U.S. DEPARTMENT OF ENERGY

Response to Findings and Recommendations of the Hydrogen and Fuel Cell Technical Advisory Committee during Fiscal Years 2018 and 2019

Seventh Biennial Report to Congress

June 2020

United States Department of Energy
Washington, DC 20585

Message from the Secretary

This is the Department of Energy's seventh biennial report to Congress, provided in response to the Energy Policy Act of 2005 ("EPACT 2005").[1] EPACT 2005 established the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) to advise the Department of Energy (DOE) on programs and activities under EPACT 2005 Title VIII, *Hydrogen*.

EPACT 2005 states that HTAC is to review and make recommendations to the Secretary on:

1. The implementation of programs and activities under Title VIII of EPACT 2005;
2. The safety, economical, and environmental consequences of technologies for the production, distribution, delivery, storage or use of hydrogen energy and fuel cells; and,
3. The plan called for by section 804 of EPACT 2005[2], known as the *DOE Hydrogen and Fuel Cells Program Plan* (formerly the *Hydrogen Posture Plan*).

Section 807 also requires the Department of Energy to transmit a biennial report to Congress that responds to recommendations made by HTAC since the previous report. This document, *Response to Findings and Recommendations of the Hydrogen and Fuel Cell Technical Advisory Committee: Seventh Biennial Report to Congress*, is the Department of Energy's official response to recommendations made by HTAC during fiscal years 2018 and 2019.

This report is being provided to the following Members of Congress:

- **The Honorable Lisa Murkowski**
  Chairman, Senate Committee on Energy and Natural Resources

- **The Honorable Joe Manchin**
  Ranking Member, Senate Committee on Energy and Natural Resources

- **The Honorable Frank Pallone, Jr.**
  Chairman, House Committee on Energy and Commerce

- **The Honorable Greg Walden**
  Ranking Member, House Committee on Energy and Commerce

- **The Honorable Eddie Bernice Johnson**
  Chairwoman, House Committee on Science, Space, and Technology

[1] Specifically, section 807(d)(2) of the Energy Policy Act of 2005, P.L. 109-58, August 8, 2005.
[2] Specifically, section 807(c) of the Energy Policy Act of 2005, P.L. 109-58, August 8, 2005.

- **The Honorable Frank Lucas**
  Ranking Member, House Committee on Science, Space, and Technology

If you have any questions or need additional information, please contact me or Mr. Christopher Morris, Deputy Assistant Secretary for House Affairs, or Mr. Shawn Affolter, Deputy Assistant Secretary for Senate Affairs, Office of Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Dan Brouillette

Executive Summary

The Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) was established under the Energy Policy Act of 2005 ("EPACT 2005"), P.L. 109-58, August 8, 2005, to advise the Secretary on programs and activities under EPACT 2005 Title VIII, Hydrogen. Section 807(c) requires HTAC to review and make recommendations to the Secretary on:

1. The implementation of programs and activities under Title VIII of EPACT 2005;
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 plan called for by section 804 of EPACT, also known as the *DOE Hydrogen and Fuel Cells Program Plan* (*Program Plan*, formerly the *Hydrogen Posture Plan*).

In this report, the Department of Energy (DOE) is responding to section 807(d)(2) of EPACT 2005, which requires that:

> *The Secretary shall transmit a biennial report to Congress describing any recommendations made by the Technical Advisory Committee since the previous report. The report shall include a description of how the Secretary has implemented or plans to implement the recommendations, or an explanation of the reasons that a recommendation will not be implemented.*

The body of this report consists of 10 recommendations made by HTAC since the previous biennial report. These recommendations were delivered through two reports, the "HTAC Subcommittee Report on Competitiveness and Competition" (March 2019) and the "HTAC 2017 Annual Report on Hydrogen and Fuel Cell Technical Development and Commercialization Activity" (delivered to DOE November 2018) and accompanying letter to the Secretary of Energy. These documents are provided in the appendices to this report.

The recommendations in HTAC's Annual Report and cover letter focused on addressing the major challenges remaining to achieve the 2020 goals of Title VIII of the Energy Policy Act of 2005,[3] particularly as related to delivered hydrogen cost and widespread availability of fueling infrastructure, as well as increasing threats to U.S. competitiveness from overseas competitors. The HTAC Subcommittee Report on Competitiveness and Competition, approved by the full HTAC in March 2019, evaluated the current global competitive position of the United States in hydrogen and fuel cells and made recommendations on potential DOE actions to address challenges or concerns. The report found that while the U.S. continues to be a technology leader based on its years of research and development investment, the U.S. manufacturing base is weak and is rapidly being taken over by international competitors. The recommendations focused on

[3] Specifically, section 805(f) (1) and (2) of the Energy Policy Act of 2005, P.L. 109-58, August 8, 2005.

conducting studies to determine the most effective ways to stimulate U.S.-based manufacturing and increases in commercial deployments.

This report to Congress presents these recommendations based on the source material (see Appendices), followed by DOE's responses.

RESPONSE TO FINDINGS AND RECOMMENDATIONS OF THE HYDROGEN AND FUEL CELL TECHNICAL ADVISORY COMMITTEE DURING FISCAL YEARS 2018 AND 2019

Table of Contents

I. Legislative Language

The Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) was established under the Energy Policy Act of 2005 ("EPACT 2005"), P.L. 109-58, August 8, 2005, to advise the Secretary on programs and activities under EPACT 2005 Title VIII, Hydrogen. Section 807(c) requires HTAC to review and make recommendations to the Secretary on:

1. The implementation of programs and activities under Title VIII of EPACT 2005;
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 plan called for by section 804 of EPACT, also known as the *DOE Hydrogen and Fuel Cells Program Plan* (*Program Plan*, formerly the *Hydrogen Posture Plan*).

In this report, DOE is responding to section 807(d)(2) of EPACT 2005, which requires that:

> *The Secretary shall transmit a biennial report to Congress describing any recommendations made by the Technical Advisory Committee since the previous report. The report shall include a description of how the Secretary has implemented or plans to implement the recommendations, or an explanation of the reasons that a recommendation will not be implemented.*

II. Recommendations from HTAC's 2017 Annual Report and Cover Letter

Recommendation

> "***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."*

Response

The Department appreciates the importance of hydrogen safety, codes, and standards to the research, development and deployment of hydrogen and fuel cell technologies. In fiscal year (FY) 2019, $7 million was invested in the Safety, Codes and Standards subprogram at the direction of Congress to ensure continued research and development (R&D) in areas including hydrogen behavior, risk assessment, hydrogen contaminant detection, and safety sensors. The Program continues to support R&D to enable reduced liquid hydrogen station footprint and to address the restriction on the use of fuel cell vehicles in tunnels in certain U.S. regions, and has launched a collaboration with the U.S. Department of Transportation's (DOT) Federal Highway Administration focused on this barrier. Following a recommendation of the HTAC, Pacific Northwest National Laboratory and the American Institute of Chemical Engineers partnered to launch the Center for Hydrogen Safety (CHS) in early 2019. The CHS is a global, neutral nonprofit dedicated to promoting hydrogen safety and best practices worldwide, with access to 60,000 members in 110 countries. The U.S. continues to be a leader in the global harmonization of regulations, codes, and standards, participating in the United Nations Global Technical Regulation 13 Phase II working group in collaboration with DOT's National Highway Traffic Safety Administration. Additionally, the U.S. was elected Chair of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) and co-chairs the Regulations, Codes and Standards, and Safety (RCSS) Working Group. This provides a key mechanism to identify gaps, barriers, and opportunities for global harmonization of RCSS. The IPHE, formed in 2003, is an international governmental partnership currently consisting of 19 member countries and the European Commission.

Recommendation

> "***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*."

Response

DOE recognizes that the National Laboratories are valuable assets for U.S. innovation and technology leadership, and strives to make these resources available to support American ingenuity. Over the last several years, DOE established four new R&D consortia focused on hydrogen and fuel cells under its Energy Materials Network (EMN). The EMN leverages the world-class capabilities of the DOE National Laboratories to accelerate progress in early-stage materials development efforts. DOE's Fuel Cell Technologies Office (FCTO) manages the EMN consortia related to hydrogen and fuel cell technologies, and issued competitive funding opportunity announcements (FOAs) in FY 2018 and 2019 to fund a number of industry and university cost-shared projects within these consortia. Each consortium has a specific focus area (as shown below) and a core team of National Laboratories that provide a range of relevant capabilities, such as advanced computational and experimental tools and state-of-the-art imaging technologies. The labs make these capabilities, or "nodes," available to collaborators (including universities/non-profits and companies) on competitively selected projects to accelerate the development of solutions to the materials challenges within their focus area. The four 'virtual' lab-led consortia and focus areas, are:

- ElectroCat for PGM-free catalysts;
- HydroGEN for advanced water-splitting;

- HyMARC for hydrogen storage materials research; and
- H-Mat for hydrogen materials compatibility R&D.

The Program also co-funds cooperative research and development agreements (CRADAs) issued by the National Laboratories. CRADAs are contractual agreements that allow industry and other non-Federal partners to collaborate with National Laboratories. Since FY 2018, the Program has funded more than 25 industry-led projects through the H2@Scale "consortium," a group of national laboratory and private sector partners that have ongoing CRADA projects focusing on hydrogen production and storage, integrating hydrogen technologies with the grid, and enabling other end uses, including hydrogen fueling stations.

Additionally, the Office of Science maintains and operates a diverse array of open-access scientific user facilities that are available for industrial research. These include neutron scattering facilities that would allow the imaging of water formation and transport as referenced in the recommendation, as well as x-ray scattering, microscopy, and advanced synthesis capabilities that could provide insight to a number of industrially-relevant approaches for advancement of hydrogen production and fuel cell operation.

Recommendation

> "***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*."

Response

From FY 2018 through FY 2019, DOE provided over $80 million in funding for H2@Scale enabling R&D, including $18 million for heavy duty fuel cell truck applications[4] and $13 million for H2@Scale pilot projects[5] to demonstrate hydrogen-focused integrated energy production, storage, and other end use applications.[6] The three pilot projects awarded in FY 2019 are cost shared by industry (totaling approximately $15 million in cost share) and provide proof of concept for key aspects of the H2@Scale vision at a demonstration scale. The selections also

---

[4] $15 million from the Fuel Cell Technologies Office and $3 million from the Vehicle Technologies Office.
[5] $11 million from the Fuel Cell Technologies Office and $2 million from the Office of Nuclear Energy.
[6] For more information on the awards selected between FY 2018 and FY 2019, see: (1) https://www.energy.gov/articles/department-energy-announces-40-million-funding-29-projects-advance-h2scale; (2) https://www.energy.gov/articles/department-energy-announces-50-million-commercial-truck-road-vehicle-and-gaseous-fuels-0; and (3) https://www.energy.gov/articles/secretary-perry-announces-38-million-new-projects-support-innovative-hydrogen-and-fuel-cell.

provide opportunities in regions outside California, which has already been the leader in deploying hydrogen technologies. The selected projects include:

1) **Leveraging Existing Nuclear Generating Stations to Produce Clean, Commercial-grade Hydrogen (Project Site: Illinois)**: In this project, Exelon will partner with Nel Hydrogen and multiple National Laboratories to demonstrate an integrated hydrogen production, storage, and utilization facility at an Exelon nuclear plant site. Exelon will install a proton exchange membrane (PEM) electrolyzer and an associated hydrogen storage system, supporting infrastructure, and a control system to enable dynamic operation of the electrolyzer. One project goal includes economic supply of carbon-free hydrogen for internal nuclear site use. In addition, Exelon will work with the labs to simulate and demonstrate dynamic control of the electrolyzer, paving the way for participation of hybrid power/hydrogen systems in organized power markets.
2) **Demonstration and Framework for H2@Scale in Texas and Beyond (Project Site: Texas)**: The University of Texas-Austin will partner with Frontier Energy and others to conduct an H2@Scale pilot using multiple co-located hydrogen production and end-use applications. Hydrogen will be produced from existing solar, wind, and landfill gas/biogas resources. Hydrogen will be consumed primarily by a data center (at Texas Advanced Computing Center, 100 kW), as well as fuel cell vehicles and aerial drones. The project will also capture data and lessons learned for other actionable H2@Scale pilot plans in Texas and the Port of Houston Gulf Coast region, including applications for marine, truck fleets, and energy storage.
3) **Demonstration of Integrated Hydrogen Production and Consumption for Improved Utility Operations (Project Site: Florida)**: In this project, Giner ELX will lead a team to demonstrate a highly integrated system that incorporates water electrolysis for hydrogen production, hydrogen storage, electricity production with fuel cells, and hydrogen fueling of fuel-cell electric vehicles (FCEVs), with dispatch decisions based on grid-level optimization controls. The dispatch of the electrolyzer will be designed to provide operational value to Orlando Utilities Commission's grid from solar electric smoothing to base load considerations. The various use-cases for the electrolyzer and fuel cell dispatch will be analyzed to determine scenarios that provide the greatest overall market value. The approach ensures that the hydrogen is produced at the lowest electricity cost, and then consumed for the greatest possible value, either as a grid asset or to support the transportation sector.

In addition, DOE's Office of Nuclear Energy funded approximately $9 million in FY 2019 (matched by over $2 million in industry cost share) to integrate an electrolyzer producing hydrogen at the Davis-Besse nuclear power station in Ohio.[7] These first-ever technology development projects are intended to show the technical feasibility and determine the

[7] U.S. Department of Energy Awards $15.2 Million for Advanced Nuclear Technology, https://www.energy.gov/ne/articles/us-department-energy-awards-152-million-advanced-nuclear-technology-0.

economic viability for using nuclear power to produce hydrogen and various other end use applications.

Recommendation

> ***"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."***

Response

In recent years, appropriations for FCTO have increased. For example, FY 2017, 2018 and 2019 funding was approximately $101, $115, and $120 million respectively. The Hydrogen and Fuel Cells Program continues to fund early-stage research and development activities that support industry efforts to develop and deploy hydrogen and fuel cell technologies that are cost competitive with conventional technologies.

Recommendation

"To overcome these [technical, commercial and logistical] challenges, we recommend that DOE take action to support the following areas:

a) The development and validation of value propositions and systems solutions for renewable energy to hydrogen for power, fuel, and grid-stabilization.
b) 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.
c) The cost of hydrogen fuel infrastructure and difficulties with station siting/permitting and reliability continues to be a challenge.
d) The delivered cost of hydrogen at current scale remains a challenge.
e) 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."

Response

The Department has taken steps to increase FCTO's focus on early-stage R&D to reduce the cost and increase the availability of hydrogen. The Program launched the H2@Scale initiative in late 2017 to enable affordable and reliable large-scale hydrogen generation, transport, storage, and utilization in the United States across multiple sectors. In FY 2019, the Program increased support for hydrogen infrastructure R&D to support the H2@Scale concept and launched a new national laboratory R&D consortium, the Hydrogen Materials Compatibility Consortium (H-Mat), to reduce the costs and enhance the durability of materials used in hydrogen service.

In FY 2018 and FY 2019, the Program has competitively funded or selected more than 50 projects through three FOAs directed at H2@Scale-related topics, for a total of more than $80 million. In addition, the Program co-funded more than 25 H2@Scale CRADA projects with the National Laboratories. These industry cost-shared CRADA project address focus areas including integrating hydrogen production with electricity generation and transmission; reducing the cost of hydrogen production technologies; and lowering the cost, reducing footprint, and improving reliability of hydrogen fueling infrastructure.

The FY 2018 FOA issued by FCTO included H2@Scale as one of its three topics. Through this FOA, the Program competitively awarded 12 projects totaling approximately $23 million in funding, including:

- Four projects to demonstrate first-of-a-kind hydrogen-focused integrated renewable energy production, storage, and transportation fuel distribution/retailing systems. These projects will demonstrate use of electrolyzers to supply grid services at a solar farm, autonomous hydrogen fueling technologies, electrolysis of wastewater, and synthesis of methanol and dimethyl ether from streams of hydrogen and carbon dioxide.
- Four projects to enable cost-competitive manufacturing of megawatt-scale electrolyzers for applications such as the provision of grid services or hydrogen production at fueling stations, and
- Four new projects directed at technologies to lower hydrogen station costs, including novel hydrogen compression and dispensing.

FCTO's FY 2019 FOA resulted in the selection of 29 projects to advance H2@Scale (announced in August 2019, with approximately $40 million in available funding). Topic areas included:

(1) Advanced Hydrogen Storage and Infrastructure R&D – including novel hydrogen carriers and H-Mat materials compatibility R&D;
(2) Innovative Concepts for Hydrogen Production and Utilization – including advanced water splitting, affordable biological hydrogen production, co-production of hydrogen and value-add byproducts, and reversible fuel cells); and
(3) H2@Scale Pilot for Integrated Production, Storage and Fueling Systems – to demonstrate a hydrogen-focused integrated energy production, storage, and transportation fuel distribution/retailing system in order to guide future early-stage R&D and enable viable business cases for increasing asset utilization across the entire energy system from production to end-use.

In addition, FCTO, the Vehicle Technologies Office (VTO), and the Bioenergy Technologies Office issued a joint FY 2019 FOA on medium- and heavy-duty trucks that included fuel cell truck and hydrogen fueling applications. This FOA resulted in $18 million[8] for 13 projects in support of H2@Scale. These selections included seven projects on advanced gaseous fuel storage, three projects on high-throughput fueling technologies for medium- and heavy-duty transportation, and three projects on high-durability, low-platinum membrane electrode assembles for medium- and heavy-duty trucks.

Also in 2019, the DOE Office of Nuclear Energy announced the award of over $9.2 million (with $2.3 million in industry cost share) for a project to develop and integrate a 1- to 3-MWe low-temperature electrolyzer to produce commercial quantities of hydrogen. Track I of the project will develop technical and economic assessments for two domestic nuclear power plant sites to support the feasibility of integrating the hydrogen generation capability at their sites (Technology Readiness Level [TRL] 3). Track II of the project will develop the major electrical and control interface technology required to apportion power output between the electrical grid and hydrogen generation unit at a Light Water Reactor in a safe and economically efficient manner (TRL 5). The project concludes with operation and verification of a 2 MW electrolyzer in 2022, at Energy Harbor's Davis-Besse Nuclear Power Station near Toledo, Ohio.

In FY 2020, the Program plans to continue using the consortium approach to invest in early-stage research and development(R&D) activities to support industry efforts to develop and deploy viable and safe technologies. Intended focus areas include: R&D on high-throughput fueling concepts to support affordable hydrogen for heavy-duty transportation sectors such as marine, rail, and trucks; advanced characterization of hydrogen release behavior and materials compatibility R&D to address regulatory barriers; and advanced concepts for affordable and reliable infrastructure component technologies.

In FY 2020, the Office of Fossil Energy (FE) is expanding its Fuel Cell R&D efforts to focus on producing hydrogen from excess electricity using solid oxide electrolysis cell (SOEC) systems at the utility scale. Significant amounts of excess electricity is available from ramping and idling coal and gas power plants that are following intermittent generation sources such as wind and solar; additionally, excess electricity from nuclear can also utilize this technology. The stored hydrogen will be used in existing steam generating systems, turbines, and solid oxide fuel cell (SOFC) systems during ramping and periods of peak electricity demand to ensure grid reliability and resiliency and store hydrogen for both short and long-term energy demand. Doing so will improve overall energy generation efficiency and reduce emissions including greenhouse gases. FE will use the expertise gained in SOFC technology and focus a significant portion of its R&D in this area on hydrogen production at the utility scale to include electrode and electrolyte materials optimization, control of electrode/electrolyte interface structure and chemistry, fabrication of commercial-scale cells, and testing of multi-cell stacks at bench scale. In addition to this, other areas of research will include cell materials and degradation, reversible SOFC-SOEC operation, system design challenges to scale to utility-scale systems, and cost reduction.

[8] $15 million from FCTO and $3 million from VTO.

DOE continues to collaborate across Federal agencies and with external partnerships (both national and international) to accelerate the market penetration and early adoption of hydrogen and fuel cell technologies and their supporting infrastructure and to share information, lessons learned and best practices (including safety, codes and standards), to enable affordable and sustainable deployment across sectors. The Hydrogen and Fuel Cells Program established an Interagency Working Group (IWG) that includes representatives from more than 10 Federal agencies and meets monthly to share information and explore opportunities for collaboration. To address opportunities for hydrogen and fuel cell use across the range of commercial transportation and military applications, key partners include the DOT and the Department of Defense (DoD).

One notable outcome during FY 2018 – FY 2019 was the October 2018 announcement of a memorandum of understanding (MOU) with the U.S. Army to collaborate on the development of hydrogen and fuel cell technologies for military and civilian use. The MOU will enable the FCTO and the Army's Ground Vehicle Systems Center (GVSC, formerly known as TARDEC – the Tank Automotive Research, Development and Engineering Center) to work more closely on technologies that can meet both organizations' goals.[9] The GVSC is the Army's research and development facility for advanced technology in ground systems aimed at developing next generation combat vehicles. FCTO and VTO co-hosted a webinar with its interagency partners at DoD in September 2019 to explore opportunities for a fuel cell mobile emergency response vehicle.[10] The webinar outlined operational requirements, vehicle specifications, and technology barriers for a concept vehicle, and requested input from industry and other stakeholders to guide a possible solicitation for a proof-of-concept demonstration to be co-funded by the agency partners. Other ongoing work with DoD includes collaborative R&D to investigate hydrogen and fuel cells for unmanned underwater and aerial vehicles and energy storage.

With regard to outreach and education, in October 2018, FCTO launched an interactive Hydrogen and Fuel Cells Career Map. The tool provides users with a way to discover and explore traditional and non-traditional career opportunities in the hydrogen and fuel cells industry. The tool also promotes workforce development in the science, technology, engineering and math (STEM) field by making information about hydrogen and fuel cell technology careers, education requirements, and skills for each career easily accessible to the public.[11]

[9] Energy Department and Army TARDEC to Collaborate on Hydrogen and Fuel Cells for Military Use, https://www.energy.gov/eere/articles/energy-department-and-army-tardec-collaborate-hydrogen-and-fuel-cells-military-use.

[10] Webinar Thursday, September 5: Fuel Cell Mobile Emergency Response Vehicle, https://www.energy.gov/eere/fuelcells/articles/webinar-thursday-september-5-fuel-cell-mobile-emergency-response-vehicle.

[11] Hydrogen and Fuel Cells Career Map, https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cells-career-map.

III. Recommendations from the Report of the HTAC Subcommittee on Competitiveness and Competition

HTAC formed this subcommittee to evaluate the current global competitive position of the United States in hydrogen and fuel cells and make recommendations on potential DOE actions to address challenges or concerns. The subcommittee was focused specifically on PEM fuel cells and related hydrogen generation and fueling infrastructure, across multiple regions of the world. The subcommittee's report was approved by the full Committee in March 2019, and included five interrelated recommendations:

1. *DOE to launch an effort to identify the top handful of large-scale commercialization demonstration and deployment initiatives, comparable in scale to the most significant offshore deployment initiatives, which will lead to significant investment in manufacturing and job creation in the United States. This study should focus on the already identified leading hydrogen and fuel cell applications including hydrogen for industrial use and fueling infrastructure for fuel cell vehicles (FCVs), FCV transit buses, FCV material handling, and commercial scale cell stack and membrane electrode assembly (MEA) production. The study should clearly identify what is required to a) elevate the focused segment to a sustainable commercial level and b) attract the type of investments to build and retain U.S. technology and manufacturing know-how onshore in support of target market segments.*
2. *DOE to determine what 'tools' or approaches are available to the U.S. government, states, and public-private organizations to provide financial incentives and market stimulus to encourage investments in domestic large-scale manufacturing of fuel cell/electrolyzer stacks and MEAs for both domestic and export markets. As part of this analysis, DOE should consider the evolution and experiences of similar technologies such as solar photovoltaic, wind, and battery which were developed principally in the U.S. and Europe, only to eventually be manufactured in large-scale in China.*
3. *DOE to conduct an initial competitiveness review and assessment to include progress on commercial demonstration and deployment initiatives; the development of intellectual property as well as the movement and transfer of intellectual property and manufacturing capacity; and the level of commercial and government investment rate to measure the effectiveness of this initiative. The initial review would recommend ongoing metrics and "dashboard" assessment and recommendations for frequency and involvement of other agencies and stakeholders.*
4. *DOE should play an active role to ensure that appropriate international codes and standards are developed to avoid jeopardizing domestic manufacturers and to foster a global market and robust supply chain. Codes and Standards are recognized as an important part of ensuring a level competitive playing field, especially in a developing industry.*
5. *FCTO should restore the Fuel Cell Technologies Market Report, an annual status report that provides a comprehensive snapshot of [industry] activity…[The report], last issued in*

2016, detailed trends in the U.S. and international fuel cell and hydrogen technologies market and highlighted continued growth in fuel cell commercial deployments in all applications and sectors. The report also provided detailed overviews and analysis of military funding/projects, DOE funding, patents, venture capital investments, sales and shipments.

Response

The Department agrees that strengthening U.S. competitiveness is a key priority. The Program plans to publish an updated *Fuel Cell Technologies Market Report* in FY 2020, and intends to work with partners to determine the best approaches for implementing future competitiveness studies and analysis to guide activities. FY 2020 DOE priorities include support for targeted integrated, system level proof of concept demonstrations to reduce the risks and lower the costs of commercial adoption. DOE management and operational priorities also include intra- and inter-agency collaboration, partner and international cooperation, and R&D to lower manufacturing costs.

The Hydrogen and Fuel Cells Program (FCTO) is supporting R&D aimed at lowering manufacturing costs, and its FY 2018 FOA awarded $7.5 million for four new projects to enable cost-competitive manufacturing of megawatt-scale electrolyzers for applications such as the provision of grid services or hydrogen production at fueling stations. In FY 2019, FCTO awarded four additional projects, including electrolyzer manufacturing R&D and three demonstration projects for $15 million total. This is in addition to 14 new hydrogen production R&D projects selected in FY 2019 for work within the HydroGEN consortium. The H2@Scale initiative plans to continue focusing resources on opportunities that could increase demand for hydrogen across multiple sectors, which would help support the growth of a U.S. supply chain, manufacturing base, and export market. The Program is also coordinating with DOE's Advanced Manufacturing Office to identify opportunities for advanced manufacturing in the production of hydrogen and fuel cell components in areas such as wide bandgap semiconductor materials, additive manufacturing, roll-to-roll manufacturing, and advanced composite materials and manufacturing.

DOE currently is involved in a number of international partnerships that focus on hydrogen and fuel cell technologies, and will work through these organizations and partnerships to develop, gather, and communicate information that can be applied to help strengthen the U.S. manufacturing base for hydrogen and fuel cells. These partnerships include the International Partnership for Hydrogen Fuel Cells in the Economy (IPHE), which the United States currently chairs; International Energy Agency; Clean Energy Ministerial; Hydrogen Energy Ministerial; and Mission Innovation. Through these partnerships, the U.S. is working with other countries to collaborate on policies, programs and projects to accelerate the commercial deployment of hydrogen and fuel cells across all sectors of the economy.

As mentioned previously, the U.S. continues to be a leader in the global harmonization of regulations, codes and standards, participating in the United Nations Global Technical Regulation 13 Phase II working group in collaboration with DOT's National Highway Traffic Safety Administration. The Hydrogen and Fuel Cells Program conducts safety related R&D as well as extensive collaborative efforts among government, industry, standards development organizations, universities, and National Laboratories aimed at harmonizing regulations, codes, and standards both domestically and internationally to enable domestic competitiveness and mass market penetration of safe hydrogen and fuel cell technologies.

As the Chair of the IPHE and its Regulations, Codes and Standards, and Safety Working Group (RCSS WG), DOE is working to accelerate progress on identifying gaps, barriers, and global opportunities in the area of RCSS. This includes codes and standards to meet the needs of H2@Scale in practice (e.g., regulatory and permit requirements for widespread hydrogen installations; heavy-duty hydrogen fuel cell vehicle operation and fueling; hydrogen use in marine, rail, and aviation applications; and large-scale hydrogen storage). DOE also participated in the Hydrogen Energy Ministerial meetings held in Japan in October 2018 and September 2019, which were attended by representatives from more than 20 countries including the Deputy Secretary of Energy. Four areas of collaboration were identified by the Ministerial participants, including one addressing RCSS:

- *Collaboration on Technologies and Coordination on Harmonization of Regulations, Codes and Standards:* Coordinate with industry to enable harmonization of relevant regulations, codes and standards such as those for refueling stations, for heavy duty transportation, for energy storage, for technologies supporting sectoral integration, for maritime and other applications, all to support a global marketplace. (Examples include nozzles and fueling protocols for heavy duty trucks and other applications.)

The Program plans to work with our international partners to identify concrete actions that can be pursued to achieve these goals. Through these and other efforts, DOE intends to continue to work to advance progress on our priorities and strengthen U.S. competitiveness.

Appendices: FY 2018 and 2019 HTAC Letters and Reports

A. HTAC 2017 Annual Report and Cover Letter
   i. https://www.hydrogen.energy.gov/pdfs/2017_htac_annual_report.pdf

B. Department of Energy Response (November 2018)
   i. https://www.hydrogen.energy.gov/pdfs/2018_doe_response_htac_secretary_letter.pdf

C. HTAC Subcommittee Report on Competitiveness and Competition (March 2019)
   i. https://www.hydrogen.energy.gov/pdfs/htac_competitiveness_subcommittee_report_2019.pdf

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

[6] E4tech, *The Fuel Cell Industry Review 2017*, http://www.fuelcellindustryreview.com.

[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.

[18] 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

[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

Department of Energy
Washington, DC 20585

February 14, 2019

Mr. Charles E. Freese
Vice Chair
Hydrogen and Fuel Cell Technical Advisory Committee
Pontiac Engineering Center
Global Propulsion Systems
850 North Glenwood Avenue
Pontiac, Michigan 48340

Dear Chairman Freese:

Thank you for your November 30, 2018, letter to Energy Secretary Rick Perry and the accompanying *2017 Annual Report of the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC).* The Department values the input of the Committee and sincerely appreciates its annual reports and recommendations.

Your report outlines many advances in United States-based hydrogen and fuel cell technology development and commercialization during 2017. It also summarizes key challenges to reaching the 2020 fuel cell and hydrogen infrastructure deployment goals envisioned in the Energy Policy Act of 2005 (EPACT), and identifies threats to U.S. competitiveness in this technology area. Your recommendations identify ways the program can work to resolve some of these concerns and we will continue to address these as we move forward.

Although the deployment of hydrogen fuel cell cars does not meet the widespread deployment targets envisioned in EPACT Section 811(a), DOE has met the EPACT Section 805(f) program goal of enabling automakers to make commitments to offer fuel cell electric vehicles (FCEVs) for sale to U.S. consumers. There are now over 6,000 commercial FCEVs on the road in the United States – more than any other country. You may be pleased to know that Deputy Secretary Brouillette attended the Hydrogen Energy Ministerial meeting in Japan in October 2018. Ministers and delegates from more than 20 countries attended and affirmed their commitment to accelerating progress in hydrogen and fuel cell technologies. In addition, the United States was elected Chair of the International Partnership for Hydrogen and Fuel Cells in the Economy in May 2018, which will help ensure that we are aware of global technical and market developments. Hydrogen safety and the harmonization of hydrogen and fuel cell codes and standards has been identified as a priority for international collaboration, and the United States will continue contributing to the development of consistent, science-based frameworks for hydrogen fuel and infrastructure.

We agree that cost continues to be a challenge, particularly the cost of hydrogen infrastructure and delivered hydrogen. Our H2@Scale initiative focuses on key challenges associated with wide-scale production and use of hydrogen across sectors, to unlock the revenue potential and value of hydrogen and fuel cells in multiple industries and applications. The H2@Scale research and development (R&D) consortium now comprises over 20 industry-led projects that are focusing on hydrogen production, integration of hydrogen technologies with the grid, and hydrogen fueling stations. These efforts will address critical national issues such as grid resiliency, energy security, domestic job creation, and leadership in manufacturing.

In addition, we recently released a Request for Information (RFI) to assess the domestic resources compatible with large-scale hydrogen production and gain insight into the technical and economic barriers associated with these production pathways. We are hopeful that the information gained through this process will improve energy affordability and security, as well as increase the resiliency and reliability of the nation's infrastructure. We also released an RFI in 2018 on reducing regulatory barriers to the development and deployment of technology, and we are currently developing plans to address this feedback.

Since you specifically mention our national laboratories, I am pleased to report that we have established a number of national laboratory consortia that expedite industry access to unique combinations of laboratory expertise and capabilities for R&D in specific areas, such as electrocatalysis, advanced water splitting, and hydrogen storage and infrastructure. These consortia will accelerate innovation in key technology areas such as zero-platinum catalysts, low-cost renewable hydrogen production, advanced materials and systems for hydrogen delivery and storage, and integrated/hybrid systems.

We continue to establish and seek partnership opportunities with federal agencies, states, and other entities to broaden acceptance for hydrogen and transition technologies to the private sector. For example, to address your comment on military applications we are working closely with the Department of Defense (DoD) to explore these opportunities. A joint Memorandum of Understanding signed by DOE and DoD in October, 2018 will foster collaboration in development of hydrogen and fuel cell technologies for military, as well as civilian use.

As you note, this industry is an important potential source of sustainable domestic job growth, future innovation, and energy leadership. It will be vital to stay at the cutting edge of innovation to maintain our leadership position, and DOE will continue to work with you and other stakeholders to identify key R&D priorities. The Department values the advice and commitment of the Committee in its efforts to continue to improve our programs and activities related to hydrogen and fuel cells. Please extend my sincerest gratitude to the Committee members for their hard work and their valuable contributions to the Department and its mission.

Sincerely,

Daniel R Simmons
Assistant Secretary
Energy Efficiency and Renewable Energy

HTAC Subcommittee Report on Competitiveness and Competition

Introduction

At the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) meeting in February 2018, Mr. Gary Flood presented to the Committee on his "Hydrogen and Fuel Cells Perspectives in China." During the ensuing discussion, several members expressed their concerns that the United States was at risk for losing some or all of its competitive leadership in the areas of hydrogen and fuel cells. This concern was evidenced by several economically and politically significant countries focusing national strategies and policies in these areas as a means to address domestic energy security and emissions issues. These countries have also committed to investing large amounts of capital to develop and implement hydrogen and fuel cell technologies. Moreover, some countries, such as China, were reported to have established goals to lead in these technologies, like they have in solar, batteries, and battery electric vehicle technologies. Because of the level of concern voiced by members, Chairman Freese formed a subcommittee, led by Mr. Harol Koyama, to conduct a high-level assessment of United States competitiveness in these areas and make recommendations for further studies.

More specifically, this subcommittee was tasked by the HTAC to evaluate the current competitive position of the United States in hydrogen and fuel cells, focused narrowly on polymer electrolyte membrane (PEM) fuel cells and related hydrogen fueling infrastructure, across multiple regions of the world, assess technology, investment and markets, and then make recommendations to the HTAC on potential options for U.S. Department of Energy (DOE) focus and actions with regard to funding, considering these regional capabilities and competitiveness and the increasing and ongoing developments in these international regions. While there are a range of fuel cell types and applications, this report focuses on low-temperature PEM, hydrogen generation, and infrastructure. The activity of this subcommittee was meant to build upon information and research resulting from the ***U.S. Clean Energy Hydrogen and Fuel Cell Technologies: A Competitiveness Analysis*** Document DE-EE-0006935, and other references as noted in this report.

1.0 Subcommittee members

Levi T. Thompson Ph.D., Harol Koyama, Morry Markowitz, Frank J. Novachek, Charlie Freese, John F. Mizroch, Kathy Ayers Ph.D., Gary Flood, Andy Marsh, and Henry Aszklar.

2.0 Conclusions

Based on patents, advanced research, system and component demonstrations, and commercial products, North America, Japan, and Europe currently hold significant technical leadership in core areas of PEM fuel cell stack, electrolyzer, and systems integration, with Europe holding a leading position in hydrogen fueling infrastructure technology. However, this could shift very quickly and may not be a reliable indicator of future, sustainable competitive advantage.

The fuel cell industry has undergone a very long period of heavy technology development and investment with steady but gradual commercialization. This slow growth but heavy investment has resulted in companies in need of cash and ready markets to continue to fuel their growth, keep investors motivated and involved, and in some cases, ensure their survival.

After many years of investment, the industry is in the critical period of transitioning from research and development and initial commercialization, to large-scale commercialization and related research and investment in manufacturing. As stated by the Hydrogen Council 2017 report *Hydrogen scaling up: A sustainable pathway for the global energy transition*, it is "about scaling existing technologies and considering the beneficial linkages and virtuous cycles of deploying hydrogen technology across the energy system." What is at stake for the United States are the jobs and economic benefits of manufacturing the more than 400 million cars, 15 to 20 million trucks, and 5 million buses by 2050, as well as the supporting hydrogen infrastructure, envisioned by the Hydrogen Council study. It would be a tragedy for the United States to have made the early-stage investments in the industry only to see the bulk of the 30 million jobs and $2.5 trillion per year of revenues forecasted by the Hydrogen Council shift offshore to countries such as China.

China is a proverbial "elephant in the room," in that it is the only country with both the means and the motivation to pursue fuel cells and electrolysis at a top national level, and it is leveraging these capabilities to rapidly absorb the best technologies and commercial capabilities in the hydrogen and fuel cell industry.

China starts from a relatively rudimentary technical basis. However, while it has taken the rest of the world decades to develop the current technological base in fuel cells and hydrogen infrastructure, China, through its concerted efforts, could acquire or control the bulk of this know-how in a few years. Further, using its home markets, China can build the volume to drive manufacturing costs lower than any other country. Ballard Power Systems is an industry pioneer and has leading-edge fuel cell technology. The recent large-scale investment by Weichai and Broad-Ocean Motors in Ballard Power Systems (http://www.ballard.com/about-ballard/newsroom/news-releases/2018/08/29/ballard-signs-historic-strategic-collaboration-with-weichai-power-advancing-china-strategy) makes possible the wholesale transfer of Ballard's capabilities to China and eventual control of the company. While most visible, Ballard is not the only fuel cell company to have already taken advantage of Chinese investments into their companies.

The year 2020, months from now, represents an important convergence of events in Japan and China. Japanese car companies will be making production component decisions for their fuel cell electric vehicles (FCEVs), catalyzed by the 2020 Tokyo Olympics. Meanwhile, China will be concluding their 13th Five Year Plan mandating thousands of FCEVs, and initiating their 14th Five Year Plan, which will likely include a massive increase in FCEVs.

The countries that developed the bulk of this technology are at an inflection point. They can either take urgent action to moderate this process and secure long-term competitive advantage or allow it to follow a similar path to that of the photovoltaic and lithium ion battery industries. The subcommittee recommends specific focus on the fiscal year (FY) 2019 and FY 2020 budgets of DOE's Fuel Cell Technologies Office (FCTO) to emphasize addressing the competitive threat.

3.0 Recommendations regarding options for DOE to address the threat to U.S. competitiveness

3.1 DOE to launch an effort to identify the top handful of large-scale commercialization demonstration and deployment initiatives, comparable in scale to the most significant offshore deployment initiatives, which will lead to significant investment in manufacturing and job creation in the United States. This study should focus on the already identified leading hydrogen and fuel cell applications including hydrogen for industrial use and fueling infrastructure for FCEVs, FCEV transit buses, FCEV material handling, and commercial-scale cell stack and membrane electrode assembly (MEA) production. The study should clearly identify what is required to (a) elevate the focused segment to a sustainable commercial level and (b) attract the type of investments to build and retain U.S. technology and manufacturing know-how onshore in support of target market segments.

3.2 DOE to determine what "tools" or approaches are available to the U.S. government, states, and public-private organizations to provide financial incentives and market stimulus to encourage investments in domestic large-scale manufacturing of fuel cell/electrolyzer stacks and MEAs for both domestic and export markets. As part of this analysis, DOE should consider the evolution and experiences of similar technologies such as solar photovoltaic, wind, and battery that were developed principally in the United States and Europe, only to eventually be manufactured in large scale in China.

3.3 DOE to conduct an initial competitiveness review and assessment to include progress on commercial demonstration and deployment initiatives; the development of intellectual property as well as the movement and transfer of intellectual property and manufacturing capacity; and the level of commercial and government investment rate to measure the effectiveness of this initiative. The initial review would recommend ongoing metrics and "dashboard" assessment and recommendations for frequency and involvement of other agencies and stakeholders.

3.4 Codes and standards are recognized as an important part of ensuring a level competitive playing field, especially in a developing industry. DOE should play an active role to ensure that appropriate international codes and standards are developed to avoid jeopardizing domestic manufacturers and to foster a global market and robust supply chain.

3.5 FCTO should restore the *Fuel Cell Technologies Market Report*, an annual status report that provides a comprehensive snapshot of activity is imperative to reinforce the status, relevance, and benefits of the fuel cell and hydrogen industry in the U.S. and around the world. The Fuel Cell Technologies Market Report, last issued in 2016, detailed trends in the United States and international fuel cell and hydrogen technologies market and highlighted continued growth in fuel cell commercial deployments in all applications and sectors. The report also provided detailed overviews and analysis of military funding/projects, DOE funding, patents, venture capital investments, sales, and shipments.

4.0 Fuel cell industry activities and references

4.1 http://www.hydrogenics.com/2017/04/28/hydrogenics-announces-us21-million-private-placement/

4.2 https://www.prnewswire.com/news-releases/china-leads-electric-vehicle-market-bev-phev-2020-forecasts-say-new-research-reports-592318931.html

4.3 http://kraneshares.com/resources/2013_10_kfyp_fan_gang_white_paper.pdf

4.4 http://ballard.com/about-ballard/newsroom/news-releases/2016/07/26/ballard-announces-strategic-collaboration-and-equity-investment-deal-with-broad-ocean

4.5 http://www.kwm.com/en/uk/knowledge/insights/china-13th-5-year-plan-key-points-summary-new-normal-innovation-20160414

4.6 http://www.chfca.ca/resources/chfca-blog/canadian-fuel-cell-sector-on-fire

4.7 PowerCell Sweden AB (publ) has received yet another order from a Chinese customer who will test the PowerCell S2 in commercial vehicles. The order value amounts to MSEK 2.3.

4.8 US Hybrid Announces China Fuel Cell Joint Venture and Unveils Class 8 Fuel Cell Port Drayage Truck for San Pedro Ports. http://ushybrid.com/us-hybrid-announces-china-fuel-cell-joint-venture-and-unveils-class-8-fuel-cell-port-drayage-truck-for-san-pedro-ports/

4.9 AFCC Vancouver to close operations in June 2018.

4.10 Standardization of PEM Fuel Cell Balance of Plant Components Report 7-23-2018.

4.11 Carmo M, Fritz DL, Mergel J, Stolten D. 2013. A comprehensive review on PEM water electrolysis. Int. J. Hydrog. Energy 38 (12): 4901–34.

4.12 Babic U, Suermann M, Büchi FN, Gubler L, Schmidt TJ. 2017. Critical Review—Identifying Critical Gaps for Polymer Electrolyte Water Electrolysis Development. J. Electrochem. Soc. 164 (4): F387–99.