HYDROGEN
& THE CHEMICAL INDUSTRY

American Chemistry Council

Hydrogen is a molecule with a diverse set of energy applications. Hydrogen plays a critical role in advancing a comprehensive energy portfolio for the United States. The use of hydrogen resources can promote energy security and resilience, as well as provide value and economic benefits for diverse applications across multiple sectors of the economy.[1]

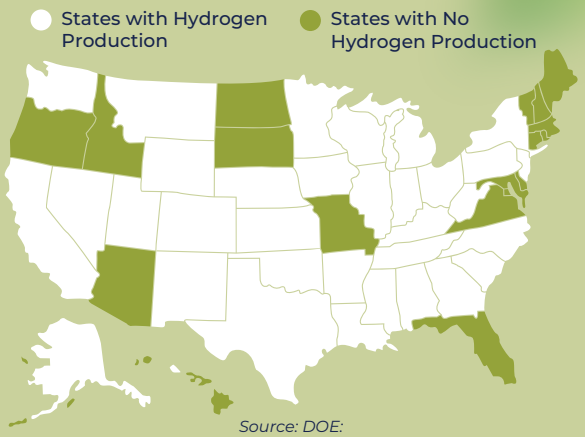
Today, most hydrogen is derived from natural gas or coal, primarily for industrial use in oil refining or the production of ammonia and other chemicals. With continued advances in production technologies and expansion of supporting infrastructure, **hydrogen has tremendous potential as lower-emission fuel or feedstock in many industrial, transportation and energy applications.**[2] Various forecasts predict that lower-emissions hydrogen could account for between 6 and 15 percent of emissions reductions, and up to 12 percent of global primary energy demand by 2050.[3]

Hydrogen In The U.S.

The United States is **one of the largest producers and consumers of hydrogen**, accounting for around 12 percent of total global hydrogen production and use.[4] Proper development and deployment of hydrogen technology can benefit the U.S. economy by enhancing U.S. manufacturing competitiveness, contributing to more resilient national and global supply chains, and creating high-quality American jobs.

The **U.S. chemical industry can play a leadership role** in expanding the nation's clean hydrogen economy – building on its deep process expertise; existing assets, sales, and distribution channels linked to hydrogen production; and access to opportunities to build new markets.

Hydrogen Production in the U.S.



Source: DOE: www.energy.gov/eere/fuelcells/fact-month-may-2018-10-million-metric-tons-hydrogen-produced-annually-united-states

U.S. annual Hydrogen production
10 million metric tons

Largest users in the U.S.

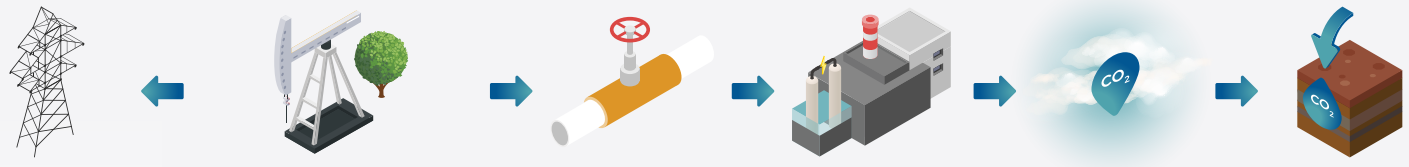
68% Petroleum Processing

21% Fertilizer Production

How Is Hydrogen Used?

- Hydrogen is a versatile lower-emissions energy carrier[5] that can fuel power plants and heavy duty-vehicles; enable fuel cells to generate electricity for cars, homes and buildings; or serve as an industrial feedstock.
- Hydrogen can be an input in processes to produce chemicals such as methanol, ammonia, hydrogen peroxide, hydrogen chloride, aniline, cyclohexane, TDI and oxo-alcohols.
- Emerging future demand for hydrogen varies from **transportation** (rail, aviation, medium/heavy duty vehicles), to **chemicals and industrial applications** (industrial heat, bio/synthetic fuels), to **power generation** (hydrogen combustion, fuel cells).[6]

The diagram below illustrates how the 2023 U.S. Department of Energy Clean Hydrogen Production Standard (CHPS) proposes tracking emissions from the various stages in the Clean Hydrogen value chain:



Generation of electricity	Extraction of feedstock	Feedstock delivery	H_2 Production & CO_2 Capture	CO_2 Delivery	CO_2 Sequestration
Fuel Combustion Fugitive emissions	Fuel Combustion Fugitive emissions Feedstock treatment (e.g. drying, purification, fertilizer for biomass) Net GHG emissions associated with production of biomass feedstock	Fuel Combustion Fugitive emissions	Fuel Combustion Fugitive emissions Process emissions	Fuel Combustion for compression, etc. Fugitive emissions	Potential emissions/ leakage

U.S. Department of Energy Clean Hydrogen Production Standard (2023): www.hydrogen.energy.gov/pdfs/clean-hydrogen-production-standard-guidance.pdf

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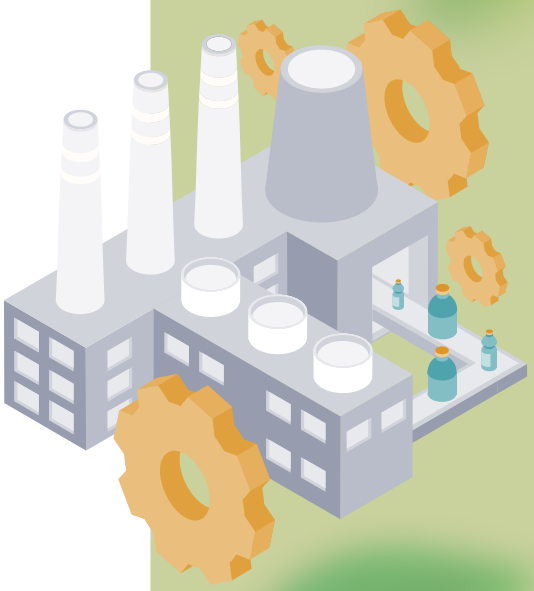
Hydrogen Production Processes

Hydrogen can be produced from a variety of feedstocks, including natural gas, coal, water or biogas. The energy used during production can come from conventional fossil fuels, nuclear and/or renewable energy (wind, solar, geothermal and biomass), depending on the location, generation mix, production processes and infrastructure.

Today, most hydrogen produced in the United States is made by stripping hydrogen from natural gas or coal feedstocks through a process known as steam methane reforming (SMR) or auto thermal reforming (ATR).[7]



Manufacturing Hydrogen from Discarded Plastics

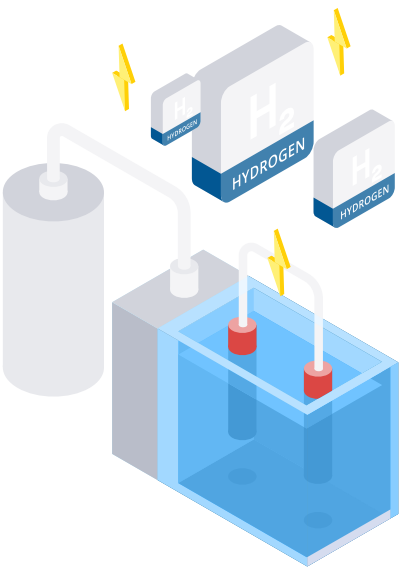
The U.S. Department of Energy's National Energy Technology Laboratory (NETL) is researching opportunities in gasification technology, using microwaves to catalytically convert materials like discarded plastics, biomass and coal, and break them down into the molecular building blocks for hydrogen-rich synthesis gas, or syngas, that can be used to make a range of chemical products.

Microwave heating to promote chemical reactions may be less costly and energy intensive than traditional heating technologies, allowing gasification to occur at lower temperatures and with shorter reaction times. NETL lab studies have found that a 1-to-1-to-1 ratio of plastic, biomass and silicone carbide (produced from coal) is an optimal mixture to produce clean hydrogen. The microwave process also produces lower amounts of carbon dioxide. According to NTEL, this research represents an important step toward the commercialization of plastic gasification for clean hydrogen production.

Learn more: NTEL Edge, Vol. 4, Issue 2, 2023, pp. 21-27

Pathways To Advancing Lower-Emissions Hydrogen Technology

The chemical industry has identified lower-emissions hydrogen as a critical technology for reducing emissions associated with manufacturing processes. **Several approaches are emerging and being deployed** in some places to support the transition to a lower-emissions hydrogen economy. For example:



- Technologies such as carbon capture, utilization and storage (CCUS) can be added to existing processes, helping to reduce CO_2 emissions from the production of hydrogen from natural gas or coal.
  - CCUS has the potential to capture production-related CO_2 emissions at the source, where it then can be transported and secured in permanent underground storage facilities or used as a feedstock or additive in chemicals, cement, synthetic fuels and other products.
- Other emerging, lower-emissions production technologies include thermal splitting of natural gas (pyrolysis) or splitting hydrogen from water using an electric current (electrolysis).
  - Pyrolysis results in the production of solid carbon in various forms instead of carbon dioxide.
  - While the electrolysis process itself does not produce carbon dioxide, it is highly energy-intensive.

These and other technologies under development have all shown promise, and federal funding and incentives have the potential to accelerate scale-up.

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Advancing Opportunities For Lower-Emissions Hydrogen

Momentum is increasing for the build-out of a lower-emissions hydrogen economy in the U.S. While new technologies are still developing, hydrogen is being recognized as a key enabler of the broader energy transition. With historic levels of investment, private sector interest and policy support, **lower-emissions hydrogen appears poised for dramatic growth**. The following strategies can help advance this growth:

Investment in Infrastructure

- Building out the nation's lower-emissions hydrogen economy will likely require a rapid, unprecedented investment in infrastructure, along with commitment by federal, state and local officials to prioritize these projects. The hydrogen market has typically faced a "chicken or the egg" problem when it comes to investment. Deployment of downstream technologies to use hydrogen in new applications is limited by a lack of steady supply of lower-emissions hydrogen, lack of critical infrastructure,[8] while development of supply is hampered by lack of steady demand.
- There are a variety of opportunities for investment in lower-emissions hydrogen infrastructure, including investments in other infrastructure that support the energy transition, such as: lower-emissions energy generation and transmission; sustainable water supplies; and carbon and hydrogen transport and storage capacity.

Federal Support for New Hydrogen Pathways and Clean Technologies

- While lower-emissions hydrogen is evolving, it may not yet be cost competitive and thus can be less attractive to investors. Federal funding, paired with effective, efficient implementation of supporting programs, could help offset these disincentives.
- For example, U.S. government funding support for lower-emissions hydrogen demonstration projects, electrolyzer and carbon capture technology development, and the formation of "hydrogen hubs" are helping to spur investment and project development under the Bipartisan Infrastructure Law (BIL). Other tax credits and incentives under the Inflation Reduction Act (IRA) may potentially enhance the cost effectiveness of lower-emissions hydrogen.

Modernizing the Permitting Process

- Lower-emissions hydrogen projects and supporting infrastructure may be subject to a variety of design, siting, and permitting requirements and reviews at the federal, state, and local levels. Like other project types, this process may be time- and resource-intensive.
- Permitting processes should be updated and improved to encourage the building and development of energy and manufacturing infrastructure and technologies of all kinds.

The future of lower-emissions hydrogen is likely to be a suite of technologies. The American Chemistry Council (ACC) and its members are working to build upon these opportunities by engaging with federal and state officials on effective design of tax credits, grants and loans, infrastructure hubs and other programs, as well as promoting public/private partnerships, that can help advance a lower-emission future.

1 Bipartisan Infrastructure Law, Title III, Subtitle B – Hydrogen Research & Development, Section 40311 (Findings; Purpose)

2 U.S. Department of Energy: Hydrogen Program Plan (2020)

3 IEA Fuels and Technologies: Hydrogen Report (2022); Goldman Sachs Equity Research: Carbonomics, The Clean Hydrogen Revolution (2022); IRENA: A Quarter of Global Hydrogen Set for Trading by 2050 (2022)

4 DOE Hydrogen and Fuel Cells Program Record: Current Hydrogen Market Size (2019)

5 Burning hydrogen, or reacting it in fuel cells, does not produce CO2: www.energy.gov/eere/fuelcells/fuel-cells

6 U.S. DOE National Clean Hydrogen Strategy and Roadmap (2023): www.hydrogen.energy.gov/clean-hydrogen-strategy-roadmap.html

7 U.S. DOE Hydrogen and Fuel Cell Technologies Office: Hydrogen Resources: www.energy.gov/eere/fuelcells/hydrogen-resources

8 OECD Demand Side Support Program: www.energy.gov/articles/biden-harris-administration-jumpstart-clean-hydrogen-economy-new-initiative-provide-market

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