- While there are specific requirement differences that necessitate some tailoring, there have been significant advancements in fuel cells that still have not yet been fully leveraged for electrolysis.
- Stacks and power electronics represent the majority of the system cost.
- Going to higher current density is probably the fastest pathway to stack cost reduction but requires changes in materials (and/or operating temp) to maintain reasonable efficiency
- There is not one single element that dominates the cost of electrolysis but there are multiple elements that can be significantly cost-reduced (per the waterfall chart I presented at H2@Scale)

Related research needs:

- Membranes tailored to electrolysis requirements (full hydration, 60-80C operating temperatures, mechanical strength for 30 bar and higher pressure operation)
- Hydrogen crossover mitigation strategies (for example, membrane treatments that still allow dry electrode fabrication methods)
- Conductive supports for oxygen evolution catalysts to enable lower loadings
- Understanding of catalyst and electrode structure to minimize loading and maximize activity
- Strategies for minimizing material usage on the oxygen side of the cell (limiting the directly exposed materials to coatings or thin layers, for example)
- Advanced manufacturing methods (closer to state of the art fuel cells) tailored to electrolysis material properties
- Porous transport layers with tailored porosity for good catalyst layer contact (needed for loading reduction) while maintaining sufficient fluid flow and mechanical strength
- Lower cost power supplies (while maintaining/improving reliability in variable power environments) and better current-voltage matching to the stack
- Larger format cells including supply chain development for some sheet stock materials

    - Quality control methods and accelerated stress testing development to ensure long field reliability
    - Polymer joining methods that will withstand the seal and active area pressures for electrolysis while minimizing membrane usage
- Dr. Ogden asked whether the analysis planned to consider the effects of various policies or incentives on costs.
    - Mr. Ruth replied that the current analysis is focusing on a straight, unsubsidized cost analysis.
- Dr. Lipman noted that for renewable power generation that is located near a hydrogen demand center, it may be advantageous to keep the electricity in direct current (DC) for electrolysis.
- Dr. Powell noted that the greening of value chains is happening in part due to corporate commitments to their customers and stakeholders. He also emphasized the strong potential benefits of hydrogen for heavy-duty vehicles, and suggested that the H2@Scale analysis may be underestimating the potential global demand from that market.
- Ms. Dunwoody suggested analysis that would consider how to build an energy system optimized for renewable hydrogen as an energy carrier, rather than modifying one built on moving electrons.
    - Dr. Pivovar agreed that a system with hydrogen at the center of the paradigm would likely look much different, but noted that one of the key benefits of hydrogen is its ability to connect the grid to other applications and have a multi-sector impact even in our current infrastructure system.
- Dr. Thompson asked whether the energy-water or energy-food nexus was being considered in the analysis. He also suggested that the H2@Scale team coordinate with the Advanced Manufacturing initiatives to leverage activities there.
- Mr. Freese suggested doing a case study analysis for a single manufacturing plant that would integrate the various uses of hydrogen, including an evaluation of the costs and benefits. He noted that real-world examples are needed to show the economics.
- Dr. Ogden suggested that the timeframes in the market analysis may be overly conservative.
- Dr. Satyapal noted that there are a number of completed and ongoing demonstrations of integrated hydrogen energy systems, both in the United States and abroad (e.g., Germany and Japan). She asked the Committee to consider what more the federal government should be doing, especially given the administration's focus on early-stage R&D, and how we can learn from the technology demonstrations. Also, given more limited budgets, input is needed on the highest R&D priorities and where innovation is really needed. She suggested the Committee consider rejuvenating the Enabling Renewables subcommittee to provide feedback on H2@Scale. She also requested that Committee members recommend contacts from industry or states to attend the upcoming H2@Scale workshops being held to gather input from stakeholders.

10. Utility Perspectives on the Hydrogen Economy, Noah Meeks, Southern Company

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_07_meeks.pdf

Dr. Meeks explained how hydrogen, as a storable energy carrier, may enable a utility to provide energy with a high capacity factor to existing customers, as well as open up new markets. He described how utilities today generate and deliver energy in real time, and presented five ways for utilities to participate in the hydrogen economy. He spoke about the potential for hydrogen to decarbonize the transportation

sector if it is produced using zero-carbon energy. Dr. Meeks then compared the pros and cons of several types of nuclear reactors and liquid hydrogen carriers.

Discussion Highlights

- Dr. Azevedo noted the opportunity for energy storage arbitrage given the price discrepancies between different energy resources (i.e., coal and natural gas).
- Dr. Powell noted the potential for liquid carriers to address some of the hydrogen delivery infrastructure problems. He also suggested coordinating on possible demonstrations with the RAPID Institute at Savannah River National Laboratory.

11. Experimental Results of H2@Scale, Rob Hovsapian, Idaho National Laboratory

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_08_hovsapian.pdf

Dr. Hovsapian discussed his project to evaluate the potential role of electrolyzers in providing grid services, as well as hydrogen for sale to FCEVs. He presented on the results to date of this first-of-a-kind distributed, real-time simulation that enables communication, control, and experimental operation between grid modeling, front end controller (FEC), electrolyzer, and economic benefit calculator. He presented demand response simulations of fast ramp-up/ramp-down of the electrolyzer, noting the ability to stabilize frequencies and the role they can play to offset variability in power production from renewables. He then reviewed scenarios of wind, solar, and FCEV deployment and the role electrolyzers could play.

Discussion Highlights

- Dr. Powell asked if the cost of the hydrogen produced has been estimated.
  - Dr. Hovsapian indicated that a complementary project is assessing the cost.

12. HTAC Annual Report and Cover Letter, Morry Markowitz and Sandra Curtin, Fuel Cell & Hydrogen Energy Association (FCHEA)

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_09_markowitz.pdf

Mr. Markowitz and Ms. Curtin presented an overview of key findings summarized in the 2016 Annual Report, followed by its conclusions. Chairman Novachek asked for input and feedback on the report's format and content.

Discussion Highlights

- Mr. Eggert suggested three key points to make sure are covered in the report or transmittal letter:
  - There has been significant progress in technological readiness due to DOE's R&D and growing market applications are generating real-world benefits and jobs.
  - Despite advances, progress is not being made fast enough.
  - DOE should continue to support the entire value chain in of R&D.
- Ms. Gobin stated that the story should be about U.S. competitiveness and U.S. jobs, as well as the opportunities for infrastructure investments.

- Dr. Ayers reported that she recently attended the international Hannover Messe conference and was struck by the number of new electrolyzer companies entering the market and the growing dominance of Asia in fuel cells. She noted that this should concern us from a U.S. competiveness standpoint.
- Dr. Powell suggested specifically mentioning the manufacturing institutes that can help with materials R&D needs, such as the Rapid Advancement in Process Intensification Deployment (RAPID) Manufacturing Institute.
- Ms. Dunwoody suggested pointing out the discrepancy in federal funding for FCEVs vs battery electric vehicles (BEVs) under the previous administration and the expiration of the FCEV tax credit.
- Mr. Koyama stated that the majority of fuel cell manufacturing and deployment is happening outside the United States.
- On a procedural matter with regard to gathering further Committee input for the HTAC Annual Report and transmittal letter via email, Ms. Gupta noted that recommendations and advice to the Secretary of Energy must ultimately be discussed publicly. If recommendations in the report or cover letter are substantively changed after private messages are exchanged, the report will have to be reviewed again in public (via an in-person or web-based HTAC meeting).
    - Whereupon, the Committee discussed and agreed to a number of changes and additions to the text of the report, including a recommendation to leverage manufacturing initiatives and the deletion of fuel cell durability as a remaining major barrier to fuel cell commercialization for the automotive industry.
- Chairman Novachek moved to maintain a consistent format for the HTAC report, using this year's report as the template. The motion was approved by the Committee.
- Chairman Novachek forwarded a suggestion to delete the more detailed "industry news" items in the report, on the basis that there are other publications that do this and that the list is inherently incomplete. After some discussion, it was agreed to keep the detailed information in the report.
- The Committee agreed to maintain the tradition of having the HTAC Annual Report be a fact-based report on industry and technology status/trends, with the recommendations to the Secretary provided in the cover letter.
- The Committee reviewed draft recommendations for the cover letter and agreed to have Committee members email revisions or additional suggestions for the cover letter tonight [May 4, 2017] so the Committee can consider and discuss them during the public meeting tomorrow [May 5, 2017]. The emails will be submitted to Sandra Curtin for compilation into a presentation for the Committee's review.

Chairman Novachek adjourned the meeting at 5:46 p.m. ET.

DAY 2 – May 5, 2017

Chairman Novachek began the meeting at 8:55 a.m. EDT.

13. Overview of DOE Quantitative Risk Assessment, Chris LaFleur, Sandia National Laboratories (SNL)

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_10_lafleur.pdf

Dr. LaFleur provided an overview of DOE's quantitative risk assessment (QRA) activities with respect to hydrogen, including Sandia National Laboratories' development of the Hydrogen Risk Assessment Model (HyRAM), a publicly available integration platform for state-of-the-art hydrogen safety models and data. She reviewed the project's approach to better understand and model hydrogen behavior, develop quantitative risk assessment tools, and enable hydrogen infrastructure through science-based codes and standards. She discussed HyRAM's definition of risk and approach to risk assessment and described its core functionality and key features. Dr. LaFleur also reviewed current QRA focus areas including establishing risk-informed separation distances for bulk liquefied hydrogen, understanding phenomena of large-scale hydrogen releases, and characterizing and calculating risk associated with material failures in hydrogen infrastructure.

Discussion Highlights

- Dr. Azevedo asked how SNL gathers input from stakeholders on risk management goals.
  - Dr. LaFleur replied that SNL's focus is to develop tools that can be used to analyze risk; it is up to the stakeholders to decide what goals to manage to.
- Ms. Dunwoody asked about the response from station developers and authorities having jurisdiction (AHJs) on HyRAM, and whether there is a mechanism for gathering feedback from them.
  - Dr. LaFleur stated that the model is being downloaded a lot and there has been very positive feedback from manufacturers, gas suppliers, etc. There is also a HyRAM forum on the H2Tools website for users to share information and feedback.
- Mr. Markowitz noted asked what evidence has been most effective in persuading people of hydrogen's safety.
  - Dr. LaFleur noted that people are typically very impressed by the amount of tank testing that hydrogen tanks go through. She also noted that comparisons to gasoline systems are illuminating, since gasoline escapes from cars much more easily and ignites relatively often.
- Mr. Freese asked how the model handles things that interact with the system, such as delivery trucks that enter a station.
  - Dr. LaFleur explained that additional fault trees are built for these kind of elements, if they are identified by stakeholders as important. She noted that some fault trees in HyRAM are static ("baked into") the model, whereas others are editable by the user. She hopes to expand the number of fault trees and their editability as the model matures.
- Dr. Satyapal noted that DOE has invested a lot of funding in developing this capability. She asked the Committee to for feedback on whether this risk assessment work should now be handed off to private industry.
  - Mr. Markowitz explained that government is seen as a credible third party; state and local officials often do not trust private industry data.
  - Ms. Dunwoody noted evaluating the technology and risks of hydrogen infrastructure (e.g., liquid hydrogen storage at fueling stations) is an essential step required for commercialization. She asserted that one company, or a group of companies, cannot do this at the level that DOE can, with its extensive national lab facilities, equipment, and expertise. She also noted the importance of having the work done in an unbiased, scientific manner, with no perceived or real conflicts or commercial interest.

- Dr. Ogden agreed that the work is critically important, noting that the project makes a vast amount of scientific information publically accessible. This view was echoed by Ms. Scott and Mr. Freese.
- Dr. Powell noted that the work requires assessing systems and integrating data from a broad array of industry players, which requires the involvement of an entity like a national lab.
- Mr. Eggert stated that he would characterize this work as early-stage R&D on the safety of these systems, and added that results can be used to provide feedback to technology R&D.

14. H2 Safety Panel Strategic Plan, Nick Barilo, Pacific Northwest National Laboratory

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_12_barilo.pdf

Mr. Barilo presented on Hydrogen Safety Panel (HSP) and its draft strategic plan. He described the recommendations of the HTAC Subcommittee on Hydrogen Safety and Event Response in their soon-to-be-released report, and how these could be addressed. He presented on the role of the HSP, its objectives and goals, and some specific projects that could benefit from HSP involvement.

Discussion Highlights

- Ms. Dunwoody noted that the recommendations in the report of the HTAC Subcommittee on Hydrogen Safety and Event Response were not meant to be prescriptive or restrictive, and suggested that the HSP strategic plan move beyond the recommendations of the subcommittee report. As an example, she identified two critical issues she hoped the report would cover: (1) how to operate the HSP to ensure it has baseline funding from year to year and (2) how to recruit new members to maintain and enrich the expertise of the HSP. She also suggested that HTAC should encourage the availability of Federal funding to help support the HSP as a vital resource.
- Ms. Scott stated that the support of the HSP has been invaluable in siting and building stations. She emphasized the importance of HSP collaboration with states, labs, and industry. She added that communication of best practices will be useful as the industry looks to roll out stations throughout the country.
  - Dr. Powell agreed and emphasized the importance of gathering, analyzing, and communicating lessons learned data on safety incidents (including near misses) as technology evolves.
- Dr. Satyapal stated that continuing DOE funding for the Hydrogen Safety Panel probably will not be possible in 2018 and beyond given the focus on early-stage R&D. She asked HTAC for ideas on other business models or ways to bring in outside funding (if appropriate or of value) for the HSP.
  - Ms. Gobin suggested adding a requirement for HSP review of design plans (etc.) in state-awarded contracts for hydrogen stations or infrastructure.
  - Others suggested a fee-based system for HSP participation in a project.
  - Ms. Dunwoody observed that some of the work conducted by the HSP is really in the category of R&D, since it feeds information from real-world applications back to R&D. She also noted that other organizations have made sizeable in-kind contributions to the HSP (e.g., HSP members who are employed by industry or state organizations and whose travel and time is paid for while they are doing HSP work). She advocated for quantifying this to demonstrate the external commitment and cost-share.

- Mr. Eggert contended that support for the HSP is an appropriate role of government in an emerging technology field. He asked how state plans for hydrogen infrastructure would be affected if the DOE stepped away from these activities.
- Dr. Powell suggested that a technical society like the Center for Chemical Process Safety at the AIChE could serve as the collaborator and organizer of the HSP.
- Mr. Novachek mentioned the Institute of Nuclear Power Operations as a possible model. This industry/utility group was formed after the Three Mile Island incident to anticipate safety issues and identify best practices and lessons learned, and was supported by member fees.
- Mr. Freese suggested extending the charter of the HTAC Safety and Event Response subcommittee to evaluate operational models for this kind of work, considering what the costs of running the HSP would be, what its role and objectives are, etc. The goal would be to develop recommendations for DOE with respect to carrying out EPACT 2005 goals related to hydrogen safety.
    - Chairman Novachek asked for volunteers to serve on the Safety Subcommittee.
        - Ms. Dunwoody declined to continue as the Subcommittee Chair, but offered to continue to provide input to the Subcommittee.
        - Mr. Freese volunteered to serve as Subcommittee Chair. He will prepare the revised subcommittee charter, and asked that DOE provide the Subcommittee with information on what activities and funding DOE plans to cut in the area of safety, codes and standards.
        - Mr. Markowitz, Mr. Novachek, Dr. Lipman, and Dr. Powell offered to serve as members. Dr. Powell also offered to bring in others from industry and to explore opportunities for working within AIChE.
        - Dr. Satyapal offered to provide appropriate experts from the national labs to serve on the subcommittee, and to help with identifying contacts at other agencies (e.g., OSHA, FAA, DoD).

15. Other HTAC Business

- Ms. Dunwoody, Chair of the HTAC Safety and Event Response Subcommittee, moved to accept the Hydrogen Safety and Event Response Report as final and send it to the Energy Secretary.
    - The motion was passed by the Committee.
- Mr. Markowitz volunteered to serve as the Chair of the External Communications Subcommittee, taking over this role from Mr. Freese.
- Chairman Novachek asked members to send Vice Chairman Freese emails with suggestions for agenda items for future HTAC meetings.
- Vice Chairman Freese will take over as Chair of HTAC on July 17, 2017.
- The next HTAC meeting is scheduled for October 25-26, 2017, in Washington, D.C.
- The Vice Chair selection process will resume once the Energy Secretary has approved the new members and reappointments for HTAC (expected late summer 2017).
- **<u>HTAC Annual Report Recommendations</u>**
    - The Committee reviewed suggestions for revising the HTAC Annual Report as well as recommendations to include in the cover letter transmitting the report, and agreed on some revisions.
    - The report will be updated with the finalized recommendations.

- The Committee moved to approve the report and cover letter with the discussed and agreed-upon changes and recommendations. The motion was passed. Chairman Novachek will finalize the report and cover letter and send it to the Energy Secretary, along with the subcommittee's Safety and Event Response Report.

16. SimpleFuel Hydrogen Fueling Station, Chris O'Brien, Ivys Energy Solutions

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_13_obrien.pdf

Dr. O'Brien on the SimpleFuel™ On-site Hydrogen Refueling Solution, winner of DOE's $1 million H2 ReFuel H-Prize competition. He described the SimpleFuel design approach, target entry market applications, validation testing, and automotive refueling scenarios. He also discussed how the SimpleFuel device provides a unique ZEV refueling solution and the distributed fueling infrastructure model, and described next steps regarding engagement, customer deployments, and outreach.

Discussion Highlights

- Mr. Koyama asked which components contribute most to the system cost.
  - Mr. O'Brien responded that the majority of cost comes from the two key sub-systems, i.e., the electrolyzer and compression/storage/delivery system. He expects cost to come down as manufacturing volume goes up

17. Hydrogen Stations, Chris White, California Fuel Cell Partnership (CaFCP)

>>see full presentation at https://www.hydrogen.energy.gov/pdfs/htac_may17_14_white.pdf

Ms. White presented on the status of hydrogen station deployment and associated issues in California. She provided statistics on the number of FCEVs owned in California and stations by operating status, and highlighted some recent station openings. She described the features of CAFCP's on-line station map and showed maps of station locations in other parts of the U.S. She reviewed lessons learned and best practices for hydrogen station deployment in California, including the development and use of the DOE-supported Hydrogen Station Permitting Handbook and the HySTEP (Hydrogen Station Equipment Performance) device. Ms. White discussed priorities for future station deployment activities, opportunities to lower costs, and emerging issues. She also advocated for enhancement of the HySTEP device to add some features and do what HySTEP does faster.

Discussion Highlights

- Dr. Satyapal remarked that the CaFCP is a great example of a successful public–private partnership that has leveraged funding from many sources to make significant and numerous achievements.
- Ms. Dunwoody noted that DOE support for the CaFCP was vital to its success in translating the R&D achievements of DOE and its partners into practical solutions and consumer options.
- Ms. White remarked that the number of retail hydrogen fueling stations deployed to date is just a tiny fraction of the number of gasoline stations, and these early stations are essentially "early market" R&D.

18. Closing Remarks

- Chairman Novachek expressed his appreciation to the Committee members and the DOE for their work and support over his two-year term as Committee Chair, which expires July 16, 2017.
- Dr. Satyapal thanked Mr. Novachek for his service, including his efforts on HTAC subcommittees, such as the Annual HTAC Report Subcommittee and the Hydrogen Enabling Renewables Subcommittee.

Chairman Novachek and Erika Gupta, Designated Federal Officer for the Committee, adjourned the meeting at 1:10 p.m. ET.

TWENTY-NINTH MEETING OF THE
HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE (HTAC)
PARTICIPANT LIST
May 4–5, 2017

HTAC Members Present

- Kathy Ayers
- Inês Azevedo
- Kathryn Clay
- Catherine Dunwoody
- Anthony Eggert
- Charles Freese
- Anne Gobin
- Drew Kodjak
- Harol Koyama
- Timothy Lipman
- Morry Markowitz
- Frank Novachek
- Joan Ogden
- Joseph Powell
- Janea Scott
- Levi Thompson

HTAC Members Not Present

- Maurice Kaya
- Paul Leggett
- Margo Oge
- Adele Ratcliff

U.S. Department of Energy Staff

Office of Energy Efficiency and Renewable Energy

- Peter Devlin
- Richard Farmer
- Erika Gupta (DFO)
- Laura Hill
- Charles (Will) James
- Fred Joseck
- Shawna McQueen
- Eric Miller
- Neha Rustagi (Speaker)
- Reuben Sarkar (Speaker)
- Sunita Satyapal (Speaker)
- Daniel Simmons (Speaker)
- Ned Stetson
- John Stevens

Members of the Public in Attendance

- Nick Barilo—Pacific Northwest National Laboratory (Speaker)
- Leland Cogliani—Lewis-Burke Associates, LLC
- Sandra Curtin—Fuel Cell and Hydrogen Energy Association (Speaker)
- Connor Dolan—Fuel Cell and Hydrogen Energy Association (Speaker)
- Leo Grassilli—Office of Naval Research, U.S. Department of Navy
- Rob Hovsapian—Idaho National Laboratory (Speaker)
- Robert Ivester (Speaker)
- Chris LaFleur—Sandia National Laboratories (Speaker)
- Noah Meeks—Southern Company (Speaker)
- Alice Muna—Sandia National Laboratories
- Chris O'Brien—Ivys Energy Solutions (Speaker)
- Mark Phirprick—ORISE fellow at DOE
- Bryan Pivovar—National Renewable Energy Laboratory (Speaker)
- Robert Rose—Breakthrough Technologies (Speaker)
- Mark Ruth—National Renewable Energy Laboratory (Speaker)
- Carl Stutz—Idaho National Laboratory
- Seth Terry—Montreaux Energy
- Chris White—California Fuel Cell Partnership (Speaker)
- Keith Wipke—National Renewable Energy Laboratory

Support Staff

- Judi Abraham—Alliance Technical Services, Inc.
- Dottie Bunn—Bunn & Associates
- Rachel Davenport—Alliance Technical Services, Inc.
- Lilia Murphy—Alliance Technical Services, Inc.
- Neil Popovich—National Renewable Energy Laboratory
- Amit Talapatra—Energetics Incorporated
- Thomas Timbario—Alliance Technical Services, Inc.