HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE MEETING MINUTES

March 9-10, 2020
955 L'Enfant Plaza, SW
Washington, DC 20024

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MARCH 9, 2020

The Designated Federal Official, Shawna McQueen, commenced the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC or Committee) meeting at 1:00 p.m. Eastern Daylight Time (EDT). Chairman Joseph Powell welcomed HTAC members both in-person and on the webinar. The full Committee then reviewed and approved the draft agenda. No public comments were presented.

Presentation summaries and highlights of the discussions that followed are provided below.

1. **Welcome from Energy Efficiency and Renewable Energy (EERE) Senior Management and Sustainable Transportation Updates, Michael Berube, Acting Deputy Assistant Secretary for Transportation, EERE, U.S. Department of Energy (DOE)**

Mr. Berube welcomed the HTAC members, DOE staff, and members of the public to the meeting and expressed his appreciation for the work and guidance the Committee provides to DOE. He reviewed DOE's key focus areas and specifically highlighted the shift in support from light-duty vehicles (LDVs) to medium- and heavy-duty vehicles (MDVs and HDVs). Mr. Berube asked the HTAC members to identify other important U.S. hydrogen and fuel cell topic areas that would benefit from DOE assistance.

Discussion Highlights

- Dr. Powell asked whether blue hydrogen is on equal footing with green hydrogen.
    - Mr. Berube stated that there is global interest in lowering the carbon footprint of energy and there are many ways to get to that.
    - Commissioner Scott noted that California is very interested in CO2-free hydrogen, and how hydrogen fits with grid support, micro-grids, etc.
- Mr. Koyama inquired if there is a concerted effort around retaining jobs, particularly growing hydrogen and fuel cell manufacturing jobs in the US versus off-shore.
    - Mr. Berube emphasized the desire to avoid a situation where other countries develop a manufacturing base for technologies that were developed in the U.S. He agreed that having a US manufacturing base is important but cautioned that net job growth needs to be the metric, taking into account job displacement in other sectors/industries. He noted that maintaining a technology lead is an important first step.
    - Ms. Rumsey agreed that technology leadership is critical, along with creation of US-based markets and workforce development.

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

>> see full presentation at https://www.hydrogen.energy.gov/pdfs/01-satyapal-fcto-updates.pdf

Dr. Satyapal provided an overview of the HTAC legislative requirements and updated the Committee on FCTO activities. She briefly reviewed current FCTO funding levels, key activities, and high-level accomplishments, as well as recent funding opportunities. Dr. Satyapal highlighted recent announcements and emphasized the different areas where DOE is specifically requesting feedback from HTAC members.

Discussion Highlights

- Ms. Scott inquired whether NREL's ARIES (Advanced Research on Integrated Energy Systems) initiative was up-and-running.
    - Dr. Satyapal replied that it is not in full operation yet. She noted that there is funding available and NREL is currently putting together a research plan. Dr. Satyapal said that over

the next year, they will begin adding equipment, such as vehicles, electrification, heavy duty, etc., as well as an electrolyzer.
    - Dr. Satyapal noted that there was a public request for information (RFI) on ARIES and requested that HTAC members send her any input they have for ARIES and she can forward to the RFI team gathering input.
- Related to fuel cells in maritime applications, Mr. Hebner suggested working with the U.S. Navy to help move ship manufacturing back in the US.

3. Electric Vehicle, Battery, and Charging Infrastructure Update, David Howell, Acting Director, Vehicle Technologies Office (VTO), EERE

>> see full presentation at https://www.hydrogen.energy.gov/pdfs/02-Howell-Review%20of%20Battery%20Technologies.pdf

Mr. Howell presented on the current state of battery electric vehicles (BEVs) and provided projections for future global sales of BEVs in relation to other technologies that utilize lithium-ion batteries. He reviewed the key market players in the industry, ongoing R&D activities, and potential pathways for the cost reduction of batteries. Mr. Howell also reviewed VTO activities and highlighted the novel research topics that DOE is exploring.

Discussion Highlights

- Mr. Aszklar noted that many areas of the world do not have functioning electric grids, which would impact the feasibility of BEVs.
- Mr. Irvin commented that resiliency is also a key concern, especially how layered demands on the electric grid could be impacted by storms or other emergencies,
- Mr. Markowitz added that one of the biggest concerns is that BEVs will be concentrated in specific areas. He noted that ratepayers may have to pay increased costs for building grid upgrades to meet increased BEV demand in those areas.
- Mr. Hebner emphasized that technology that pushes the cost down is a huge driver, noting that solutions and decisions for transportation and grid-based solutions need to be made at the local level. He observed that BEVs being added to power distribution systems has not been an issue in Austin, TX. However, he believes the additional BEVs could be a problem for resiliency. Certain regions could not currently support BEV charging for all customers in the case of a natural disaster, which makes this a local problem.
- Mr. Mount suggested that it would be valuable to have a standard industry definition of fast charging. He noted that there is a big difference between 25K fast chargers and 100K fast chargers.

4. Preliminary Techno-Economic Analysis of Hydrogen Carriers, Ned Stetson, Hydrogen Fuel R&D Program Manager, FCTO

>> see full presentation at https://www.hydrogen.energy.gov/pdfs/03-Stetson-Overview%20of%20Chemical%20Carriers%20for%20Hydrogen.pdf

Dr. Stetson presented on an FCTO-funded techno-economic analysis of hydrogen carriers as compared to gaseous hydrogen production (via steam methane reforming) and delivery (via tube trailer). He explained the key driving factors and variables to consider and compared selected hydrogen carriers (ammonia, methanol, and methylcyclohexane/toluene) in different scenarios, from production to distribution. Dr.

Stetson summarized the preliminary findings and noted numerous topics and activities that were planned for the future.

Discussion Highlights

- Dr. Powell suggested comparing carbon sequestration on the Gulf Coast versus California.
- Mr. Koyama asked whether there are additional details behind the cost calculations, particularly the capital costs for producing the hydrogen.
    - Dr. Stetson said they have cost breakdowns for all the steps discussed.

5. Liquid Hydrogen – A Carbon Free Complementary to Liquid Natural Gas (LNG), Nikunj Gupta, Team and Portfolio Lead – Hydrogen Value Chains, Shell

>> see full presentation at https://www.hydrogen.energy.gov/pdfs/04-Gupta-Liquid%20Hydrogen.pdf

Dr. Gupta spoke on the potential applications and benefits for liquid hydrogen (LH2) and noted that LH2 could provide the opportunity for industry segments to decarbonize. He reviewed the global supply chains of hydrogen and compared the scale up and technological challenges between LH2 and liquefied natural gas (LNG). Additionally, Dr. Gupta provided an overview of recent technology developments and real-world examples.

Discussion Highlights

- Mr. Koyama commented that on the cost breakdown, it appears that scale-up alone would reduce the cost to $5-6 per kg.
    - Dr. Gupta confirmed that this is correct. There is no technological development needed to achieve those costs. He added that at $6 per kg, hydrogen is expensive compared to natural gas, and noted that the export market needs a subsidy.
    - Mr. Koyama asked if there's any region that can stimulate demand to reach these estimates.
    - Dr. Gupta responded that in Japan consumers are more ready to adopt but still need a subsidy.
- Mr. Berube asked if carbon capture and sequestration (CCS) cost is included in these numbers.
    - Dr. Gupta responded that yes, this is contributing to the $6 per kg cost.
- Mr. Koyama emphasized the opportunity and importance of scaling up LH2.
- Mr. Marsh added that he is familiar with the U.S. market for LH2. He stated that there are 3 plants in the 30-ton per day (or more) range, and that it can be picked up at the source for about $3.50 per kg and then it costs about 20 cents for every hundred miles for transportation. He noted that with these realistic estimates, there may be a bigger opportunity to explore in the U.S.

6. H2 Council Update: Council Priorities and Hydrogen Cost Report Updates, Traci Kraus, Director of Government Relations, Cummins, Inc. (on behalf of Hydrogen Council)

>> see full presentation at https://www.hydrogen.energy.gov/pdfs/05-Kraus-H2%20Council%20Update.pdf

On behalf of the Hydrogen Council, Ms. Kraus provided an update on the organization's membership and current activities. She stated the Hydrogen Council's vision to solidify hydrogen's place in future energy systems and detailed their four key priorities. Ms. Kraus also reviewed a recent Hydrogen Council report on the pathways to accomplish cost competitiveness of hydrogen in different applications. She further discussed cost reduction levers for key hydrogen applications and the cost reductions achievable from

2020-2030. Ms. Kraus also presented key targets for scaling-up based on different critical market segments, including the estimated required investment to achieve these objectives.

Discussion Highlights

- Dr. Powell inquired about the cost reduction for fuel cell trucks and whether they expect to have a competitive fuel cell truck in the market by 2030.
    - Ms. Rumsey emphasized that certain regulations are expected to drive this: e.g., nitrogen oxide (NOx) emission control rules, advanced clean truck policy in California, and a $50 per ton social cost of carbon.
- Ms. Rumsey added that over time, hydrogen fuel cells can play a notable role in the 2030 timeframe and be cost-competitive with ICE technology. She asked how the Hydrogen Council considers green versus blue hydrogen, and inquired whether the organization prioritizes green hydrogen or includes a focus on creating economies-of-scale with other types of hydrogen.
    - Ms. Kraus noted that there are differences of opinion on this – some think it is best to focus first on green hydrogen to "win the hearts and minds" whereas others think the focus should be on blue and gray hydrogen to build affordable hydrogen supply and economies of scale faster. She added that all hydrogen is useful to propel us towards the goal of economies of scale.
- Mr. Berube remarked his surprise that the demand shown for large passenger vehicles/SUVs is not larger.
    - Ms. Kraus noted that since this was a global study, the share of SUVs is relatively small.
- Mr. Koyama noted that the cost of hydrogen may not need to be the same for all applications to achieve the cost-competitive threshold shown in the upper right quadrant on slide 12. He noted that some applications are willing to pay a higher cost for hydrogen than others.

7. Gas Turbines: Hydrogen Capability and Experience, Dr. Jeffrey Goldmeer, Emergent Technology Director, General Electric

>> see full presentation at https://www.hydrogen.energy.gov/pdfs/06-Goldmeer-Hydrogen%20Gas%20Turbines.pdf

Dr. Goldmeer presented on gas turbines and combustion technology and detailed GE's experience with hydrogen over the past few decades. He also reviewed the potential for both new and existing facilities to utilize hydrogen as a fuel. Dr. Goldmeer also explained the impact of hydrogen on power plant systems and the possible reductions in carbon emissions from blending hydrogen with natural gas at various percentages. In addition, he discussed the potential challenges of converting current systems to use hydrogen as fuel.

Discussion Highlights

- Commissioner Scott asked whether other components of the gas turbine systems are being examined to facilitate hydrogen use in gas turbines.
    - Dr. Goldmeer said that it is all existing technology and it is a matter of applying them to this specific application.
- Mr. Aszklar inquired about the comparison of NOx emission reductions between 100% natural gas and 100% hydrogen. He asked whether existing burners accept up to 100% hydrogen without adjustments or replacement to the burner.
    - Dr. Goldmeer stated that it depends on the system. He explained that at a minimum NOx doubles when using 100% hydrogen. He also noted that it is probably around 10-25 ppm for natural gas depending on the system and probably 20-50 ppm for hydrogen.

- Mr. Aszklar asked about blending hydrogen in existing systems. He inquired whether existing dry low-NOx burners would achieve benefits without notable changes to the system.
    - Dr. Goldmeer responded that some existing industrialized systems can achieve 30-33% blending. He noted that newer combustion systems can achieve up to 50% blending, but accessory systems are configured for natural gas (leakage, seals, valves, etc.), so it depends how much is blended. He also explained that there are no issues for systems below 5% blends, but blends above this percentage need better sealing and safety considerations.
- Mr. Hebner inquired about the implications for cooling turbines if using hydrogen.
    - Dr. Goldmeer noted that all turbines need to be cooled, and this equipment has been designed and treated for effective active cooling.
- Mr. Leggett asked what lessons could be taken from current projects at the plants that were discussed during the presentation.
    - Dr. Goldmeer emphasized that existing projects are incorporating blends of hydrogen and stakeholders are asking what it takes to get to 100% hydrogen. He added that the cost of the hydrogen is the key driver. Dr. Goldmeer explained that cost of hydrogen must go down to meet natural gas or the cost of natural gas must increase for hydrogen to be cost-competitive.

8. HTAC Business and Discussion of Other Key Items

Update on the U.S. Hydrogen Roadmap Subcommittee

Chairman Powell reported that the Hydrogen Roadmap Subcommittee has reviewed the Executive Summary of the Hydrogen Council's US Hydrogen Roadmap, but is waiting for the full report to be published in order to conduct a full review. In the meantime, DOE will provide the subcommittee with a briefing on its draft Multi Year Plan. After some discussion, the Committee agreed to the following actions.

ACTIONS:

- Members to complete the report and deliver a condensed 2019/2020 version to DOE with a June 15 target. DOE suggested that the 2020/2021 report be delivered in March/April 2021 to better synch with budget cycles.
- Morry Markowitz will consolidate note-worthy developments and statistics for the 2019/2020 short-form version (including highlights from US Hydrogen Roadmap – with help here from Andy Marsh).
- Convene meeting of the subcommittee in the next two weeks to brief the subcommittee on the draft FCTO MYP.

The March 9, 2020 meeting adjourned at 6:20 pm EDT.

MARCH 10, 2020

The Designated Federal Official, Shawna McQueen, resumed the HTAC meeting at 8:30 am EDT.

9. **Liquid Organic Hydrogen Carrier Technologies, Rafael Schmidt, Senior Business Development Manager, Hydrogenious**

>> see full presentation at https://www.hydrogen.energy.gov/pdfs/07-Schmidt-Liquid%20Organic%20Hydrogen%20Carriers.pdf

Mr. Schmidt reviewed projections for increased global demand for hydrogen as a fuel and feedstock. He explained that, in this high-demand scenario, differences in hydrogen production cost would make hydrogen a globally traded commodity creating demand for intercontinental large-scale transport of hydrogen. He noted, however, that existing transport/storage technology for compressed and liquid (cryogenic) hydrogen is not well suited for large-scale international transport. Mr. Schmidt then detailed Hydrogenious' experience with storage of hydrogen in liquid organic hydrogen carriers (LOHC) and explained the technology with multiple examples of ongoing projects.

Discussion Highlights

- Dr. Powell thanked Mr. Schmidt for the presentation and noted that LOHC are the carrier of choice.
- Dr. Satyapal asked about levelized costs of LOHC.
    - Mr. Schmidt replied that with hydrogen production costs between $1-1.5/kg a total cost of $3-3.50/kg is achievable. (This assumes a higher hydrogen demand scenarios with central dehydrogenation.)
    - Dr. Powell inquired about cycle efficiency.
        - Mr. Schmidt estimated roughly 9 kWh per kg. He explained that there is a difference between dehydrogenation and hydrogenation, adding that one can control the process much better with an endothermic process.
- Dr. Satyapal asked about any remaining challenges.
    - Mr. Schmidt responded that the process is very well developed. He explained that it's now up to scaling and presenting to the hydrogen community that carriers can work on a larger scale.

10. **Center for Hydrogen Safety: Overview of Hydrogen Safety Activities, Accomplishments and Needs, Nick Barilo, PNNL/Center for Hydrogen Safety**

>> see full presentation at https://www.hydrogen.energy.gov/pdfs/08-Barilo-Center%20for%20H2%20Safety.pdf

Mr. Barilo provided an overview of the Center for Hydrogen Safety (CHS) including the goals, membership, and recent activities. He highlighted the importance of the organization for the wider hydrogen industry and stressed the need for reliable communication and information. Mr. Barilo also reviewed a timeline of upcoming milestones and when new resources will become available to members. He reviewed the capabilities of the Hydrogen Safety Panel (HSP) and discussed its purpose within the CHS.

Discussion Highlights

- Dr. Powell asked for further elaboration on the Hydrogen Academy.
    - Mr. Barilo specified that they are looking to develop a Hydrogen Academy that will be broader in scope than safety alone.
- Ms. Rumsey inquired if the goal was to move forward and develop standards globally.

    - Mr. Barilo clarified that the CHS is not directly involved in standards development. He explained that they are more focused on applied safety and identifying gaps, which could indirectly influence standard development.
- Mr. Mount noted that Mr. Barilo will be presenting at the Hydrogen Forum in April.
- Mr. Hebner suggested that there is an opportunity for the CHS to lead efforts to develop industry voluntary standards to fill gaps.
- In response to a question about the size and scalability of the HSP, Mr. Barilo noted that the panel is currently at the largest it has ever been and CHS is looking to bring in additional experts. Mr. Barilo noted that the CHS is prepared for strong demand.
- Mr. Thompson suggested that the CHS look for ways to increase engagement with universities, e.g., by increasing university membership or establishing student chapters on hydrogen safety.
- Mr. Freese asked whether the CHS has considered providing a certification program.
    - Mr. Barilo expressed concerns about the possible liabilities and requirements. He explained that the CHS is not in a position to be in a certifying role and are more of an expert resource to identify vulnerabilities.
    - Mr. Freese suggested that, alternatively, CHS could develop a minimum standard to meet – a CHS "Seal of Approval" – similar to an ISO certification.
    - Mr. Barilo said that he will bring that advice back to the executive board.
    - Dr. Powell added that AIChE has a legal division that can also be consulted.
- Dr. Satyapal asked HTAC members to comment on what parts of the CHS are the most valuable and what more the CHS can do.
    - Dr. Powell replied that global outreach is the highest priority, so that people in other countries are meeting high safety standards and are communicating and sharing best practices and lessons learned.
    - Ms. Hill noted that clear communication about the technology and its safety is very important in order to help stakeholders understand that hydrogen is safe.
    - Dr. Powell also highlighted the importance of standardization of permitting. He stated that streamlining codes and standards is necessary to reduce costs in order to deploy.

The Committee discussed next steps for the **HTAC Hydrogen Safety Subcommittee:**

- Members: Joe Powell (Chair), Charlie Freese (+ designated GM staffperson), Bob Hebner, Jennifer Rumsey, Bob Mount, Andy Marsh, Laura Hill and Sunita Satyapal (DOE). Invited experts: Tim Cortes (Plug Power), Carlyn Greenhalgh (Shell), Craig Skidmore (Power Innovations), Aaron Harris (Air Liquide), Jean Baronas (CEC), Dave Farese (Air Products), Kathy Ayers (Nel), Al Burgunder (Praxair), Nick Barilo (PNNL/CHS).
- **ACTIONS**:
    - DOE to circulate the link to the original hydrogen safety report from the previous subcommittee.
    - Members to email Joe Powell and Sunita Satyapal with safety-related gaps/needs by March 27.
    - Joe Powell to organize follow-up subcommittee meeting to discuss: charter, objectives/deliverables (e.g., review of CHS and recommendations for other activities needed/gaps not being addressed; development of incidents database with lessons learned), and next steps (One-pager? Recommendations? Others to engage (e.g., Clean Cities, NTSB, OSHA?).

11. Closing Remarks

Chairman Powell thanked everyone for joining the meeting and Dr. Satyapal expressed her appreciation to the HTAC members for their continual guidance. Mr. Powell adjourned the official meeting at 9:50 a.m. EDT.

THIRTY-FOURTH MEETING OF THE
HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE (HTAC)
MEETING PARTICIPANT LIST
March 9-10, 2020

HTAC Members Present

- Henry Aszklar
- Charles Freese (*Remote*)
- Robert Hebner
- Nick Irvin (*Remote*)
- Harold Koyama
- Paul Leggett (*Remote*)
- Anthony Leo (*Remote*)
- Morry Markowitz
- Andrew Marsh (*Remote*)
- Robert Mount (*Remote*)
- Daniel Nocera (*Remote*)
- Frank Novachek (*Remote*)
- Joseph Powell (*Remote*)
- Paul Rogers (*Remote*)
- Jennifer Rumsey (*Remote*)
- Janea Scott
- Levi Thompson (*Remote*)

U.S. Department of Energy Staff

Office of Energy Efficiency and Renewable Energy (EERE)

- Vanessa Arjona (*Remote*)
- Michael Berube (Speaker)
- Elizabeth Connelly (*Remote*)
- Pete Devlin (*Remote*)
- Nancy Garland
- Laura Hill
- Donna Ho (*Remote*)
- David Howell (Speaker)
- Brian Hunter (*Remote*)
- Maxim Lyubovsky
- Shawna McQueen (HTAC Designated Federal Officer)
- Eric Miller
- Dimitrios Papageorgeopoulos
- Mark Richards (*Remote*)
- Neha Rustagi (*Remote*)
- Sunita Satyapal (Speaker)
- Ned Stetson (Speaker)

Members of the Public in Attendance

- Katherine Ayers, Nel Hydrogen (*Remote*)
- Nick Barilo, Pacific Northwest National Laboratory (Speaker)
- Leland Cogliani, Lewis-Burke (*Remote*)
- Gerard Conway, Plug Power (*Remote*)
- Tim Cortes, Plug Power (*Remote*)
- Greg Dolan, Methanol Institute
- David Edwards, Air Liquide
- Laura Erlacher, GE Gas Power
- David Farese, Air Products
- Zubayr Fentas, New Energy and Industrial Technology Development Organization (NEDO)
- Monterey Gardiner, BMW (*Remote*)
- Jeffrey Goldmeer, GE Gas Power (Speaker)
- Nikunj Gupta, Shell (*Remote Speaker*)
- Eric Guter, Air Products (*Remote*)
- Traci Kraus, Cummins, Inc. (*Remote Speaker*)
- John Parkan, Mac (*Remote*)
- Rafael Schmidt, Hydrogenious (*Remote Speaker*)
- John Zagaja, Nel Hydrogen (*Remote*)

Support Staff

- Lauren Giles, Energetics
- Gale Guerrieri, Energetics
- Kristian Kiuru, Energetics
- Todd Ramsden, National Renewable Energy Laboratory (*Remote*)
- Zoe Respondek, Energetics