Congressional Research Service
Informing the legislative debate since 1914

IN FOCUS

December 7, 2022

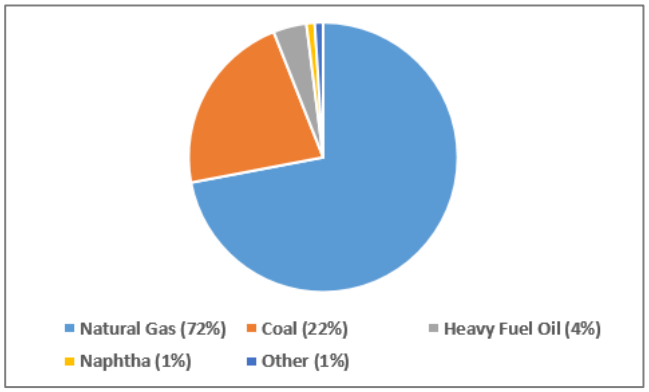
Ammonia's Potential Role in a Low-Carbon Economy

Ammonia, composed of nitrogen and hydrogen (NH_3), is the second-most produced chemical in the world by mass, according to a 2022 publication from the International Renewable Energy Agency (IRENA). Most ammonia is used to produce fertilizer. Ammonia production is energy intensive and emits greenhouse gases. In the same report, IRENA estimated that ammonia production represents 15-20% of all carbon dioxide (CO_2) emissions from the chemical sector. Some ammonia applications also release nitrogen oxides, a potent greenhouse gas that can trap more heat than CO_2. Experts view decarbonizing ammonia production, referred to as *low-carbon ammonia*, as expensive, but this cost could fall should costs of hydrogen produced from renewable energy or fossil fuels paired with carbon capture lower. Ammonia is seen as a potential hydrogen carrier and as a fuel for ocean-going vessels. These potential end-uses could employ existing infrastructure supporting a well-established global ammonia trade.

Today's Ammonia Economy

Ammonia is produced through a high-pressure, high-heat catalytic reaction of nitrogen and hydrogen. The nitrogen is generally obtained from air and the hydrogen from a fossil fuel feedstock. Around 183 million metric tonnes (Mt) of ammonia is produced annually worldwide.

Figure 1. Ammonia Feedstocks



Source: IRENA, "Innovation Outlook: Renewable Ammonia," May 2022, https://www.irena.org/publications/2022/May/Innovation-Outlook-Renewable-Ammonia.

Notes: Naphtha and heavy fuel oil are petroleum products.

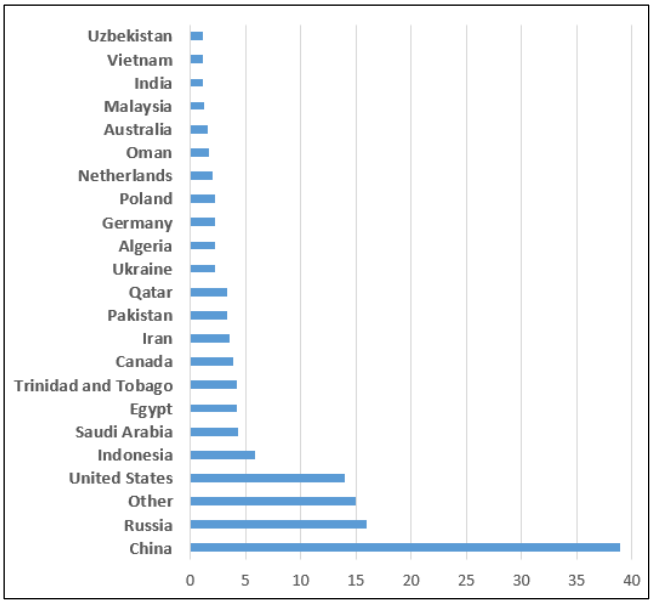
Feedstocks

Due to the comparatively low costs of natural gas and coal, almost all ammonia today is produced from fossil fuels. Over 70% of ammonia is generated from natural gas, and over 20% is generated from coal (**Figure 1**). IRENA estimates that less than 0.02 Mt of global ammonia produced in 2021 was "renewable ammonia," which IRENA defines as "produced from renewable hydrogen, which in turn is produced via water electrolysis using renewable energy."

Ammonia is produced globally. China produces almost a third of the world's ammonia supply (**Figure 2**), using coal as the primary hydrogen feedstock. The United States and most other producers use natural gas. In 2021, the United States had 35 active ammonia production plants across 16 states, with 60% of production capacity located in Louisiana, Oklahoma, and Texas.

Figure 2. World Ammonia Production, 2021

Mt



Source: U.S. Geological Survey, Mineral Commodity Summaries, "NITROGEN (FIXED)—AMMONIA," January 2022, https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-nitrogen.pdf.

Global Trade

A well-established global ammonia trading system features pipelines, tankers, and infrastructure at around 200 ports. According to IRENA, 18-20 Mt of ammonia is shipped around the world annually. Ammonia can also be transported via truck, train, and pipeline. The United States is an active participant in this market, exporting almost 19% of its domestically produced ammonia, and importing about 14% of its total consumption, according to the U.S. Geological Survey (USGS) in 2022. The USGS reports that top import sources for the United States for 2017-2020 were Trinidad and Tobago (63%), Canada (34%), and Venezuela (2%).

Uses and Demand: Fertilizer and Other Chemicals

According to the International Energy Agency's (IEA) in 2021, 70% of all ammonia produced globally is used to

make nitrogen-based fertilizer. 88% of ammonia consumed in the United States is for the same purpose, according to USGS in 2022. The chemical is also used to produce various explosives, plastics, synthetic fibers, resins, and other chemicals used in refrigeration, waste treatment, pharmaceuticals, and air treatment.

Ammonia production is expected to increase based on a range of projected future demands. USGS estimates demand for ammonia to increase 1% annually, driven by demand increases in Latin America and south Asia. The IEA estimates ammonia production capacity will need to increase by nearly 40% by 2050 to account for expected global population and economic growth.

Ammonia's Potential Future Uses

Ammonia production relies heavily on fossil fuel feedstocks to supply hydrogen and heat due to low costs and wide availability. Efforts to decarbonize ammonia production have identified alternative approaches to feedstock and energy. Existing ammonia plants can be retrofit to have lower carbon dioxide emissions through use of hydrogen generated from renewable energy or existing fossil fuel resources paired with carbon capture and sequestration (CCS). The first renewable hydrogen supply was retrofit to an existing ammonia plant in Spain in 2021. Additional low-carbon ammonia capacity is currently under construction. In May 2022, IRENA estimated that the combined capacity of announced ammonia projects produced from renewable hydrogen, if constructed, would total 15 Mt in 2030, equivalent to approximately 8% of production.

Zero- and low-carbon ammonia is not currently considered commercially viable due to high production costs. IRENA estimated in 2022 that the cost to produce ammonia from renewable hydrogen at $720-1,400 per metric tonne, compared to $110-340 for production from natural gas and coal.

Potential Applications for Low-Carbon Ammonia

Ammonia has a wide variety of potential uses beyond its current role in food and chemical production. Applications in earlier stages of development may include stationary power generation, industrial heat, or vehicle fuel. Other proposals include:

- **Hydrogen carrier**: Hydrogen, if developed and employed as a fuel at scale, could contribute to reducing CO_2 emissions in a wide variety of industries and processes. Ammonia can be decomposed via a catalyst to produce hydrogen and atmospheric nitrogen ("ammonia cracking"). Some assert that the transport and delivery infrastructure of ammonia could be combined with ammonia cracking to facilitate use of hydrogen as a fuel source. For more information on development of hydrogen as a fuel in the United States, please see CRS Report R47289, *Hydrogen Hubs and Demonstrating the Hydrogen Energy Value Chain*, by Martin C. Offutt.
- **Low-carbon maritime fuel**: Ammonia has been considered for use as a possible future maritime fuel either through ammonia-based fuel cells or through direct use as fuel. Testing and prototyping of such approaches in maritime vessels is ongoing. Utilizing available ammonia terminals could expand ammonia's use as a fuel to reduce the shipping sector's emissions, but ships would need to be built or retrofit to consume ammonia as a fuel.

Federal Action

Federal involvement supporting low-carbon ammonia production is primarily through research, development, demonstration, and deployment (RDD&D) activities, as detailed in **Table 1**.

Table 1. Selected Federal Support for Low-Carbon Ammonia

Program Name	Statutory Authority	Details
Department of Energy's Advanced Research Projects Agency—Energy	42 U.S.C. §16538	Funds a variety of RDD&D projects involving ammonia
Tax Credit for Carbon Oxide Sequestration	26 U.S.C. §45Q	Provides deployment incentives for utilizing CCS
Environmental Protection Agency's ENERGY STAR Efficiency Fertilizer Plant Certification	42 U.S.C. §7403	Provides incentives for greenhouse gas reduction in fertilizer production

Source: Program name and details, besides Section 45Q tax credit, adapted from International Energy Agency, *Ammonia Technology Roadmap: Towards more sustainable nitrogen fertiliser production*, Paris, October 2021, p. 137, https://www.iea.org/reports/ammonia-technology-roadmap.

Notes: For more on the Clean Air Act, please see CRS Report RL30853, *Clean Air Act: A Summary of the Act and Its Major Requirements*, by Richard K. Lattanzio.

To make low-carbon ammonia more commercially viable, Congress could explore policies that make low-carbon ammonia more cost competitive, such as a carbon price or tax. Increasing funding for RDD&D could incentivize further development of early stage technologies that may eventually help increase the scale of low-carbon ammonia production. Congress might support approaches to provide low-carbon ammonia project financing that could also help scale low-carbon ammonia and incentivize innovation from the private sector.

Lexie Ryan, Analyst in Energy Policy

IF12273

Disclaimer