Scaling Up Hydrogen: The Case for Low-Carbon Ammonia

A BNEF and Climate Technology Coalition White Paper

January 11, 2024

BloombergNEF

Contents

Section 1. Background to this White Paper

This paper was commissioned as part of BloombergNEF's work as Research Partner for the *Bloomberg New Economy Climate Technology Coalition*. The Coalition was formed in 2022 by a global group of stakeholders that are well placed to provide insights on approaches to industrial decarbonization. It has set an agenda to identify and support the rapid scale up of the next generation of climate-critical green technologies that will be instrumental in achieving the world's goals to avoid climate catastrophe. The planet simply cannot wait for polluting industries to slowly shift strategy and technologies.

This initiative seeks to inspire and lead by example. It will take getting into specifics to make any tangible progress and, to that end, the Coalition – composed of technology specialists, researchers, financiers, industrialists and public sector experts – is initially focused on tackling roadblocks to scaling up the clean hydrogen ecosystem, and further on decarbonizing 'hard-to-abate' sectors (industries where cleaner alternatives are currently lacking or prohibitively expensive) through initiatives on low-carbon ammonia, methanol and steel.

Coalition members have given insight into their own projects and efforts in these areas, some of which can be found in this BNEF-produced report. The Coalition finds it encouraging that BNEF's thorough analysis shows potential for decreasing green hydrogen costs, identifying pockets of demand and increasing clean hydrogen and ammonia production capacity.

Steering committee:

Michael Bloomberg, Founder of Bloomberg LP and Bloomberg Philanthropies, and three-term Mayor of New York City

Mark Carney, UN Special Envoy for Climate Action and Finance and Chair of Brookfield Asset Management; Head of Transition Investing; Chairman of the Board, Bloomberg, Inc.

Natarajan Chandrasekaran, Chairman, Tata Sons

Bruce Flatt, Chief Executive Officer, Brookfield Asset Management

Dr. Andrew Forrest AO, Chairman, Fortescue

Sara Menker, Founder and Chief Executive Officer, Gro Intelligence

H.E. Khaldoon Khalifa Al Mubarak, Managing Director and Group Chief Executive Officer, Mubadala

Neil Shen, Founding & Managing Partner of HongShan (Sequoia China)

Lord Adair Turner, Chairman, Energy Transitions Commission

Lei Zhang, Founder and Chief Executive Officer, Envision Group

Section 2. The case for low-carbon ammonia

185

Number of announced low-carbon ammonia projects in BNEF's Hydrogen Database

8%

Share of announced low-carbon H_2 projects in BNEF's Hydrogen Database aimed at producing ammonia that have reached financial close or are under construction

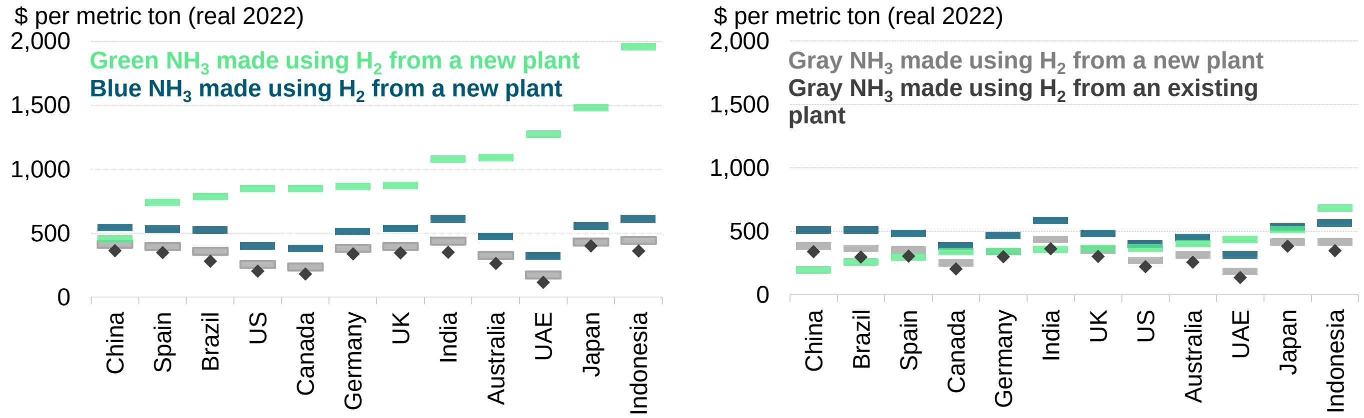
178 million tons

Annual ammonia consumption by the shipping sector in 2050 in BNEF's New Energy Outlook 2022 Net Zero Scenario

In the quest to clean up industry and scale low-carbon hydrogen, the ammonia sector will likely be an early adopter. Decarbonizing ammonia would lead to large reductions in greenhouse gas emissions from agriculture, shipping and chemicals production. Developers have announced a pipeline of 180 million metric tons of low-carbon ammonia plants that could be built by 2035, but the challenge is now to secure offtake contracts and financing for this production. This BNEF/Climate Technology Coalition White Paper provides new cost analysis for low-carbon ammonia production and outlines potential commercial actions and policy considerations that, if implemented, should stimulate the required demand and set the industry on a path to decarbonization.

- Ammonia is one of the most common industrial chemicals and represents a $76 billion market. It is essential for the agriculture sector, with more than 75% of ammonia produced being used to make fertilizers. Other applications include mining explosives and the manufacture of nylon.
- Today, ammonia is made with natural gas or coal, and its production and use account for 2% of the world's CO_2 emissions. Decarbonizing ammonia will not only lead to emissions savings for agriculture, it will also open the door for ammonia to play a role as a clean fuel for shipping and power generation.
- But for this opportunity to be realized, and for the world to meet its net-zero goals, large-scale projects would need to begin to produce low-carbon ammonia in the coming few years. There is no lack of ambition among developers: the pipeline of low-carbon ammonia projects waiting to get built by 2035 is large enough to decarbonize most of the 187 million tons of ammonia currently used each year (Figure 2).

Figure 1: Cost of ammonia production in 2023 (left) and 2030 (right)

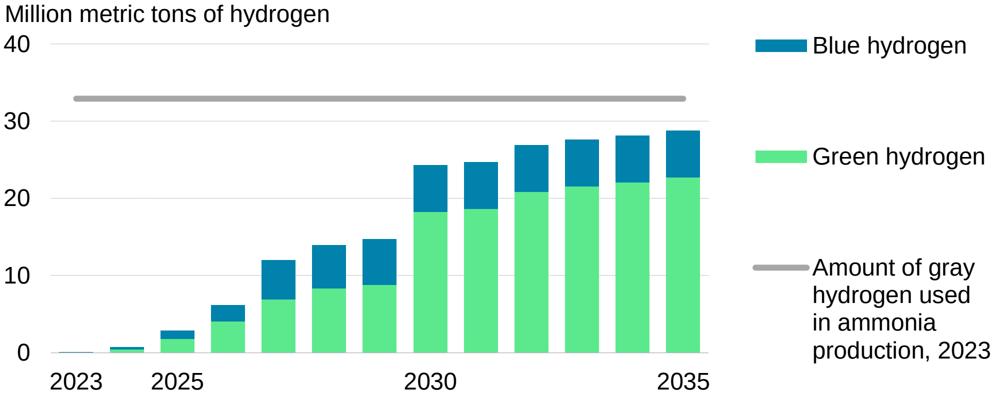


Source: BloombergNEF. Note: Assumes an existing ammonia (NH_3) plant is used. Uses levelized cost of hydrogen from BNEF's 2023 Hydrogen Levelized Cost Update: Green Beats Gray (web | terminal) as input for cost of ammonia production.

- 'Green' ammonia produced using renewable energy is more expensive than 'gray' ammonia, made from fossil fuels, today. But the costs are dropping. BloombergNEF expects green hydrogen costs to plunge 66% by 2030, to $1-4.1 per kilogram, on the back of cheaper equipment and renewable energy. As the world's green hydrogen capacity grows, green ammonia costs are forecast to reach parity with gray in some markets from 2024-25 and become cheaper than gray in more than half the 29 markets modeled by BNEF from 2034.

- To hit cost parity and open the door to lower-cost larger projects, industry would need to start building low-carbon ammonia facilities quickly. Of the 185 low-carbon ammonia projects BNEF tracks, 45 have offtake agreements, and 15 projects are under construction or have financing secured. The Climate Technology Coalition believes it is not technical barriers that are delaying the scaling of low-carbon ammonia, rather the time lag between the work that has been done on supply and that which has been done on demand. New policy signals, targeted commercial interventions, and increased buyer confidence in low-carbon standards should enable offtake agreements to be inked.
- Several low-carbon ammonia and fertilizer offtake agreements have been signed already, and some small volumes have been delivered. These include a test shipment of OCI's low-carbon fertilizer to be applied to Simpsons Malt's malt and barley for alcoholic drink decarbonization; the application of OCI's low-carbon fertilizer to Dossche Mills' wheat to make bread; and an agreement to apply Fertiberia's low-carbon fertilizer to barley to make Heineken beer.
- There are also signals beyond agriculture. Keppel Infrastructure is collaborating with Envision on green ammonia for power generation; Enaex is working with Engie to make green ammonia for mining explosives production; and Lotte Chemicals is teaming up with OCI to source low-carbon ammonia in the chemicals sector. Shipping is also a potentially significant demand center for low-carbon ammonia, with dozens of maritime freight companies piloting low-carbon fuel or ordering vessels able to run on ammonia.

Figure 2: Announced low-carbon H_2 production destined for ammonia production



Source: BloombergNEF. Note: As of October 19, 2023.

- To stimulate early volumes of low-carbon ammonia and provide a bridge until cost-competitive production arrives, the Climate Technology Coalition **has identified a number of potential commercial actions and policy interventions**.
- The **commercial actions** consider both existing users of gray ammonia or its derivatives, plus potential new consumers of low-carbon ammonia. Specifically:
  - **The formation of a new consumer coalition – the 'Clean Ammonia 100':** By communicating a keen interest in low-carbon ammonia and intentions to purchase (where appropriate in accordance with antitrust laws), this group could provide a

positive signal for investors and the financiers of production, always within the confines of antitrust regulations. By making focused policy considerations and testing consumer interest, it could further accelerate learnings. Members could be large food and beverage brands whose 'Scope 3' emissions – indirect emissions from their value chain – are impacted by gray fertilizers, and companies that are new to the ammonia sector such as shipping firms. Precedents include the Climate Group's EV100 initiative to accelerate corporations' adoption of electric vehicles and the RE100 collective that is focused on boosting corporate uptake of renewable energy.

  - **The adoption of a 'ladder' approach:** In order to scale demand as quickly as possible, developers of low-carbon ammonia projects could employ a 'ladder' approach – for example identifying near-term pockets of low-carbon ammonia demand to sell into and get early production up and running. These could include firms for mining explosives or ammonia use in gas power plants, with larger pockets of demand from fertilizers and shipping coming later. This approach could also be applied to production: the first step of a production ladder might be to retrofit retired gray ammonia facilities, which can be done more quickly than building on new sites.

- The **policy actions** focus on bridging early economic differentials in markets where the political economy has high potential degrees of alignment. Specifically:
  - **Reduce the exposure of the agricultural sector to international natural gas price volatility:** Regions with abundant renewable resources but limited natural gas could focus on the production of domestic green fertilizers as a way of reducing the reliance of their agricultural sectors on international natural gas supply. This could increase economic security and be cheaper than importing gray ammonia or fertilizer, which is particularly relevant for markets with state-owned domestic fertilizer producers.
  - **Shift agricultural subsidies to low-carbon fertilizers:** Where governments already subsidize farmers' purchase of gray fertilizers, this assistance could shift to funding the purchase of low-carbon fertilizers. This would be done with measures to reduce the risk of fertilizer overapplication, which can itself lead to significant greenhouse gas emissions.
  - **Establish complementary supply and demand subsidies and mandates:** Government support for new technologies works well when there is a mandate to make, or buy, that new product, paired with a subsidy for production. Policymakers could establish mandates to replace gray ammonia with low-carbon ammonia, paired and calibrated with financial support for ammonia producers or users to improve the economics. The European Union has introduced a quota to replace gray hydrogen with green in heavy industry, which should stimulate the ammonia sector to decarbonize. A 'fixed premium' auction held by the European Union starting in November 2023 will help subsidize green hydrogen production, as companies strive to meet this quota.

- A potential risk to greater adoption of ammonia is safety. While ammonia has been handled safely for many decades, deadly accidents have happened. Ammonia is a hazardous substance and its increased use – particularly in new sectors – will pose safety and security challenges.

Section 3. Overview of the ammonia sector

The ammonia market consumes 33 million tons of hydrogen (H_2) annually[1], the second-largest sector after oil refining for the 94 million tons[2] of global hydrogen demand in 2021. It will be much easier to spur low-carbon hydrogen uptake if the ammonia sector plays a role in stimulating demand.

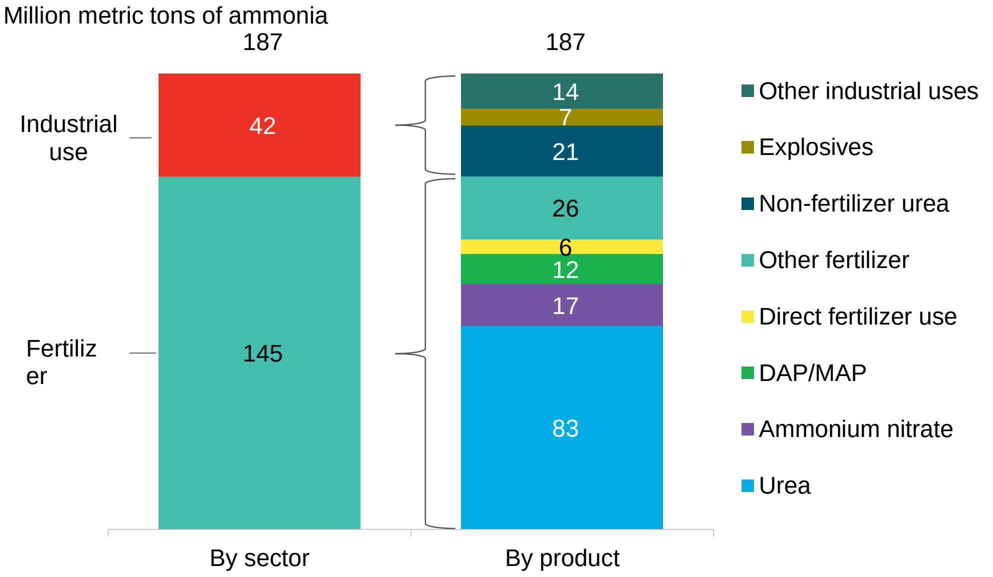
This report provides an overview of the ammonia sector – the uses, markets and emissions profiles – before exploring routes to decarbonizing production and new business opportunities for low-carbon ammonia. It reviews the current status quo for low-carbon ammonia and provides considerations for policymakers and corporations on how they can, and might, stimulate demand for low-carbon ammonia, which in turn will play a key role in scaling up clean hydrogen.

3.1. Use and production

Most countries apply fertilizer as urea or nitrates, rather than directly as ammonia

A pungent, colorless gas, ammonia (NH_3) is an important chemical. Some 54% of all fertilizers are made with ammonia, accounting for 77% of ammonia demand[3]. The remaining 23% is used in industrial applications such as chemical manufacturing, explosives and plastics (Figure 3). Ammonia is rarely applied directly to fields because it requires specialist equipment and climate conditions. Outside the US, where this does occur, most countries apply it as urea or nitrates.

Figure 3: Ammonia demand by sector in 2021



Source: BloombergNEF. Notes: DAP/MAP are di- and mono-ammonium phosphate.

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[1] Based on one ton of ammonia containing 0.176 tons of hydrogen a 187 million tons ammonia demand in 2021 (Figure 3). 187 million tons of ammonia * 0.176tons of hydrogen/ton of ammonia = 32.912 million tons of hydrogen.

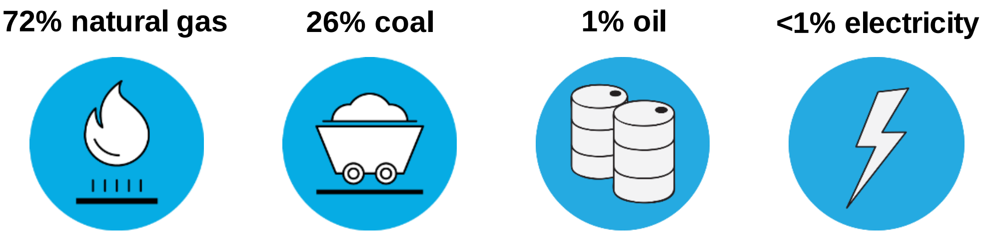
[2] International Energy Agency, *Global Hydrogen Review 2022*.

[3] See BNEF's *Ammonia Market Primer: The Struggle to Go Green* (web | terminal) for more.

Some 99% of ammonia production is dependent on fossil-fuel feedstocks

One kilogram of ammonia contains 0.824kg of nitrogen and 0.176kg of hydrogen. Nitrogen may be acquired directly from the air, while hydrogen is largely sourced from hydrocarbons, overwhelmingly natural gas and coal (Figure 4).

Figure 4: Ammonia production by feedstock



Source: Nutrien, BloombergNEF

3.2. Market

Size and regional trends

There is significant production overcapacity in the ammonia market

Global ammonia production capacity stands at 243 million tons a year, with China accounting for almost a third of this (Figure 5). The next largest producers are Russia, India and the US. According to Bloomberg Green Markets, capacity has grown at a compound annual growth rate of 1.5% since 2011 and should continue at a slower rate of 1% per year until 2032, not accounting for potential changes in existing use patterns and uptake in the new sectors mentioned in Section 4. Once built, ammonia plants can last 20-50 years[4]. Utilization rates are currently around 80%[4], meaning there is significant overcapacity, disincentivizing new plant builds.

Table 1: World's largest ammonia producers

Company (country)	Capacity (million metric tons per year)
CF Industries (US)	10.5
Yara (Norway)	9.2
Nutrien (Canada)	7.5
OCI (Netherlands)	6.9
Ostchem (Ukraine)	4.3

Source: Bloomberg

Ammonia production capacity is distributed across regions, broadly aligned with demand for fertilizer – in other words, reflecting the fact that China and India have some of the largest agriculture sectors. Only 10% of supply is traded internationally as-is, with another 16% traded as urea.[4] The low share of traded ammonia is a result of ammonia and fertilizer companies (which can often be partly government owned) opting to establish local production capacity to ensure security of food supply.[5]

Pricing and contracts

Ammonia production costs vary widely by region – from around $100-1,000 per ton[4], depending on the region's energy costs – but have averaged $305 per ton since 2013.[4] West Asia, Eastern Europe and North America are the cheapest areas to produce ammonia, with China normally being the marginal producer (therefore setting the global price). Western Europe is at the top end of costs, due to high energy prices.

Some 90% of traded ammonia is sourced under short-term contracts.[4] These tend to have a one-to-three-year duration with a fixed quantity and take-or-pay structures.[4] Pricing is usually linked to monthly Tampa ammonia prices (the global benchmark), which are effectively tied to the rise and fall of natural gas prices.[4]

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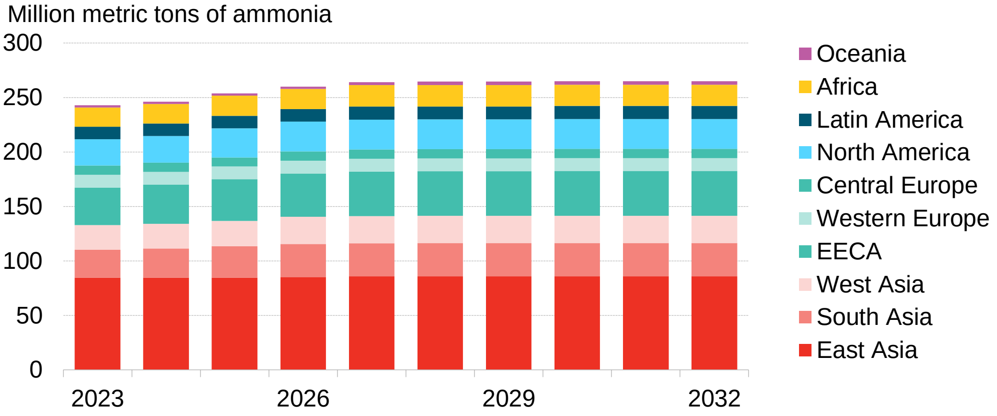
[4] See BNEF's *Ammonia Market Primer: The Struggle to Go Green* (web | terminal) for more.

[5] There are exceptions. Brazil, for example, imports over 80% of its fertilizer needs.

Figure 5: Projected ammonia capacity by region



Source: Bloomberg Green Markets, BloombergNEF. Notes: EECA refers to Eastern Europe and Central Asia.

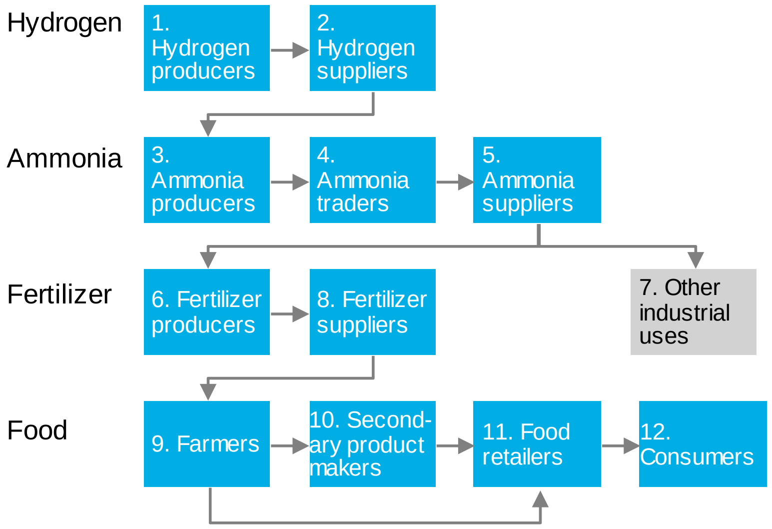
Players

Ammonia production emitted roughly 2% of global CO_2 in 2022

The five largest ammonia producing companies (Table 1) only account for around 15% of capacity. The remainder is made by around 820 firms.[4] Most ammonia companies are integrated across the value chain, meaning they might make ammonia and fertilizer, or make and trade ammonia, or make, trade, and buy ammonia and fertilizer. One company might therefore fulfill the roles in Figure 6 labeled 3, 4, 5 and 6.

Once the fertilizer has been made, it is mostly sold directly to retailers who sell it to farmers domestically. Of the portion that is internationally traded, five companies account for up to 70% of that traded volume: Yara Clean Ammonia, Trammo, OCP, Mosaic and IFFCO.[4] This means a small group of players have an outsized impact on the traded price of ammonia

.Figure 6: Simplified ammonia value chain



Source: BloombergNEF

3.3. Emissions

Table 2: Breakdown of fertilizer value chain emissions

Point of emissions	Share of fertilizer emissions
Production	39%
On-farm	42%
Escaped	17%
Transport and application	2%

Source: BloombergNEF. Note: "Escaped" refers to emissions from denitrification and volatilization. In both processes, fertilizers chemically break down and emit harmful gasses.

Ammonia production emits roughly 2%, or 500 million tons, of global CO_2 equivalent emissions ($MtCO_2e$).[4] Among primary chemicals, it is the largest emitter according to the International Energy Agency. Some 90% of ammonia manufacturing emissions come from the creation of hydrogen used to make ammonia, according to the Royal Society.

Across all emission scopes – 1, 2 and 3 – emissions from ammonia-derived fertilizers total 1,129 $MtCO_2e$, with ammonia production accounting for 39% of all lifecycle emissions (Table 2).[4] On-farm emissions stem from chemical reactions after fertilizer application (on-farm and escaped) and are responsible for 59% of total emissions. These emissions have gained greater recognition in recent times, with legislative and corporate efforts being made to address them (see Section 4.2).

What are Scope 1, 2 and 3 emissions?

Scope 1 emissions are direct emissions from assets owned or controlled by a company. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, both upstream and downstream.

Section 4. Cleaning ammonia

4.1. How can ammonia be decarbonized?

The decarbonization of ammonia production requires low-carbon hydrogen. Low-carbon H_2 can be made in two main ways. First, by the electrolysis of water, to split it into oxygen and hydrogen using clean electricity – termed 'green' hydrogen when using power from renewables, or 'pink' when the electricity is from nuclear. Second, by incorporating carbon capture and storage into a fossil fuel-based process – often termed 'blue' hydrogen. Both routes have a lower carbon footprint than traditional 'gray' H_2 production, which is made from fossil fuels with the emissions left uncaptured.

Green ammonia made in China could, in theory, be cheaper today than gray ammonia made in countries with high fossil-fuel prices

By bolting on a carbon capture unit to a fossil-fuel-based ammonia project, it is possible to capture 90-95% of the CO_2.[6] But this is rarely achieved due to the cost. At 95% capture, blue hydrogen production would cost $1.80-4.68 per kg in 2023, equivalent to a blue ammonia production cost of $317-824 per ton among modeled markets (Figure 1).

Today, green hydrogen costs between $2 and $12 per kg, depending on the electrolyzer technology and the kind of renewable electricity used.[7] BNEF expects falling equipment and renewable energy costs to bring green hydrogen costs down 66% by 2030, to $1.1-3.9 per kg. This is equivalent to a marginal green ammonia cost of $194-686 per ton among modeled markets (Figure 7), making it competitive with almost all blue ammonia and, in some countries, gray too. This includes China, Brazil, Spain, India and Germany (the latter only for new-build gray ammonia). By 2040, green ammonia should become cheaper than gray in the vast majority of markets (Figure 8).

Figure 7: Cost of ammonia production in 2030

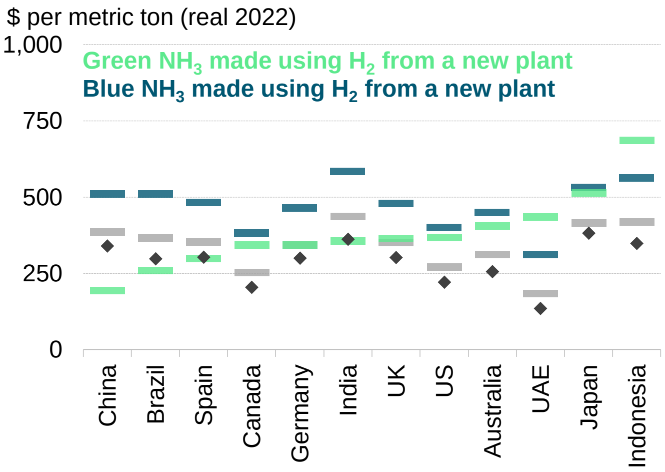
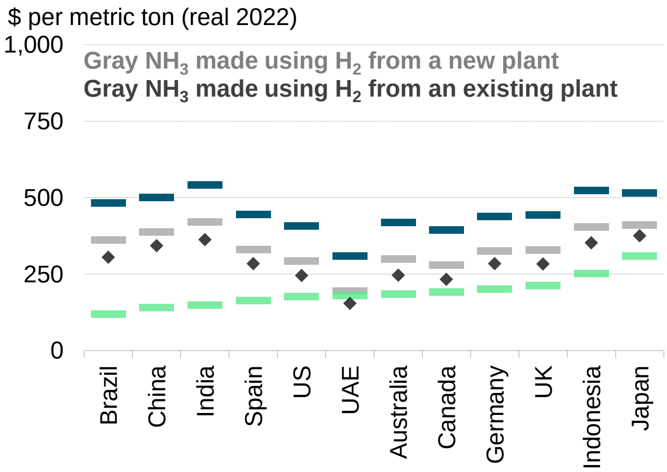


Figure 8: Cost of ammonia production in 2040



Source: BloombergNEF. Note: Assumes an existing ammonia plant is used. Uses levelized cost of hydrogen from BNEF's 2023 Hydrogen Levelized Cost Update: Green Beats Gray (web | terminal) as input for cost of ammonia production.

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[6] See BNEF"s *Blue Hydrogen Primer Part 1: Technology* (web | terminal) for more.

[7] See BNEF's *2023 Hydrogen Levelized Cost Update: Green Beats Gray* (web | terminal) for more.

Alternative paths exist to produce low-carbon ammonia, but these lack the potential to scale up. Biomass-based ammonia, for example, may only account for 3-4% of ammonia supply by 2050 due to scarce production of sustainable biomass, which will have competing uses.

4.2. Dealing with downstream emissions

The bulk of ammonia-based fertilizer emissions are generated after the fertilizer product is applied to the field

While they are termed ‘clean’ or ‘low carbon’, green and blue ammonia only address the share of emissions released during production. The bulk of emissions associated with ammonia-based fertilizers are generated after the fertilizer product is applied to the field, from processes that will still occur when green or blue ammonia is used (Table 2).

Reducing these emissions will rely on technologies that raise the efficiency of nitrogen uptake, changes in agronomic practices that reduce fertilizer use, and the development of biological fertilizers[8]. All these developments will take time and would need to be done in tandem with decarbonizing ammonia-based fertilizer process emissions.

Urea, the most common type of ammonia-based fertilizer, also contains carbon molecules, which are emitted as CO_2 by the urea on the field. To decarbonize urea, producers would need to acquire carbon-neutral CO_2. This can be done via direct air capture – extracting CO_2 directly from the atmosphere – or by capturing biogenic CO_2 (derived from plant-based materials). But both sources are costly and this may lead to substitution of urea with other nitrogen fertilizers, such as ammonium nitrate.

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[8] For example, solutions such as PivotBio’s Proven 40 treatment – see *The Tiny Microbes Taking On a Giant Source of Global Heating* (web | terminal) for details.

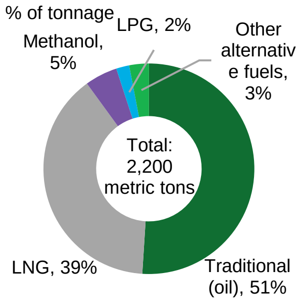
Section 5. New opportunities for low-carbon ammonia

New demand sources for ammonia will appear, such as shipping and power generation

The future of ammonia demand is uncertain. Demand from agriculture could fall if farms improve fertilizer application or scale up non-ammonia-based fertilizers. Or demand could grow if there is no change in application or technology and if the global population reaches the projected 10 billion by 2050, from 8 billion today. If ammonia production decarbonizes, demand could emerge in new sectors, such as shipping and power generation, with ammonia being used as a transport vector for hydrogen. However, ammonia is a hazardous substance that needs to be handled with care, so increased usage poses safety and security concerns.

5.1. Maritime shipping

Figure 9: New build vessel orderbook by fuel type



Source: BloombergNEF, Clarksons Research

The decarbonization of maritime shipping will depend on national and international efforts. The International Maritime Organization, which regulates shipping, has recently established new 2050 net-zero greenhouse gas emissions targets.[9] Low-carbon ammonia is a possible pathway to this goal, applicable to long-haul shipping.

For shipping to reach net zero, its demand for ammonia reaches 178 million tons per year by 2050 under BNEF's Net Zero Scenario[10] – roughly as much as today's ammonia demand from the fertilizer and chemical sectors (Figure 3)[11].

Ammonia's adoption as a fuel is hindered by high costs[12]. Running a ship on ammonia (or on methanol – another H_2-based fuel) requires different engines, which means new ships. By deadweight tonnage, 51% of new builds ordered by May 2023 will use oil and another 39% will rely on liquefied natural gas, according to Clarksons Research (Figure 9). Most of these assets will run until 2050, given an average operating range of 20-30 years[13]. Some 10% of orders were for ships that will use alternative fuels (mostly methanol). Another 191 ammonia-ready, 130 methanol-ready and 9 H_2-ready vessels were on order by May, data from Clarksons Research indicates. BNEF expects this number to grow in the coming years.

5.2. Power

Hydrogen and ammonia could play a role in seasonal balancing and a backup power source to complement renewables at times when the sun does not shine, or the wind does not blow.

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[9] See BNEF's *New IMO Plans for Net-Zero Emissions Are Key for Shipping* (web | terminal) for more.

[10] See BNEF's *New Energy Outlook 2022* (web | terminal) for more.

[11] BNEF's Net Zero Scenario estimates hydrogen demand for shipping. Ammonia demand was calculated assuming all hydrogen is converted to ammonia and that a ton of ammonia needs 0.176 tons of hydrogen.

[12] See BNEF's *Clean Shipping: Slow Progress But Signs of Hope* (web | terminal) for more.

[13] See BNEF's *2022 Marine Fuel Outlook: The Rise of LNG* (web | terminal) for more.

Germany has taken a step in this direction, aiming to hold an auction to build gas-fired power plants capable of burning hydrogen[14].

Japan and South Korea are promoting the co-firing of ammonia with coal for *baseload* power, generation that can run 24/7. This is incompatible with net zero and would be costlier than other options such as offshore wind – a technology Japan could develop in large quantities (Figure 10)[15]. The Japanese government and thermal power industry, however, see an economic opportunity in commercializing ammonia co-firing technology, which means certain volumes of clean ammonia may be used for coal co-firing. Ammonia and hydrogen could be more suited as a baseload power source in locations with gas power plants, where developing large volumes of renewable power is difficult. One such location is Singapore, whose National Hydrogen Strategy notes that “hydrogen has the potential to supply up to 50% of our projected electricity demand by 2050”.

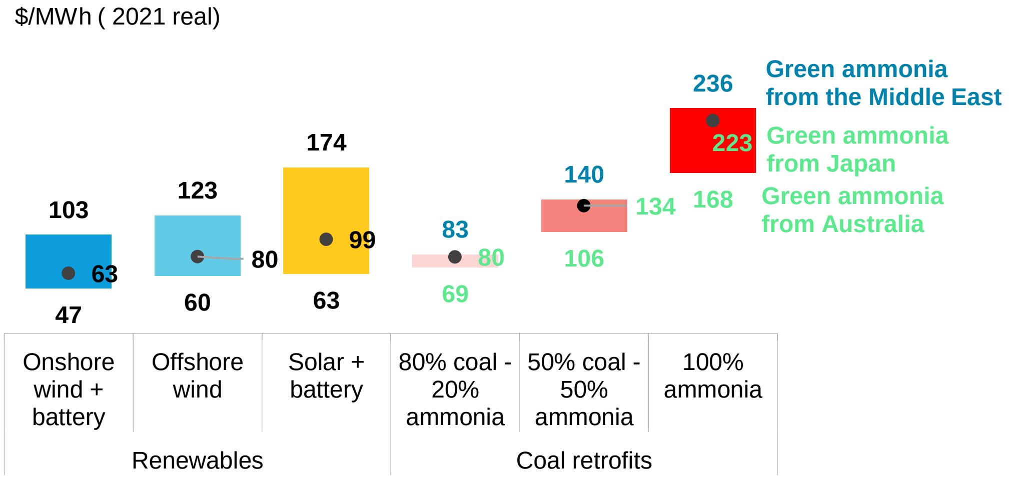
Ammonia has a potential role to play in seasonal balancing and as backup in power generation

Singapore-based Keppel Infrastructure is exploring low-carbon ammonia solutions for power and could import this fuel from locations such as the US, China, Australia and India, where it has collaborated with local companies to evaluate the economic feasibility of doing so. Keppel Infrastructure is currently building a 600 megawatt hydrogen-ready combined-cycle gas turbine power plant and is examining the possibility of developing a 60 megawatt ammonia-fueled power plant.

One of the companies that is in supply discussions with Keppel is Envision Energy, which is currently building a green ammonia production facility in China with an annual capacity of 1.52 million tons. It has plans to use its scale and low-cost renewable energy and electrolyzers to produce cost-competitive green ammonia.

But even in Singapore, hydrogen and ammonia will need to compete with other options for decarbonizing power, such as electricity imports by high-voltage direct current cables from neighboring countries and even Australia.

Figure 10: Comparison of levelized cost of electricity for different technologies in 2050



Source: BloombergNEF. Note: The levelized cost of electricity refers to the long-term offtake price that a power plant needs to break even.

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[14] See BNEF’s *Germany’s Hydrogen-Ready Gas Plant Plan Does Half the Job* (web | terminal) for more.

[15] See BNEF’s *Japan’s Costly Ammonia Coal Co-Firing Strategy* (web | terminal) for more.

5.3. Ammonia as a transport medium for hydrogen

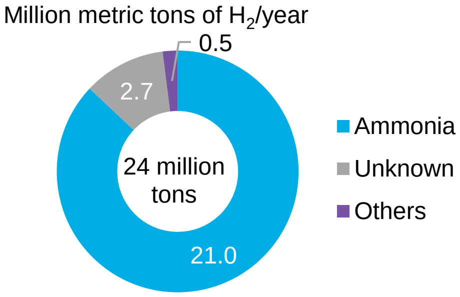
Only 30% of planned ammonia export capacity is within 20 kilometers of existing ammonia terminals

Ammonia could play a role as a medium for shipping hydrogen. It has favorable physical properties – for one, liquid ammonia's volumetric energy density is 50% greater than that of liquid hydrogen – and it is already traded globally. Consequently, 87% of planned hydrogen export capacity aims to ship hydrogen in the form of ammonia (Figure 11).[16] This application is currently limited by a lack of suitable infrastructure. Only 30% of planned ammonia export capacity is within 20 kilometers (12.4 miles) of existing ammonia terminals, which will require additional investment to accommodate the greater volumes (Figure 12).

Green ammonia shipped from where it is cheap to places where it is costly could be competitive if used as is, such as for fertilizer production. But conversion back to hydrogen would make ammonia transport uneconomical. Ammonia exports could be particularly competitive when supported by subsidies such as the tax credits included in the US Inflation Reduction Act.[17]

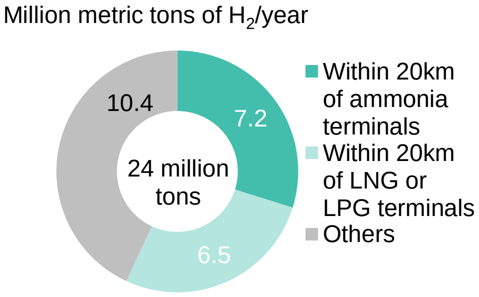
When produced in the US, due to the IRA, exported ammonia has greater potential to be competitive

Figure 11: Planned hydrogen export capacity in end-product form (2022)



Source: BloombergNEF

Figure 12: Proximity of planned hydrogen export capacity to ports (2022)



Source: BloombergNEF

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[16] See BNEF's *Hydrogen Export: Tough Competition Ahead* (web | terminal) for more.

[17] See BNEF's *Mideast Hydrogen Projects Financed Amid US Subsidy Threat* (web | terminal) for more.

Section 6. State of the low-carbon ammonia market

6.1. Current state and expectations

BNEF has identified 185 low-carbon hydrogen projects with plans to make ammonia, totaling 28.7 million tons of annual production (Figure 13, Figure 14 and Figure 15).[18] Of these, 45 projects have offtake agreements, and there is a total of 15 projects that are under construction or have financing secured. This tally excludes projects that have not disclosed a planned commissioning date.

Figure 13: Blue hydrogen projects with ammonia output

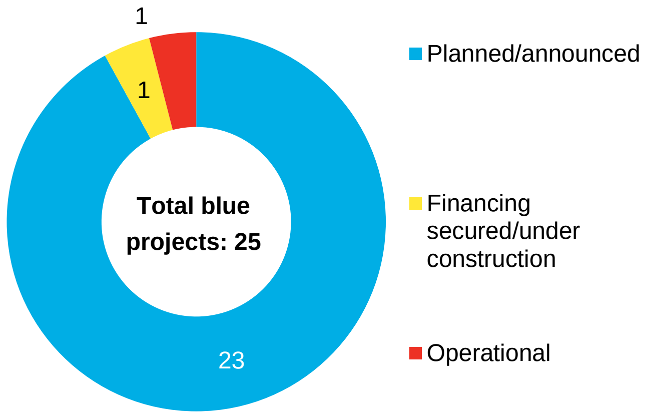
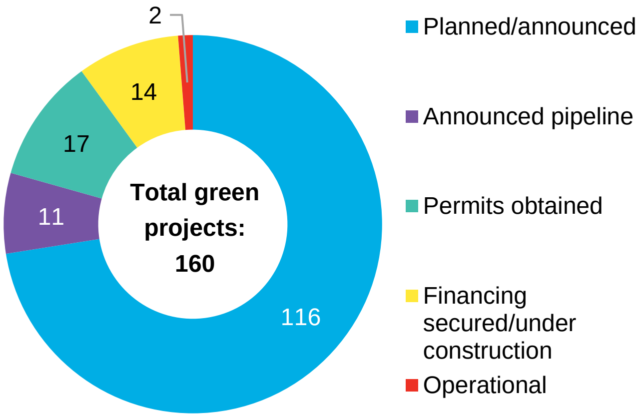


Figure 14: Green hydrogen projects with ammonia output



Source: BloombergNEF. Note: As of October 19, 2023. Announced pipeline means stage two of an announced project or beyond.

6.2. Policy

Globally, three jurisdictions plan to incentivize the consumption of low-carbon ammonia. This has come in the form of mandates, targets set in strategy documents, and the inclusion of ammonia-reliant technologies in new markets. The slant towards greening gray ammonia in Europe is quite different to the focus on ammonia for power decarbonization in Asia. It is likely that companies in these two regions will take quite different approaches to the near-term adoption of low-carbon ammonia.

Europe: The EU has agreed quotas to replace at least 42% of existing H_2 demand with green H_2 by 2030.[19] This complements the target for 20 million tons of annual renewable H_2 demand set under the REPowerEU plan. Being the largest users of H_2, ammonia producers will be impacted and how they respond will depend on costs. Local fertilizer producers may well turn to imported

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[18] See BNEF's *Hydrogen Project Database* (web | terminal) for more.

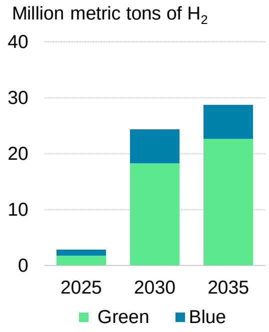
[19] There is no clarity on how EU member states will enforce the quotas and so no guarantee they will be met. See BNEF's *EU Hydrogen Quotas Raise Global Demand For Green Molecules* (web | terminal) for more

green ammonia from the US due to its lower costs – a reflection of the subsidies included in the Inflation Reduction Act.

Japan and South Korea aim to commercialize the co-firing of ammonia with coal by 2030. South Korea is launching a new auction mechanism aimed at promoting power generation using hydrogen, for which ammonia will be eligible.[20] Japan is seeking to develop a capacity market for which H_2 and ammonia co-firing would be eligible.[21]

Beyond Europe, Japan and South Korea, policy incentives for low-carbon ammonia are limited. India is considering a green ammonia mandate for fertilizers but has yet to announce details.

Figure 15: Announced low-carbon H_2 production with the aim to produce ammonia



Source: BloombergNEF. Notes: As of October 19, 2023. Only includes projects with announced completion dates.

Policy to reduce demand for fertilizers

As well as policy to incentivize the greening of the ammonia sector, some countries are implementing policy to reduce the carbon footprint (and environmental impact) of fertilizers by eliminating demand:

- China has implemented a zero-growth policy in synthetic fertilizer use
- Germany has mandated the use of urease inhibitor to increase nitrogen uptake efficiency
- New Zealand plans to implemented a carbon tax on farmers, which should lower fertilizer application, starting at the end of 2025
- The EU Common Agricultural Policy recommends reduced fertilizer application.

Also important are the supranational efforts led by the UN's Global Biodiversity Framework, and the EU's Farm to Fork Strategy and 2030 Biodiversity Framework, all of which call for a 50% reduction in nutrient loss by 2030. The EU's Integrated Nutrient Management Action Plan also wants to cut fertilizer use by 20%.

6.3. Challenges to ammonia decarbonization

The high cost of producing low-carbon ammonia remains a major impediment to its wider adoption. This is especially so in agriculture. There are, broadly, two main factors that have made it hard for the ammonia sector to decarbonize to date:

1. Overcoming cost-related challenges

Many players in the ammonia value chain have indicated that there are currently cost-related challenges with low-carbon ammonia due to the potential for additional costs of a green product compared to a conventional product.

Farmers, with their small or negative profit margins, are not in a position to pay a significant premium for fertilizers and there is limited understanding of how policy can incentivize green fertilizer adoption. Other players in the value chain include the fertilizer and ammonia makers themselves, or the consumer brand companies nearer the end of the value chain. The former are unwilling to invest in low-carbon ammonia capacity while there is no demand for it (or willingness to pay), and consumer goods companies that would like to buy lower-carbon products appear to be too far down the value chain to influence ammonia producers.[22]

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[20] See BNEF's *Korea's Hydrogen Power Auction Misses Mark on Three Things* (web | terminal) for more.

[21] See BNEF's *Japan Hydrogen Strategy Update Steps in Right Direction* (web | terminal) for more.

[22] See BNEF's *Future Food for Thought: Perspectives of Agri-Food Leaders* (web | terminal) for more.

2. Financing of green ammonia plants could be better served by long-term, fixed-price, contracts. This is not how the gray ammonia sector currently works.

The green ammonia industry has exhibited a trend toward very different contract structures to those that ammonia buyers are used to. For example, to secure renewable energy for their green hydrogen project, a green hydrogen/ammonia developer might need to sign a 20-year, fixed price contract for that power. Therefore, to attract project financing for a green ammonia facility, some bankers are telling producers that they must secure a 20-year, fixed-price offtake, to ensure debt service coverage ratios.

Existing ammonia buyers appear to have no incentive to sign long-term, fixed-price contracts

But green ammonia producers will be selling into a market that is used to ammonia pricing tied to natural gas prices, and where it is rare to sign contracts longer than a few years. Ammonia buyers do not appear to be incentivized to sign long-term fixed price contracts for low-carbon ammonia when they are uncertain as to market demand in the future and where the price can be two to three times that of gray ammonia. Blue ammonia producers, who are still tied to the price of natural gas, can afford to be more flexible with their contracts but still need to attract project financing for their carbon capture and storage capacity.

Section 7. Commercial actions

This chapter highlights potential actions that actors across the value chain could take to increase low-carbon ammonia adoption. The options presented are based on discussions with producers, traders and users of ammonia, and information made publicly available by companies. Most options address the fertilizer sector because this is the main market for ammonia. However, as discussed in the 'Ladder Approach' section below, there are other markets that can help accelerate the cost competitiveness of clean ammonia.

7.1. Forming the 'Clean Ammonia 100'

Context

In the short term, demand will be small and from European brands with the willingness to pay a premium

There is some demand coming from food and beverage companies for products made with low-carbon fertilizer, some examples of which are provided in this chapter. This is especially true of European brands with an individual emissions-reduction goal and a willingness to differentiate their products with the consumer. But the size of this demand is limited and needs to grow if it is to provide a positive investment signal to ammonia and fertilizer manufacturers.

Many large integrated ammonia-fertilizer companies each have their own emission reduction goals and the production of ammonia is part of their individual Scope 1 emissions footprint. They appear to be interested in pursuing green or blue fertilizer manufacturing and have exhibited a desire to sign long-term ammonia or fertilizer offtake deals in order to scale up production. This is an unusual form of contract for the traditional fertilizer sector so partnerships between consumer goods brands and fertilizer manufacturers, often at opposite ends of the agriculture value chain, could be a way to drive decarbonization.

This section discusses the potential to develop a corporate purchasing coalition for ammonia, always within the constraints of antitrust rules, similar to RE100 and EV100, which have had an impact on demand for renewable electricity and electric vehicles.

Case study: Food and beverage company agreements

Dossche Mills and Agravis Raiffeisen will use OCI's Lower Carbon Nutramon to make low-carbon wheat

Chemicals companies OCI and Yara both have carbon emission reduction goals and have secured low-carbon fertilizer offtake deals. OCI delivered the first test shipments of its Lower Carbon Nutramon fertilizer in 2023 to UK-based Simpsons Malt Ltd., which has a 2030 carbon-neutrality goal for its barley and wheat. The fertilizer uses biomethane feedstock, reducing its carbon footprint by 50%, according to OCI. Lower Carbon Nutramon is applied to malting barley and distilling wheat contracted by Simpsons Malt, which could reduce the barley's carbon footprint by up to 20% and cut the carbon emissions of its whiskey distilling customers. There are several companies with net-zero goals that grow and buy malt, including brewers Ambev, Asahi and Kirin.

Similarly, OCI is collaborating with Dossche Mills and Agravis Raiffeisen to produce low-carbon wheat, using Lower Carbon Nutramon. This will be used to make bread to stock German grocery stores to meet customer interest and stay in line with European regulations.

Besides consumer goods companies, there are some limited examples of agricultural growers sourcing low-carbon fertilizers. Yara, the world's second-largest ammonia producer, has signed a commercial agreement for low-carbon fertilizer with Swedish firm Lantmännen, an agricultural cooperative owned by 18,000 northern European farmers. Lantmännen is aiming for a 50% reduction in CO_2 emissions every decade and to reach net zero by 2050. While not a consumer brand owner, any products that include Lantmännen's produce are labeled with a special brand so that it can differentiate itself. Yara's product uses green hydrogen-based ammonia. The ammonia will be produced at Yara's plant in Porsgrunn, Norway, retrofitted to include a small grid-connected electrolyzer with an estimated H_2 production capacity of 772 tons per year.

Case study: Chemical and explosives agreements

Markets like the EU have policies that incentivize the decarbonization of industrial products

Beyond fertilizer manufacturing, ammonia is used in over 30 other products, ranging from cosmetics to explosives. Companies are incentivized to decarbonize the manufacture of industrial products in markets with existing or anticipated decarbonization policies, such as the EU, or where these products contribute significantly to the company's carbon footprint.

For example, Lotte Fine Chemical, a South Korean ammonia distributor and user, signed a memorandum-of-understanding with OCI to purchase low-carbon ammonia to produce bio-certified plastics for the European market. These are eligible for tax benefits in Europe.

For Enaex, a Chilean mining explosives manufacturer, ammonia represents 90% of its carbon footprint. It is working with Engie, which will build a 26-megawatt green electrolysis project to produce 18,000 tons of green ammonia, with phase one due to be finished in 2025. Phase two is slated to complete in 2030 and will produce 0.7 million tons of green ammonia. These clean explosives will be sold to mining companies to address their Scope 3 emissions.

Case study: FertigHy

Consumer brands working in isolation are unlikely to move the industry forward as rapidly as other appropriate forms of collaboration

Consumer brands can also invest in low-carbon ammonia projects. Heineken, for example, is experimenting with investing in a green fertilizer company. The Dutch brewing company is part of a consortium, FertigHy, launched in June 2023, that plans to start construction of a plant in 2025 to produce more than 1 million tons of low-carbon nitrogen-based fertilizers per year using 100% renewable electricity and green hydrogen.

FertigHy notes the role of investor-offtakers InVivo and Heineken in "stimulating demand" and its "cross value-chain combination of initial investors". Other partners include RIC Energy and the MAIRE group – both firms with experience building renewable energy projects. InVivo, a European agriculture cooperative, will use the green fertilizer on its crops, selling some of them to its customer Heineken.

Considerations and caveats

Hundreds of consumer goods brands have their own, individual net-zero targets (for example, the five large food and beverage brands in Figure 16), and they might turn to sourcing crops grown with low-carbon fertilizer to reduce their Scope 3 emissions in the next few years.[23] To secure supply, they may be driven to invest directly in green fertilizer production, like with FertigHy, bypassing the farmers. But each of them working in isolation on their own initiatives are unlikely to move the industry forward as rapidly as other appropriate forms of collaboration (at all times remaining mindful of compliance with antitrust laws).

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[23] See BNEF's *Corporate Net-Zero Assessment Tool* (web | terminal) for more.

RE100 and EV100 are global corporate initiatives for renewable energy and electric vehicle purchasing, respectively, that have had success in stimulating demand. Founded in 2014, RE100 has over 400 members buying 440 terawatt-hours of renewable electricity every year (roughly as much as France uses), impacting their Scope 2 emissions. EV100, meanwhile, was set up in 2017 and its 128 members, who own a combined 5.5 million vehicles, are committed to switching to EV fleets and/or installing chargers for staff and/or customers by 2030, impacting their Scope 1 and 3 emissions.

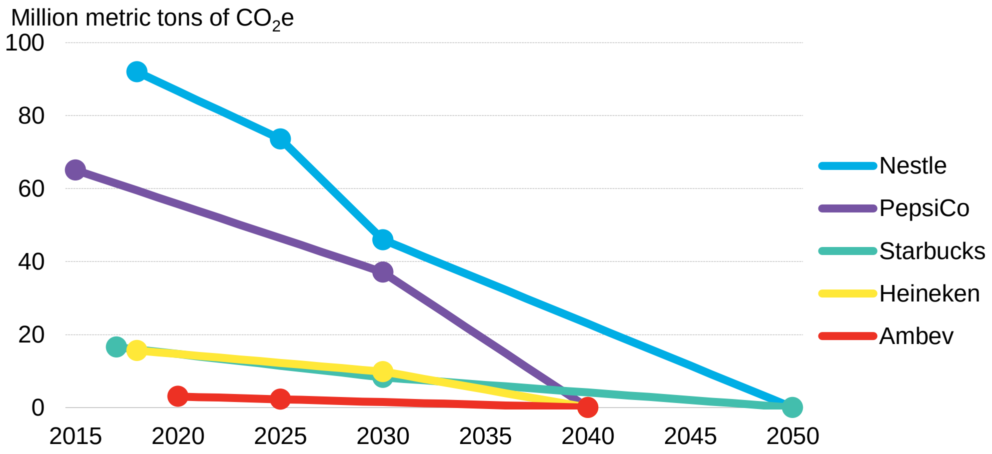
Both coalitions, and the RE100 in particular, contain many food, beverage and fertilizer brands, showing that these larger firms are used to joining low-carbon buyer coalitions (Table 3).

Table 3: Selected food, beverage and agriculture members of RE100

RE100
AB InBev
Asahi Group
Carlsberg
Danone
Diageo
General Mills
Group Bimbo
Heineken
Kellogg
Nestle
Nissin Food

Source: RE100, BloombergNEF

Figure 16: Net-zero targets for five large food and beverage brands



Source: BloombergNEF

A ‘Clean Ammonia 100’ coalition, acting in accordance with antitrust laws, could bring together the brands whose emissions (be it Scope 1, 2 or 3) are most impacted by ammonia. Like with RE100 and EV100, its members could share best practices and engage with policymakers and ammonia manufacturers. This might help create the positive investment signals suppliers are looking for and help governments set the best policies.

A ‘Clean Ammonia 100’ coalition could help create positive investment signals

Such a coalition should also be attractive to buyers outside of the food and beverage sectors, such as mining explosives and maritime freight transport. Many mining and shipping companies with independent net-zero goals have a vested interest in seeing the low-carbon ammonia sector scale and may be more willing than fertilizer buyers to sign long-term, fixed price, offtake agreements.

An alliance centered around clean ammonia could be complementary to the Ammonia Energy Association, a global non-profit industry group that (where appropriate in accordance with antitrust laws) “promotes the responsible use of ammonia in a sustainable energy economy”.

7.2. Adopting a ‘ladder’ approach

While a buyer’s coalition such as the Clean Ammonia 100 could stimulate demand over the coming years and develop robust value chains, it is not the only feasible approach. A complementary consideration is for the low-carbon ammonia sector to develop a ‘demand ladder’ picture – which could take different forms across regions – where producers target the pockets of demand that are ready to move today.

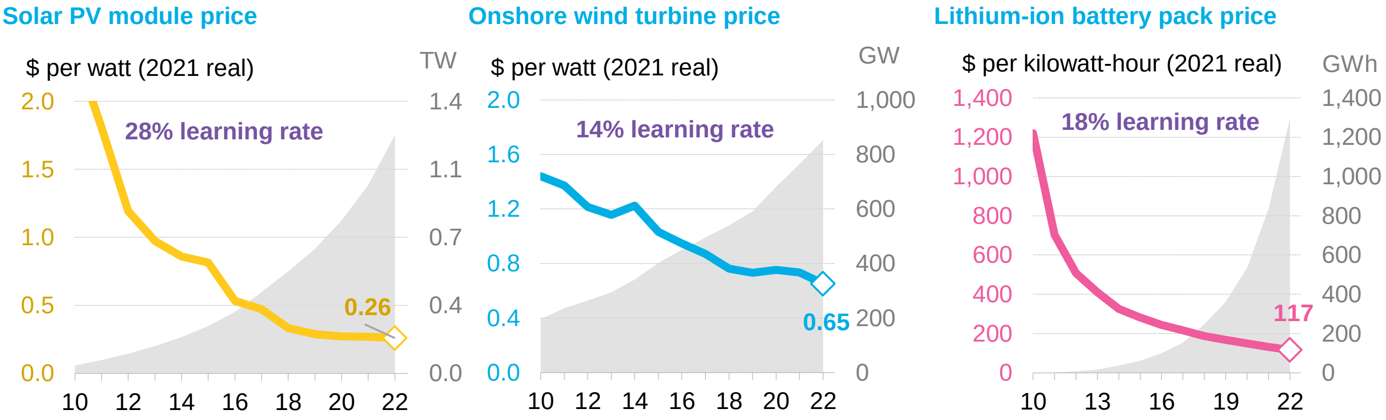
Context

Increasing uptake of clean technologies is key in getting costs to fall

BNEF research from the solar, wind and battery sectors show that increasing uptake is key to getting costs to fall. Since, 2010, for every doubling in the cumulative deployed capacity of solar modules costs have fallen by 28%. For lithium-ion batteries and wind turbines, the equivalent learning rate has been 18% and 14%, respectively (Figure 17). A similar relationship exists for hydrogen electrolyzers but identifying the learning rate in this sector has been hard due to its lack of maturity.

The first rungs of this demand 'ladder' might be for smaller markets such as mining explosives or higher-end chemicals, or for new markets such as shipping. As costs get lower, more rungs on the low-carbon ammonia ladder should unlock, helping costs fall further, and so on. This approach is not only useful for creating a demand ladder,but could also be helpful for developing a 'production ladder', identifying the lowest-cost (and fastest) routes for making low-carbon ammonia, even if the lowest rungs of the ladder do not produce large volumes.

Figure 17: Price benchmark for solar modules, onshore wind turbines and battery packs, by year



Source: BloombergNEF. Note: Cost estimates as of 1H 2022. Modest technology improvements create a ripple effect of cost savings. For example, solar cell efficiency gains allow for more watts per panel, which allows for more panels to be installed per man-hour, per meter of racking and wiring, and per hectare of land. Larger, more powerful wind turbines can have a similar effect. GW = gigawatt; TW = terawatt; GWh = gigawatt hour.

Case study: Ammonia blending and retrofits

Fortescue Future Industries, with partner Incitec Pivot Limited (IPL), plans to produce green ammonia at Gibson Island in Brisbane, Australia, from a former gray ammonia plant operated by IPL. The plant will produce up to 0.4 million tons of green ammonia per year. The companies expect this project to be faster to commission because it already has hydrogen storage, an electricity grid connection, access to port infrastructure and an ammonia production plant.

Another route to making low-carbon ammonia as cheaply and as fast as possible is to blend green hydrogen into gray hydrogen at existing ammonia plants. Norwegian chemicals company Yara and French utility Engie plan to blend green H_2 in Yara's Pilbara ammonia plant in Australia starting in 2024. A 10-megawatt electrolyzer operated by Engie will produce up to 640 tons of green hydrogen per year, enough to supply 3% of the ammonia plant's hydrogen demand.

Blended green H_2 volumes will be ramped up over time. Engie took final investment decision on the electrolyzer in 2022. The companies hope to export the ammonia overseas.

Takeaways and caveats

In order to stimulate hydrogen demand and begin a similar technology learning curve journey to the ones enjoyed by solar, wind, and batteries, low-carbon ammonia producers could identify the first rungs of the demand and production ladders.

For the demand ladder, individual producers could choose to identify which of their customers may be willing to support uptake of low-carbon ammonia and be interested in signing longer-term fixed-price offtake agreements. Today, these include mining explosive firms, shipping companies and power generators. Co-firing ammonia in coal power plants is more expensive than alternatives and will not drive emissions to zero. However, in countries with few other options (such as Singapore), combusting ammonia alone does offer a near-term source of demand to drive the clean ammonia market.

Sharing, or repurposing, ammonia infrastructure would reduce costs

Keppel expects Singapore will import 0.2 million tons of low-carbon ammonia a year by 2028 for use in the power sector. If all ammonia for the explosives market went clean, this would mean over 7 million tons of additional demand for low-carbon ammonia. While few dedicated ammonia-fueled ships may be commissioned this decade, nearer-term opportunities in dual-fuel ships in Asia could emerge by 2027-28 according to conversations with the Climate Technology Coalition members. While these ‘rungs’ possibly represent just a few million tons of demand, together they could help increase the number of ‘doublings’ for electrolyzer sales, driving green H_2 costs down.

For the ‘production ladder’, companies can pinpoint situations where sharing or repurposing, of infrastructure is possible, to reduce the time and cost taken to build anything new. This includes building hydrogen electrolyzers adjacent to gray ammonia plants and retrofitting retiring gray ammonia plants to use green H_2. While these sites might not be ideally situated for the best solar and wind resources (which would enable the electrolyzers to run as effectively as possible), they will likely come online much faster and provide the most economic near-term supply to the lower rungs of the ‘demand ladder’.

Section 8. Conclusion: Supportive policies

For any companies hoping to produce low-carbon ammonia, the associated price premium limits uptake in all sectors, especially in agriculture. While some useful commercial actions are possible, as outlined in Section 7, policy support will be required on both the supply and demand sides to further adoption. This section highlights policy actions that could support low-carbon ammonia adoption, with relevant examples.

8.1. Replacing fossil-fuel imports

Context

Policy support is required on both the supply and demand sides to further adoption

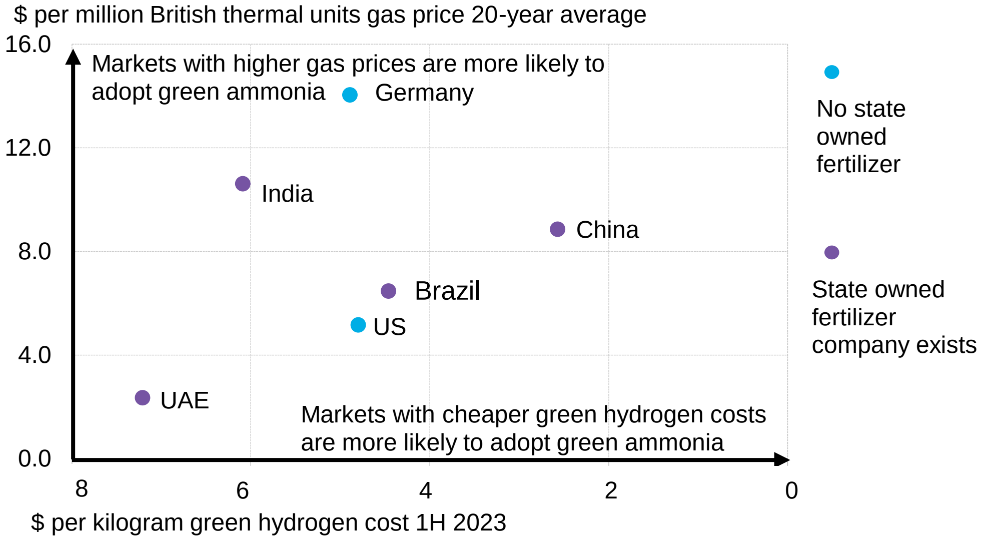
Given its importance for food production, access to fertilizer is a national security issue. Some countries with a large agricultural sector, such as Brazil, India and Turkey, lack fossil-fuel resources and rely on importing expensive natural gas to make fertilizers, or on importing fertilizers. Because ammonia contracts are often shorter than three years, and linked to natural gas prices, many of these countries were squeezed by the very high ammonia prices seen during the recent energy crisis. On the other hand, some of them have abundant renewable energy resources, which could make domestically produced green ammonia cost competitive in the near term.

Other countries, such as those in Sub-Saharan Africa, are set to become much larger users of fertilizer in the coming decades. It makes sense for governments in these markets to prioritize solar-powered green ammonia production domestically, right from the start of their nascent industry. An example of this is the planned Minbos green ammonia plant in Angola, set to supply half the country's commercial cultivation fertilizer needs.

A combination of high fossil-fuel prices and low renewable energy costs make a strong case for green ammonia

A combination of high fossil-fuel prices and low renewable energy costs could make a strong case for green ammonia (Figure 18).

Figure 18: Natural gas prices and green hydrogen costs in selected markets



Source: BloombergNEF. Note: Assumes Chinese alkaline electrolyzers for China and western alkaline electrolyzers for other countries. Excludes impact of hydrogen subsidies.

The replacement of gray ammonia with green is already happening, and particularly with state-owned operators. For example, Brazilian fertilizer company Unigel is building a green ammonia plant to replace imports of gray ammonia, and Morocco's state-owned fertilizer company OCP is planning a green ammonia project to replace imports.

Table 4: Select state-owned fertilizer producers

Company	Country
Sinofert	China
National Fertilizers	India
OCP	Morocoo
SABIC	Saudi Arabia
QAFCO	Qatar
Petrobras	Brazil

Source: Bloomberg

Policy considerations

Policy supporting domestic green fertilizer production may be easiest to implement for markets with a government-owned fertilizer company that controls most of the production or import of fertilizers. The government could then more easily mandate or incentivize these players to adopt green fertilizers. Table 4 shows select state-owned fertilizer producers.

This policy could be applied in a variety of ways. If the government already subsidizes fossil-fuel imports, it could redirect these to low-carbon fertilizers. For countries with a handful of government-owned fertilizer players, mandating the manufacture of green ammonia is an option.

8.2. Shifting fertilizer subsidies to protect farmer margins

Context

While fertilizer production is the largest end-use sector for ammonia, the long value chain makes decarbonization particularly challenging. Farmers, being extremely vulnerable to any cost premiums, are a part of the value chain unlikely to pay a premium for low-carbon inputs. Fertilizers can comprise 25-30% of a grower's input costs, so paying two to three times as much for green fertilizers would be very challenging. Given how sensitive many countries are to increases in food prices, it is therefore inadvisable to mandate the use of low-carbon fertilizer by farmers without financial support.

At the same time, any subsidies need to be carefully designed to discourage fertilizer overuse. The cheaper fertilizers are, the stronger the incentive for farmers to use them more extensively, leading to negative consequences for soil health and natural water bodies. Furthermore, only 40% of fertilizer greenhouse gas emissions come from ammonia production (Table 2), while the rest are produced after the application of fertilizers. This applies to green fertilizers too, so overapplication must be avoided.

Policy considerations

Policymakers could move existing subsidies for gray fertilizers to apply to low-carbon fertilizers instead

Policymakers could consider targeted subsidies for low-carbon fertilizers to bring pricing closer to gray fertilizers. As farmers are vulnerable to cost increases, the subsidies should go directly to farmers, or to fertilizer producers if it is made sure they do not pass the cost premium on to farmers. This policy would be most suitable in places where fertilizer subsidies are already part of the policy framework – for example, in India and some African nations.

In such cases, policy makers could remove existing subsidies for gray fertilizers and apply them to low-carbon fertilizers instead, flexing the subsidy level based on carbon content. Governments should take care not to make low-carbon fertilizer significantly cheaper than gray fertilizer for fear of over-application.

The subsidies could also run parallel to incentives for other decarbonization technologies – for instance, farmers that adopt green fertilizers could be granted access to funds for precision agriculture equipment or regenerative farming.

8.3. Closing economic gaps between supply and demand

Context

The combination of supply- and demand-side incentives has proven effective

The combination of supply- and demand-side incentives and mandates has proven effective in other areas of the energy transition – most notably renewable electricity. Mandates work best where there is a concentrated number of suppliers that policymakers can easily monitor and control. Subsidies can then be applied before and/or after the part of the value chain that mandates are targeting.

In some instances, policymakers have applied mandates to the demand side and subsidies to the supply side. This policy design helped the growth of renewable energy in the US, for instance, where the government provides tax credits to renewable energy developers and applies a renewable portfolio standard on utilities (which requires increased production of energy from renewables). Similarly, European feed-in tariffs are a combination of production subsidies and demand-side mandates (with grid utilities required to buy the subsidized renewable energy). The problem with this approach is that suppliers might not necessarily pass on the subsides to the demand side, unless the supply market is competitive and buyers have influence over the pricing.

Other successful policies have applied mandates on the supply side and provided demand-side subsidies. This way suppliers can pass on part of the cost premium to the demand side. This policy is working well for scaling EV adoption in the US and China, where governments mandate a minimum EV production capacity for vehicle manufacturers and provide EV purchase subsidies. This could take various forms, such as tax credits or purchase subsidies.

Another route to closing the economic gap is to subsidize both supply and demand, although this could place a significant burden on the taxpayer. Rather than one government subsidizing both sides, an international framework to produce complementary supply- and demand-side support in different markets might be suitable.

Policy considerations

Policymakers could look to the success of policy mandates and subsidies for EVs in the US and China

To make mandates easier to implement, policymakers could look at the parts of the value chain with the smallest number of large active companies. In the case of the ammonia value chain, it would most likely be fertilizer producers or any other industrial buyers of ammonia.

The mandate could happen in parallel to subsidies for producers of low-carbon H_2 or ammonia. As ammonia supply is fragmented and competitive, these suppliers would likely pass on some of the subsidies to fertilizer producers, who have a stronger pricing power in the market. Another approach is to provide subsidies to the farmers buying fertilizers (Section 8.2).

Governments should also collaborate internationally. Where one region has a supply-side subsidy, making ammonia cheaper to export (such as Canada's new hydrogen investment tax credit), importing countries might want to implement demand-side subsidies so that their domestic industries are incentivized to buy lower-cost ammonia from exporters (like what Germany is proposing with its H2Global scheme). This would relieve the financial weight on the taxpayer and ensure that export projects find international customers.

Hydrogen policy case study

Policy must not cause technology lock-in

Countries are designing hydrogen policies to address both supply and demand. The EU agreed on quotas to use low-carbon hydrogen in industrial sectors including ammonia, while providing subsidies for the production of low-carbon hydrogen. India is considering a mandate for fertilizer producers and oil refiners to use green H_2 while providing a subsidy for hydrogen production through a $2 billion budget under its National Green Hydrogen Mission.[24]

Some jurisdictions are also planning subsidies for the demand side of hydrogen, such as the EU's proposals for a hydrogen contract for difference and the proposed $1 billion demand incentive budget in the US.[25] Policymakers need to carefully design these subsidies to target the right players in the value chain so that the supply- and demand-side subsidies can work in synergy.

8.4. Minimizing emissions without picking technology winners

Context

The best policies focus on emissions reduction first, rather than the adoption of specific climate-technologies. Policymakers should avoid supporting a particular ammonia production pathway, such as blue ammonia, at the expense of green. Blue ammonia is not emissions-free and by 2030, BNEF analysis shows that green ammonia will be cheaper to make than blue in most markets. Policy should be careful not to make it so attractive to build infrastructure to go blue over green, such that it causes technology lock-in that prevents markets from moving to green as it becomes cheaper.

Policy considerations

Policymakers should design a simple standard for how to measure emissions reduction

To ensure policy can suitably favor the lowest-carbon pathway, policymakers could implement a clear methodology and design a simple standard for how to measure the emissions reduction of each technology option. Subsidies should then be based on the depth of the emissions cut. Quantifying the low-carbon features of various ammonia products, or the H_2 they are derived from, would make it easier for suppliers to price in the green premium and trade internationally.

Policymakers could design subsidy schemes to provide a higher subsidy for a lower-carbon product. The low-carbon features could also be separated from the products and traded as credits on the market, which would allow producers that exceed their low-carbon production mandate to gain an additional revenue stream. This sort of policy has been used effectively in California's Low-Carbon Fuel Standard.[26]

Hydrogen policy case study

The EU Emissions Trading System and Carbon Contracts for Difference (CCfd) schemes are good examples of incentivizing optimal emission reduction.[27, 28] Putting a price tag on every ton of carbon emitted encourages different low-carbon technologies to compete. The EU has already

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[24] See BNEF's *India's $2.1 Billion Hydrogen Mission Needs Demand Boost* (web | terminal) for more.

[25] See BNEF's *Bidenomics $1 Billion Hydrogen-Demand Plan Hits Right Note* (web | terminal) for more.

[26] See BNEF's *Low Carbon Fuel Standard Scenarios Tool (1.2)* (web | terminal) for more.

[27] See BNEF's *Carbon Contracts for Difference: The Netherlands* (web) for more.

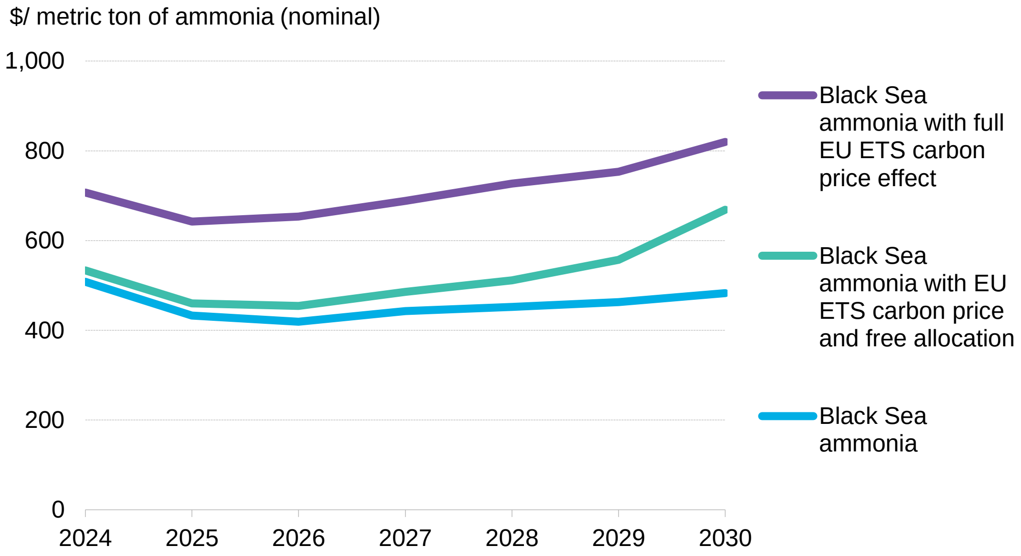
[28] See BNEF's *Smart Policy to Drive Clean Hydrogen Uptake* (web | terminal) for more.

legislated to phase out the free emission allowances that ammonia and fertilizer producers receive, so both domestic and overseas suppliers of these products will need to pay a carbon price starting from 2026. Ammonia and fertilizers prices will increase as a result (Figure 19).

The EU is also discussing a CCfD scheme, such as the one Germany is implementing, to close the cost gap between gray and low-carbon ammonia for end users.

Policymakers cand distinguish their subsidies based on CO_2 emissions intensity, rather than subsidizing all low-carbon hydrogen or ammonia that falls under an emissions threshold. Any carbon pricing or subsidies will therefore be more effective when combined with an emissions certification, such as in Denmark, the Netherlands and Australia, which have or are planning Guarantee of Origin (GO) schemes that put an emissions stamp on green fuels.

Figure 19: Black Sea ammonia price with EU ETS carbon prices



Source: Bloomberg Green Markets, BloombergNEF

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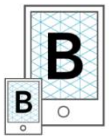

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