# HYDROGEN FOR AMMONIA

**Prospects**

EXCELLENT

This fact sheet is part of an Energy Innovation paper assessing clean hydrogen's value for cutting climate pollution from 12 end uses. The full report includes context, analysis, policy recommendations, and citations—see QR code or link at bottom.

**Chemical fertilizers have inherent problems, but hydrogen can clean up their production.**

**CONTEXT:** Ammonia production is one of the main uses of hydrogen today. The Haber process reacts hydrogen with nitrogen from the air at high temperatures and pressures with a catalyst to make ammonia. Nearly 90 percent of ammonia is in turn used to make chemical fertilizers, with the remainder used to produce other compounds like explosives, plastics, and synthetic fibers. Ammonia demand may grow considerably for use as a carbon-free fuel in sectors like marine shipping. However, this overview will highlight ammonia's use for fertilizer.

**INFRASTRUCTURE NEEDS:** The U.S. had 35 ammonia production facilities in 2022, operated by 16 companies in 16 states. More than half of ammonia production capacity is in Louisiana, Oklahoma, and Texas due to their large natural gas reserves. The U.S. has over 3,000 miles of ammonia pipelines linking the Gulf Coast with agriculture in the Midwest and Great Plains.

Most hydrogen used for ammonia comes from integrated steam methane reformation (SMR) facilities that make and use natural gas-based hydrogen on-site. The remainder comes from merchant SMR plants that may have long-term natural gas delivery contracts upstream, hydrogen offtake contracts with ammonia facilities, and privately owned hydrogen pipelines. These dynamics make it difficult for electrolytic hydrogen to access the ammonia market on price alone (i.e., without regulatory intervention), as it may require stranding often-integrated assets, breaking contracts, or harming relationships with important partners.

Conventional ammonia production plants also generally need a consistent hydrogen supply for their operations, which SMR has traditionally delivered. Moving these plants fully to electrolytic hydrogen is thus likely to require on-site storage or pipelines to smooth gaps in production, as electrolyzers should only run when clean energy is abundant and cheap (which are necessary conditions for lower-cost, zero-carbon hydrogen production). However, new technologies are enabling more flexible and modular ammonia production, allowing for start-up within hours instead of days and adjusting output rates over minutes instead of hours. Building new ammonia plants at smaller sizes in renewables-rich regions would require less reliance on hydrogen midstream infrastructure—though as clean ammonia production grows in the U.S., it may be beneficial to use ammonia pipelines to access the Gulf for exports.

**SOCIAL IMPACTS:** Cleaning up ammonia production is essential but insufficient to solve chemical fertilizers' climate and environmental problems. Most of ammonia-based fertilizer's climate emissions come from its use. Only about half of chemical fertilizers' nitrogen is taken up by crops, with the rest lost to groundwater or the atmosphere. This includes nitrous oxide emissions (a greenhouse gas 265 times more potent than $CO_2$ over a 100-year period that drives nearly half of agriculture's climate emissions), nitrogen-fueled algal blooms from runoff that create aquatic dead zones, and polluted drinking water and local air quality.

Adopting clean hydrogen for ammonia production would reduce health risks associated with fossil fuel production and combustion. However, it would not mitigate risks from downstream fertilizer use; this requires improving rates of nitrogen uptake in soil, reducing fertilizer use, and relying on alternatives like organic fertilizers. It also would not prevent more general risks associated with ammonia—itself a toxic substance that must be carefully managed.

**COMPETING TECHS:** As hydrogen is a fundamental part of ammonia production, there are no known alternatives to clean hydrogen for reducing emissions from this process. Instead, hydrogen's "competitors" for this market are technologies or practices that shrink the need for ammonia. For fertilizer, these include organic fertilizers and new technologies that skip the Haber process entirely (as well as best management practices for increasing efficiency).

**Organic fertilizers** derive from biogenic sources, such as manure, bone meal, and "digestate" (rich residual material leftover from anaerobic digestion of organic matter). Relative to chemical fertilizers, they improve the structure, health, nutrient density, and water retention of soil; they also release nitrogen more gradually, thereby reducing climate emissions per unit of applied fertilizer. However, they are limited in supply and have their own problems if not properly managed. Nascent technologies include **plasma reactors**, which use air, water, and electricity to make fertilizer with fewer field emissions, and **genetically edited microbes**, which can be applied to soil to directly fix atmospheric nitrogen into a form plants can use.

Separately, in seeking to clean up existing ammonia production facilities, electrolytic hydrogen may face greater competition from SMR hydrogen with carbon capture and sequestration (often called "**blue hydrogen**"). Blue hydrogen has its own problems in perpetuating fossil fuel infrastructure and dependence on subsidies to beat out unabated SMR hydrogen. However, in the near term for newer integrated SMR-ammonia systems, it may cost less to add carbon capture equipment than to switch to electrolysis, as it allows for the continued use of SMR facilities and does not require breaking or restructuring natural gas contracts.

**TAKEAWAY:** Clean hydrogen is essential for climate-friendly ammonia production—the demand for which may only rise with new applications like marine shipping fuels—and can reduce emissions from fertilizer use. However, it's worth maximizing efficiencies in fertilizer application and management, as well as pursuing organic fertilizers and new technologies that reduce the need for ammonia-based fertilizers, to further reduce climate pollution (and other public health and environmental hazards) associated with chemical fertilizers.

**FURTHER READING:**


- International Energy Agency, "Ammonia Technology Roadmap: Towards more sustainable nitrogen fertiliser production," October 2021, https://iea.blob.core.windows.net/assets/6ee41bb9-8e81-4b64-8701-2acc064ff6e4/AmmoniaTechnologyRoadmap.pdf
- Bloomberg New Energy Finance and Climate Technology Coalition, "Scaling Up Hydrogen: The Case for Low-Carbon Ammonia," January 11, 2024, https://assets.bbhub.io/professional/sites/24/CTC-whitepaper_Ammonia_Final.pdf
- Jeffrey Rissman, *Zero-Carbon Industry: Transformative Technologies and Policies to Achieve Sustainable Prosperity*, Columbia University Press, 2024, https://zerocarbonindustry.com/#chapter-2, p.37-61
- **Featured story:** Chris Baraniuk, "Why firms are racing to produce green ammonia," BBC, February 26, 2024, https://www.bbc.com/news/business-68230697
- **Full report:** https://energyinnovation.org/publication/hydrogen-policys-narrow-path-delusions-and-solutions