CENTER FOR CLIMATE AND ENERGY SOLUTIONS

TECHNOLOGY WORKING GROUPS

Powering Possibility:
The Clean Hydrogen Dividend

December 2025

Hydrogen is a critical commodity in major industrial and chemical processes, from petroleum refining to fertilizer production. In the United States, approximately ten million metric tons of hydrogen are produced annually, with demand concentrated in three main end uses: petroleum refining (55 percent) and the production of ammonia and methanol (collectively 35 percent).[1] Most hydrogen today is produced through conventional methods that involve the unabated release of greenhouse gases into the atmosphere.

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Clean hydrogen refers to hydrogen whose production results in lifecycle emissions significantly below those of conventional pathways. The U.S. Department of Energy's current Clean Hydrogen Production Standard sets a target of no more than four kilograms of carbon dioxide equivalent emissions per kilogram of hydrogen produced, compared to the approximately 10 kilograms emitted through incumbent methods.[2] Clean hydrogen is a strategically important commodity for American trade competitiveness, job creation, domestic manufacturing and supply chain resilience, and technology leadership.

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HIGHLIGHTS

Trade Pressure: With global markets increasingly adopting carbon-based trade standards, the use of clean hydrogen can offer the United States a competitive advantage by reducing the carbon intensity of energy-intensive, trade-exposed (EITE) products.

Job Engine: Producing clean hydrogen in the United States can retain and grow high-quality jobs in the existing oil, gas, and industrial workforce.

Competitive Manufacturing Base: Developing a robust domestic supply chain for key clean hydrogen production equipment will strengthen U.S. competitiveness against early leaders in the global clean hydrogen market.

Innovation Unlocks Value: Continued federal investment in innovation is essential to unlocking the full potential of clean hydrogen and other emerging technologies. Sustained federal funding for research, development, and demonstration not only accelerates the creation of new clean hydrogen approaches with added value but also enhances existing approaches by making them more cost-effective, energy-efficient, and scalable.

FIGURE 1: HYDROGEN PRODUCTION METHODS

Water electrolysis: Clean electricity powers a device called an electrolyzer which splits water into hydrogen and oxygen.

SMR with carbon capture: The carbon dioxide produced from SMR is captured at its source and subsequently sequestered into permanent storage or utilized as an input for carbon-based products.

Biomass gasification: High temperatures are used to convert organic matter into hydrogen, carbon monoxide, and carbon dioxide.

Methane pyrolysis: Energy is used to break methane molecules into hydrogen and solid carbon products (e.g., carbon black).

Key Clean Hydrogen Production Approaches

Hydrogen is extracted from other molecules, like methane or water, before it can be utilized.[3] In the United States, nearly all commercial production of hydrogen is by steam-methane reforming (SMR), which produces hydrogen and carbon dioxide from water and methane in natural gas. Innovative, lower-carbon production methods are being pursued to leverage the strategic value of clean hydrogen and its applications. These methods include, but are not limited to, water electrolysis, SMR with carbon capture, biomass gasification, and methane pyrolysis (see **Figure 1**).[4]

The Value of Clean Hydrogen

While clean hydrogen's versatility is often compared to that of a Swiss Army Knife, its near-term value is best assessed under a narrower set of applications for the U.S. industrial base. Petroleum production, fertilizer, iron and steel, chemicals, and novel marine and jet fuels are among the most robust uses for clean hydrogen when considering efficiency, cost, and the viability of currently available alternative solutions.[5]

Strategic industrial uses and trade leverage

As global markets rapidly move to carbon-based trade rules, using clean hydrogen strengthens U.S. competitiveness, as it lowers the carbon intensity of certain energy-intensive, trade-exposed (EITE) products. For example, the E.U.'s Carbon Border Adjustment Mechanism (CBAM) will impose tariffs on imports of hydrogen and hydrogen-based products, such as fertilizer and ammonia, that do not meet European carbon-intensity standards.[6]

The United States is also uniquely positioned to establish footholds in new product markets. Clean hydrogen is used to produce emerging aviation and maritime fuel products called "e-fuels." Aviation fuel mandates in both the European Union and United Kingdom are establishing early demand signals for this fuel type. The United States is leading the world with multiple e-fuel production facilities under development and establishing key export opportunities.

Seeding Export Growth

In 2023, about 24 percent of the E.U.'s nitrogen fertilizer imports came from Russia, while 8 percent came from the United States. The European Union plans to impose tariffs of up to 100 percent over the next three years on nitrogen-based fertilizers imported from Russia—effectively ending annual trade flows currently valued at $1.5 billion. The United States could help fill this supply gap, provided that its fertilizer products meet CBAM's carbon intensity standards.

Source: Reuters, "EU Open to Lowering Tariffs on US Fertilisers in Trade Talks," *USNews*, June 6, 2025, https://money.usnews.com/investing/news/articles/2025-06-06/eu-open-to-lowering-tariffs-on-us-fertilisers-in-trade-talks.

LNG Parallel

The United States could build its SAF foothold in a way that mirrors the success of liquified natural gas (LNG). In 2016, the first LNG produced in the continental United States was exported overseas. Less than a decade later, in just the first six months of 2025, the United States exported more than 2,589,358 million cubic feet of LNG. Looking ahead, the nation is similarly well positioned to emerge as a leading exporter in the rapidly expanding global market for clean hydrogen derivatives, including SAF.

Sources: "Liquified Natural Gas," U.S. Department of Energy, accessed August 29, 2025, https://www.energy.gov/fecm/liquefied-natural-gas-lng; see also "Natural Gas Imports and Exports Monthly 2025," U.S. Department of Energy, accessed August 29, 2025, https://www.energy.gov/fecm/articles/natural-gas-imports-and-exports-monthly-2025.

Job Creation

Investing in a clean hydrogen workforce provides a pathway to retain and grow the skilled U.S. workforce into emerging chemical, energy, and manufacturing industries (see **Table 1**). Many of the technical skills used in these industries are highly transferable to the hydrogen industry—including production, transportation, storage, and end uses. For instance, the U.S. oil and gas industry currently employs around 705,000 workers—many of whom have deep expertise in safely handling and transporting gases over long distances.[7] Clean hydrogen offers a secure and strategic opportunity to grow this existing workforce into roles needed to develop the domestic clean hydrogen sector.[8]

Domestic Manufacturing and Supply Chain Resilience

Producing a robust domestic supply of key clean hydrogen production equipment will enhance U.S. competitiveness against early movers in clean hydrogen deployment—namely Europe, Japan, and South Korea, which together account for 30 percent of new global clean hydrogen demand.[9] As of 2024, six of the top ten global electrolyzer manufacturers were based in China, three in Europe, and only one in the United States.[10] With global investments in electrolyzer projects surpassing $2 billion in 2023 alone, the United States is at a pivotal moment to invest in this growing sector and secure a competitive foothold in clean energy manufacturing.[11]

TABLE 1: JOBS CREATED FROM CLEAN HYDROGEN PRODUCTION

Clean Hydrogen Production Approach	Jobs During Investment/Build Phase	Ongoing Operational Jobs	Key Regions
Electrolytic	~330 jobs per commercial-scale facility (investment phase)	~45 ongoing operational jobs annually per commercial-scale facility	Regions with high renewable energy penetration and existing energy infrastructure, like in the Gulf Coast, Midwest, Pacific Northwest, and the Interior West.
SMR with carbon capture	~520 jobs annually per conventional SMR facility (4-year retrofit)	~80 ongoing jobs over the operational lifetime of the facility	Regions with existing SMR facilities and established infrastructure—particularly the Gulf Coast, Midwest, and California.

Source: Galen Bower et al., *Clean Hydrogen Workforce Development: Opportunities by Occupation* (Washington, D.C.: Rhodium Group, 2023), https://rhg.com/research/clean-hydrogen-workforce-development/.

> **To fully realize the benefits of clean hydrogen and other emerging technologies, continued federal investment in innovation is essential**

Unlocking Added Value with Innovation

The United States has long stood at the forefront of innovation by pairing public investment in new technologies with the ingenuity and scale of the private sector. These partnerships position the country to lead in the development and deployment of emerging technologies—including clean hydrogen. To protect these advantages, continued federal investment in innovation is essential. Clean hydrogen pathways are advancing, each with the potential to reduce costs, improve efficiency, scale deployment, and add additional value. Sustained funding for scientific research and demonstration will continue to unlock these and more opportunities.

Endnotes

1 "Hydrogen Production," U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office, accessed November 6, 2025, https://www.energy.gov/eere/fuelcells/hydrogen-production; see also U.S. Department of Energy, *U.S. National Clean Hydrogen Strategy and Roadmap* (Washington, D.C.: U.S. Department of Energy, 2023), https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf?sfvrsn=c425b44f_5.

2 *U.S. Department of Energy Clean Hydrogen Production Standard (CHPS) Guidance*, (Washington, D.C.: U.S. Department of Energy, 2023), https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/clean-hydrogen-production-standard-guidance.pdf?sfvrsn=173e9756_1.

3 Large amounts naturally occurring hydrogen gas (i.e., geologic hydrogen) do exist subsurface, and ongoing research is required to determine whether it can be located and exploited economically.

4 John Holler and Doug Vine, *Methane Pyrolysis for Hydrogen Production* (Washington, D.C.: Center for Climate and Energy Solutions, 2025), https://www.c2es.org/document/methane-pyrolysis-for-hydrogen-production/.

5 Rachel Parkes, "Hydrogen Ladder | Seven H2 applications relegated in updated use-case analysis, but three promoted," *Hydrogen Insight*, October 23, 2023, https://www.hydrogeninsight.com/policy/hydrogen-ladder-seven-h2-applications-relegated-in-updated-use-case-analysis-but-three-promoted/2-1-1540086.

6 "Carbon Border Adjustment Mechanism," European Commission, accessed December 8, 2025, https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en.

7 Hannah Murdoch et al., *Pathways to Commercial Liftoff: Clean Hydrogen* (Washington, D.C.: U.S. Department of Energy, 2023), https://yardsale.energy/wp-content/uploads/2025/05/DOE-Liftoff-Clean-Hydrogen-2023.pdf.

8 Ibid.

9 Hydrogen Council and McKinsey and Company, *Hydrogen for Net-Zero: A critical cost-competitive energy vector* (Hydrogen Council and McKinsey and Company, 2021), https://hydrogencouncil.com/wp-content/uploads/2021/11/Hydrogen-for-Net-Zero.pdf.

10 Leigh Collins, "BNEF reveals top ten hydrogen electrolyser makers in the world by delivered in 2024—six are Chinese," *Hydrogen Insight*, April 11, 2025, https://www.hydrogeninsight.com/electrolysers/bnef-reveals-top-ten-hydrogen-electrolyser-makers-in-the-world-by-deliveries-in-2024-six-are-chinese/2-1-1806757.

11 Francesco Pavan et al., *Electrolysers* (Paris, France: International Energy Agency, 2025), https://www.iea.org/energy-system/low-emission-fuels/electrolysers.