8

Ammonia industry net-zero tracker

While increased production costs of blue and green ammonia remain a challenge, demand from newer sectors like shipping and power can be key for ammonia decarbonization.

Key emissions data[388, 389, 390]

1%
Contribution to global GHG emissions

0.46 $gtCO_2e$
Scope 1 and 2 emissions

2%
Emissions growth (2019-2022)

2.6 tCO_2
Emissions intensity (per tonne of ammonia, 2020)

97%
Fossil fuels in the fuel mix (2021)

3 times
Expected demand increase by 2050

<1%
Current low-emission production

2.2%
Reduced emission production

Readiness key takeaways

Technology
Clean hydrogen production is critical for ammonia decarbonization. The green premium for low-emission ammonia can vary from 40% to over 100%[391] depending on production route and region. Globally, steam methane reforming (SMR)/auto thermal reforming (ATR) with CCUS is cheaper.

Infrastructure
To meet the increase in demand, infrastructure investments of around $2.3 trillion are required.[392] The majority directed to increasing clean power capacities to 1,260 GW by 2050.[393]

Demand
Green premiums of 10-100%[394] will be difficult to absorb for fertilizer companies without policy support. Demand will be boosted by shipping, power and hydrogen carrier applications.

Policy
Policies for ammonia are emerging, particularly within the broader hydrogen landscape. Policies should focus on electrolyser manufacturing, CCUS implementation and regulatory frameworks.

Capital
1.5 times current investments required for decarbonization efforts. However, the business case remains weak, given 13% industry profit margin and 9% WACC.[397]

Stated energy transition goals

- The ammonia industry aims for a 27% emissions intensity reduction by 2030 and a 96% reduction by 2050. [395]
- 91%[396] of large publicly traded ammonia companies consider climate change in their decisions-making processes.

Emission focus areas for tracker

Ammonia emissions can be divided into two main categories:

1. **Energy-related emissions** primarily due to fossil fuel use to produce the required process heat and pressure for production of hydrogen.
2. **Process emissions** stem mainly from using fossil fuels as feedstock in the hydrogen production process.

Sector priorities

Exisiting assets

Reduce near-term emissions intensity by:

- Retrofitting existing fossil-fuel-based production with CCUS where access to CO_2 handling infrastructure is feasible
- Investing in CO_2 storage and transport to enable CCUS-based hydrogen production
- Adopting energy efficiency measures across existing plants.

Next generation assets

Accelerate technology and infrastructure development to drive absolute emissions reduction by:

- Investing in electrolyser plants to generate electrolysis-based green hydrogen
- Investing in sufficient clean power capacity, accelerating the maturity of methane pyrolysis and biomass gasification through pilots across lowest cost regions.

Ecosystem

De-risk capital investment to scale infrastructure capacity by:

- Investing in R&D to reduce costs, scale up the electrolyser capacity and the deployment of CCUS
- Supporting policies that stimulate demand from new applications
- Enabling infrastructure access through strategic partnerships.

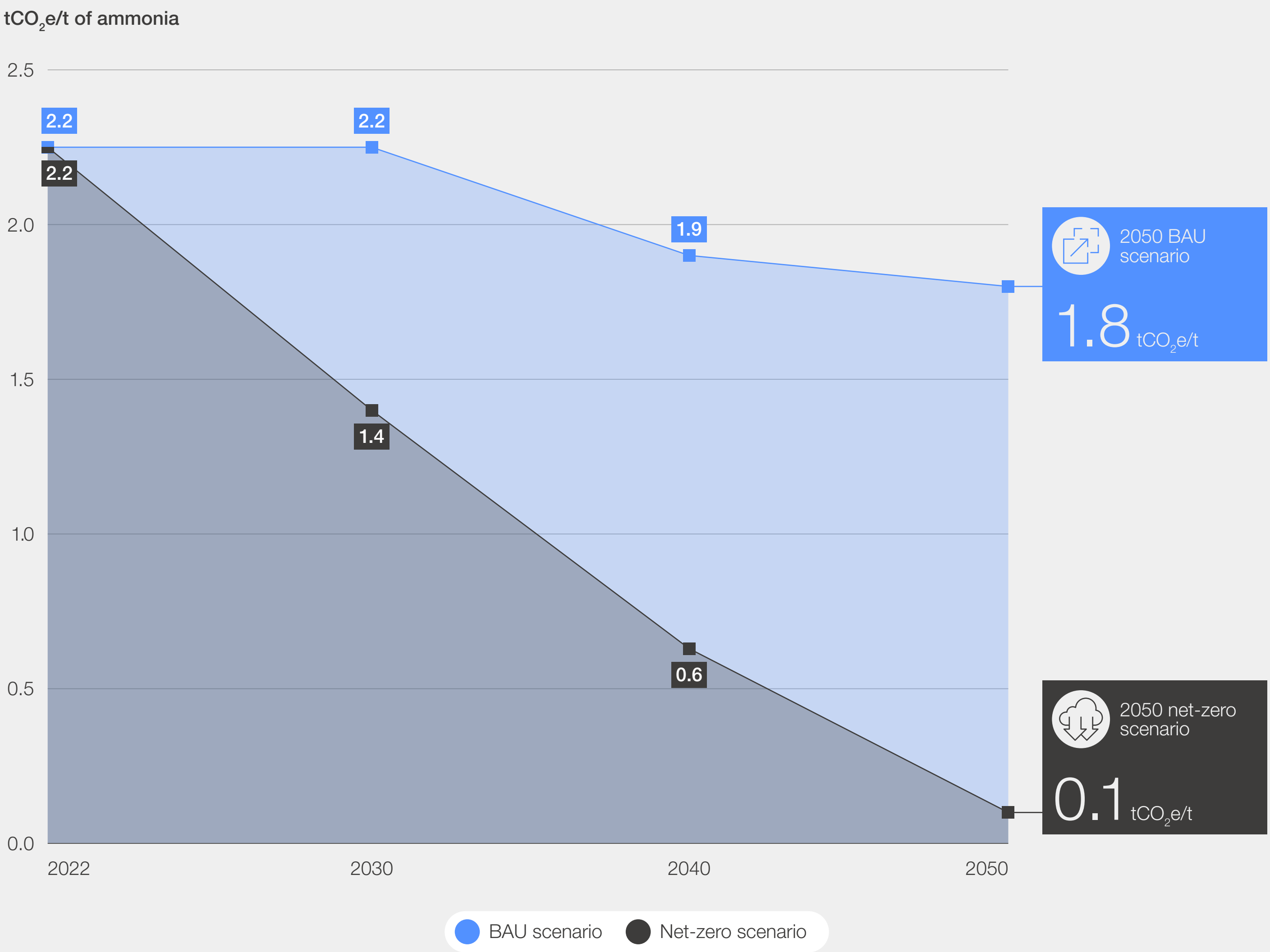
Performance

Approximately 98% of ammonia value chain emissions stem from the hydrogen production stage, which is heavily reliant on fossil fuels, particularly natural gas, for both feedstock and energy needs.[398]

Over the past five years, ammonia scope 1 and 2 emissions have plateaued at approximately 0.42 $gtCO_2$.[399] Current production processes like SMR and ATR, rely heavily on natural gas, rely heavily on natural gas and contribute to 73% of ammonia production, resulting in a high emission intensity of 2.4 tCO_2e per tonne.[400] Coal gasification, accounting for 26% of ammonia production, carries an even higher emission intensity of around 3.9 tCO_2e per tonne. To meet the industry net-zero trajectory by 2030, emissions must be reduced by 37%.[401]

The overall energy intensity of ammonia, averaging at 34 GJ/t,[402] is a function of various factors including: hydrogen production, fossil fuel use and the reaction kinetics involving high pressures and temperatures necessary to facilitate the formation of ammonia.

FIGURE 59 **Ammonia emissions intensity**

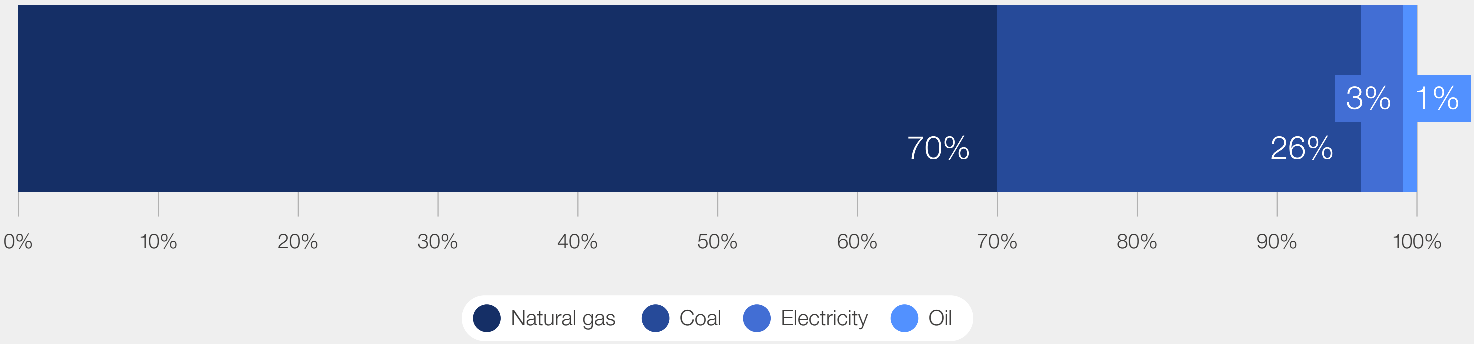


Source: IEA Ammonia Technology Roadmap

Path forward

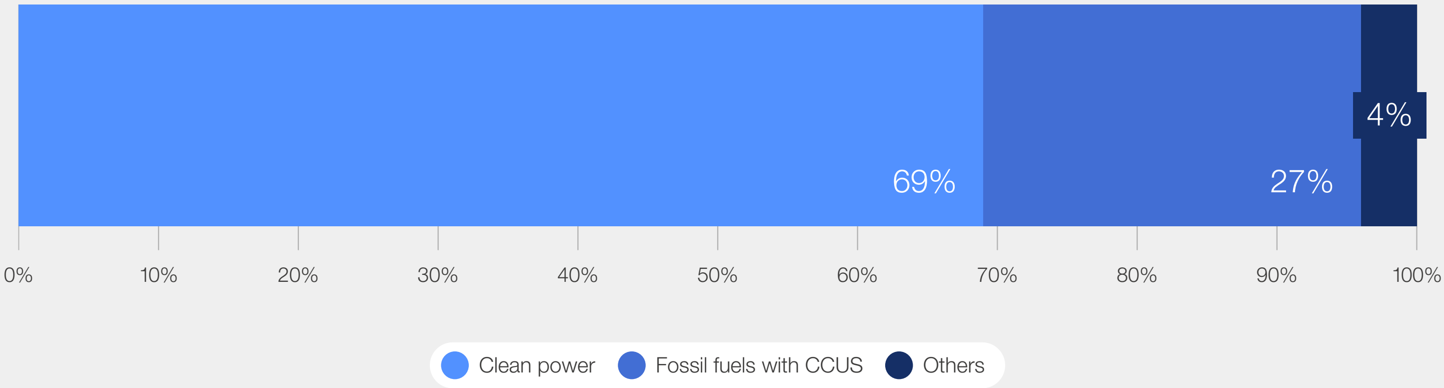
The 2050 net-zero fuel mix necessitates reducing the fossil fuel share from 99% to around 30%.[403] This transition can be primarily achieved by decarbonizing the hydrogen input, either through electrolysis-based hydrogen or CCUS-based blue hydrogen, resulting in a potential 93% reduction in cumulative emissions by 2050.[404] To achieve net zero, these pathways should be complemented by biomass-based ammonia production or methane pyrolysis.

FIGURE 60 | **2021 fuel mix**



Source: IEA Stated Policies Scenario

FIGURE 61 | **2050 fuel mix – net-zero scenario**



Source: MPP

AMMONIA

3 Technology

To decarbonize the ammonia sector, the primary pathway involves clean hydrogen production. This can be achieved through green ammonia, using electrolysis powered by clean power, or blue ammonia, which combines CCUS with existing SMR/ATR processes. The production cost increase for low-emission production can vary from 40% to over 120% depending on the production route and region.[405] Globally, SMR/ATR with CCUS is cheaper than electrolysis, though regional variations exist.

Green ammonia

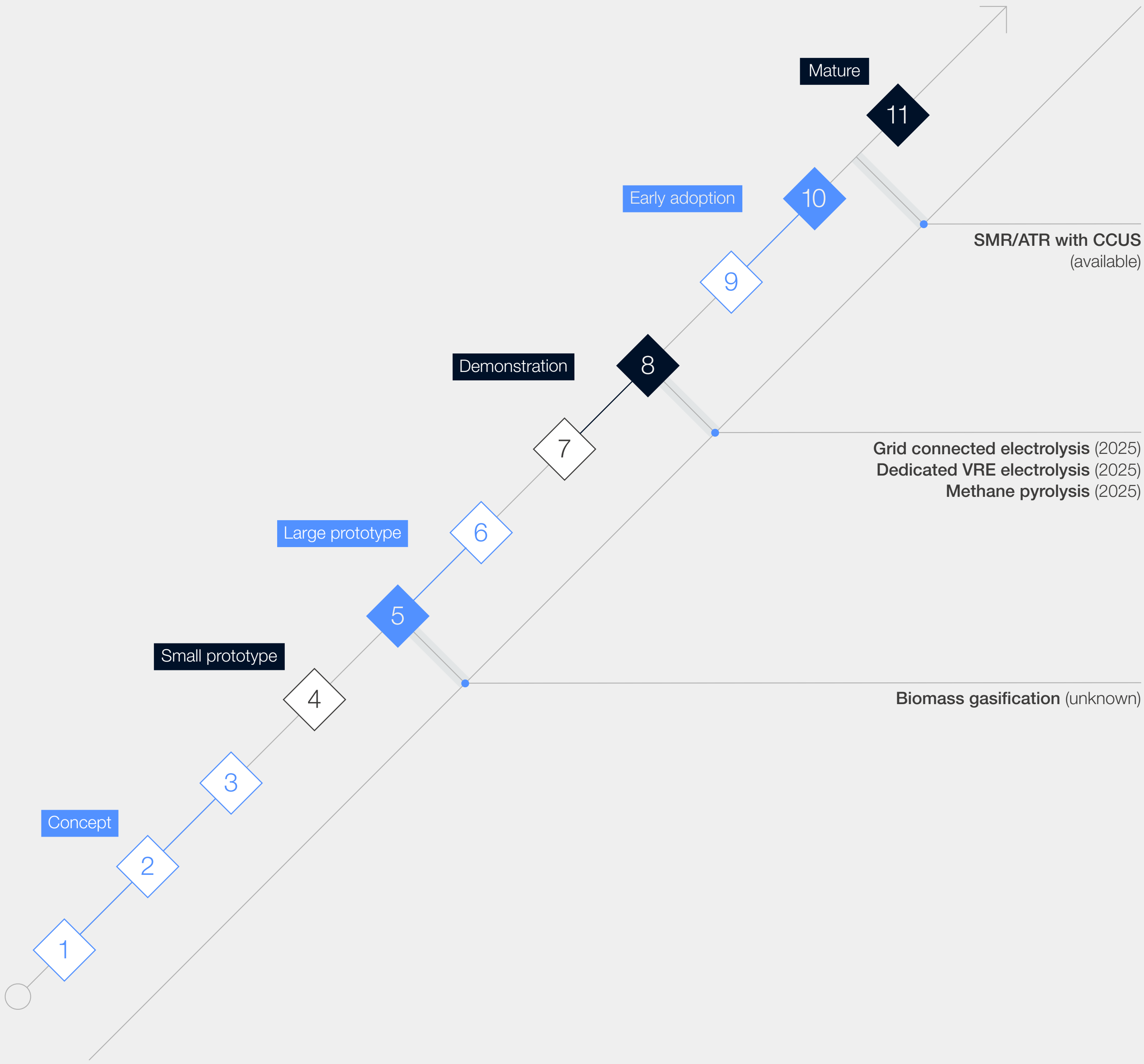
Electrolysis for hydrogen production offers a means to eliminate CO_2 emissions entirely from ammonia production and break away from fossil feedstocks. However, it is expected to be available only after 2025 and might come at a production cost increase of a minimum of 120%. The current planned electrolysis project pipeline capacity is around 180 MT, with 50% of that expected to be online by 2030.[406] Green ammonia production technologies are gaining momentum. For instance, ThyssenKrupp Industrial Solutions has developed a technology that can produce green ammonia from water, air and electricity generated from renewables using alkaline water electrolysis technology.[407]

Blue ammonia

To decarbonize fossil fuel-based ammonia production via SMR or ATR, capturing emissions through CCUS is crucial. Capture technologies like amine-based scrubbing are already established to capture rich CO_2 process streams, but technologies for capturing dilute streams need to be further advanced. Producing blue ammonia incurs a production cost increase of a minimum of 40%. Currently, around 1% of the production is blue ammonia, with a planned capacity of approximately 40 MT.[408]

The future role of supporting technologies like methane pyrolysis and biomass gasification in low-emission ammonia production remains uncertain due to technical challenges such as low hydrogen purity and biomass availability. Methane pyrolysis is expected to be commercially available by 2025, but the readiness of biomass gasification is uncertain.

FIGURE 62 **Estimated TRL and year of availability for key technology pathways**



Source: IEA

AMMONIA

1 Infrastructure

Meeting a three-fold increase in demand for low-emission ammonia by 2050[409] requires significant investments in clean power capacity and CO_2 handling infrastructure, estimated at $2.6 trillion.[410]

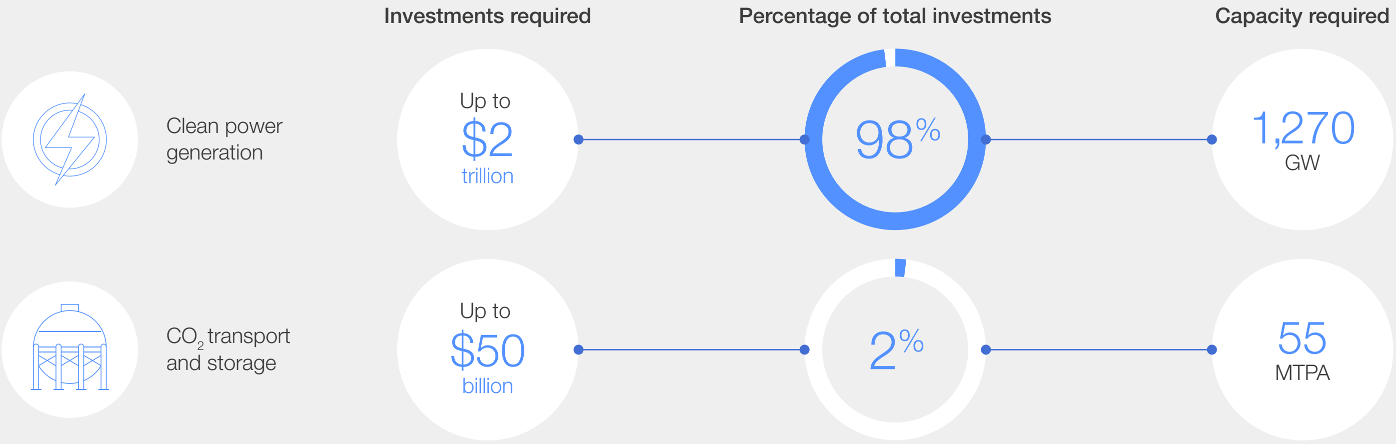
Most of these investments will be needed for clean power capacity to generate electrolysis-based green hydrogen, which will account for around 70% of ammonia in 2050.[411] To achieve this, the industry will need up to 1,320 GW of clean power capacity by 2050, equivalent to the entire generation capacity of the US.[412]

The remaining funds will be allocated for CO_2 storage and transport to enable CCUS-based hydrogen production. As technology advances and the learning curve progresses, CapEx for these infrastructure needs is expected to decrease, potentially accelerating their adoption.

Currently, technologies like methane pyrolysis and biomass gasification are projected to play a very small part in ammonia manufacturing by 2050,[413] and their infrastructure requirements remain uncertain.

The choice of technology adoption will depend on regional infrastructure availability. In regions where CO_2 transport and storage infrastructure will be affordable, technologies like SMR and ATR with CCUS will continue to scale up. Such geographies showing early promise include North America and the North Sea. Similarly, clean hydrogen may be adopted in locations where low-cost clean power sources are already accessible. For instance, ENGIE and Mitsui are collaborating on one of the world's first industrial-scale clean power-based hydrogen projects to supply feedstock to Yara's existing ammonia operations in Western Australia.[414]

FIGURE 63 **Investments required for enabling infrastructure**



Source: Accenture analysis based on multiple sources to include MPP, IEA and IRENA

AMMONIA

2 Demand

The ability of customers to absorb a green premium of 40-120% per tonne remains untested beyond prototype projects as low-emission ammonia represents less than 1% of global supply.[415]

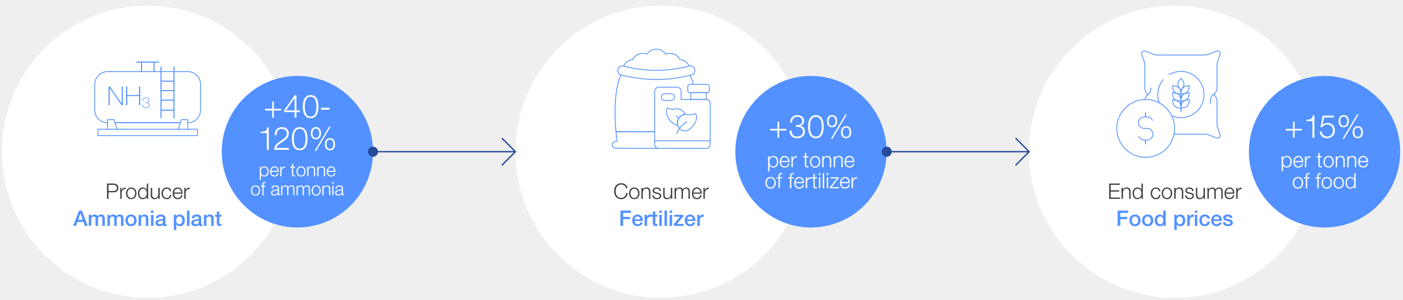
Higher fertilizer prices resulting from the added production of low-emission ammonia could lead to an increase in food prices by up to 15%, posing a risk to food security.[416] Therefore, demand for low-emission ammonia from conventional applications is likely to remain limited until policy measures, such as cross-industry subsidies, come into effect.

Embracing low-emission ammonia will have a disproportionate impact on low-income and developing countries, where fertilizer prices are more closely linked to food security.[417]

Ammonia players will need to strategically adapt to effectively address increased demand from new applications like shipping, power and hydrogen transport. This will include scaling the required low-emission production capacity and proactively securing early offtake agreements to ensure market foothold. However, several factors can impact the eventual demand for low-emission ammonia like weak regulations or availability of substitutes like availability of methanol as a shipping fuel or long-distance pipeline network to transport hydrogen.

Recent evidence indicates emerging demand signals. The first shipment of independently-certified blue ammonia has already arrived in Japan for use as fuel in power generation.[418] The ammonia was produced by SABIC Agri-Nutrients with feedstock from Aramco and sold by Aramco Trading Company to the Fuji Oil Company. Also, the launch of the new Platts ammonia forward curve is an indication of the growing interest in green and blue ammonia,[419] underscoring the increasing importance of price transparency in this sector. The absence of standardized definitions, certifications and traceability may hinder consumers from making informed decisions on paying a premium for green ammonia and limited the industry's understanding of market potential.

FIGURE 64 **Estimated B2B and B2C green premium**



Source: BloombergNEF

AMMONIA
2 Policy

Many producing regions are adopting policy measures across technology, infrastructure, demand and capital.

Public policies supporting clean ammonia production are emerging, particularly within the broader hydrogen policy landscape. However, additional policy frameworks are essential to facilitate the necessary technology and infrastructure deployment. Policies should also drive decarbonization while safeguarding food security.

These policies should promote the expansion of electrolyser manufacturing capacities and the implementation of CCUS technologies to facilitate clean ammonia production. Regulatory frameworks should encourage the growth of clean power generation and CO_2 transport and storage infrastructure.

Furthermore, policies should aim to stimulate demand for ammonia in new applications, such as a fuel in shipping or as a hydrogen carrier.

Many producing regions are beginning to adopt policy measures across the four readiness enablers, especially those with clean hydrogen consumption targets. For instance, the US and the EU have implemented encouraging policy frameworks that include innovation funds, infrastructure support and production tax credits.

Existing policy landscape

TABLE 11 **Policy summary**

Enabler	Policy type	Policy instruments	Key examples	Impact
Technology	Incentive-based	Direct R&D funds/grants	– EU Innovation Fund[420]	R&D grants of around $2 billion to green hydrogen projects, including green ammonia production projects.[421]
	Market-based	Carbon price	– EU-ETS[422]	Incentivizes ammonia producers to reduce emissions.
		Border adjustment tariff	– EU CBAM (pending implementation)[423]	Emission-intensive ammonia exporters to the EU face increased costs of compliance. Pre-Ukraine, ammonia imports to the EU amounted to 20% of total consumption.[424] Needs to be complemented by transparent and fair carbon accounting standards.
Infrastructure	Incentive-based	Direct funding support	– US funding of clean hydrogen hubs	$8 billion allocated towards the creation of hydrogen hubs across the US.[425]
Demand	Mandate-based	Industrial consumption targets	– India's green hydrogen consumption obligation policy	10% green hydrogen consumption targets for fertilizer and refining industries by 2030 – equivalent to a demand of 1.3 MTPA.[426]
		Direct targets	– RePowerEU's import targets of ammonia as a hydrogen carrier	Targets to import 4 MTPA of clean hydrogen in the form of ammonia – equivalent to a demand of 20 MTPA of ammonia.[427]
Capital	Incentive-based	Tax credits and subsidies	– IRA tax-credits for clean hydrogen production	50% reduction in clean hydrogen production costs that can boost scaling of clean hydrogen-derived ammonia.[428]

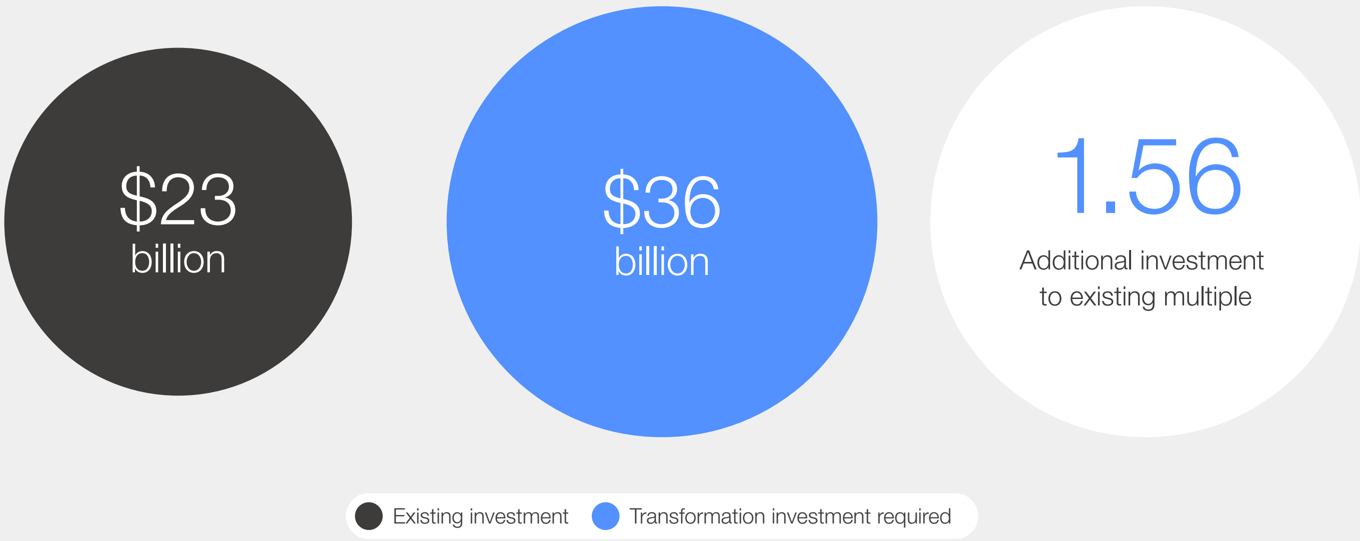
AMMONIA

1 Capital

The ammonia industry will need almost 1.5 times the amount of current investments annually to transition to low-emission assets with capital directed towards deploying electrolysers and CCUS.[429] These technologies could require cumulative investments of $970 billion by 2050. This implies annual investments of $36 billion, in addition to the regular annual CapEx of $23 billion.[430] Ammonia plants have long lifespans (up to 50 years). The current average age is around 25 years, but this varies regionally. Plants in Europe (9% of production) are around 40 years old on average and expected to witness an investment cycle in the next 10 years, so the investment should focus on low-emission assets to avoid emissions lock-in.[431]

Current industry profit margins of 21%[432] and WACC of 9%[433] suggest that the industry is not positioned to absorb these additional costs and generate sufficient returns to fund through its own generated cash flows. Some region-specific investment momentum exists. For example, Neom Green Hydrogen Company has achieved financial close on the world's largest green hydrogen production facility at a total investment value of $8.4 billion.[434]

FIGURE 65 **Additional investment required to existing investment ratio**

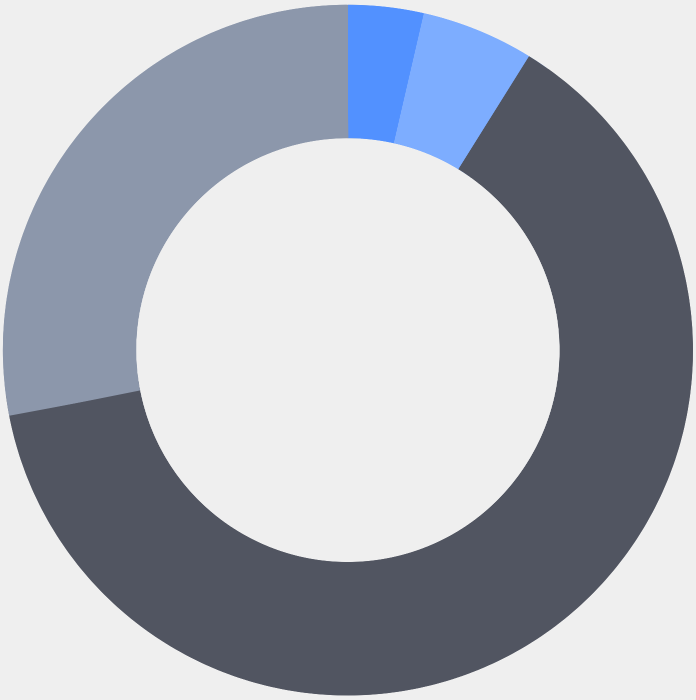


Source: Accenture analysis based on MPP and IEA data

Various financing models can be considered based on sectoral and regional context. The early investment of public funds, which could be done efficiently through development banks, could lead to faster deployment of the technologies and hence a faster decline in their cost. This could create competitive advantages to countries and regions that act fast and position themselves ahead of the curve. Regional variation in capital requirements will depend on the technology route and access to capital. Regions with low-cost CO_2 transport and storage and existing investment momentum like North America could direct capital towards deploying ammonia assets with CCUS as compared to regions with lower cost renewables, to earmark capital for electrolyser deployment.

Approximately 91% of large publicly traded companies consider climate change as a key consideration for their strategic assessment and integrate it into their operational decision-making.[435] Meanwhile, 5% of companies are building basic emissions management systems and process capabilities. Finally, 4% of companies acknowledge climate change as a business issue.

FIGURE 66 **Distribution of companies in the ammonia sector according to the management of their GHG emissions and of risks and opportunities related to the low-carbon transition**



0	**Level 0:** Unaware	0.0%
1	**Level 1:** Aware	3.5%
2	**Level 2:** Building capacity	5.3%
3	**Level 3:** Integrating into operational decision-making	63.2%
4	**Level 4:** Strategic assessment	28.1%

Note: Scope of data for this assessment covers chemicals companies, including ammonia.

Source: LSE-TPI Centre

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