COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY
U.S. HOUSE OF REPRESENTATIVES
HEARING CHARTER

H2Success: Research and Development to Advance a Clean Hydrogen Future
Thursday, February 17, 2022
10:00AM ET

Purpose

The purpose of this hearing is to examine the state of hydrogen research and development in the United States. Witnesses and Members will discuss hydrogen research, development, and demonstration activities as they relate to the advancement of clean hydrogen, including production, storage, transportation, and utilization. The role of hydrogen in the decarbonization of energy and industrial sectors, as well as opportunities and challenges for hydrogen deployment and utilization will also be discussed. The hearing will examine potential strategies for this Committee to direct the activities of the Department of Energy's (DOE's) Hydrogen and Fuel Cell Technologies Office.

Witnesses

- **Mr. Keith Wipke**, Laboratory Program Manager, Fuel Cell and Hydrogen Technologies Program, National Renewable Energy Laboratory
- **Dr. Julio Friedmann**, Chief Scientist and Head Carbon Wrangler, Carbon Direct
- **Ms. Rachel Fakhry**, Senior Advocate, Climate and Clean Energy Program, Natural Resources Defense Council
- **Dr. Tomás Díaz de la Rubia**, Vice President for Research and Partnerships, University of Oklahoma
- **Mr. Sheldon Kimber**, Chief Executive Officer and Co-Founder, Intersect Power

Background

The International Energy Agency (IEA) names hydrogen as one of the "biggest innovation opportunities" to reduce global carbon dioxide (CO_2) emissions to net zero by 2050, limit global temperature rise to 1.5 degrees Celsius, and avert the worst effects of climate change.[1] Hydrogen has long been identified as a clean alternative fuel as it is a potent energy carrier that does not emit any CO_2 at its point of use, with 1kg of hydrogen gas (H_2) containing 2.4 times as much energy as natural gas.[2] Hydrogen is also versatile and can be used in a variety of different applications, such as transportation and power generation. According to the Hydrogen Council, an industry-led group, hydrogen could meet 18% of global energy demand by 2050 and reduce CO_2 emissions by 6.6 Gt per year.[3]

[1] https://www.iea.org/reports/net-zero-by-2050
[2] https://www.nrel.gov/docs/gen/fy08/43061.pdf
[3] https://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf

The United States produces more than 10 million metric tons (MMT) of hydrogen annually, with approximately 60% of hydrogen manufactured in "dedicated" facilities as the primary product. Global hydrogen production was approximately 70 MMT in 2019 and global demand stood at 90 MMT in 2020. Almost all hydrogen produced globally is currently used for ammonia and fertilizer production or petrochemical refineries.[4]

Hydrogen Production

There are a variety of hydrogen production processes, with the most widely used commercial method being steam-methane reforming (SMR). Through this process, hydrogen is extracted from a reaction between a methane source, usually natural gas, and high-temperature steam. This process is currently very carbon intensive, producing 9 kg of CO_2 per kg of hydrogen.[5] However, research shows that if carbon capture and storage (CCS) is coupled to SMR, emissions can fall to ~2.5kg of CO_2 per kg of hydrogen.[6] This method of hydrogen production is often referred to as "blue" hydrogen. Globally 76% of hydrogen is produced through SMR (without CCS), while in the US it's 95%.[4]

Coal gasification, another commercially used method to produce hydrogen, involves reacting coal with oxygen and steam under high pressures and temperatures to extract hydrogen, which is extremely carbon intensive. The hydrogen produced through this method is referred to as "black" or "brown" hydrogen.[7] Currently 22% of the global hydrogen production is achieved through coal gasification and accounts for 4% of US production.[4]

The last commercially used method is electrolysis, which uses electricity to split water into hydrogen and oxygen. Electrolysis generates no direct greenhouse emissions, and if the input electricity is generated through zero emission energy sources, then there are no CO_2 emissions associated with the process and it results in what is known as "green" hydrogen. Only 2% of global hydrogen production comes from electrolysis and 1% of US production.[4]

The Department of Energy (DOE) is pioneering a variety of additional methods for hydrogen production technologies that are still in the early stages of research and development. The most promising methods are biological hydrogen production, biomass and waste conversion, photoelectrochemical water splitting, and solar thermal water splitting.[8,9]

Hydrogen production currently accounts for 6% of global natural gas use, 2% of coal consumption, and 830 $MtCO_2$ of annual CO_2 emissions.[10]

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[4] https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf
[5] https://greet.es.anl.gov/publication-smr_h2_2019
[6] https://www.catf.us/2021/09/we-need-blue-hydrogen-and-we-need-to-get-it-right/
[7] https://www.rff.org/publications/reports/decarbonizing-hydrogen-us-power-and-industrial-sectors/
[8] https://www.energy.gov/eere/fuelcells/hydrogen-production
[9] https://www.nrel.gov/hydrogen/hydrogen-production-delivery.html
[10] https://www.iea.org/fuels-and-technologies/hydrogen

Hydrogen Storage and Transportation

Hydrogen storage, transportation, and distribution are some of the challenges facing hydrogen integration into the overall energy economy system. Hydrogen has low-volumetric energy density at room conditions and can permeate metal-based materials, making storage and transportation difficult.[4]

Hydrogen is typically stored as a gas or a liquid. Storage options include compression or cryogenic systems, chemical production systems, such as ammonia, nanomaterial-based storage, and geological storage. Currently, the most common way to store large amount of hydrogen is in cryogenic systems. However, cryogenic systems require component compression and cooling systems, making them difficult and expensive to operate.[11]

Gaseous hydrogen is usually transported via pipelines or tube trailers, and liquid hydrogen is moved by road tankers. In the US, most hydrogen is transported using dedicated infrastructure, currently consisting of 1,608 miles of active pipeline.[12] More than 90% of these pipelines are located along the Gulf cost of Texas, Louisiana, and Alabama, serving refineries and ammonia plants in the region.[13] Several new hydrogen pipelines are being considered in different parts of the US to meet the demand for hydrogen.

Hydrogen Utilization

Today, hydrogen is primarily used as a chemical feedstock in ammonia, food, and drug production. It is also used in processes such as crystal growth, metal production, and thermal processing. However, research shows that hydrogen can be used to also to decarbonize several hard-to-abate industrial sectors, including petrochemical and cement, iron, and steel production.[4] In the case of steelmaking, approximately 7% to 9% of global greenhouse gas emissions are due to steel manufacturing. By using hydrogen instead of coal, the conventional way to produce steel, those emissions can be dramatically reduced.[14]

In transportation, hydrogen-powered fuel cell vehicles offer high efficiency and low emissions. Research shows that hydrogen fuel cell vehicles can help reduce emissions for the heavy-duty and larger scale transportation sector such as trains, ships, and planes.[4] Lastly, hydrogen can be used for power generation and long-term storage to balance seasonal variations in electricity.[15,16]

Challenges

While hydrogen possesses significant potential to replace fossil fuels and help combat climate change, several challenges remain that need to be addressed before we obtain full hydrogen implementation. The path to clean hydrogen, produced from low-carbon methods, requires

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[11] https://www.energy.gov/eere/fuelcells/hydrogen-storage
[12] https://www.energy.gov/eere/fuelcells/hydrogen-pipelines
[13] https://www.everycrsreport.com/files/2021-03-02_R46700_294547743ff4516b1d562f7c4dae166186f1833e.pdf
[14] https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf
[15] https://www.iea.org/reports/the-future-of-hydrogen
[16] https://energystorage.org/why-energy-storage/technologies/hydrogen-energy-storage/

solutions to continual technological concerns, cost and economics, and infrastructure needs. For example, SMR with CCS will still produce CO_2 emissions, and when coupled with upstream methane emissions and scaled up, this method produces significantly more emissions.[17,18] Electrolysis also faces the challenge of high costs, both for manufacturing and operations, and issues with energy and system efficiencies. [4,19] Other clean hydrogen production methods, such as biological hydrogen, are not mature technologies and require further research and development.

Other challenges include hydrogen storage, transportation, durability, costs, and safety. Storage and transportation challenges stem from hydrogen's requirement of specific materials and components to address its ability to permeate metal-based materials, which leads to leaks and raptures. Existing natural gas pipelines can only handle between 5%-20% hydrogen blends without hydrogen causing embrittlement of materials. In addition, the cost of on-board hydrogen storage systems is excessive, especially in comparison with conventional storage systems for petroleum fuels.[4, 20, 21]

Lastly, hydrogen is not without some environmental and health challenges. When hydrogen is combusted, it can generate NO_x emissions, a harmful pollutant. NO_x is shown to lead to serious damage to human health, including respiratory diseases, as well as environmental damage, such as acid rain which is known to harm sensitive ecosystems.[22] There are also concerns that pollution from hydrogen fuel, through combustion, could widen inequality by disproportionally impacting urban populations.[23]

Infrastructure Investment and Jobs Act

The Infrastructure Investment and Jobs Act (P.L. 117-58) establishes a clean hydrogen research and development program, which provides $8 billion over 4 years for the creation of Regional Hydrogen Hubs and requires the Secretary of Energy to develop a national energy strategy and roadmap to facilitate widescale production, processing, delivery, storage, and use of clean hydrogen.[24]

Department of Energy

The Energy Policy Act of 2005 authorized DOE to be the lead federal agency for directing and integrating activities in hydrogen and fuel cell R&D. The Hydrogen and Fuel Cell Technologies Office (HTFO) is responsible for coordinating the R&D activities for DOE's Hydrogen and Fuel Cell Program. This includes activities within four DOE offices: the Office of Energy Efficiency

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[17] https://www.nytimes.com/interactive/2019/12/12/climate/texas-methane-super-emitters.html
[18] https://www.pembina.org/reports/hydrogen-climate-primer-2020.pdf
[19] https://iopscience.iop.org/article/10.1149/MA2012-02/5/348/pdf#:~:text=Important%20challenges%20in%20the%20further,dynamics%20of%20the%20entire%20system.
[20] https://www.energy.gov/eere/fuelcells/hydrogen-storage-challenges
[21] https://www.nrel.gov/docs/fy13osti/51995.pdf
[22] https://www.epa.gov/no2-pollution/basic-information-about-no2#Effects
[23] https://www.nature.com/articles/d41586-021-01926-8
[24] https://www.congress.gov/bill/117th-congress/house-bill/3684/text

and Renewable Energy (EERE), Office of Fossil Energy and Carbon Management (FECM), Office of Nuclear Energy (NE), and the Office of Science.[25]
DOE's total funding for hydrogen activities was approximately $285 million in Fiscal Year 2021. The President's Fiscal Year 2022 Budget Request is approximately $400 million for DOE's hydrogen activities.[26]

Hydrogen and Fuel Cell Technologies Office (HFTO)

Within EERE, HFTO focuses on research, development, and demonstration of hydrogen and fuel cell technologies across multiple sectors.[27] Their research spans a variety of programs including hydrogen production, storage, and delivery R&D, fuel cell technologies R&D, and technology validation. HFTO also conducts a range of activities to address economic and institutional barriers. These activities include education and outreach, market transformation, and safety, codes, and standards.[28] HFTO also funds lab-led consortia to coordinate laboratory research and development activities and serve as a resource for universities and industry.[29]

H2@Scale and Hydrogen Shot

In 2016, the Hydrogen and Fuel Cell Technologies Office launched the H2@Scale initiative to explore the potential for hydrogen to enable affordable, reliable, clean, and secure energy across sectors. The initiative brings together National Laboratories, industry experts, and other stakeholders to accelerate and advance research, development, and demonstration of hydrogen production, delivery, storage, infrastructure, and end-use applications. It also identifies new and emerging markets where hydrogen technologies can add value to economic, energy, and environmental resilience applications.[30]

Since its inception, H2@Scale has provided approximately $112 million in funding for 56 projects that range from hydrogen production, infrastructure, end uses, grid integration, and safety, codes, and standards.[31] The most recent round of funding was announced in October 2021, which provided nearly $8 million for nine cooperative projects that will complement existing H2@Scale efforts. It will also support DOE's Hydrogen Shot initiative, which seeks to reduce the cost of clean hydrogen by 80% to $1 per 1kg in 1 decade ("1 1 1"). DOE states that, if successful, Hydrogen Shot will reduce carbon emissions by 16% by 2050 and lead to $140 billion in revenue and 700,000 new jobs by 2030.[32]

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[25] https://www.energy.gov/eere/fuelcells/about-hydrogen-and-fuel-cell-technologies-office
[26] https://www.energy.gov/sites/default/files/2021-06/doe-fy2022-budget-volume-3.1-v5.pdf
[27] https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office
[28] https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office-key-activities#international
[29] https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office-consortia
[30] https://www.energy.gov/eere/fuelcells/h2scale
[31] https://www.energy.gov/sites/default/files/2021/02/f82/h2-at-scale-crada-projects-2021.pdf
[32] https://www.energy.gov/eere/fuelcells/hydrogen-shot