



PROGRESS IN HYDROGEN AND FUEL CELLS

The **U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office (HFTO)** leads research, development, and demonstration (RD&D) of hydrogen and fuel cell technologies across sectors—enabling innovation, a strong domestic economy, and abundant, affordable energy. HFTO is part of a portfolio of government and industry activities driving progress across the United States.

NATIONAL PROGRESS

Federal Initiatives, Reports, and Plans

America's [National Hydrogen Strategy](#) identifies potential sources and demands for hydrogen across multiple sectors that could enable production of 50 million metric tons (MMT) annually by 2050. Led by HFTO and coordinated across multiple DOE offices and federal agencies, the [Strategy](#) also shows the potential for 100,000 new jobs by 2030. The [Hydrogen Interagency Task Force](#) unites federal agencies in a collaborative whole-of-government effort to execute the national hydrogen strategy.

The [Department of Energy Hydrogen Program Plan](#), published in 2020 and updated in 2024, identifies key focus areas across DOE's Hydrogen Program—a coordinated effort involving multiple [hydrogen-related offices](#). HFTO's [Multi-Year Program Plan](#) sets forth HFTO's mission, goals, and strategy—explaining how HFTO's efforts will help overcome key obstacles to realizing the full potential of hydrogen and fuel cells.

The [Hydrogen Energy Earthshot](#), led by HFTO, aims to reduce the cost of producing hydrogen to \$1 per 1 kg in 1 decade ("1-1-1").

The [Pathways to Commercial Liftoff](#) report on hydrogen—led by the DOE Of-

INDUSTRY INVESTMENT & GROWTH

Federal funds have catalyzed even greater private sector investments and growth, including:

- ⇒ **25-fold increase in electrolyzer installations** (planned and installed) since 2021—from 0.17 gigawatts (GW) in 2021 to 4.5 GW in 2024
- ⇒ **>\$40 billion in private-sector investment** in the H2Hubs
- ⇒ **>15 new or expanded manufacturing facilities** announced for electrolyzers, fuel cells, and components—over \$2.9 billion of investment
- ⇒ Nearly **70,000 fuel cell forklifts** and **over 500 MW of backup power fuel cells** deployed—markets initiated and spurred by HFTO-supported deployments over 15 years ago

fice of Infrastructure, supported by HFTO and other offices—examines how hydrogen can reach large-scale deployment and achieve "commercial liftoff."

The [Infrastructure Investment and Jobs Act \(IIJA\)](#) provided \$9.5 billion for hydrogen initiatives:

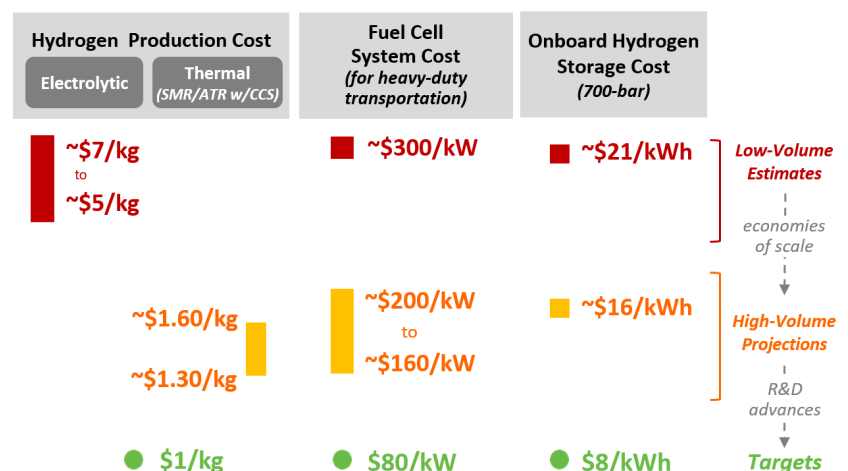
- In 2023, DOE announced the selection of seven [Hydrogen Hubs \(H2Hubs\)](#), with \$7 billion in funding, which will create tens of thousands of jobs across the country in multiple industries.
- In 2024, HFTO announced the [selection of 52 projects](#) across 24 states for projects to develop and demonstrate electrolysis technologies and advance technologies and processes for manufacturing and recycling materials and components involved in hydrogen production and use. This will enable a 10 GW/year production capacity for electrolyzers and 14 GW/year capacity for fuel cells, creating over 1,500 direct jobs and thousands of indirect jobs. This investment supports production of 1.3 MMT of hydrogen per year and enough fuel cells for 50,000 new trucks per year.

These efforts complement financing by DOE's Loan Programs Office, which is providing **\$3 billion in federal loan guarantees** for hydrogen-related projects.



ACCOMPLISHMENTS

HFTO drives progress and cost reduction in key areas to enable commercial viability and market adoption. The figure to the right shows the cost of current technologies, based on low-volume manufacturing estimates and projected for high-volume manufacturing—illustrating the need for additional RD&D advances along with efforts to boost deployment and achieve economies of scale.



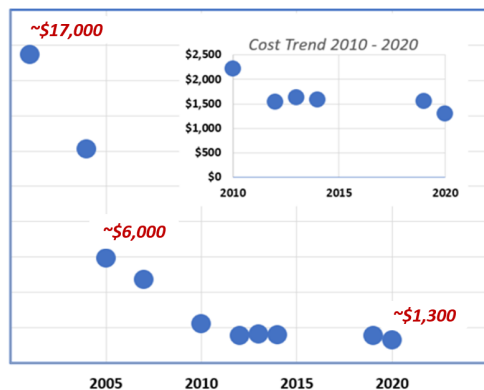
Advancing Technologies for Producing, Delivering, Storing, and Using Hydrogen

Examples of progress due to HFTO-funded efforts include:

HYDROGEN PRODUCTION

Accelerated H₂ production R&D. Achieved world records in direct photoelectrochemical H₂ production, screened more than 1,000 materials for thermochemical H₂ production, and launched a **Hydrogen Shot Incubator Prize** to incentivize breakthrough concepts.

Reduced the cost of electrolyzers by over 90% since 2001 and 80% since 2005.



HYDROGEN DELIVERY AND STORAGE

Reduced the cost of compressed on-board hydrogen storage systems by ~40% since 2013 and launched new projects to reduce cost of carbon fiber for high-pressure tanks.

Launched a first-in-the-U.S. facility to demonstrate 10 tons hydrogen storage capacity using engineered sub-surface storage at a national laboratory.


Demonstrated fast fueling of high-pressure H₂ (700 bar), with 10 kg/min average and a peak rate of 27 kg/min. (achieved in collaboration with Safety, Codes & Standards).

Demonstrated that liquid organic H₂ carriers can be viable for GW-scale storage with a levelized storage cost of less than \$2/kg-H₂.

FUEL CELLS

Reduced high-volume cost of fuel cells for heavy-duty long-haul trucks from \$200/kW in 2021 to approximately \$155/kW in 2023.

Launched the L'Innovator initiative to accelerate tech transfer, with **\$2 million of HFTO funds enabling \$160 million of private-sector investment** for a high-temperature fuel cell membrane facility.



>1,080
H₂ and Fuel Cell
PATENTS

ENABLED BY HFTO FUNDS SINCE 2004

→ ... leading to 30 commercial technologies and another 65 technologies that could be commercial in the near future.

Improved performance of platinum-group-metal-free catalysts by 60% over 2021 baseline.

Launched H2CIRC, a recovery and recycling consortium including 15 partners to enable end-of-life strategies for fuel cell and electrolyzer systems and components.

SYSTEMS DEVELOPMENT & INTEGRATION

Supported the launch of seven Hydrogen Hubs for \$7 billion.

Launched SuperTruck III projects to demonstrate 11 MD/HD (medium-/heavy-duty) fuel cell trucks.

Demonstrated the nation's first direct-coupled nuclear-to-hydrogen production facility, with a ~1-MW electrolyzer.

Demonstrated integration of hydrogen in steelmaking at a scale of 1 tonne per week of iron ore reduction.

Demonstrated a first-of-its-kind MW-scale hydrogen fuel cell at a data center.

Launched H2Rescue fuel cell truck for disaster relief, and enabled a world record for longest distance traveled by a fuel cell electric truck without refueling – 1,806 miles on one tank of hydrogen (in collaboration with DOD).

Launched 'Station of the Future' – 4 projects to develop and demonstrate low-cost, scalable station designs for fueling MD/HD vehicles.

SAFETY, CODES & STANDARDS

Informed code revisions (NFPA-2) that reduces the footprint of liquid-H₂ stations by ~40%.

Developed an ASME code case that extends design life of storage vessels by up to 3X, reducing costs by enabling longer storage vessel life and reducing the need for expensive and challenging testing.

Published a regulatory roadmap, identifying federal oversight of hydrogen systems and opportunities for federal coordination.

Launched projects to improve understanding of hydrogen-emissions impacts (in collaboration with NOAA), and launched over \$8 million in hydrogen sensor RD&D.

Released H2Tools resources and supported the Center for Hydrogen Safety to enable training for a range of stakeholders.

DATA, MODELING, AND ANALYSIS

Updated GREET model to support allow for simple, transparent, user-friendly life cycle analyses.

Established models and tools now used worldwide to analyze the cost of H₂ production, delivery, and infrastructure (H2A, H2A Lite, H2FAST, HDSAM, HESET, HRSAM, StoreFAST).

Co-led the 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.

R&D CONSORTIA

HFTO leverages national lab resources to foster industry partnerships—to address key challenges and accelerate progress.

ElectroCat: PGM-free catalysts for fuel cells and electrolyzers

H2NEW: Electrolyzer component and materials integration

H-Mat: H₂ materials compatibility

HyBlend: H₂ blending in natural gas pipelines

HydroGEN: Advanced water splitting

HyMARC: Advanced H₂ storage materials

Million Mile Fuel Cell Truck: Fuel cells for long-haul trucks

Roll-to-Roll Consortium: Efficient, high-throughput manufacturing

HFTO also supports international initiatives in co-leadership roles—including IPHE, CEM H2I, MI, IEA TCPs, and others—coordinated through the BtA, which is co-led by the U.K., U.S., and India. Accomplishments include: launching the H2 Twin Cities initiative to share best-practices across continents; analyses to enable robust certification processes; and fostering collaborations resulting in 38 countries endorsing an intent for mutual recognition of certification for hydrogen trade.