

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 a secure, resilient, and equitable clean energy future. HFTO's activities are part of a broad portfolio of government and industry investment driving progress and enabling jobs across the United States.

NATIONAL PROGRESS

Federal Initiatives, Reports, and Plans

The [U.S. National Clean Hydrogen Strategy and Roadmap](#), published in 2023, identifies potential sources and demands for clean 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 and Roadmap* also shows the potential for 100,000 new jobs by 2030 and reductions in total greenhouse gas (GHG) emissions of up to 10% by 2050. The [Hydrogen Interagency Task Force](#) unites federal agencies in a collaborative whole-of-government effort to execute the national clean 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 clean hydrogen and fuel cells.

The [Hydrogen Energy Earthshot](#) ("Hydrogen Shot"), launched in 2021 and led by HFTO, aims to reduce the cost of producing clean hydrogen to \$1 per 1 kg in 1 decade.

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

[Pathways to Commercial Liftoff: Clean Hydrogen](#)—led by the Office of Infrastructure, supported by HFTO and other offices—examines how clean hydrogen can reach large-scale deployment and achieve "commercial liftoff."

The **Bipartisan Infrastructure Law (BIL)** provided \$9.5 billion for clean hydrogen initiatives:

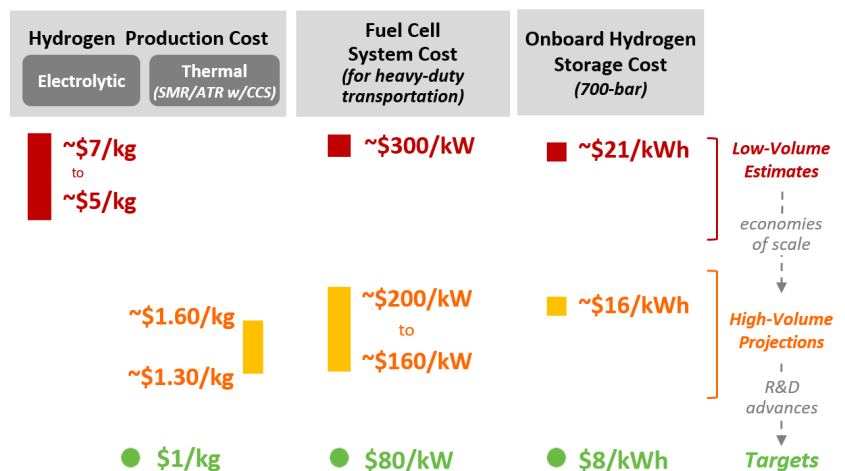
- In 2023, DOE's Office of Clean Energy Demonstrations (OCED) announced the selection of seven [Regional Clean Hydrogen Hubs \(H2Hubs\)](#), with \$7 billion in BIL funding, which will create tens of thousands of jobs across industries.
- In 2024, HFTO announced the [selection of 52 projects](#) across 24 states for the BIL-funded **Clean Hydrogen Electrolysis** and **Clean Hydrogen Manufacturing and Recycling** programs. This will enable a 10 GW per year production capacity for electrolyzers and 14 GW per 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.



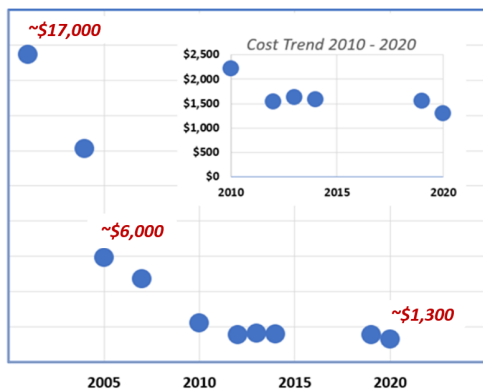
Advancing Technologies for Producing, Delivering, Storing, and Using Hydrogen

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 the 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 leveraged cost of storage of less than \$2/kg-H₂.

FUEL CELLS

Reduced high-volume costs 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



**>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.**

investment for a high-temperature fuel cell membrane facility.

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

Launched H2CIRC, a Recovery and Recycling Consortium for \$64 million, 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 Regional Clean Hydrogen Hubs for \$7 billion, managed by DOE’s OCED.

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

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

Demonstrated steel decarbonization using hydrogen at a scale of 1 tonne per week of iron ore reduction, enabling up to 90% reduction in emissions.

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

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, which identifies 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 diverse stakeholders.

DATA, MODELING, AND ANALYSIS

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

Established analysis 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	
ElectroCat:	PGM-free catalysts for fuel cells and electrolyzers
H2NEW:	Electrolyzer component and material integration
H-Mat:	H ₂ materials compatibility
HyBlend:	H ₂ blending in natural gas pipelines
HydroGEN:	Advanced water splitting
HyMARC:	Advanced H ₂ 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 clean hydrogen trade.