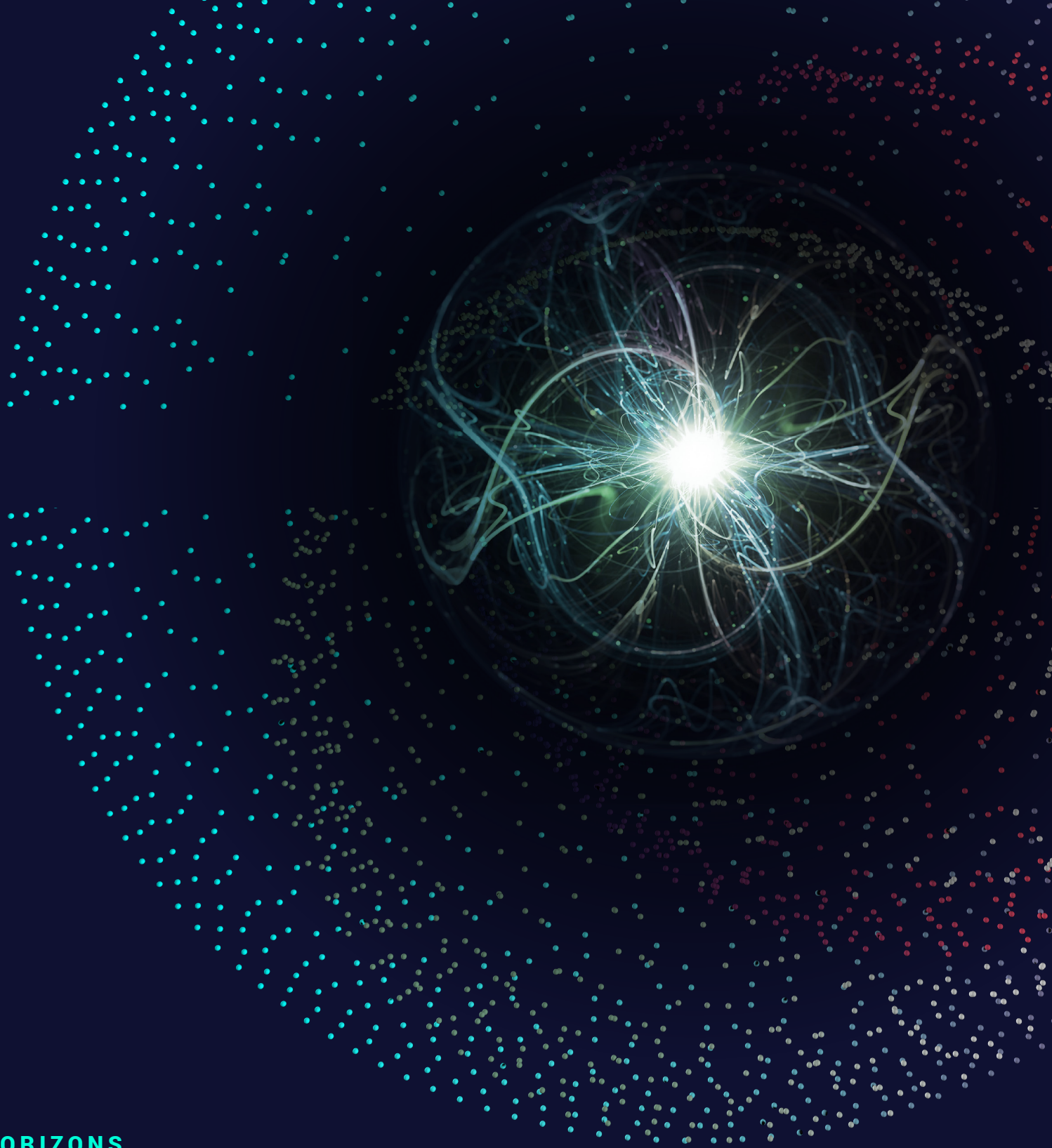

HORIZONS

Avoiding pand-ammonia:

How to kick-start a global low-carbon ammonia industry

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How to kick-start a global low-carbon ammonia industry

Ammonia shapes modern life in every way imaginable. As the basis for all nitrogen fertilisers, industrial ammonia has truly changed the world. Its impact on our daily life goes well beyond food, however. Ammonia makes the fibres of our clothes, the dyes that colour them and the cleaning products we use; with it, we purify water, refrigerate our food and cool our homes.

Now the sector stands on the cusp of a revolution, created by the need to cut greenhouse gas (GHG) emissions. Conventional ammonia production uses natural gas as a feedstock and is hugely energy intensive, resulting in high levels of carbon dioxide (CO2) emissions. And many companies are exploring potential new uses for ammonia as a route to transforming low-carbon hydrogen into a useful source of energy.

There is already a huge market for ammonia that is absolutely essential

Much of the interest in low-carbon ammonia is driven by the hydrogen hype. What is often less widely discussed is that there is already a huge market for ammonia that is absolutely essential – our food supply depends on it – and it needs to be decarbonised, quickly.

Ammonia producers and consumers need to take a step back from focusing on energy uses and turn their attention to the existing market, which is critical to hopes of achieving the Paris climate goals. The traditional ammonia market is highly price sensitive. To bring down costs, the world needs to scale up low-carbon supply well before energy demand for ammonia is a mature market. If our economies are to meet emission reduction targets, they cannot wait for energy uses of ammonia to evolve.

It is a chicken-and-egg problem: many low-carbon ammonia projects will not go ahead without certainty that demand exists, while potential customers will not commit to purchases while costs remain so much higher than for conventional ‘grey’ ammonia. The challenge for the industry and its stakeholders is to solve this conundrum.

Policymakers, in particular, have the power to build the global low-carbon ammonia market, supporting the development of markets and trade infrastructure between locations that have advantaged supply and those with demand. At the pace that policy is developing, for established ammonia producers, it could be a case of ‘evolve or die’.

Ammonia has a critical role to play in the energy transition

Global ammonia production currently stands at 200 million tonnes per annum (Mtpa), making it one of the largest commodities produced by the petrochemicals sector, equivalent in scale to ethylene. It is mostly used in fertiliser production, which accounts for about 70-80% of global demand, with the balance going to myriad final products, including acrylonitrile (a widely used intermediate for plastics), rubber (nitrile butadiene) and fibres (nylon 6 and nylon 66).

Ammonia can be combusted without emitting CO2 and be converted back into hydrogen

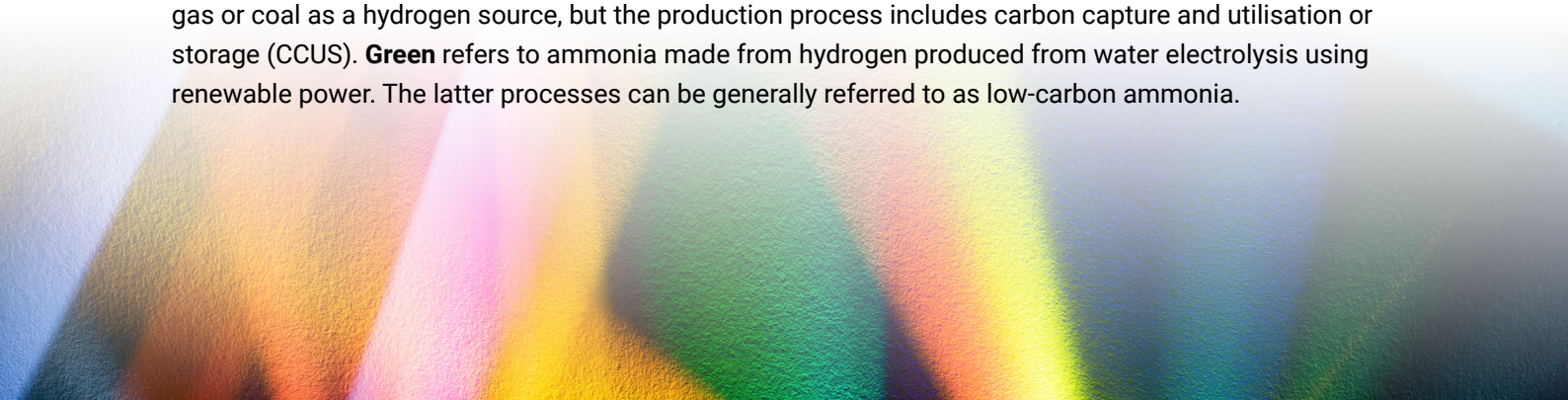
However, ammonia processing is hugely energy intensive. Indeed, it accounts for some 2% of total global energy consumption, about 40% of which is consumed as feedstock.

Ammonia production consequently comes with a hefty GHG footprint; the direct carbon dioxide emissions from the sector are an estimated 450 Mt CO2e per year: about 0.9% of total global greenhouse gas emissions. A shift to low-carbon ammonia, therefore, has a vital role to play in a net-zero-emissions economy. The way to achieve lies mostly in the hydrogen production step. This can still be done by way of natural gas steam reforming, provided carbon capture and utilisation or storage (CCUS) is in place, or by ditching fossil fuels entirely by electrolysing water with renewable-based power.

But the buzz around low-carbon ammonia comes not just from the challenge of addressing traditional uses such as fertiliser and other chemicals, but from ammonia's potential for energy use. The promise comes from the fact that ammonia can be combusted without emitting CO2 and also be converted back into hydrogen. So where are the opportunities and what is their potential scale?

The ammonia rainbow

Like hydrogen, ammonia comes in an array of colours. **Grey** refers to ammonia whose hydrogen source is natural gas. **Brown** and black refer to ammonia produced from coal as feedstock. In our analysis, we typically refer to grey, black and brown as conventional ammonia. **Blue** refers to ammonia that uses gas or coal as a hydrogen source, but the production process includes carbon capture and utilisation or storage (CCUS). **Green** refers to ammonia made from hydrogen produced from water electrolysis using renewable power. The latter processes can be generally referred to as low-carbon ammonia.



Ammonia is often called 'the missing link' in the energy transition

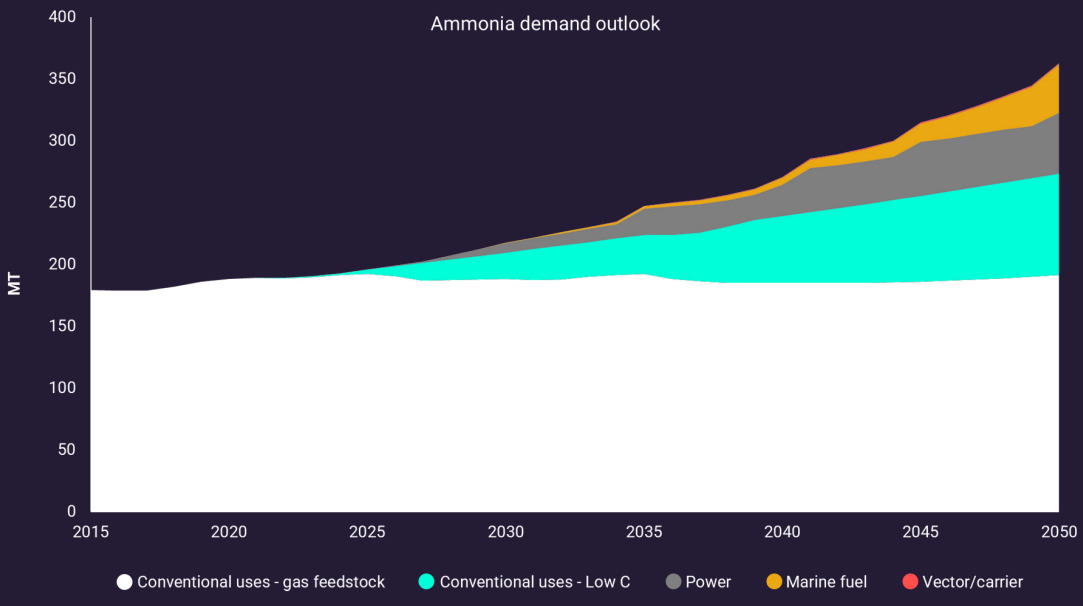
Low-carbon ammonia for energy

Ammonia, comprising three atoms of hydrogen and one of nitrogen, could play an important role in the emerging hydrogen sector. It could be even more interesting than hydrogen in some cases: it is cheaper to liquefy, less flammable (even though it is hazardous) and, thanks to large-scale existing demand, already has shipping and handling infrastructure in place around the world. Ammonia can be burned directly or cracked into hydrogen to be used in turbines or fuel cells.

New energy markets for low-carbon ammonia are likely to emerge in three key sectors: power generation, maritime services and as a carrier for hydrogen. Several markets, most notably Japan, South Korea and the European Union (EU), are driving research and development and policy support into building and fast-tracking these new energy-related markets for ammonia. Because of its huge potential in these sectors, ammonia is often called 'the missing link' in the energy transition.

However, it is important to be realistic about its prospects. Energy technologies for ammonia currently have no real commercial presence, and demand from those sources could take decades to reach a scale comparable to that of traditional end uses.

Ammonia demand outlook by industry and by high/low carbon



Source: Wood Mackenzie

1. Power

Ammonia as a fuel can be burned on its own, or as part of a fuel mix (ammonia co-firing). There are major obstacles to burning 100% ammonia in power plants: it has a low combustion speed, so requires a much larger combustor than gas or coal; and because ammonia contains nitrogen, any system using it as a fuel will need to address the NOx emissions it generates. Despite these hurdles, there is research and development evolving for direct ammonia combustion.

The combustion speed improves when co-firing ammonia with other fuels. This also supports retrofitting ammonia co-firing into existing power plants. Power plants, especially coal-based plants, could benefit from co-firing with ammonia, reducing CO2 emissions. Many developed countries are moving away from coal and have set targets to retire coal-based power plants once they reach end of their economic lives. In some Asian markets, however, the coal assets are still relatively young, so ammonia has a greater role to play.

By 2050, the global potential for ammonia in both coal- and gas-based power generation is estimated at some 50 Mt in our base-case scenario, but could reach levels more than 100 Mt in a high-end scenario, where technology advances faster.

2. Maritime

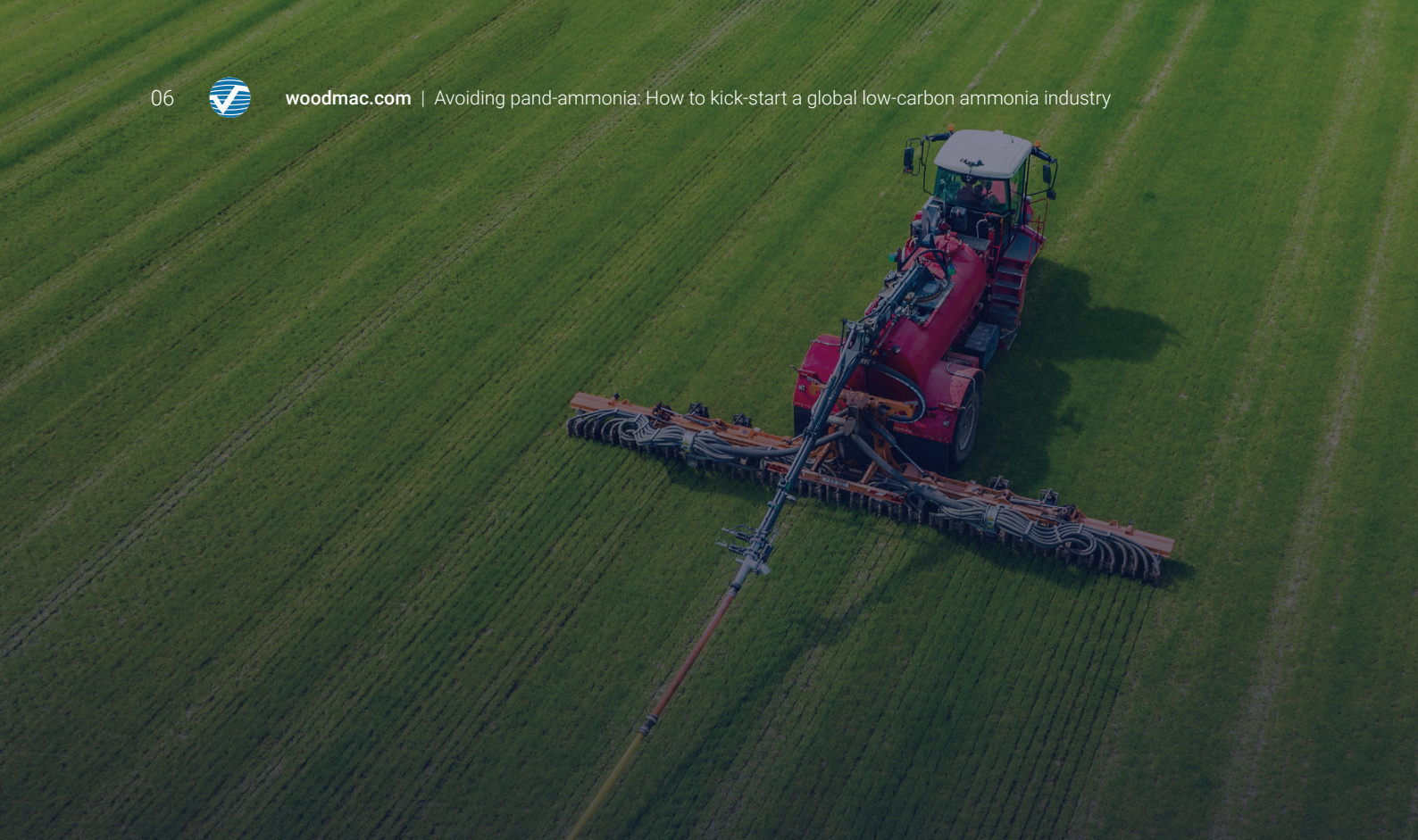
Ammonia could account for around 40% of global e-fuels by 2050

The International Maritime Organisation aims to reduce GHG emissions by 50% by 2050, creating significant growth potential for e-fuels – synthetic fuels made from hydrogen – including ammonia. Current projections by Wood Mackenzie's Downstream research team indicate that ammonia could account for around 40% of global e-fuels by 2050, accounting for 40MT of demand.

Singapore, the United Arab Emirates, Saudi Arabia and Japan are expected to be the first hubs to adopt ammonia as a marine fuel from 2027, while other major global hubs are expected to follow from the mid-2030s. Southeast Asia (dominated by Singapore) and China will be the largest demand regions, together accounting for half of all marine-sector ammonia demand by 2050.

3. Using ammonia as a carrier for hydrogen

Ammonia is currently the most economical way to export hydrogen over long distances. Developments in traditional, power and marine space can also unlock supply and infrastructure to trade more ammonia as a hydrogen carrier, further impacting trade flows. Developing the infrastructure and value chain to support the delivery of ammonia as a hydrogen carrier will take time and investment, but holds the potential to make a substantial impact on total low-carbon ammonia demand beyond 2040.



Traditional ammonia uses are key to investment

For all the exciting potential that new energy applications offer, it will take time for them to translate into real demand on a scale that will incentivise the investments necessary to bring low-carbon capacity into production, and for efficiencies and competition to bring down prices. In our base-case outlook, it is not until 2025 that any meaningful demand from these routes comes into the market, and even a decade from now, they will merely account for 6% of total traditional ammonia demand.

The only markets with the scale to stimulate the necessary investments are, therefore, the traditional ammonia applications. If the traditional sectors decarbonise their consumption soon, this will drive investments that build a global-scale low-carbon ammonia market far earlier than waiting for projects driven by energy demand. The challenge is that ammonia is a commoditised market. Its main use – in fertiliser for food production – is highly price sensitive. And although the recent spike in natural gas prices has helped to close the price gap, low-carbon ammonia remains significantly more expensive than conventional supply.

The EU is the only market targeting the full decarbonisation of the existing ammonia sector by 2030

Under the RePowerEU directive, the EU is the only market targeting the full decarbonisation of the existing ammonia sector by 2030. While other countries, notably Japan and South Korea, also have targets, this means it is Europe that will have to lead the way in building a global low-carbon ammonia supply chain over the next 10 years or so.

Today, the EU accounts for some 14%, or 26 Mt, of global ammonia demand. This means the bloc would need about 26 Mt of low-carbon supply in 2030 to ensure the decarbonisation of its existing ammonia supply chain. We do not expect the EU to fully meet its 2030 target, but we do expect the policy support that arises from having those targets in place and the resulting switch to low-carbon demand in the region to underpin the development of a global low-carbon market on a commercial scale.

In our base-case forecast, we expect the global traditional demand switch to low-carbon to reach some 21 Mt by 2030. If the EU actually met its decarbonisation targets, global low-carbon demand for the traditional sectors in 2030 would jump to more than 43 Mt; that is almost one-quarter of the current global ammonia market.

Our base-case forecast also includes traditional demand switching to low-carbon sources in Asia and North America, supported by the planned start-up of some low-carbon hydrogen/ammonia capacity in these regions over the next 10 years. In China alone we expect some domestic investments to be announced in the coming years, supplying some 10 Mt of low-carbon ammonia into its traditional sector by 2030. Our assumption is based on ongoing investment in renewables supply and China's own decarbonisation targets (plus the underlying scale-up potential the country has historically boasted from the get-go when implementing new technologies).

To provide a sense of potential scale from traditional demand compared with new end uses, by the same year, our base-case forecast puts low-carbon ammonia demand for energy-related end uses at about 8 Mt in 2030.

So what are the implications of this for the future of the ammonia industry in Europe and beyond?

European demand, global supply?

Costs for the nascent low-carbon ammonia are likely to remain significantly higher than for established grey ammonia for at least the next 10 years. If European users have to switch to low-carbon feedstock, policies will have to be in place to prevent those industries from moving overseas. Producers of ammonia derivatives, such as fertiliser, will need feedstock costs that allow them to compete against imports into the domestic market, as well as in export markets.

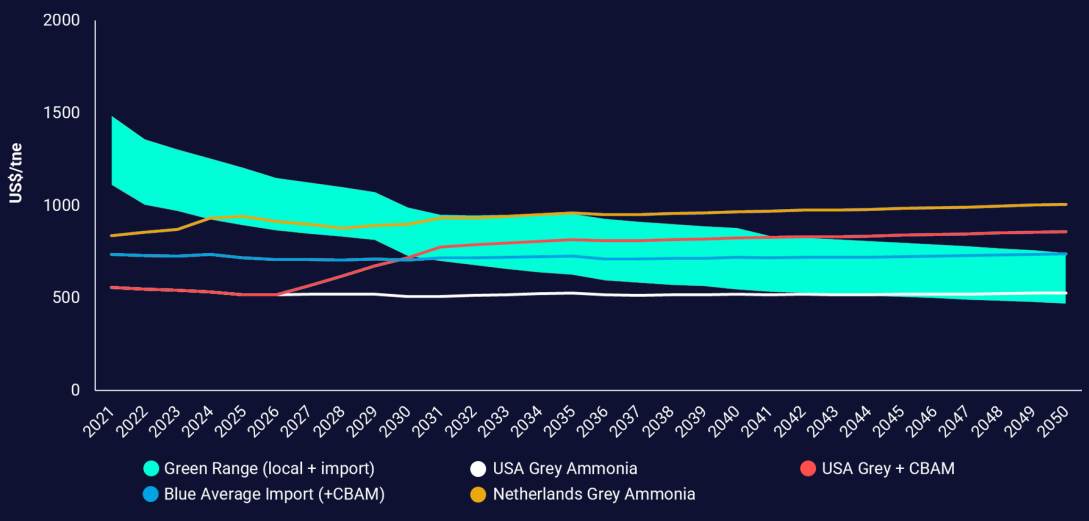
By 2050 even the least competitive green ammonia sources outcompete the alternatives

We have analysed the cost scenario of multiple sources of ammonia into Europe (Germany) to 2050. We have considered logistics costs, as well as existing tariffs and planned carbon taxes within the EU and with the Carbon Border Adjustment Mechanism (CBAM) when it is implemented around 2027.

Our analysis concludes that grey ammonia from North America will be the most competitive source in the near-term, as local production faces elevated gas prices. This advantage is eroded, with blue ammonia from producers in the Middle East and North America out-competing grey, as the CBAM starts to take effect after its expected implementation in 2027.

With limited low-carbon capacity to meet European demand in the near term, the most competitive source – even applying CBAM at the rate of difference between the EU and export country's carbon price – remains imported grey ammonia from low-cost sources, such as the US. CBAM is necessary to level the playing field but additional policy support is required to invoke an earlier shift to low-carbon alternatives. Indeed, imported grey hydrogen remains competitive with European low-carbon production through to the mid-2030s. By 2050, however, a combination of scale, efficiency and competition means that even the least competitive green ammonia sources outcompete the alternatives.

Cost comparisons for grey, blue and green ammonia into Europe

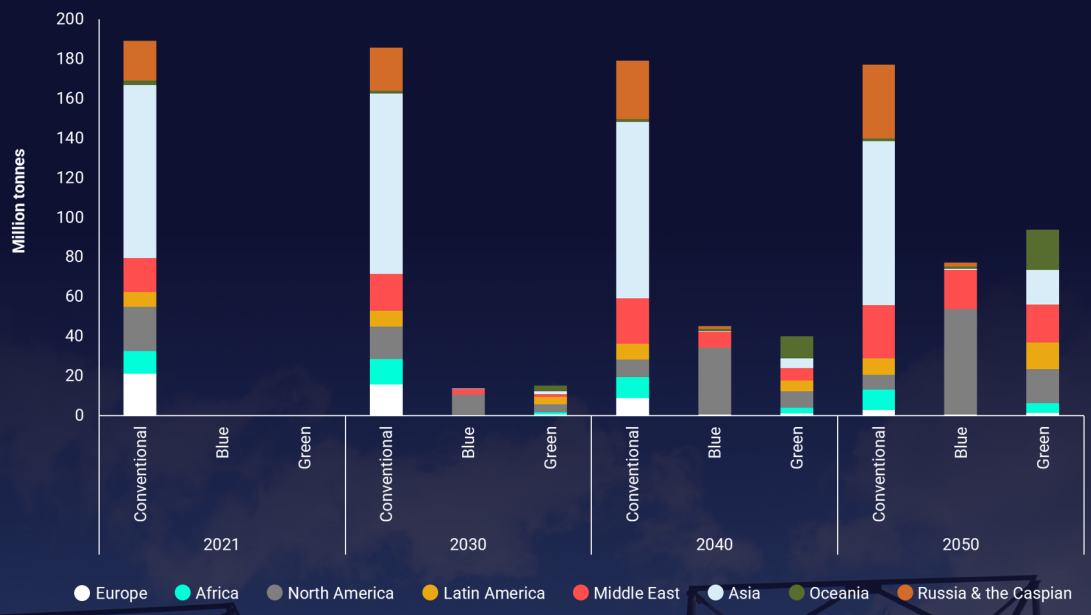


Source: Wood Mackenzie

However, as this transition occurs, European policymakers will want to avoid imported, carbon-intensive ammonia undermining European production, particularly because the fertiliser sector has important implications for food security. Their challenge is three-fold: they need to ensure that European ammonia producers can weather the current storm of elevated gas prices, while enabling them to invest in low-carbon production and, at the same, time encouraging additional low-carbon supply from overseas to outcompete imported grey ammonia.

The RePowerEU plan highlights deals made with offshore suppliers of low-carbon hydrogen and ammonia, including North and sub-Saharan Africa, the Middle East, the Gulf, Chile, the US and Australia. These 'green corridors' could help drive multiple investments outside Europe itself and start to build supply sources for a truly global market.

Ammonia production outlook for low-carbon ammonia, by country/region



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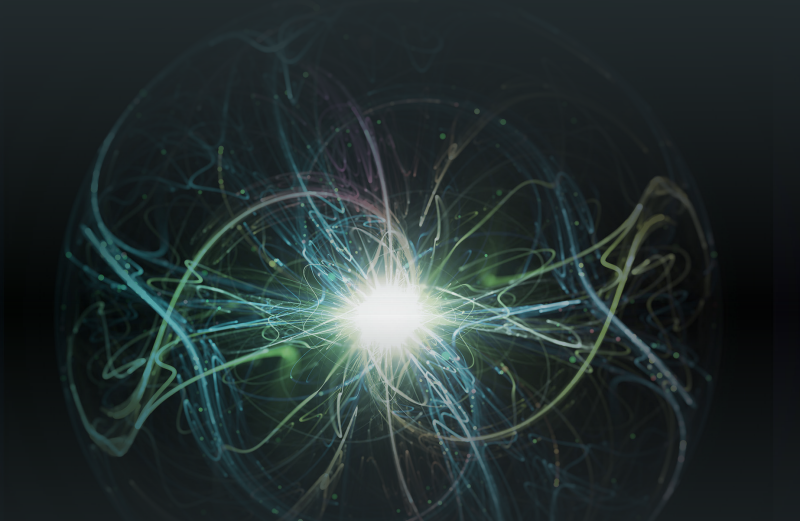

Conclusion:
Evolve or die

Low-carbon ammonia has a vital role to play in a net-zero-emissions economy, but to achieve cost-competitive supply, the market requires liquidity and, therefore, scale. Energy demand for ammonia is unlikely to reach commercial-level volumes before 2030. Until then, the decarbonisation of traditional markets will be the most significant driver of demand.

With the right policy support, incentivising strong volume growth in both supply and demand, a global low-carbon ammonia market can develop. Europe is set to play a key role, particularly in the early stages of that market. There are potential pitfalls, however. If EU policies create increased demand for low-carbon ammonia, but do not provide enough support for domestic production to decarbonise, then the European industry could be crushed by lower-cost imports. EU policymakers will need to work closely with the market to avoid major setbacks to European industry.

Established ammonia suppliers seem well-positioned to serve the new demand for low-carbon product. They have the logistics in place, existing relationships with key sector clients and extensive market knowledge. But the significant low-carbon production capacity announced by entirely new entrants into the ammonia sector is a risk to current producers. More suppliers focusing on traditional markets need to announce their first steps towards transitioning to low-carbon product.

At the pace that policy is developing, it could be a case of ‘evolve or die’.

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