HORIZONS

Isn't it ironic?
How Europe's oil refiners could offer a route to scale up green hydrogen

August 2025

Murray Douglas, Vice President, Hydrogen & Derivatives Research
Alan Gelder, SVP of Refining, Chemicals & Oil Markets

Wood Mackenzie

Low-carbon hydrogen has gained momentum over the past decade, driven by climate targets and supportive policy frameworks. Project development is stalling, however, as buyers baulk at stubbornly high costs and expensive long-term supply agreements.

Somewhat ironically, European oil refining could hold the key to unlocking demand growth. Even as growth in electric vehicles across the continent continues to erode road-transport fuel demand, European Union (EU) regulations are forcing the bloc's beleaguered refiners to decarbonise faster than anywhere else.

Low-carbon hydrogen also offers help to the hard-to-decarbonise marine and aviation sectors. Electrolytic green hydrogen's ability to deliver almost carbon-free hydrogen through renewables means that EU regulations – and subsidies – broadly favour it over blue hydrogen, which uses carbon capture and storage to cut emissions from fossil-fuel feedstocks.

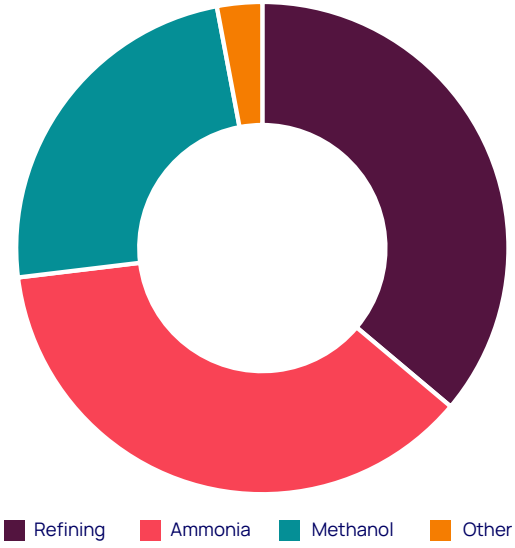
Consequently, European refiners are set to become significant producers or buyers of green hydrogen, initially to decarbonise the refining sector and its derivatives as fuel for marine and aviation. Numerous green hydrogen projects have already targeted the sector. Of the 6 Mtpa of low-carbon hydrogen capacity that has taken a final investment decision (FID), European refineries have already committed more than US$5 billion of capital.

The investment case for these projects has been boosted significantly by the latest revision of the EU's Renewable Energy Directive (known as RED III), which is helping to minimise the delays and cancellations now all too common when it comes to green hydrogen globally. Other EU policies to speed up the decarbonisation of the maritime and aviation sectors pave the way for sustained future demand growth.

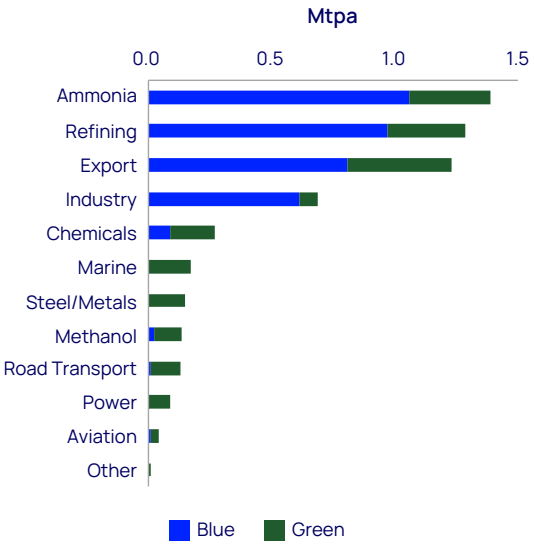
Current policy will only take the sector so far, however. The cost of green hydrogen production must continue to fall, while regulation will need to go even further to fully kick-start demand. If these hurdles can be overcome, European refiners could play a critical role in scaling up the green hydrogen industry.

Figure 1:
Refining, ammonia and methanol dominate hydrogen demand

Hydrogen demand by end-use sector, 2024



Post-FID low-carbon hydrogen capacity by end-use sector (August 2025)



Source: Wood Mackenzie Lens Hydrogen

Refining is the major driver of hydrogen demand

Globally, refining, ammonia and methanol account for around 100 million tonnes a year of conventional, carbon-intensive hydrogen consumption. That's equivalent to 98% of all hydrogen demand.

Hydrogen is a key ingredient in the chemical conversion and upgrading of crude oil into transport fuels and petrochemical feedstocks. It is also used to remove contaminants from road fuels, essential for sulphur-free fuels. Hydrogen is also a by-product of the conversion of naphtha to gasoline. But the volumes produced are insufficient to meet the refineries' own needs, so additional hydrogen production from steam methane reforming is essential. Traditionally, this additional production involves the energy-intensive conversion of natural gas, releasing significant amounts of CO_2 in the process.

This comes at a cost, however. European refiners have been part of the EU Emissions Trading Scheme for more than a decade and are charged for the CO_2 they emit beyond a certain free allowance.

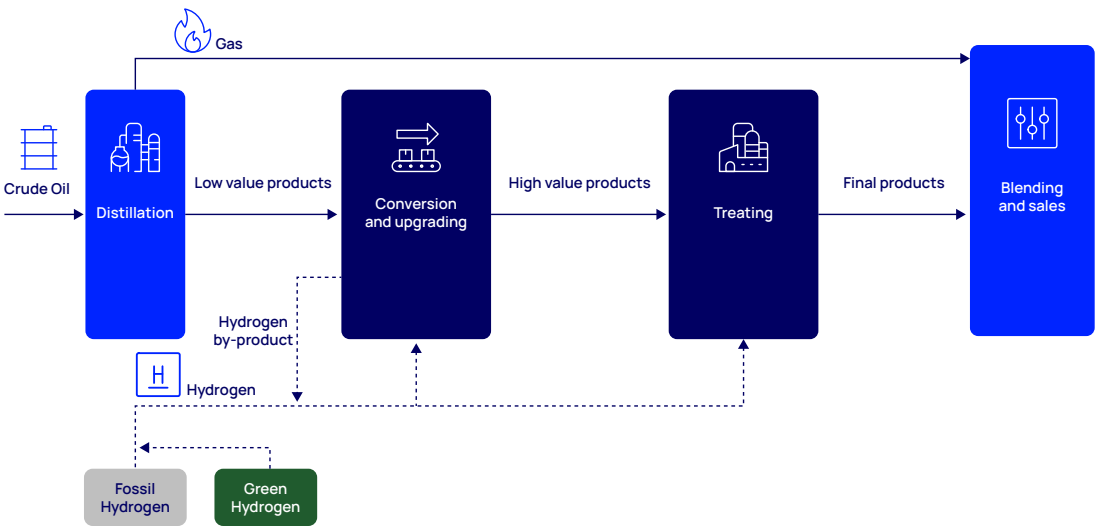
To promote the broader adoption of green hydrogen, governments must consider bold policy initiatives and incentives

This allowance will gradually be eliminated over time, raising the cost for refiners. Producing green hydrogen on site using renewable-powered electrolysis would eliminate many of those CO_2 emissions and, hence, emission-related carbon costs.

The rising burden of emissions costs has promoted energy-efficiency initiatives and made the idea of producing on-site green hydrogen more appealing. However, high European electricity costs have stymied this to some extent. So, to promote the broader adoption of green hydrogen, governments must consider bold policy initiatives and incentives, such as investment subsidies and favourable financing.

Figure 2:
How refineries create and use 'low-value products', 'high-value products', 'Crude oil' 'Fossil hydrogen' and 'Green hydrogen'

Simplified schematic of refinery hydrogen generation and use



Source: Wood Mackenzie

The EU policy solution

The EU's Renewable Energy Directive (RED) aims to drive reductions in the energy sector's carbon emissions by increasing the contribution of renewable sources. The latest iteration, RED III, provides essential support for green hydrogen adoption, as it seeks to promote 'renewable fuels of non-biological origin' (RFNBOs) — that is, liquid or gaseous fuels that derive no energy content from biomass. Green hydrogen is deemed an RFNBO if it meets strict EU sustainability and traceability criteria.

There are three main ways of meeting the EU RFNBO targets: e-fuel use in the transport sector, green hydrogen use in fuel-cell vehicles and green hydrogen use in the refining process. The EU uses "multipliers" in its RED III accounting methodology. The actual RFNBO content is accounted for at higher levels, promoting use in those sectors with the highest multipliers, such as e-fuels for aviation and maritime. Because of the high cost of e-fuels and limited uptake of fuel-cell vehicles, the refining route is currently the most suitable and achievable means of compliance.

We forecast European refiners will require around 0.5 million tonnes per year (Mtpa) of green hydrogen to comply with regulations

This would replace about 30% of Europe's current refinery-based, CO_2-emitting, purposely produced hydrogen – at a substantial investment of more than US$15 billion for the green hydrogen production capacity.

On paper, RED III bodes well for green hydrogen's near-term growth in the European refining sector, at least once adopted into national legislation by the 27 EU member states. But much more is still required. RED III requires that RFNBOs account for only a minimum of 1% of the energy used by the transport sector by 2030. This share, low by any measure, is in large part an acknowledgement of the challenges involved in expanding RFNBO supply.

Clearing the green hydrogen hurdles

Locking in significant longer-term growth will require further action in three key areas: costs, technology and the wider regulatory environment.

Tackling costs to secure offtakers

The major hurdle for European refiners is the cost of producing green hydrogen, which remains significantly higher than for traditional hydrogen production units. Renewable electricity sourcing is the overwhelming driver of these high costs, though the levelised cost of renewable electricity in Europe is forecast to decline one-fifth by the end of this decade. Automated manufacturing, standardisation and efficiency improvements will also help drive cost reductions for electrolyser stacks.

Accessing low-cost renewables and operating electrolysers at high utilisation levels are essential, with the latest market signals offering encouraging signs. The European Commission launched its European Hydrogen Bank in 2023 to support domestic production of green hydrogen. The most recent auction results reveal how costs have changed since the pilot auction was awarded in 2024.

The average levelised cost of hydrogen (LCOH) across all bids from the second-round auction, which closed in February 2025, fell 18% to US$8.35/kg$H_2$, with average bids in Germany falling more than 55%. The results also provide offtake prices that each end-use sector is willing to pay. Here, refineries were among the highest, at a weighted average of US$9.23/kg$H_2$, demonstrating a willingness to pay a premium to meet regulatory mandates. Wood Mackenzie's asset-level modelling of projects targeting the refining sector in Europe produces an LCOH of US$7.04 to US$8.30/kg – reinforcing the progress in this sector.

> Critically, many European refiners are now looking to produce green hydrogen on site to decarbonise their refinery operations and supply fuels compliant with RED III

Cost reductions also hinge on ongoing project deployment, which should enable improvements in project delivery and operation.

Critically, many European refiners are now looking to produce green hydrogen on site to decarbonise their refinery operations and supply fuels compliant with RED III. By producing their own green hydrogen, refiners can guarantee offtake and overcome a significant challenge facing many other project developers.

Technology risks and competing technologies

Developers continue to wrestle with contingency costs for these first-of-a-kind projects, with lenders, in turn, applying a risk premium. Reducing premiums relies on successful technology deployment and the developers' ability to demonstrate timely commissioning and operational reliability. Accelerating the deployment of such capital-intensive technology is difficult, illustrating why government support is so essential early on.

Chinese-made electrolysers are competing with Western technology. Yet, to date, post-FID European projects have opted for Western electrolysers. Others, however, are weighing up the benefits of the upfront capital cost savings offered by Chinese alkaline electrolysers. Electrolyser manufacturers face stiff competition, which promises lower project costs, but it's piling the financial pressure on many of them, with some already failing.

Electrolyser manufacturers face stiff competition, which promises lower project costs

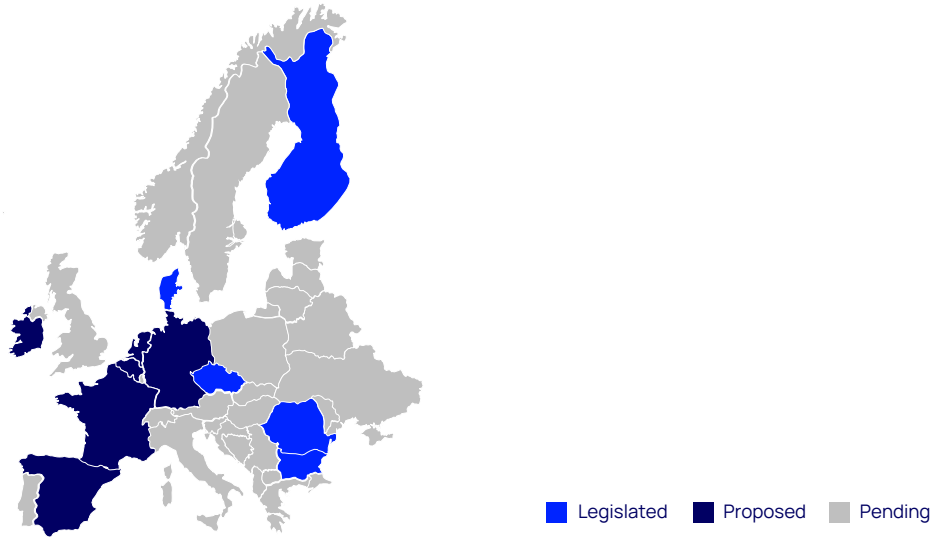
Green hydrogen is not the only route open to refiners, though, and alternative paths to decarbonisation are gaining traction. Carbon capture and storage will be more suitable for some. This can help to manage emissions across the broader refinery complex. It can also support a switch to blue hydrogen, although for European refiners, this will not directly contribute to their RED III targets.

Policy and regulatory uncertainty

The EU's RED III legislation is an important part of the push to grow the green hydrogen economy in Europe, with both Repsol and TotalEnergies confirming in recent earnings calls that green hydrogen is the most competitive route to regulatory compliance. Member states have been slow to convert the ambition of RED III into national law, however, which has slowed green hydrogen project development across most of the EU. As of August 2025, national legislative adoption was as illustrated in Figure 3:

There are also differences in how the legislation is being transposed into national law, which impacts the incentives that member states are offering to refiners to help close the cost gap between green and conventional hydrogen. In Germany's legislative framework, certificates used to confirm RED III compliance are projected to be US$250 to US$300/tonne in 2030. This is sufficient to provide a reasonable rate of return on a refinery electrolyser investment. The key questions are whether other countries will follow suit, and whether refiners and, ultimately, consumers need to directly bear the cost burden of this regulation.

Figure 3:
EU countries are dragging their heels on adopting RED III



Source: Wood Mackenzie

Marine and aviation offer growth opportunities

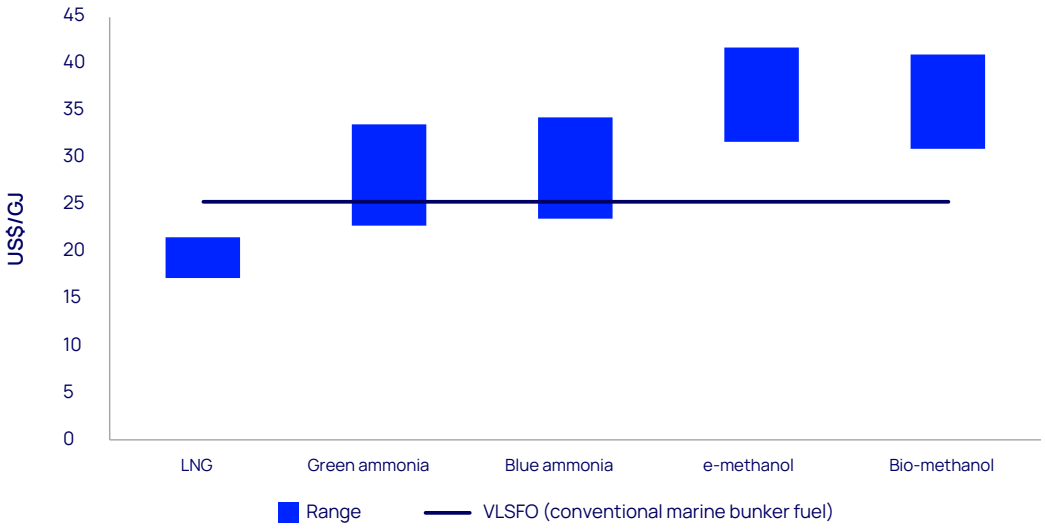
The potential for green hydrogen to help cut emissions from refining while complying with RED III obligations is the strongest investment case at present, but green hydrogen can also deliver lower-carbon fuels to other transport sectors. Marine and aviation are already starting to make progress.

Decarbonising the maritime sector

The marine sector flies the flag for green hydrogen project development, though policy support, as ever, is required. Europe's FuelEU Maritime Regulation and the imposition of carbon costs on shippers have helped to drive interest, with the added benefit of the multiplier for RFNBO-compliant hydrogen and its derivatives in the marine sector to meet RED III transport targets. Europe has also carved out €800 million from its latest Hydrogen Bank auction to support maritime supply projects.

The International Maritime Organization's (IMO) Net Zero Framework, published in April 2025, broadens interest globally. It introduces global greenhouse gas fuel intensity targets and a credit-trading system, with a fund potentially unlocking more than 80 Mtpa of hydrogen-derived fuels in the long term. However, under the current IMO pricing mechanism, it will take time for hydrogen-based fuels to be competitive with incumbent fuels, and further penalties or rewards will be required to displace fuel oil more quickly.

Figure 4:
The IMO has approved the first global carbon pricing mechanism for shipping



Source: IMO Net Zero Framework adjusted shipping fuel costs, 2035

Sustainable aviation fuel

Aviation is also a key growth driver for green hydrogen. International bodies and governments are committed to reducing aviation carbon emissions, with the EU leading the charge. Improvements in aircraft efficiency, infrastructure and other operational improvements are minor compared with the opportunity to deploy sustainable aviation fuel (SAF) that is either bio-based or synthetic (e-SAF).

Aviation is also a key growth driver for green hydrogen

The ReFuelEU Aviation regulatory framework requires SAF to power 6% of the jet pool by 2030, of which an average of 1.2% is to be e-SAF, produced from RFNBO-compliant green hydrogen. If met, this alone would require around 0.35 Mtpa of green hydrogen. As aviation is subject to RED III legislation, this would reduce refineries' requirement for green hydrogen adoption growth to 0.15 Mtpa by 2030 for overall targets to be met.

By 2050, the SAF blending mandate is 70%, of which half must be e-SAF. This would require 8 Mtpa of green hydrogen, a compound annual growth rate of over 15% in the EU for this sector alone.

Cue the project developers, governments and buyers

Project developers

Faced with high costs and uncertain market conditions, several major low-carbon hydrogen developers have scaled back their ambitions for the industry. This reflects a broader trend of project developers becoming more selective, prioritising capital efficiency and risk mitigation over expansive hydrogen portfolios.

At the same time, Shell, BP and TotalEnergies have all reaffirmed their commitment to decarbonising their European refining operations with green hydrogen. Companies must continue to pursue cost reductions, maximise capture of available government incentives and capitalise on future demand growth opportunities in fuel supply to the marine and aviation sectors.

Governments

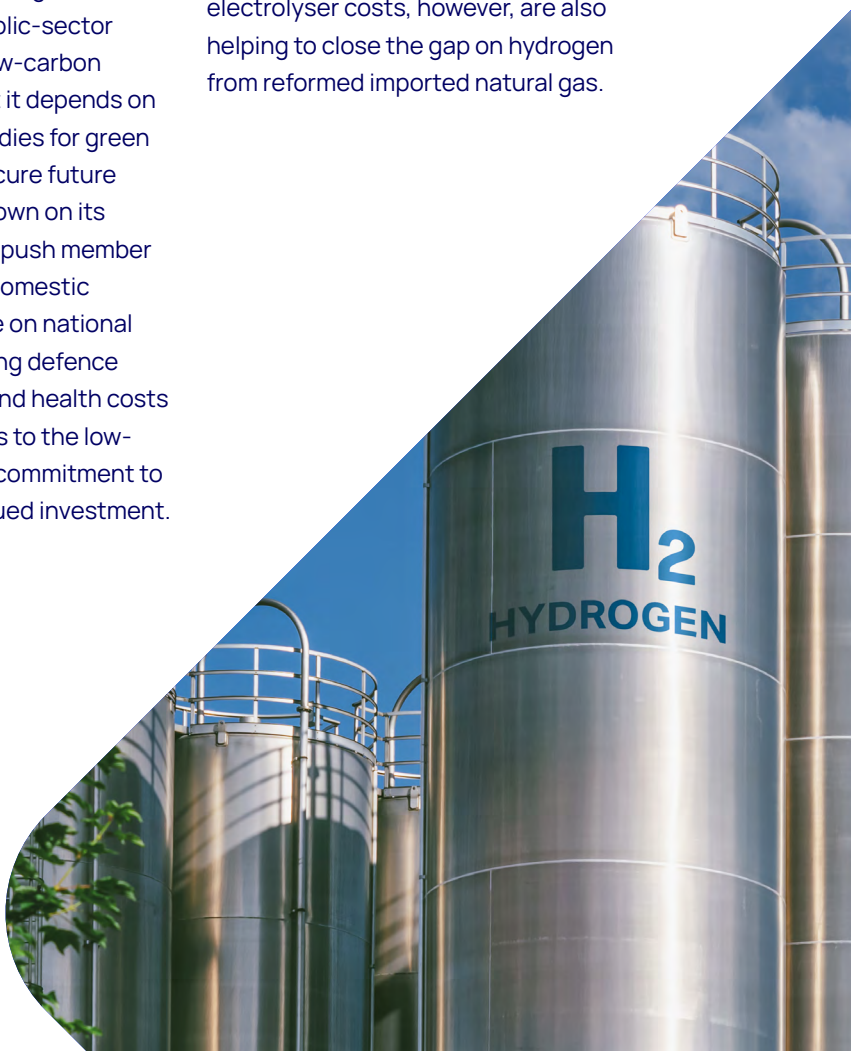
The EU's RED III regulation supporting green hydrogen use in the refining sector has led the way in terms of public-sector incentives. This is critical to low-carbon hydrogen demand growth, but it depends on the provision of national subsidies for green hydrogen development. To secure future growth, the EU must double down on its efforts to drive the sector and push member states to codify support into domestic laws and regulations. Pressure on national government budgets from rising defence spending and higher welfare and health costs risks a curtailment of subsidies to the low-carbon economy. Reaffirming commitment to these sectors will spur continued investment.

The EU must double down on its efforts to drive the sector and push member states to codify support into domestic laws and regulations

Markets

Europe has been the standard bearer to date, but other markets will need to lock in green hydrogen demand growth to help decarbonise liquid transport fuels. Wider refinery adoption needs three things to happen: lower renewable power prices, the imposition of a cost on carbon emissions and credits for the lower carbon intensity of greener products. To date, few markets outside Europe fit the bill.

Adoption in China is largely driven by government mandate and sometimes lacks full green credentials. Low industrial power prices and competitive domestic electrolyser costs, however, are also helping to close the gap on hydrogen from reformed imported natural gas.



Conclusion: where next for hydrogen?

The opportunities for low-carbon hydrogen have come full circle. The traditional sectors of refining, ammonia and methanol are showing the most progress, ahead of the many other new demand sectors being touted for hydrogen. Parts of the refining sector can be decarbonised quickly – and at an acceptable cost. But it requires policy intervention to lower green hydrogen production costs and increase the refineries' offtake. Without such policies, the incentive to switch will not emerge.

Marine and aviation hold much of the long-term potential for hydrogen derivatives, as these sectors are the most challenging to electrify. The challenge lies in competing fuels, the costs of production and the final shape of the policies providing support.

Without major cost reductions, coupled with unwavering policy and subsidy support, projects will continue to stall

Stuttering green hydrogen development neatly sums up the hurdles facing numerous low-carbon technologies. Without major cost reductions, coupled with unwavering policy and subsidy support, projects will continue to stall as buyers shy away from long-term offtake deals. The irony will not be lost on Europe's struggling refiners should they prove to be the catalyst for growth.

Wood Mackenzie™, is a trusted intelligence provider, empowering decision-makers with unique insight on the world's natural resources. We are a leading research and consultancy business for the global energy, power and renewables, subsurface, chemicals, and metals and mining industries.
For more information visit: **woodmac.com**

Europe: +44 131 243 4400
Americas: +1 713 470 1600
Asia Pacific: +65 6518 0800
Email: contactus@woodmac.com
Website: www.woodmac.com

Wood Mackenzie