

PROGRESS IN Hydrogen and Fuel Cells

The U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office (HFTO) focuses on research, development, and demonstration of hydrogen and fuel cell technologies across multiple sectors—enabling innovation, a strong domestic economy, and a clean, equitable energy future. HFTO's funding has spurred significant progress in several areas.

Key Program Activities

Led the development of the U.S. National Clean Hydrogen Strategy and Roadmap. The *Strategy and Roadmap* provides a snapshot of hydrogen production, transport, storage, and use in the United States today and explores the potential for clean hydrogen to contribute to national goals across multiple sectors, with a goal of producing 50 million metric tons of clean hydrogen annually by 2050. Key strategies include targeting high-impact uses for clean hydrogen; reducing the cost of clean hydrogen; and focusing on regional networks.

Contributed to *Pathways to Commercial Liftoff: Clean Hydrogen*. This report, the result of an effort spanning multiple DOE offices, provides industry and other private-sector partners with a valuable, engagement-driven resource on how and when clean hydrogen can reach full scale deployment.

\$9.5 billion in funding from the Bipartisan Infrastructure Law announced for clean hydrogen initiatives, including Hydrogen Hubs and Clean Hydrogen Electrolysis, Manufacturing, and Recycling

Reducing Cost and Improving Durability and Performance of Fuel Cells

Continued to reduce high-volume costs of heavy-duty transportation fuel cells, achieving ~10% reduction from the 2021 baseline. Cost reductions build on prior advances and reflect ongoing R&D progress, including improvements in fuel cell catalysts and membrane electrode assemblies. Modeled cost of heavy-duty fuel cells is \$179/kW when produced at 50,000 units per year, and enhanced durability is projected to meet one million miles (25,000 hours) needed for long-haul trucks.

Enhanced performance of fuel cell catalysts. Improved the performance of specific platinum-group-metal-free catalysts by approximately 60% over the 2021 baseline.

Advancing Technologies for Producing, Delivering, and Storing Hydrogen

PRODUCTION

Accelerated hydrogen production R&D. Achieved a world record in solar-to-hydrogen conversion efficiency in a photoelectrochemical device and screened more than 1,000 materials for thermochemical hydrogen production.



DOE launched the **Hydrogen Shot** as the first of the Energy Earthshots in 2021—with a goal to cut the cost of clean hydrogen by 80% to \$1 per 1 kilogram in 1 decade ("1-1-1")



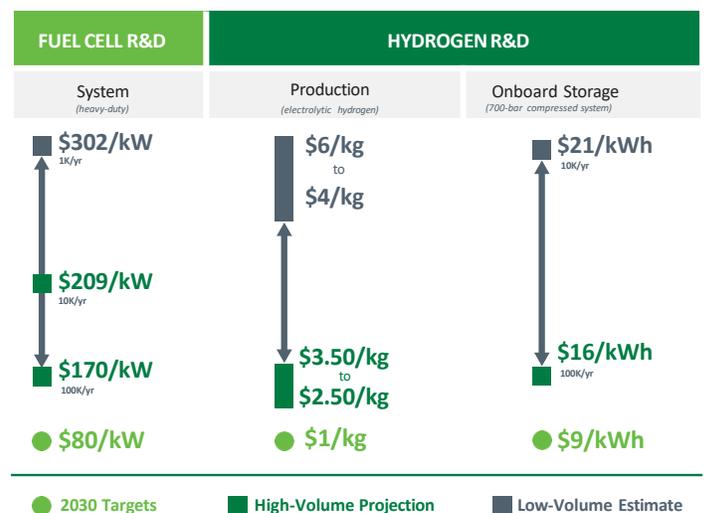
Reduced the cost of producing hydrogen from renewables. R&D advancements have reduced the cost of electrolyzers by over 90% since 2001 and 80% since 2005.

DELIVERY AND STORAGE

Commissioned first-of-a-kind test facility for high-throughput fueling. The test facility for high-throughput (10 kg/min) fueling at NREL will inform codes and standards and advance fueling components.

Reduced the cost of dispensed hydrogen. Technology advancements have been made and pathways identified to enable the projected costs of hydrogen production, delivery, and dispensing for 700-bar fueling to be reduced to about \$5–\$7/kg (assuming high-volume production and widespread deployment), making it nearly cost competitive with gasoline.

Reduced the cost of advanced compressed onboard hydrogen storage systems by 30% since 2013. In addition, HFTO advanced the theory and modeling necessary to develop a material that bonds to hydrogen tightly enough to meet both gravimetric and volumetric capacity targets, with more than 85% reduction in pressure compared with today's technology (from 700 bar to ≤100 bar).



Cost values incorporate different assumptions of volume production, economies of scale, and technology pathways.

Note: Graphs not drawn to scale and are for illustration purposes only

SYSTEMS DEVELOPMENT AND INTEGRATION

Began deployment of hydrogen and fuel cell delivery trucks. Project plans to deploy 15 fuel cell-powered delivery vans in disadvantaged communities in California.

Began production at the nation’s first electrolyzer directly coupled with nuclear power. Clean hydrogen production began at a nuclear plant in Oswego, New York.

Initiated work on SuperTruck III projects. The three projects will demonstrate a total of 11 medium- and heavy-duty hydrogen fuel cell electric trucks with driving ranges, payload, and fueling times competitive with incumbent technologies.

Demonstrated steel decarbonization using hydrogen. One tonne per week of iron ore reduced using hydrogen, enabling greater than 25% emissions reduction.



HFTO activities align with the H2@Scale initiative for affordable hydrogen production, storage, distribution, and utilization across multiple applications and sectors in the economy

ANALYSIS TOOLS

Updated GREET to allow for user-friendly analysis. Recent updates to the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) model allow for transparent analysis of user-defined hydrogen production facilities.

Established hydrogen technology analysis tools. Developed models and tools now used worldwide to assess the cost of hydrogen production, delivery, and infrastructure (H2A, H2A Lite, H2FAST, HDSAM, HESET, HRSAM, StoreFAST).

Co-led development of life cycle analysis best practices with the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE). Currently informing an ISO Code Case on Life Cycle Analysis of Hydrogen.

<p>Formed Consortia Consortia leverage national-lab resources to address key challenges and accelerate progress</p>
<p>H₂NEW U.S. DEPARTMENT OF ENERGY Electrolyzer Component and Material Integration</p>
<p>ACTE MILLION MILE FUEL CELL TRUCK U.S. DEPARTMENT OF ENERGY Million Mile Fuel Cell Truck</p>
<p>HyMARC Hydrogen Materials Advanced Research Consortium Advanced H₂ Storage Materials</p>
<p>ElectroCat Electrocatalysis Consortium PGM-Free Catalysts for Fuel Cells and Electrolyzers</p>
<p>HydroGEN Advanced Water Splitting Materials Renewable Hydrogen Production</p>
<p>H-Mat Hydrogen Materials Compatibility Consortium H₂ Materials Compatibility</p>



1,306
H₂ and Fuel Cell
PATENTS

ENABLED BY HFTO FUNDS

APPROX.

36%

OF THOSE PATENTS
ARE FROM
NATIONAL LABS

SAFETY, CODES & STANDARDS

Informed revision to NFPA-2 that reduces the footprint of cryogenic-liquid hydrogen stations by about 40%.

Developed an ASME Code Case that extends design life of storage vessels by up to 3X. Reduces costs by enabling longer storage vessel life, removes need for expensive and challenging testing, and provides harmonization of design curves.

Published a regulatory roadmap, *Federal Oversight of Hydrogen Systems*, which provides an overview of the regulations that apply to hydrogen and identifies opportunities for federal coordination.

Launched portfolio of RD&D projects to improve understanding of the global warming potential of hydrogen, in collaboration with NOAA—includes advancing hydrogen sensors and improving climate modeling.

Released additional resources on H2Tools. Added critical lessons-learned resources and a codes and standards database to H2Tools, a free online hydrogen safety training resource for emergency responders.

SPURRING DEPLOYMENTS AND CATALYZING INNOVATION

First round of H-Prize: Hydrogen Shot Incubator awarded. Nine winning teams received \$10,000 in cash and \$50,000 in vouchers to spend at national laboratories to further develop their concepts in the second phase of the \$2.6 million competition.

Catalyzed fuel cell deployments. HFTO funds have also enabled the uptake of hydrogen fuel cells for forklifts and backup power applications. For example, years ago, HFTO cost-shared with industry the deployment of approximately 700 forklifts, and today there are more than 60,000 fuel cell forklifts in operation at major warehouses.

Fostered an American-made hydrogen refueling system. Launched *H2 Refuel H-Prize* competition, which awarded \$1 million to SimpleFuel, which is now exporting their small-scale hydrogen refueling station.

For more information, visit: energy.gov/eere/fuelcells



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