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Federal Energy RD&D: Hydrogen & Fuel Cells

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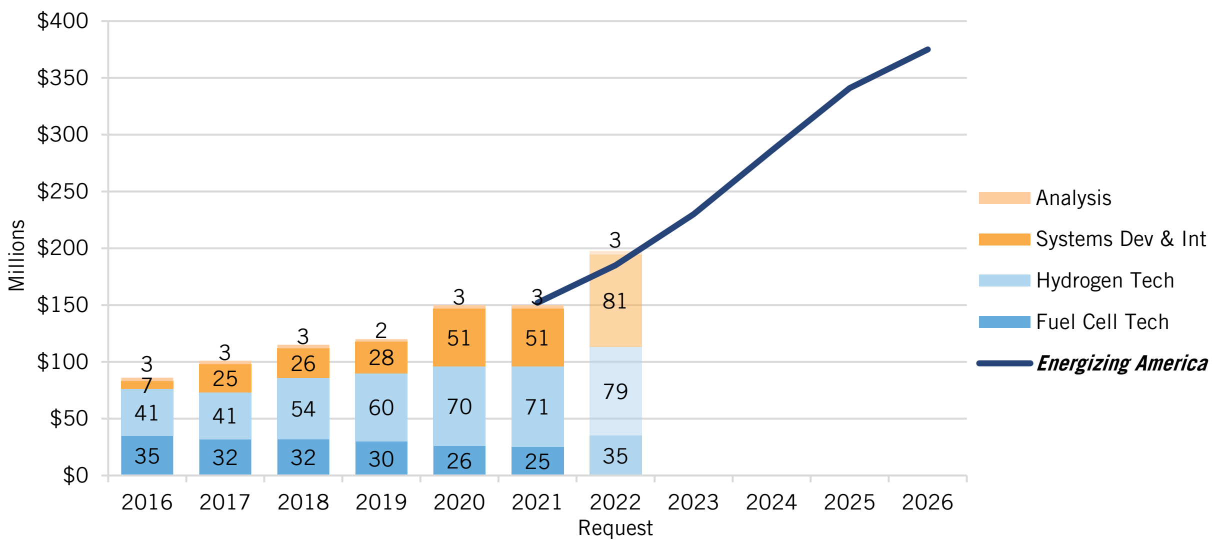
Hydrogen's versatility as an energy carrier and feedstock, and its lack of greenhouse gas emissions at the point of use, makes it an attractive alternative to fossil fuels for hard-to-abate energy sectors. Hydrogen is already produced on a large scale using copious quantities of natural gas, so it is an important sector to decarbonize in any case. And its potential to help other sectors decarbonize will only be realized if clean hydrogen production is dramatically scaled up. Fuel cells convert the chemical energy of hydrogen into electricity, without emitting carbon or conventional pollutants. The Hydrogen & Fuel Cells Technologies Office (HFTO) conducts research, development, and demonstration (RD&D) on three complementary technologies: low-cost clean hydrogen production; infrastructure for hydrogen compression, transmission, storage, and delivery; and fuel-cell technologies that can be used in electric vehicles and other applications.[1]

Figure 1: *Energizing America* recommends increasing funding by 150 percent by FY 2026.[2]



What's at Stake

Hydrogen has enormous potential to address multiple critical decarbonization challenges.[3] It can serve as a form of long-duration electricity storage, a feedstock in the production of synthetic hydrocarbon fuels and chemicals, and a source of high-temperature heat for industrial applications that have few alternative emissions-reduction solutions.[4] Because of its wide range of end uses, hydrogen can facilitate greater integration of energy systems across sectors—leading many to call for the creation of a "hydrogen economy."[5] However, realizing its potential will require continued RD&D, and early deployment support to bring down costs for production and delivery systems as well as end-use applications.

The United States currently produces 10 million metric tons per year (MMT/yr) of hydrogen (about 15 percent of global production), primarily for use in oil refining, fertilizer production, and biofuels production.[6] But current hydrogen production methods are incredibly carbon-intensive, releasing an average of 11 tons of carbon dioxide (CO_2) for every 1 ton of hydrogen.[7] Clean hydrogen production pathways include methane reforming with carbon capture and storage, water electrolysis (water splitting) using zero-carbon electricity, and biomass gasification with carbon capture and storage.

Demand for hydrogen could grow dramatically if it realizes its potential applications in hard-to-abate energy sectors. A recent report from the National Renewable Energy Laboratory (NREL) estimates the technical potential at 106 MMT/yr across a range of industrial, transportation, and energy storage applications.[8] Princeton's Net-Zero America Project found that hydrogen use could grow by more than 700 percent by 2050 in a decarbonized energy system, with growth primarily from liquid fuel synthesis, medium- and heavy-duty vehicles, industrial boilers, gas turbines for electricity generation, and steel production.[9]

The United States has historically been a world leader in the development and deployment of hydrogen production and related technologies. Over the past 20 years, the U.S. Department of Energy (DOE) has invested more than $4 billion in hydrogen production, resulting in more than 1,100 patents.[10] And the United States is home to several leading electrolyzer and hydrogen component and system manufacturers, as well as large multinational hydrogen companies.[11]

However, the United States may be ceding its early leadership in hydrogen technologies, just as electrolyzers are maturing to the point of commercial-scale deployment. The International Energy Agency (IEA) found that the average size of new electrolyzer capacity increased from 0.1 MWe in 2000–2009 to 1.0 MWe in 2015—2019, indicating a shift from small pilot and demonstration projects to commercial-scale applications.[12] This trend occurred against the backdrop of growing investment in hydrogen around the world, and declining public support in the United States. China, Japan, and the European Union have now surpassed the United States in public funding for RD&D of hydrogen technologies. And many countries are developing national hydrogen strategies and setting targets for electrolyzer deployments, which are intended to attract greater private sector investment.[13] A key question is whether this investment will occur in the United States or elsewhere.

On the end-use side, DOE's HFTO has primarily focused on hydrogen applications in transportation—specifically on fuel cell electric vehicle (FCEV) technology for light-duty cars. However, the current portfolio may be misaligned with future opportunities. Due to the recent dramatic cost declines in lithium-ion batteries, battery electric vehicles (BEVs) will likely reach cost parity with conventional gasoline-powered cars sooner than will hydrogen FCEVs. Additionally, DOE has underinvested in hydrogen applications in the harder-to-abate sectors with the greatest potential for growth.

To accelerate the development of domestic hydrogen technologies, DOE has established innovation targets for hydrogen production ($2 per kilogram) and storage ($1 per kilogram), as well as targets for FCEVs.[14] DOE's goals for light-duty FCEVs include decreasing fuel cell costs to 30 dollars per kilowatt ($30/kW), decreasing onboard hydrogen storage costs to 8 dollars per kilowatt-hour ($8/kWh), and improving fuel cell durability to 8,000 hours (approximately 240,000 miles of driving), by 2030.[15]

The Energy Act of 2020 provides the first reauthorization of DOE's Sustainable Transportation program—which includes Hydrogen and Fuel Cells Technologies, the Bioenergy Technology Office (BETO), and the Vehicle Technologies Office (VTO)—in over a decade. The bill authorizes $830 million for FY 2021, $855 million for FY 2022, and $880 million for FY 2023 for Sustainable Transportation, but does not specify the amount to be allocated to each office.

Figure 1 shows historical DOE investment in hydrogen and fuel cells RD&D by subprogram, for FY 2016 through FY 2021, and the FY 2022 budget request. DOE merged the Hydrogen Fuel and Hydrogen Infrastructure subprograms into a single Hydrogen Technologies subprogram in its FY 2021 budget request. DOE also merged the Technology Acceleration and Safety, Codes, and Standards subprograms into a single Systems Development and Integration subprogram. The blue line shows recommended funding levels from the *Energizing America* report (see box 1). Because hydrogen plays such an important role in addressing multiple harder-to-abate sectors, *Energizing America* recommends a fast ramp-up to 150 percent above FY 2020 levels over the next five years.

Box 1: An Innovation Agenda for Hydrogen & Fuel Cells Technologies

The *Energizing America* report co-authored by the Information Technology and Innovation Foundation (ITIF) and Columbia University's Center on Global Energy Policy offers several recommendations to accelerate innovation in hydrogen and fuel cells. Similarly, ITIF's March 2021 report "Building Bank Cleaner with Industrial Decarbonization Demonstration Projects" makes recommendations to DOE and Congress:

- Congress should ramp up investment in hydrogen RD&D by 150 percent over the next five years. This increase is needed to drive down costs of hydrogen production and realize its potential applications in hard-to-abate industrial and transportation sectors.[16]
- The Biden administration's infrastructure package should include $5 billion over five years for cost-shared demonstration projects that mitigate process and combustion emissions in heavy industries such as steel, cement, and chemicals by using clean hydrogen.[17]
- Congress should reauthorize HFTO and expand its mandate to encompass industrial applications, including thermal process heating, direct-reduction of iron for steel production, synthetic fuels, long-duration energy storage, electricity generation, and building heating. Congress should explicitly authorize demonstration projects in large-scale electrolyzers, steel production, and gas turbines.[18]
- HFTO and the DOE Office of Basic Energy Sciences (SC-BES) should coordinate to facilitate the hand-off of basic research—e.g., at the Joint Center for Artificial Photosynthesis—to the applied RD&D programs as promising zero-carbon-fuel production pathways mature. Additionally, the technology challenges identified in the applied programs should inform the basic research directions pursued by SC-BES.[19]

Hydrogen & Fuel Cells RD&D Subprograms

RD&D in the Hydrogen & Fuel Cells program is distributed across six subprograms:[20]

- **Fuel Cell Technologies** supports RD&D to develop technologies that enhance the durability, reduce the cost, and improve the performance of fuel cells, with a goal of achieving cost competitiveness with internal combustion engine light-duty vehicles and heavy-duty trucks.
- **Hydrogen Fuel Research and Development (R&D)** focuses on novel hydrogen production—including by electrically splitting water—and storage technologies, as well as direct conversion of natural gas to hydrogen and carbon coproducts (beyond the conventional steam methane reforming process). The FY 2021 budget request proposes merging the subprogram with Hydrogen Infrastructure R&D.
- **Hydrogen Infrastructure R&D** focuses on reducing costs of such hydrogen fueling infrastructure systems as liquid pumps, compressors, storage, chillers, dispensers, and other hydrogen delivery and station components.
- **Data, Modeling, and Analysis** performs research that provides a technical basis for informed decision-making for the program's R&D direction and prioritization.
- **Systems Development and Integration** focuses on advancing the technologies that allow for the integration of hydrogen systems with a wide range of sectors, including marine, trucking, rail, steelmaking, ammonia production, electrofuels production from CO_2, and renewable and nuclear resources.

Key Elements of the FY 2022 Budget Proposal[21]

The budget proposal seeks $197.5 million for the Hydrogen & Fuel Cells program, a 32 percent boost from FY 2021 enacted levels. Some highlights include:

- **A 40 percent increase in Fuel Cell Technologies,** including a shift from early-stage R&D to demonstration of hydrogen fuel cells in heavy or medium duty trucks as part of the SuperTruck funding opportunity.
- **An 11 percent increase in the Hydrogen Technologies,** including increased funding for manufacturing, development, and demonstration of electrolyzer systems and components and balance of system components.
- **A 59 percent increase in Systems Development & Integration,** with a $30 million increase in funding to integrate and demonstrate electrolyzers powered by renewable power sources and clean hydrogen as feedstock or direct reducing agent for ammonia and steel production.
- **No change in Data, Modeling & Analysis.**

Further Reading

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ENDNOTES

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