The Hydrogen and Fuel Cell Technical Advisory Committee

Washington D.C.

The Honorable Rick Perry
Secretary of Energy
U.S. Department of Energy
1000 Independence Ave. SW
Washington D.C. 20585

November 30, 2018

Dear Mr. Secretary:

On behalf of the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC), I submit the Committee's 2017 Annual Report. The HTAC duties, under Title VIII of the Energy Policy Act of 2005 (EPACT), SEC. 807, are to review and make recommendations to you, the Secretary, on: (1) the implementation of programs and activities under Title VIII; (2) the safety, economic, and environmental consequences of technologies for the production, distribution, delivery, storage, or use of hydrogen energy and fuel cells; and (3) the Department of Energy (DOE) plan under section 804. Typically, the Annual Report focuses on a broad assessment of issues and progress related to development and commercialization of these technologies. Although substantial advancements have been made toward U.S.-based fuel cell and hydrogen infrastructure commercialization, commercial deployments are primarily focused in narrowly focused applications (e.g., forklift applications) and in regional markets (primarily California).

While these advancements represent encouraging progress in specific areas, the overall US deployment is substantially short of the widespread distribution that was envisioned for the 2020 milestone. Meanwhile, there has been substantial progress toward commercial introductions outside the United States.

Given the rapidly approaching 2020 milestone and recent advancement of global competitors, the Committee found it prudent to establish a sub-committee to focus on a global hydrogen fuel cell competitive assessment with the intent of making recommendations regarding actions needed to maintain U.S. competitiveness and leadership in hydrogen and fuel cell technology. Japan and Europe remain important markets for future hydrogen fuel cell and infrastructure deployment. However, China is investing considerable resources to secure domestic hydrogen fuel cell technology and manufacturing capability. Developments in these markets constitute threats to the U.S. position as a global hydrogen fuel cell leader and will impact future technology investments, job creation, production and infrastructure investments, energy security, and national security. Key preliminary conclusions from the sub-committee's study are the following:

- China's national focus on hydrogen and fuel cell technology acquisition has made them a major national competitor in a very short period, and threatens to surpass the US position with additional commercial expansion in 2020.
- There are discrete actions that the U.S. can take now, in the FY19 and FY20 budgets, to counter this competitive threat.

- Refining the U.S. long-term investment processes in this technology and potentially partnering with close allies can secure sustainable competitive advantage as the hydrogen and fuel cell industries undergo significant expansion beyond 2020.

The sub-committee will present its final draft report to the full Committee at the December 2018 HTAC meeting.

Based on these and other observations gathered over the past year, HTAC recommends the following priorities for DOE:

- In addition to supporting early-stage research, it is critical that DOE remain actively engaged in developing broader goals for safety, codes, and standards as these areas require government leadership to develop broad, consistent frameworks to govern hydrogen and fuel cell deployment.
- Make National Laboratory assets and funding available for collaboration with private industry as they provide specialized facilities and expertise that cannot realistically be duplicated in private industry. Neutron imaging of water formation and transport in an operating fuel cell is an example of this type of capability.
- Focus on initiatives and research that support the transition between early subsidized deployments and ultimate commercial Hydrogen at Scale concept for a mature ecosystem. It is critical that DOE facilitate and support early commercial applications that allow hydrogen and fuel cell technologies be positioned where they can stand on their own, based upon their own economics. Supporting efforts to deploy centrally fueled "tethered" commercial vehicle fleets is an example of a transition application.
- Acknowledge that hydrogen fuel cell capability in the commercial sector is inextricably linked to the necessary capabilities for applying fuel cell technology for military purposes.

In his January 4, 2018 letter to Frank Novachek, Assistant Secretary Daniel R. Simmons stated that the Department will work to develop a strategy to outline ongoing efforts toward the Title VIII EPACT goals. The Committee is prepared to engage with the Department on these plans and is available to support the creation of this strategy.

The Committee looks forward to continuing our service to you, the DOE, the Fuel Cell Technologies Office, and the nation in advancing a competitive 21st century U.S. energy system. We welcome your feedback and look forward to hearing your perspectives on how we can best support you and the Department of Energy.

Sincerely,

Charles E. Freese V.

Chairman, HTAC
On Behalf of the Hydrogen and Fuel Cell Technical Advisory Committee

2017 ANNUAL REPORT of The Hydrogen and Fuel Cell Technical Advisory Committee

Hydrogen and Fuel Cell Technical Development and Commercialization Activity

This Annual Report of the United States Department of Energy (DOE) Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) highlights worldwide advances and challenges with regard to the hydrogen and fuel cell industry during 2017.

Industry Progress

Overall, hydrogen and fuel cell industries continued to progress from 2016 into 2017, with growing installations and research and development (R&D) progress around the world. The year was marked by the achievement of key market developments in the transportation, materials handling, and grid application sectors. Noteworthy events in 2017 included:

- The Hydrogen Council was launched at the World Economic Forum in Davos as a global initiative of leaders from the energy, transport, and industrial sectors with a common vision and ambition for hydrogen to foster the energy transition.[1] It includes major companies such as Toyota, GM, Honda, Hyundai, Shell, Air Liquide and others with a collective revenue of over $1 trillion and 1.7 million employees around the world.[2]
- China emerged as a growing influence on the hydrogen and fuel cell industry. Following initiation of China's 13th Five Year Plan in 2016, which included major funding for hydrogen and fuel cells, 2017 saw a substantial acceleration of technology and commercial activity in hydrogen and fuel cells moving from the USA, Japan and Europe to China.
- Ballard Power Systems of Canada established a joint manufacturing business in China, which now represents more than 50 percent of Ballard's product business.
- Amazon agreed to buy $70 million in fuel cell forklifts from manufacturer Plug Power and over 2000 were delivered in 2017. [3]
- In January, 2017 General Motors Co. and Honda Motor Company announced that they have established the auto industry's first manufacturing joint venture to mass produce an advanced hydrogen fuel cell system that will be used in future products from each company. Fuel Cell System Manufacturing, LLC will operate within GM's existing battery pack manufacturing facility site in Brownstown, Michigan, south of Detroit. Mass production of fuel cell systems is expected to begin around 2020 and create nearly 100 new jobs. The companies made equal investments totaling $85 million to launch the joint venture.[4]
- Several large-scale electrolyzer projects were planned. For example, in Germany, Shell partnered with ITM Power to install a 10 megawatt (MW) electrolyzer at the Wesseling refinery site.[5]

Additionally, a 2017 industry assessment by *E4Tech* reports that the size of the global hydrogen and fuel cell technology market (in total megawatt [MW] terms) expanded by about 30% from the prior year. The report estimates almost 660 MW of total shipments across sectors in 2017 compared with 525 MW in 2016 and 340 MW in 2015. The North American region grew the most in 2017, with a total of over 300 MW of shipments, followed by Asia also with about 300 MW. European sales remain relatively small (less than 50 MW in 2017), with slow commercialization in the rest of the world.[6]

Progress towards Policy Goals

2015 and 2020 are milestone years called out in the U.S. Energy Policy Act of 2005 (EPACT), Title VIII, which includes the following goals:

1) "To enable a commitment by automakers no later than year 2015 to offer safe, affordable, and technically viable hydrogen fuel cell vehicles in the mass consumer market and to enable production, delivery, and acceptance by consumers of model year 2020 hydrogen fuel cell and other hydrogen-powered vehicles that will have, when compared to light duty vehicles in model year 2005: 1) fuel economy that is substantially higher; 2) substantially lower emissions of air pollutants; and 3) equivalent or improved vehicle fuel system crash integrity and occupant protection;" and

2) "To enable a commitment not later than 2015 that will lead to infrastructure by 2020 that will provide: 1) safe and convenient refueling; 2) improved overall efficiency; 3) widespread availability of hydrogen from domestic energy sources; and 4) hydrogen for fuel cells, internal combustion engines, and other energy conversion devices for portable, stationary, micro, critical needs facilities, and transportation applications."

Progress has been made toward these goals since 2005, and the 2015 commitments have been partially met. Efforts such as the California Fuel Cell Partnership and H2USA have brought industry and government together in important ways toward achieving these goals.

California is likely the only jurisdiction that will meet the 2020 goals due to the state's strong commitment to the hydrogen

and fuel cell market through policies and subsidies. For the rest of the U.S. the 2020 goals will likely will not be met without increased federal commitment to the hydrogen and fuel cell market.

Commercialization Initiatives

Fuel cells continue to make significant inroads into an array of commercial sectors, further highlighting the broad potential impact of these technologies. Key sectors include transportation markets (e.g., cars, buses, trucks, and forklifts) stationary power markets (i.e., primary and backup power), electricity grid-support applications, military applications, underwater vehicles, and small electronics. Hydrogen as an industrial chemical also has broad impact for ammonia production, metal and semiconductor processing, and refining of petrochemicals.

Fuel Cells for Passenger Cars

2017 was a significant year for fuel cells for passenger cars, with key commitments for vehicle commercialization and hydrogen infrastructure development. Key developments include:

- Fuel cell electric vehicles (FCEVs) have been fully commercialized by three manufacturers, with more due to be on the market by 2020. By 2021 more than a dozen automakers are expected to offer FCEVs.
- Through the end of 2017, it was estimated that nearly 6,500 FCEVs were on the road world-wide, half of those being in California.[7] This is roughly double the number of FCEVs from 2016.
- To support FCEVs in the strongest U.S. market, California has 35 open-retail hydrogen refueling stations, with another 29 in development.[8] This number is up from 25 at the end of 2016.
- In the northeast U.S., Europe, Japan, China, and Korea, networks of hydrogen refueling stations are being developed in anticipation of growing FCEV markets in each region.[9]

Fuel Cells for Buses

Fuel cell buses continued to make excellent progress in performance. Separate bus trial programs in the U.S. and Europe both established over 20,000 hours of fuel cell system durability for buses in regular fare service. In addition:

- The Federal Transit Administration is investing millions of dollars in programs that are developing and demonstrating zero-emission transit buses.[10]
- As of August 2017, there were 26 fuel cell transit buses in operation throughout the U.S.[11]
- In California, there are over 21 fuel cell buses in operation in 2017, and an additional 32 in development.[12]

Fuel Cells for Material Handling:

Fuel cell powered forklifts in warehouses are becoming the preferred option for some of the largest retailers. They save warehouse floor space, refuel quickly, and run more efficiently than traditional lead-acid battery forklifts. Walmart is already using fuel cell forklifts at 30 of its distribution centers with over 7,000 units, and has plans to expand use at several more throughout the U.S.[13]

Fuel Cells for Grid Applications

Fuel cells continue to make steady inroads into power markets. In 2017, shipments were up by about 4,000 units, accounting for just a few MWs.[14]

- In the U.S., Bloom Energy signed power purchase agreements to supply 50 MW to U.S. utility Southern Company, as well as 37 MW of units in California and New York.[15]
- Doosan Fuel Cell America entered into agreement with Wells Fargo Vendor Financial Services to provide financing for Doosan Energy solutions.[16]

There's More to Be Done

Despite this progress, fuel cell and hydrogen R&D programs are still developing technologies to address ongoing technical, commercial, and logistical challenges. Major technical improvements have been realized in recent years in reducing costs and improving system durability, but cost targets are not yet achieved in key markets. Achieving cost competitiveness will require a combination of increased production volume and additional efforts to reduce costs of both fuel cell and electrolyzer stacks and "balance of plant" components. However, achieving complete cost parity may not be necessary because some types of fuel cell systems can serve multiple applications (for example, primary power and also backup power with onsite fuel storage).

In addition to reducing costs with technical improvements, the industry faces a full spectrum of other challenges. To overcome these challenges, we recommend that DOE take action to support the following areas:

- The development and validation of value propositions and systems solutions for renewable energy to hydrogen for power, fuel, and grid-stabilization.
- Address the potential for fuel shortages. For example, in Southern California where FCEV purchases have been strong, hydrogen fuel capacity is being outpaced by demand. Sustained investments in additional production capacity buildout is needed.
- The cost of hydrogen fuel infrastructure and difficulties with station siting/permitting and reliability continues to be a challenge. However, lessons learned in California have been documented in a guidebook to inform project siting to reduce costs and timelines.[17]
- The delivered cost of hydrogen at current scale remains a challenge.
- There is still critical work to be done with education and outreach to demonstrate the benefits and viability of fuel cells and hydrogen in different applications to a wide range of audiences. This is especially true in early-stage markets

such as energy storage, microgrids, and infrastructure development.

Research and Development

Research and development activities around hydrogen and fuel cell technologies continued at a steady pace in industrial, government lab, and university settings.

In 2017, the U.S. Department of Energy's Hydrogen and Fuel Cells Program focused its efforts on new consortia that are geared towards making the capabilities of National Labs more accessible to researchers and industry for early stage R&D and innovation:

- Electrocatalysis Consortium (ElectroCat): Demonstrated significant progress in zero platinum group metals (PGM) fuel cell catalyst development, active-site characterization, and high-throughput PGM-free modeling and synthesis.
- HydroGEN Advanced Water Splitting Materials Consortium (HydroGEN): Provided industry access to more than 80 world-class research capabilities to integrate and accelerate R&D on advanced water splitting technologies for hydrogen production.
- Hydrogen Materials Advanced Research Consortium (HyMARC): Continued to make significant progress to address gaps to advancement of materials-based hydrogen storage and hydrogen carriers.
- L'Innovator pilot program: Launched to make bundles of intellectual property from national labs available to industry to commercialize, the first company was selected for potential licensing in 2017.
- H-Prize: Enabled the first small-scale hydrogen fueling "appliances" through the DOE H-Prize.

The DOE Hydrogen and Fuel Cells Program continued to develop and refine the H2@Scale concept, a DOE initiative to explore the potential for wide-scale hydrogen production and utilization across multiple energy and economic sectors. The goal of H2@Scale is to leverage low-cost intermittent energy sources (such as solar and wind), low-cost baseload power (such as nuclear), and other domestic resources for hydrogen production. In 2017, a major accomplishment was leveraging public and private sector funds by using national Lab capabilities to address challenges to the H2@Scale vision.[18]

HTAC Activities In 2017

Key HTAC activities in 2017 include:

- Published the 2016 HTAC Annual Report and HTAC's associated letter to the Secretary of Energy, Rick Perry in July 2017.
- Released the *Safety and Event Response Subcommittee Report* that reviewed and assessed existing resources such as safety plans, event response plans, government requirements, and case studies. The report summarized the subcommittee's findings and makes several recommendations to address identified gaps.[19]

Financial Climate

In 2017, over 72,000 fuel cell units were shipped worldwide, accounting for nearly 660 MW of power, and approximately $2 billion in revenue.[20]

U.S. government support for hydrogen and fuel cell technology development efforts remained relatively constant from recent years, with $101 million in FY 2017 for the DOE Energy Efficiency and Renewable Energy (EERE) Fuel Cell Technologies Office, as detailed in Figure 1. However, this is less than half the historical peak funding level of over $215 million for this office. HTAC recommends that at minimum, funding is maintained at current spending levels for DOE FCTO, but recommends restoring to be closer to peak funding levels in past years. The current budget for hydrogen and fuel cell technologies is approximately 5% of the total $2.1 billion FY 2017 budget for EERE. DOE's Office of Fossil Energy also received $30 million in FY 2017 appropriations for its Solid Oxide Fuel Cell Program.

Figure 1: Fuel Cell Technologies Office FY 2017 Budget

Key Activity EERE FCTO	FY 2017 Enacted (in thousands)
Fuel Cell R&D	**$32,000**
Hydrogen Fuel R&D	**$41,000**
Systems Analysis	**$3,000**
Technology Acceleration	**$18,000**
Safety, Codes and Standards	**$7,000**
Total	**$101,000**

Conclusions

The overall outlook for hydrogen and fuel cell technologies remains promising and 2017 saw continued progress in commercial and research developments, and also noteworthy progress in transportation, materials handling, and grid applications. This industry is an important source of sustainable domestic job growth, future innovation, and energy leadership.

Importantly, the international competitive climate for these technologies has increased significantly. Key near term areas of attention to maintain or increase the U.S. competitive position include accelerated development of hydrogen refueling infrastructure and hydrogen fuel cell demand stimulus.

While hydrogen and fuel cell technologies continue to demonstrate promising progress, the U.S. is still not positioned to meet the 2020 goals for FCEVs and refueling infrastructure, as defined in U.S. EPACT, Title VIII. In its response to the Committee's 2016 Annual Report[21] recommendation for an explicit plan showing the pathway for achieving the 2020 goals, DOE committed to "work to develop a strategy to outline ongoing efforts towards these goals."[22] The Committee again asserts the need for development of this plan.

This industry is capable of providing momentous climate and economic benefits, energy security, domestic job creation, national security, leadership in innovation, and improved water and air quality in the U.S. However, achieving these objectives will require sustained commitment and innovative thinking for the U.S. to meet its 2020 and beyond goals, and remain globally competitive in this dynamic market.

Endnotes

[1] Hydrogen Council, 2018, http://hydrogencouncil.com/

[2] DOE *Hydrogen and Fuel Cells Program FY 2017 Annual Progress Report*, p. 10 https://www.hydrogen.energy.gov/pdfs/progress17/i_0_satyapal_2017.pdf

[3] Plug Power 2017 Fourth Quarter & Full Year Update Letter, Plug Power, Inc., 2017, https://s21.q4cdn.com/824959975/files/doc_financials/2017/Q4/investor-letter-fourth-quarter-2017.pdf

[4] GM and Honda to Establish Industry-First Joint Fuel Cell System Manufacturing Operation in Michigan, 2017, https://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2017/jan/0130-tunein.html

[5] Nasdaq, *The Most Overlooked Renewable Energy Source*, https://www.nasdaq.com/article/the-most-overlooked-renewable-energy-source-cm987228

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[7] InsideEVs, https://insideevs.com/there-is-only-6500-hydrogen-fuel-cell-cars-in-the-world-half-in-california-report/

[8] California Fuel Cell Partnership, https://cafcp.org/by_the_numbers

[9] The Fuel Cell Industry Review 2017, E4tech, p. 20.

[10] NREL, *Fuel Cell Buses in U.S. Transit Fleets: Current Status 2017*, p. 3, https://www.nrel.gov/docs/fy18osti/70075.pdf

[11] *Ibid.*

[12] California Fuel Cell Partnership, https://cafcp.org/by_the_numbers

[13] Plug Power 2017 Fourth Quarter & Full Year Update Letter, Plug Power, Inc., 2017, https://s21.q4cdn.com/824959975/files/doc_financials/2017/Q4/investor-letter-fourth-quarter-2017.pdf

[14] E4tech, *The Fuel Cell Industry Review 2017*, p. 4.

[15] *Ibid*, p. 34.

[16] *Ibid.*

[17] California Governor's Office of Business and Economic Development, *Zero-Emission Vehicles in California: Hydrogen Station Permitting Guidebook*, http://www.businessportal.ca.gov/wp-content/Documents/ZEV/Hydrogen-Permitting-Guidebook.pdf.

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[19] HTAC, *Hydrogen Safety and Event Response Subcommittee Report*, https://www.hydrogen.energy.gov/pdfs/htac_hser_report_6-17.pdf

[20] E4tech, *The Fuel Cell Industry Review 2017*, p. 46.

[21] The Hydrogen and Fuel Cell Technical Advisory Committee, 2017, https://www.hydrogen.energy.gov/pdfs/2016_htac_annual_report.pdf

[22] Department of Energy Response Letter, 2018, https://www.hydrogen.energy.gov/pdfs/2017_doe_response_htac_secretary_letter.pdf