Northwest European Hydrogen Monitor 2025

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Abstract

Northwest Europe is at the forefront of low-emissions hydrogen[1] development. This region accounts for around 40% of Europe's total hydrogen demand, and it has vast and untapped renewable energy and carbon storage potential in the North Sea. It also has a well-developed, interconnected gas network that could be partially repurposed to facilitate the transmission and distribution of low-emissions hydrogen from production sites to demand centres.

The development of the low-emissions hydrogen market in Northwest Europe could gradually scale up in the short- to medium-term. Northwest European countries now have ambition to develop up to 30 to 35 gigawatts (GW) of electrolyser capacity by 2030. However, most low-emissions hydrogen projects are currently in the early stages of development. Their success will depend largely on supportive policies and regulatory frameworks. The cost-efficient development of low-emissions hydrogen markets also necessitates a regional approach that maximises existing synergies among national markets.

This is the third edition of the *Northwest European Hydrogen Monitor*. It provides an annual update of low-emissions hydrogen market developments in Northwest Europe and is the result of collaboration among the countries involved in the Hydrogen Initiative of the Clean Energy Ministerial (CEM-H2I) workstream entitled "Roundtable on the North-West European Region" and the hydrogen working group of the Pentalateral Forum.

The countries analysed in this *Monitor* are Austria, Belgium, Denmark, France, Germany, Luxemburg, the Netherlands, Norway, Switzerland and the United Kingdom. Market monitoring is accompanied by regular dialogues with key stakeholders to facilitate the exchange of information and data collection.

[1] When the term "low-emissions hydrogen" is used, the International Energy Agency refers to hydrogen produced via electrolysis where the electricity is generated from a low-emission source (renewables or nuclear), biomass or fossil fuels with carbon capture usage and storage (CCUS). This does not necessarily reflect the official definitions of the countries involved in the Monitor on the carbon intensity or sustainability of hydrogen production methods.

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Executive summary

Low-emissions hydrogen can play a significant role in decarbonising energy systems and is critical to many countries' efforts to meet their energy and climate targets. It can also reduce reliance on fossil fuel imports over the longer-term, bolstering energy security.

Northwest Europe is at the forefront of low-emissions hydrogen development. The region accounts for around 40% of Europe's total hydrogen demand. It has vast and untapped renewable energy potential in the North Sea, as well as substantial carbon storage capabilities. The region has a well-developed, interconnected gas network and underground storage sites that could be partially repurposed to facilitate the transmission, distribution and storage of low-emissions hydrogen. Despite the region's significant potential, the development of low-emissions hydrogen has faced challenges. These include limited progress on demand creation, relatively high production costs, complex logistics and remaining technological hurdles.

Low-emissions hydrogen is defined here as hydrogen produced via electrolysis where the electricity is generated from a low-emissions source (renewables or nuclear), biomass, or fossil fuels with carbon capture, utilisation and storage (CCUS). A detailed overview of the terminology is provided in Annex I.

The regulatory and policy framework for low-emissions hydrogen has continued to evolve

Setting hydrogen strategies, including the establishment of medium- and long-term targets, is considered essential to provide the necessary impetus and guidance for the development of hydrogen markets.

To date, the majority of the countries in Northwest Europe have adopted production targets for electrolytic hydrogen, while Norway has opted for a technology-neutral approach. In April 2025, France published a revised National Hydrogen Strategy. While recognising progress made in the hydrogen sector, the Strategy lowered the installed electrolyser capacity target for 2030 to 4.5 GW (from 6.5 GW previously) and added a 2035 target of 8 GW. In July 2024, Germany adopted its hydrogen import strategy, following the update of the country's National Hydrogen Strategy in 2023. In December 2024, Switzerland released its long-awaited National Hydrogen Strategy, highlighting the importance of developing its hydrogen market so that it is closely integrated with neighbouring markets.

Altogether, Northwest European countries have ambition to develop as much as 30 to 35 GW of electrolyser capacity by 2030. However, recent market developments, inflation and cost increases could drive countries to further adjust their targets and/or delay the implementation of low-emissions hydrogen projects.

Greater policy attention is required on demand creation

Hydrogen demand in Northwest European currently stands at around 3 million tonnes (Mt) per year, making up 3% of total global demand. Unabated natural gas is the primary source of hydrogen supply in Northwest Europe, with demand largely concentrated in the refining and chemicals subsectors.

Creating demand for low-emissions hydrogen, including via quotas, fuel standards and public procurement rules, is a key instrument to stimulate investment in supply. Meanwhile, demand security is essential for the conclusion of long-term offtake agreements, which in turn can help to de-risk investment and improve the economic feasibility of low-emissions hydrogen projects.

In the European Union, the revised Renewable Energy Directive (RED III) came into force in November 2023, with a deadline for member states to transpose its stipulations into national law by May 2025. RED III establishes binding targets for the share of renewable hydrogen in industry and transport. Though the transposition process is moving ahead, it is understood that its implementation is lagging behind in several member states.

In addition, Northwest European countries are promoting hydrogen-derived fuels for use in the maritime sector, primarily driven by new international regulations. This year's *Monitor* provides a special focus on the potential use of hydrogen-derivatives as a marine fuel.

Regional low-emissions hydrogen production could reach almost 8 Mt by 2030, though less than 8% of projects are in advanced stages of development

Based on the latest IEA analysis, Northwest Europe's production of low-emissions hydrogen (and derivatives) could reach close to 8 Mt per year by 2030 if all planned projects become commercially operational (taking into account assumptions on efficiency and utilisation factors). This could cover approximately 2% of the region's total primary energy demand.

Based on the project pipeline, electrolytic hydrogen supply would account for almost 60% of total low-emissions hydrogen production, while fossil fuel-based hydrogen projects equipped with CCUS would account for around 40%. Based on announced projects, Denmark, Germany, the Netherlands and the United Kingdom are expected to account for three-quarters of Northwest Europe's low-emissions hydrogen production by 2030.

According to the Hydrogen Production Projects Database, less than 8% of the projects that could provide low-emissions hydrogen supply by 2030 have been committed, meaning they are in operation, have reached a final investment decision (FID) or are under construction. More than 90% are currently undergoing feasibility studies or are in the concept phase.

This year's *Monitor* provides a special focus on gas-based low-emissions hydrogen. Several major CCUS infrastructure projects in Northwest Europe reached FID in 2023 and 2024 that could support its development. These include the Porthos CO_2 transport and storage project in the Netherlands and the Northern Lights CO_2 transport and storage facility in Norway. Additionally, in April 2025, a financial close was reached for the Liverpool Bay CCS project in the United Kingdom.

Northwest Europe is at the core of the European electrolyser industry, but companies face growing challenges

Another focus of this year's *Monitor* is the development of electrolyser production capacities. Northwest Europe is home to 85% of electrolyser manufacturing capacity in Europe, with France, Germany and Norway accounting for the majority of the region's electrolyser plants.

Expanding electrolyser production capacity could support Northwest Europe's ambition to scale up renewable hydrogen production over the medium-term while strengthening the region's technological leadership along the emerging low-emissions hydrogen value chain. Total production capacity in Europe could increase eight-fold from 2023 levels if all announced projects are implemented, reaching more than 36 GW per year by 2030. Northwest Europe could account for around 70% of this capacity.

While several companies aim to expand their production capabilities, lack of electrolyser demand due to project delays and lower-than-expected orders have recently led some manufacturers to rationalise production rates, revise downward expansion plans and, in some cases, file for in-court restructuring. This year's *Monitor* explores the development of electrolyser production capacities in Northwest Europe.

Steep cost reductions are needed to make renewable electrolytic hydrogen competitive with unabated gas-based hydrogen

Initial price discovery suggests that renewable hydrogen prices in 2024 were almost two-and-a-half times the assessed levelised cost of hydrogen (LCOH) from unabated natural gas. This highlights the need to improve the cost-competitiveness of low-emissions hydrogen. Based on today's policy settings, a carbon price of USD 140 per tonne of CO_2-equivalent could ensure that the levelised cost of gas-based low-emissions hydrogen could be comparable with the hydrogen from unabated gas in the region by the end of the decade.

Ensuring the effectiveness of hydrogen support mechanisms requires a holistic and cross-regional approach

The relatively low share of committed projects underscores the need for a comprehensive approach to support the nascent low-emissions hydrogen sector. Scaling it up will require an effective framework of support mechanisms along the entire value chain – including research and development, production, transportation and, in particular, demand creation.

The *Monitor* provides a detailed overview of the various subsidy schemes and support mechanisms available both at the European Union level and nationally in Northwest European countries.

Northwest Europe could play a key role in developing international trade in low-emissions hydrogen

Based on the announced projects that aim to trade hydrogen or hydrogen-based fuels and its derivatives, 8 million tonnes of hydrogen equivalent (Mt H_2-eq) could be moved around the globe by 2030. Almost half of the export-oriented projects by 2030 have defined a destination. Northwest European countries account for close to 60% of global import volume by 2030 for which a final destination has been identified.

Instruments like auctions (such as Germany's H2Global auction-based mechanism) can be used to create competition for contracts and help close the gap between production costs and the prices consumers are willing to pay. In December 2024, the European Commission approved the second round of H2Global auctions with a budget of up to EUR 3 billion. In addition, the European Commission is planning to launch a hydrogen pilot mechanism by September 2025. The new mechanism will aim to connect international hydrogen producers with offtakers in Europe.

Northwest Europe's hydrogen network could reach nearly 13 000 km by the early 2030s, though firm investments are lacking

Achieving ambitious targets for low-emissions hydrogen deployment will require accelerating the development of hydrogen infrastructure for transport and storage. Based on the pipeline of project announcements, the length of the region's hydrogen network could reach almost 13 000 kilometres (km) by the early 2030s. However, only 6% of projects announced (measured by length) have reached FID.

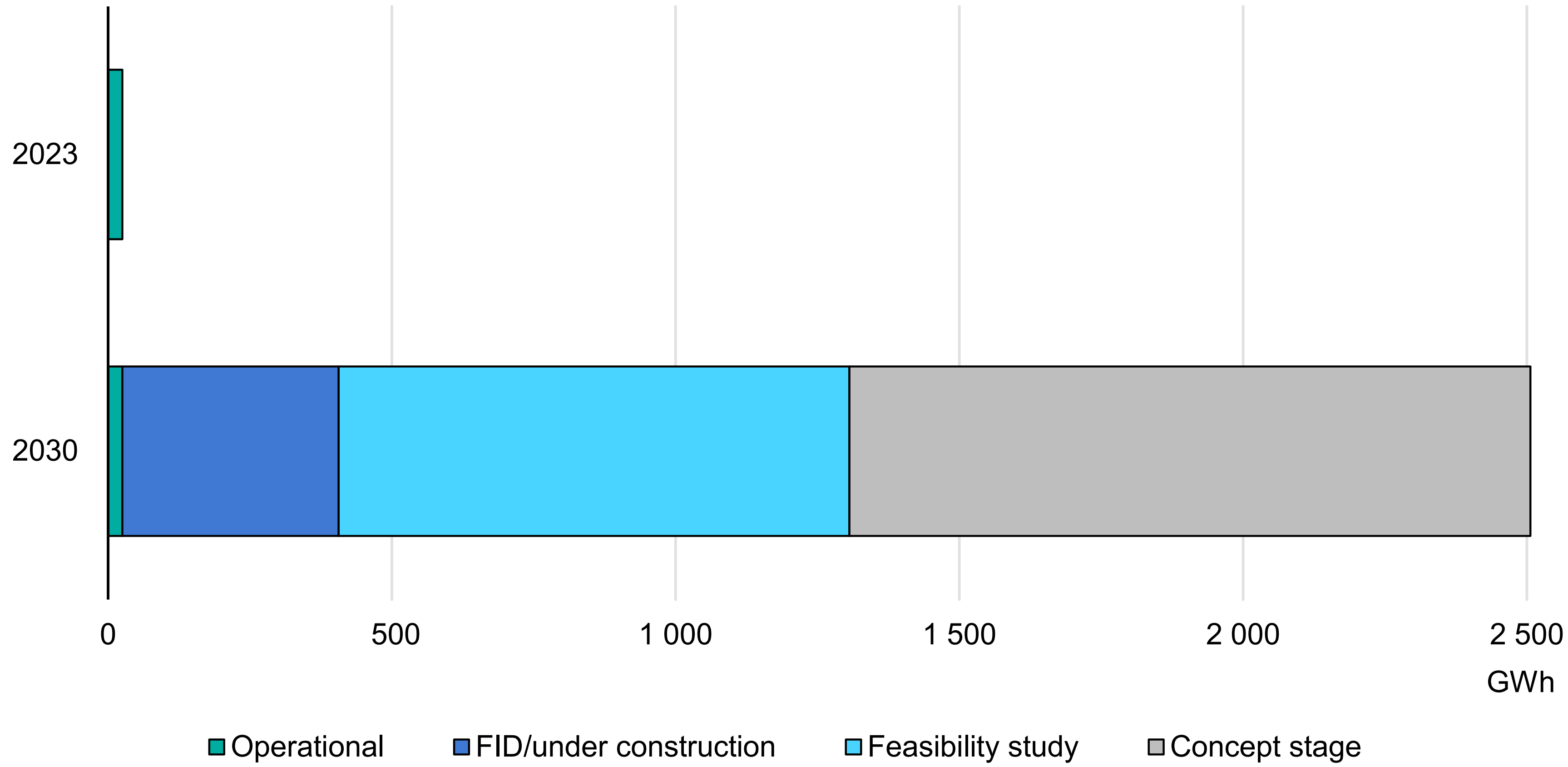
Almost half of hydrogen pipelines that could be operational by 2030 could be repurposed natural gas pipelines. Repurposing existing natural gas pipelines to serve hydrogen can result in substantial cost savings and shorter lead times compared with new-build hydrogen networks.

Underground storage will be key to enhancing the flexibility of the region's future low-emissions hydrogen network

Developing underground storage capacity for hydrogen will be crucial for it to reach its full potential as an energy carrier and respond to the evolving flexibility requirements of a more complex energy system. According to IEA analysis of hydrogen infrastructure projects, Northwest Europe could develop almost 16 terawatt-hours (TWh) of hydrogen storage capacity by 2030. However, just 3% of the potential capacity by 2030 has reached FID and/or is under construction. Considering the relatively long lead times for new-build hydrogen pipelines and hydrogen storage projects, immediate action by all stakeholders is required to meet the targets set for 2030.

More than 90% of low-emissions hydrogen projects in Northwest Europe remain in early phases of development

Potential low-emissions hydrogen production in Northwest Europe by status, 2023 vs 2030



Hydrogen policies and regulation

EU policy advances continue to build clarity around a future hydrogen market

In 2024, the European Union (EU) hydrogen policy and regulatory evolution focused on providing greater clarity and structure to the fledgling sector, notably through three key measures. Long in the works, the fourth gas package offers a regulatory framework for future market development, based on the fundamental principles underpinning the continent's long-standing integrated natural gas market and cross-border trade.

Faced with an energy affordability and economic competitiveness crisis, the European Union responded with the Clean Industrial Deal, highlighting its political and legal will to tackle energy and economic challenges simultaneously.

Finally, the European Union aims to improve transparency around hydrogen demand and supply, developing a virtual platform that can act not only as a marketplace, but also as a tool for hydrogen price discovery.

The European Union continues to make progress in constructing a hydrogen market

The European Union adopted its hydrogen and gas decarbonisation package – commonly referred to as the fourth gas package – in May 2024, updating EU gas market rules while also introducing a regulatory framework for hydrogen infrastructure. EU member states are expected to transpose the new rules into national law by mid-2026.

The package applies some of the fundamental EU natural gas market regulation principles to the nascent hydrogen market, ensuring the unbundling of network operation activities from production and supply. It also makes strides in EU-wide hydrogen infrastructure planning, setting the groundwork for creation of a European Network of Network Operators for Hydrogen (ENNOH) to co-ordinate the planning, development and operation of EU hydrogen infrastructure. Finally, it sets out guidelines for converting existing natural gas infrastructure for hydrogen use.

As the package seeks to facilitate the integration of hydrogen and other renewable and low-carbon gases into the energy mix, it recognises the different lead times required to scale up each technology. Thus, low-carbon fuels could play a greater role in the short term because scaling up renewable hydrogen production and demand takes longer. Discounted network tariffs for low-carbon gases is one of the tools that could be used to support the uptake of these alternative gases, as is a hydrogen blending allowance that would allow up to 2% by volume to be integrated into the gas grid (although direct applications for hydrogen take priority over blending).

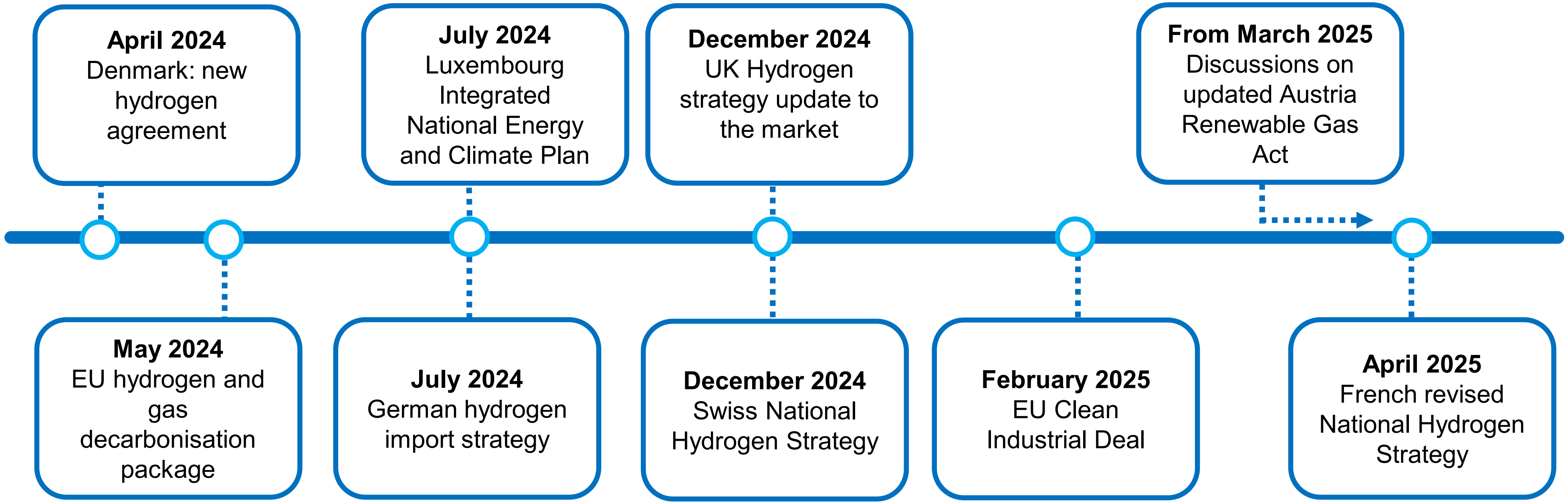
In February 2025, the European Commission published the Clean Industrial Deal to address the dual challenges of economic competitiveness and decarbonisation. To help the European Union shift its heavy industry to more climate-friendly fuels and to support the clean-tech sector, the Deal is expected to boost demand for renewable and low-carbon fuels such as hydrogen. Targeting hydrogen specifically, the European Union is expected to finalise its delegated act on low-carbon hydrogen in 2025, providing a clear definition for what constitutes “low-carbon” hydrogen.

Furthermore, the European Commission plans to launch a hydrogen pilot mechanism by September 2025 to connect international hydrogen producers with European offtakers. To address current supply and demand uncertainty, the platform is intended to make interest from both sides of the market more visible, enhancing transparency and allowing for a degree of price discovery.

Designed to operate through multiple procurement rounds per year, the mechanism will gather expressions of demand-side interest from European (not just EU) buyers and then allow producers (European and international) to respond with supply offers. This increased visibility within an organised marketplace is expected to support the development of other hydrogen market elements, notably infrastructure. Developing market structures for trade is a key step in establishing the international supply chains needed to support EU ambitions to import large quantities of low-emissions hydrogen.

European countries remain committed to building regulatory framework for a burgeoning hydrogen sector

Key hydrogen policy and regulatory evolutions in the European Union and Northwest European market, 2024-2025



Most Northwest European countries continue to develop hydrogen-related regulatory and policy structures

Austria is looking to bolster the regulatory framework around the hydrogen market and infrastructure

Austria is in the process of updating and reissuing its Gas and Hydrogen Market Act (GWG), aiming to bolster the regulatory framework around a future hydrogen market and infrastructure. Simultaneously, the government is working on the transposition of RED III requirements through its proposed Renewable Expansion Acceleration Act.

The new government that took office in March 2025 has also announced the formulation of a new hydrogen import strategy, integrating a particular focus on de-risking projects along strategic supply corridors.

Belgium reiterates its ambitions to be a hydrogen hub for the region

In April 2024, the Belgian government announced the appointment of Fluxys as the country's hydrogen network operator (HNO), in line with the procedure established in its 2023 Hydrogen Act. Following this appointment, and in light of the possible role of repurposed natural gas pipelines in building a hydrogen transmission network, in July 2024 the Belgian energy regulator (CREG) published an asset valuation methodology to determine the network's regulated asset base.

In February 2025, the new Belgian government reiterated the country's ambition to act as a hydrogen hub, connecting with neighbouring markets by pipeline, while widening the scope of its hydrogen policy towards low-carbon hydrogen in all its forms.

Denmark shows political will for hydrogen connections with neighbours

In the wake of Denmark's Power-to-X Strategy (2022) and a first political agreement on hydrogen infrastructure ownership and operation (May 2023), an alliance of the country's political parties (both government and opposition) presented a new hydrogen agreement in April 2024. The document reiterates support for Denmark's hydrogen leadership in Europe and clarifies the state's role in supporting hydrogen transport and export infrastructure.

Furthermore, it recognises the need for a clear hydrogen market regulatory framework, particularly for transport infrastructure. Because hydrogen infrastructure companies are expected to be natural monopolies, they will be subject to the revenue cap regulations being developed. The agreement also highlights a number of regulatory principles to be applied in the Danish market in line with EU legislation, notably third-party access to infrastructure and infrastructure tariffs for all users (although it also indicates the need for flexibility around these tariffs).

Additionally, to support the nascent hydrogen market, the agreement sets out the conditions by which the state will take on risk and invest capital to develop hydrogen infrastructure. The risk involved in building hydrogen infrastructure – particularly the "Jutland hydrogen backbone" connected to Germany's system – is to be borne by the state, the network operator, market players and German counterparties. However, progress on state participation in bearing risk will require (among other specificities) contractual capacity commitments by market players and cross-border agreements between network operators.

In January 2025, the Danish government announced its commitment to provide both subsidies and loans to develop the hydrogen backbone.

Finally, while the agreement does not hold regulatory or policy weight, it recognises clear ties between hydrogen development and realisation of the country's offshore wind potential.

France's new National Hydrogen Strategy recognises slower progress than expected, but doubles down on hydrogen sector importance

Five years after releasing an initial plan, in April 2025 the French government published its revised National Hydrogen Strategy. The updated strategy highlights how hydrogen sector development would help decarbonise the energy sector, support economic and industrial resilience, and enhance the country's energy independence.

While recognising progress made in the burgeoning hydrogen sector, the new document also acknowledges slower progress in deploying hydrogen technologies and in developing a market. As such, the strategy emphasises the importance of: 1) supporting the entire hydrogen value chain, including for manufacturing and exporting electrolyser technologies; 2) promoting grid-based electrolysis to produce low-carbon hydrogen; 3) refocusing the decarbonisation potential of hydrogen towards industry and certain types of heavy transport; and 4) relying entirely on domestic hydrogen production through 2035.

In adapting to the pace of hydrogen sector progress, France's updated Hydrogen Strategy lowers the installed electrolyser capacity target for 2030 to 4.5 GW (from the previous 6.5 GW) and adds a 2035 target of 8 GW. It also reiterates the state's financial support mechanisms for hydrogen production.

France's hydrogen market is also set to develop around hubs, with centralised industrial clusters retaining priority status for production and infrastructure development.

Finally, the strategy emphasises the French government's intention to continue adapting legal, regulatory and educational frameworks as the hydrogen sector evolves.

In addition, France held consultations in November and December 2024 for the next edition of its National Low-Carbon Strategy (SNBC) and its Multiannual Energy Plan (PPE), two key publications for establishing the country's energy objectives. The updated versions, to be released later in 2025, are expected to offer current guidance on hydrogen policy.

Germany has made strides in planning infrastructure and outlining the role of hydrogen imports

In July 2024, the German government adopted a hydrogen import strategy, following the update of its National Hydrogen Strategy in 2023. To meet its ambitious hydrogen demand targets, Germany expects to rely heavily on imports of the fuel, estimating that 50-70% of its supply could come from imports. Its import strategy therefore provides a framework for scaling up and securing supplies of hydrogen and its derivatives.

While the strategy emphasises the need for domestic green hydrogen in the long term, it recognises that broader low-carbon imports will be required in the near term to meet rising hydrogen demand. To diversify the country's supply portfolio, the plan prioritises the dual development of pipeline and maritime-based import routes and plans.

More broadly, the strategy reiterates some of the underlying principles of Germany's National Hydrogen Strategy, namely the need to improve clarity around future demand for hydrogen and its derivatives, to support production through relevant funding schemes when necessary, to expand cross-border infrastructure, to outline clear standards for hydrogen and its derivatives, to develop multilateral co-operation in diversifying hydrogen supply and to maintain support for research and development in the sector.

In October 2024, Germany's Federal Network Authority (*Bundesnetzagentur*) approved the country's network operators' application for a hydrogen core network. The plan, outlining the buildout of the country's hydrogen transport infrastructure, prioritises connecting industrial clusters, ports, storage facilities and cross-border interconnection points, relying on the conversion of existing natural gas pipelines for approximately 56% of the network. Under the approved application, 9 040 km of pipeline would be built or converted by 2032, implying a EUR 18.9-billion investment.

In March 2024, the German Bundestag approved a new version of the 37th Ordinance on Implementation of the **Federal Emission Control Act** (BImSchV), transposing EU requirements for Renewable Fuels of Non-Biological Origin (RFNBO) into national law.

The amendment, which came into effect in July 2024, defines the conditions under which electricity used to produce hydrogen and its derivatives can be considered renewable.

Also in 2024, the Federal Ministry for Economic Affairs and Climate Action published the concept paper Lead Markets for Climate-Friendly Basic Materials (including steel, cement and base chemicals), outlining its objective of creating a supportive framework for clean and competitive industrial activities. The study is meant to serve as a foundation for the establishment of national and EU-level measures to accelerate the industry sector's transition to climate-friendly fuels and processes. As a starting point, the concept paper introduces definitions of climate-friendly basic materials as a precondition for developing labelling systems.

Luxembourg introduces a framework to guide the buildout of its hydrogen network

In July 2024, the Luxembourg government presented its updated Integrated National Energy and Climate Plan (PNEC) covering multiple energy-related topics and providing updates for hydrogen. Key among them is the goal of integrating Luxembourg into the wider regional hydrogen market, ensuring adequate pipeline interconnections with neighbouring countries to facilitate imports in the medium term. Importantly, the plan also provides more detailed hydrogen demand estimates to 2030, highlighting the increased potential for heavy industry to be a demand driver.

In March 2025, the country's legislature adopted a law on the hydrogen transmission network, establishing a legal framework for the planning, development and use of hydrogen transport infrastructure. The law introduces a procedure to designate a future hydrogen network operator and defines its roles and responsibilities.

The Netherlands makes progress on transposing RED III into national law

In the process of transposing the most recent Renewable Energy Directive (RED III) into national law, the Netherlands presented potential RFNBO targets that fall below EU-level indications. Responding to industry concerns over competitiveness and significant political debate, the Dutch government introduced a binding obligation for 4% of hydrogen used in the industry sector to come from RFNBOs by 2030.

Regarding the transposition of RED III Article 25 on green hydrogen use in transport, the Dutch proposal would allow hydrogen used directly in transport and in refining processes to be treated equally to meet overall transport sector targets.

Norway

There have been no significant hydrogen policy and regulation updates in Norway since the last edition of this monitor, but implementation of support schemes and mechanisms continues.

Switzerland adopts a Hydrogen Strategy

In December 2024, Switzerland adopted a National Hydrogen Strategy, providing the strongest structural signal yet of the country's ambitions and expectations for hydrogen, and for power-to-X more broadly. The strategy sets the direction for hydrogen use in the country and recommends key measures to develop a domestic hydrogen market and to integrate it into the wider European market.

Although hydrogen demand is expected to remain low until the mid-2030s, the Swiss strategy promotes hydrogen's usefulness in improving energy system flexibility and in decarbonising hard-to-abate sectors. It perceives the need for imports to support significant hydrogen uptake and, as such, highlights the importance of infrastructure interconnections with neighbours to develop its own market.

The United Kingdom plans to refresh its Hydrogen Strategy

The United Kingdom plans to publish an updated hydrogen strategy later this year, revising its strategic approach to accommodate recent findings and ensure that hydrogen's unique role in the government's mission to make Britain a clean energy superpower can be realised.

The United Kingdom also continues to report on progress through regular updates, with the most recent market update published in December 2024. While this report mostly documents advances made in developing a hydrogen ecosystem, it also reiterates UK hydrogen commitments and objectives.

Key to upcoming changes are the Hydrogen Transport Business Model and the Hydrogen Storage Business Model, which have been under development since 2023 and are expected to be announced in 2025. The programmes aim for regional pipeline infrastructure to be built and up to two storage projects to be in operation or construction by 2030.

Finally, the December 2024 update to the market also emphasises the country's views on how hydrogen can have the most impact. The Demand section of the report outlines in which sectors it will play a key role.

In October 2024 the United Kingdom established a National Energy System Operator (NESO), a new publicly owned organisation that will take an enhanced whole-system approach to energy sector planning and operations. NESO oversees strategic planning for the electricity and natural gas networks, as well as system operations for Great Britain's entire electricity system. The aim is for NESO to be responsible for strategic planning of hydrogen transport and storage infrastructure from 2026.

In November 2024, the Scottish government unveiled a plan to transform **Scotland** into a key producer and exporter of green hydrogen by 2045. The strategy emphasises leveraging Scotland's natural resources, aiming for annual production of up to 3.3 million tonnes, and highlights the importance of developing infrastructure and skills in the hydrogen sector.

Subsidy schemes and support mechanisms

European countries maintain subsidy schemes to support uptake of hydrogen and its derivatives

European Union

In 2023, just one year after its initial announcement, the European Union opened the much-anticipated first auction round of the European Hydrogen Bank. Created to support the development of renewable hydrogen production across the European Economic Area (EEA), the financing instrument provides funding as a fixed premium for hydrogen produced (in EUR/kg), provided that the hydrogen is certified as a renewable fuel of non-biological origin. By providing production-linked support, the mechanism aims to reduce project risk in an effort to avoid crowding out upfront private investment.

Hydrogen Bank funding comes from the EU Innovation Fund, the funding instrument designed to support the bloc's climate and energy targets and ambitions. The Innovation Fund itself is fully funded by sales of its Emissions Trading System (ETS) allowances, which increased from 450 million to 530 million allowances following the ETS Directive Revision in 2023.

The inaugural Hydrogen Bank domestic auction round (the IF23 Auction) – which lasted from November 2023 to February 2024 – attracted 132 individual bids, oversubscribing the EUR 800-million budget by a factor of more than 15. At the end of April 2024, seven projects with bids in the range of EUR 0.37-0.48/kg of hydrogen produced were selected to receive financial support for ten years. Six of these projects ended up signing grant agreements in October 2024 for a total capacity of 1.4 GW_e and overall funding of nearly EUR 700 million. Of these six projects, two are to be established in Portugal, two in Spain, one in Finland and one in Norway. Targeted end- and intermediate-use segments include refining and petrochemicals, road transport, e-methane production and ammonia production for fertilisers, shipping, and industrial applications.

The Hydrogen Bank also provides an Auctions-as-a-Service scheme, through which member states can commit extra funds to participating projects from their own country that meet the eligibility requirements of the auction system but are not selected for EU-level funding. In effect, the scheme provides the auction structure as well as rules for the resulting premiums that are attributed, while member states supply extra funds for their own eligible projects.

Germany was the first country to participate in the scheme in the first auction round, making EUR 350 million available. However, no agreement was ultimately concluded between Germany and the European Commission on awarding of the funds through the Auctions-as-a-Service scheme.

The second European Hydrogen Bank auction round (the IF24 Auction) ran from 3 December 2024 to 20 February 2025, providing up to EUR 1.2 billion in funding for electrolysis projects. Unlike the first auction round, the total IF24 Auction funding envelope was split into two areas: EUR 200 million for projects supplying the maritime sector (maritime topic) and EUR 1 billion for all other projects regardless of targeted end-sector (general topic).

While the auction structure remained broadly the same as in the first round, some qualification requirements were tightened in the second round. First, the ceiling bid price was lowered from EUR 4.5/kg to EUR 4/kg, although the constraining effects of this new requirement may be limited given that the six selected and contracted bids in the IF23 Auction were all below EUR 0.50/kg. Also, the maximum grant amount for any single project was reduced from around EUR 267 million (i.e. one-third of the total IF23 Auction budget of EUR 800 million) to EUR 250 million in the general-topic area and EUR 200 million for maritime projects.

Another key evolution in qualification requirements for the second auction round was the introduction of resilience-related considerations, notably for the "security of supply of essential goods and contribution to Europe's industrial leadership and competitiveness." In the IF24 Auction, project promoters had to limit the sourcing of electrolyser capacity from Chinese manufacturers to a maximum of 25% of installed MW_e capacity. This rule was designed to limit dependency on the world's largest electrolyser manufacturer.

Finally, the value of the project-completion guarantee increased from 4% to 8% of the maximum grant amount, signalling stricter rules for project commissioning timelines. If a project either does not reach financial close within 2.5 years of signing the grant agreement or does not reach operational status within five years of the grant signature, the completion guarantee can be called in.

As in the inaugural auction round, the IF24 Auction allowed EEA countries to provide extra funding through the Auctions-as-a-Service instrument. In November 2024, Austria, Lithuania and Spain all announced their intention to participate in this scheme, providing a maximum potential funding pool of over EUR 800 million.

In the end, the IF24 Auction attracted 61 bids from 11 EEA countries, with 8 bids submitted under the maritime topic. Total requested grants reached over EUR 4.8 billion, vastly oversubscribing the EUR 1.2-billion budget. Successful bids are to be announced by the end of May 2025, and the European Commission aims to launch the third auction before the end of 2025.

The second key EU-wide support programme for hydrogen projects is the **Important Projects of Common European Interest** (IPCEI) scheme. Since launching of the scheme in late 2020, four groups of projects have been approved and have attained IPCEI status:

- Hy2Tech (July 2022), covering a wide part of the hydrogen technology value chain, from generation to end-user applications, with 15 member states providing up to EUR 5.4 billion of public funding. This funding is expected to unlock an additional EUR 8.8 billion in private investment.
- Hy2Use (September 2022), focusing on hydrogen production (electrolysers) and transport infrastructure, as well as on the

integration of hydrogen into industrial processes, with 13 member states providing up to EUR 5.2 billion of public funding. A further EUR 7 billion in private investment is expected to result from the public funding scheme.

- Hy2Infra (February 2024), targeting the deployment of: 1) 3.2 GW of large-scale electrolysers; 2) around 2 700 km of new and repurposed hydrogen transmission and distribution pipelines; 3) at least 370 GWh of large-scale hydrogen storage facilities; and 4) port infrastructure to handle 6 000 tonnes of liquid organic hydrogen carriers per year. In total, seven member states are set to provide up to EUR 6.9 billion in public funding, unlocking up to EUR 5.4 billion in further private investment.
- Hy2Move (May 2024), targeting technological innovations for mobility and transport applications, including fuel cell technologies and vehicle platforms, onboard hydrogen storage solutions and the production of fuel-cell-grade hydrogen, with a potential envelope of EUR 1.4 billion. It could unlock a further EUR 3.3 billion in private investment.

In 2024, the European Union took steps to devise another tool to support the development of a European hydrogen market. The pilot hydrogen mechanism, which will operate under the European Hydrogen Bank, aims to facilitate hydrogen market discovery through direct engagement with demand- and supply-side stakeholders. The digital platform seeks to assess potential demand for hydrogen across Europe, as well as connect offtakers and suppliers to improve information sharing and transparency at the early stages of market development.

The pilot hydrogen mechanism builds on the approach to the earlier AggregateEU platform for the pooling and joint purchasing of natural gas, and could also eventually facilitate the joint purchasing of low-emissions hydrogen and derivatives. The platform is expected to be launched in 2025.

In October 2024, the Innovation Fund awarded projects from its 2023 call for submissions. The European Commission announced a total investment of EUR 4.8 billion in a group of 85 selected net zero-oriented projects, 24 of which are hydrogen-related. Taken together, these projects result in 61 ktpa of RFNBO production and 9.3 GW/yr of electrolyser manufacturing capacity.

The EU RED III, which came into force in November 2023 and sets binding 2030 RFNBO targets in industry and transport, will reach a key milestone in 2025, as EU member states are obligated to transpose the directive’s main elements into national law by 21 May 2025.

Austria

In May 2024, the Austrian government adopted the Hydrogen Production Support Act, earmarking up to EUR 400 million to support electrolysis capacity, to be allocated through the European Hydrogen Bank’s second auction round (December 2024-February 2025). This made Austria one of three EU member states to make extra funds available through the Auctions-as-a-Service scheme for that auction round. Although funds had yet to be attributed at the time of writing, any amounts awarded through the competitive tender process would be distributed over a 10-year period. Further aid totalling up to EUR 420 million is to be made available starting in 2026, although definitive plans have yet to be announced.

Belgium

There have been no significant updates to hydrogen subsidy schemes and support mechanisms in Belgium since the last edition of this Monitor.

Denmark

Following a successful first tender to subsidise the production of green hydrogen and hydrogen derivatives in 2023 (EUR 177 million awarded to six projects), Denmark is set to launch a series of further bidding rounds to support the production of biomethane and hydrogen-derived e-methane. In December 2024, the European Commission approved a Danish state aid package of up to EUR 1.7 billion, to be allocated through a series of five competitive auction rounds through 2030. The resulting average funding per tender would reach EUR 340 million per round, nearly doubling the available funding per auction compared with the first tender round completed in 2023.

Under the new state aid package, project promoters will be able to submit bids for new projects as well as for upgrades to existing projects. The new auction rounds are to be structured around a 20-year payout period, instead of the 10-year contracts of the inaugural round.

In April 2024, the Danish government announced a political financing agreement for a domestic hydrogen pipeline network, establishing the underlying rules and principles by which the state would help finance the network. Importantly, the agreement is structured around the need for national regulation to be flexible enough to reduce economic risks for early market participants. More details on specific support mechanisms and available funding are to be released later.

France

In 2023, France provided initial details on the attribution of its first tranche of EUR 9 billion of funding for domestic hydrogen production through 2030. Three successive tender rounds are expected to distribute up to EUR 4 billion to support total electrolysis capacity of 1 000 MW. The first tender was open from December 2024 to March 2025, targeting projects of 5-100 MW, for a total combined capacity of 200 MW. The second tender is expected in 2025, for 250 MW, and the third in 2026, targeting 550 MW. Support will be in the form of contracts for difference of up to 15 years, with a ceiling price of EUR 4/kg of hydrogen produced. Importantly, eligible projects must demonstrate that their targeted hydrogen production is intended for direct industrial use. In the evaluation of bids, a weighting of 70% is given to the bid price and 30% to non-price factors.

Demand-side applications for hydrogen also received support in 2024, notably through the *Première Usine* programme, targeting new industrial sites across France. Although the programme is open to industrial projects of all kinds, the ten winners in the fifth tender round (EUR 42 million budget) included two hydrogen-related projects. While one plans to produce stationary and mobile hydrogen fuel cell generators, the other aims to cut steel production emissions through the reduction of iron with hydrogen.

The sixth round of the programme awarded EUR 42.8 million in September 2024 to 12 projects, two of which were also hydrogen-related, targeting solid hydrogen storage technology and decentralised electrolyser technology.

Industry was also the focus of the DECARB IND 25 tender, which ran from December 2024 through mid-March 2025. The programme, which builds on the original DECARB IND scheme and is managed by the ADEME (French Agency for Ecological Transition), aims to support decarbonisation efforts at large industrial sites with up to EUR 30 million in funding per project. Only projects with an investment of at least EUR 3 million and with targeted emissions reductions of at least 1 000 tonnes of CO_2-eq per year will be considered, and while adapting industrial processes to use hydrogen as a feedstock is permitted, hydrogen as an energy input is not eligible for the scheme.

France has also widened existing support measures for hydrogen use in the road transport sector. The long-standing TIRUERT mechanism – incentivising charging and hydrogen refuelling station operators to sell certificates to traditional fuel suppliers to fulfil their renewable fuel obligations – was expanded to include low-emissions hydrogen, whereas renewable hydrogen had been included in the mechanism in 2023.

Germany

Germany is another EU member state that has sought EU approval for state aid schemes to support domestic hydrogen market development. Multiple key schemes received European Commission authorisation in 2024.

The first was a EUR 3-billion package to support construction of the Hydrogen Core Network to connect key hydrogen production, storage and demand centres across the country. The state aid – in the form of a state guarantee allowing more favourable loan terms for nominated TSOs – will target the repurposing of existing natural gas transmission infrastructure, as well as the construction of new pipelines and compressor stations. The *Kreditanstalt für Wiederaufbau* (KfW) is to provide the loans at below-market rates, with payback instalments being backloaded to account for a progressive uptake in network usage and hydrogen demand.

In December 2024, the European Commission gave its approval to the second round of the German-Dutch H2Global state aid scheme totalling roughly EUR 3 billion and aimed at developing RFNBO production (including renewable hydrogen) abroad for later import into the European Union. Tenders are expected to be launched in 2025 through a double auction system, simultaneously identifying RFNBO producers globally (outside of Germany and the Netherlands, organised into four regional groupings and one global lot) and consumers in Germany and the Netherlands. The funding – EUR 2.7 billion put up by Germany and EUR 300 million by the Netherlands – will be used to bridge the gap between supply- and demand-side bid prices, supporting the construction of at least 1.875 GW of electrolysis capacity.

Also in December 2024, the European Commission approved an extra EUR 350 million in state aid to produce synthetic aviation fuel (by combining green hydrogen with CO_2 captured from an existing cement plant). The funding – to be provided as a direct grant for project construction – corresponds to the amount the German government originally earmarked (but never awarded) as an extra subsidy to be provided through the first European Hydrogen Bank auction.

Germany also made strides in its flagship Carbon Contracts for Difference (CCfD) scheme, completing its first auction round in 2024 and awarding a total of EUR 2.8 billion in funding (out of a designated EUR 4 billion) to 15 companies. The scheme specifically targets the decarbonisation of energy- and emissions-intensive industry sectors (notably through high-heat applications) and remains technology-agnostic, but five hydrogen-based solutions are among the chosen projects.

Unlike other support schemes that directly support hydrogen production, the CCfDs are meant to act on the demand side of the market equation, using allocated funds to close the cost gap between conventional and low-emissions industrial production methods. As a result, the final payout will depend on the evolution of EU emissions allowances over time.

While the payout is set to last for 15 years, it remains conditional on a 60% reduction in greenhouse gas (GHG) emissions in the first three years of operation and a 90% reduction by the end of the contract term. Pre-notification for the second round took place from July to September 2024 and the European Commission approved the revised funding criteria in March 2025, but the tender has not yet been launched.

Luxembourg

Renewable and electrolytic hydrogen figure among the potential decarbonisation solutions included in a new state aid scheme approved by the European Commission. With a total budget of EUR 20 million, the plan aims to support investments to manufacture decarbonisation technologies, including electrolysers, in strategic sectors.

In November 2024, Luxembourg's Ministry of Economy launched a pilot tender for electrolyser projects in the country, offering both investment support (up to 45% of eligible investment expenditures) and operational aid (with a ceiling price of EUR 7/kg H_2 for up to ten years) to selected projects. With a total budget of EUR 110 million, the tender (which closed in mid-February) is targeting a total installed capacity of 12 MW.

Finally, Luxembourg also updated its demand-side support in 2024 with a new purchase subsidy for electric and hydrogen fuel cell vehicles, mostly aimed at passenger vehicles.

Netherlands

In 2024, the Netherlands extended hydrogen production support through the OWE scheme (subsidy scheme for large-scale hydrogen production using an electrolyser), with a EUR 1-billion tender open from mid-October to end-November. The scheme was open to electrolysis projects of at least 0.5 MW that had not yet received funding through the 2023 OWE round or the Sustainable Energy Production and Climate Transition Incentive Scheme (SDE++) (whose scope went beyond strictly hydrogen projects).

Through the scheme, selected projects will be eligible to receive funding for up to 80% of their associated CAPEX, as well as a subsidy for renewable hydrogen produced over a period of 5-10 years. Results for the 2024 bidding round were expected to be announced in the first quarter of 2025.

Selected projects for the 2023 OWE round – which ran in autumn 2023 and had a total budget of EUR 250 million – were announced in April 2024. Ultimately, seven projects were selected, with a total combined capacity of 101 MW.

In the first quarter of 2024, the Dutch Ministry of Economic Affairs and Climate held a consultation process on incentives for manufacturing climate technologies. Among the proposed measures was a subsidy for electrolyser manufacturers, totalling up to EUR 50 million per manufacturer and corresponding to a certain percentage of eligible costs depending on location and company size. Although results of the consultation procedure were expected in the second quarter of 2024, few announcements have since been made.

In July 2024, the European Commission approved a further Dutch state aid scheme totalling EUR 750 million to decarbonise the industry sector, this time under the 2023 Temporary Crisis and Transition Framework. The funding programme welcomes the submission of many different decarbonisation solutions, including renewable and electrolytic hydrogen.

Finally, a key development for the Netherlands was the European Commission's approval of the German-Dutch H_2Global state aid scheme in December 2024 (see Germany section for further details). The Netherlands will be providing EUR 300 million in funding through the joint tender, which is expected to be launched in 2025.

Despite continued financial support for hydrogen uptake, negotiations during formation of the Dutch government in 2024 revealed likely cuts to renewable-hydrogen-related subsidies through 2030, compared with earlier announcements.

Norway

In Norway, the shipping sector is a key vector in the strategy to develop a domestic hydrogen market. Enova, a state enterprise tasked with facilitating technological shifts in energy use and production, made significant announcements to this effect in 2024. In June, it awarded NOK 300 million (Norwegian kroner, EUR 26 million) for the construction of five hydrogen-powered dry bulk vessels. Then in November, it awarded a further NOK 777 million (EUR 66 million) to five hydrogen production projects distributed along the Norwegian coast, with a total announced capacity of 100 MW.

Road transport is also a focus for hydrogen, with the Norwegian Ministry of Transport issuing a tender in November 2024 (open to mid-February 2025) for a series of hydrogen refuelling stations as an early step in the development of a wider network.

Switzerland

Switzerland adopted its National Hydrogen Strategy in December 2024, setting out a longer-term vision for a Swiss hydrogen market and listing support mechanisms that have been developed or are in development.

On the supply side, measures include a system of guarantees of origin for all fuels set for 2025, financial support (between 2025 and 2030) to encourage investments in hydrogen and P2X technologies, and the reimbursement of grid fees for power used to produce hydrogen and its derivatives.

To spur demand, the strategy suggests establishing indicative GHG emissions reduction targets across the building, transport and industry sectors, and exploring potential financial support to develop a network of hydrogen refuelling stations.

United Kingdom

The UK Autumn Budget 2024 confirmed support for 11 projects selected in the first Hydrogen Allocation Round (HAR1), totalling 124 MW of production capacity. These projects will access more than GBP 2 billion in revenue support from the Hydrogen Production Business Model (HPBM) and over GBP 90 million in capital expenditure support through the Net Zero Hydrogen Fund strand 3. They will invest over GBP 400 million upfront over the next three years.

In December 2024, the United Kingdom published an Update to the Market on the delivery of its hydrogen strategy, confirming and strengthening a number of hydrogen ambitions. Central to UK support for hydrogen production remains the **Hydrogen Production Business Model**, for which the second Hydrogen Allocation Round (HAR2) closed in April 2024. The tender was oversubscribed, attracting 87 applications for a total combined potential production capacity of more than 2.8 GW. Twenty-seven shortlisted projects across England, Scotland and Wales have been invited to the next stage of the HAR2 process, which includes due diligence and cost assurance. The next allocation rounds (HAR3 and HAR4) are now being discussed, with potential evolutions in approach and delivery stemming mainly from a market engagement exercise.

Closure and awarding of the **Net Zero Hydrogen Fund**'s (NZHF's) second auction round also happened in 2024. In total, the NZHF scheme has a budget of up to GBP 240 million, focused on four strands: 1) support for front-end engineering and design (FEED) studies and post-FEED costs; 2) CAPEX for projects that do not require hydrogen production business model support; 3) CAPEX for non-CCUS-enabled projects that require hydrogen business model support; and 4) CAPEX for CCUS-enabled projects that require hydrogen business model support. The second tender round targeted the first two strands, allocating funds to seven projects – down from the GBP 38 million awarded to 15 projects in the first tender round in 2022.

The UK government also directed funding towards CCUS and industrial hydrogen use in 2024, committing up to GBP 21.7 billion to the HyNet cluster and the East Coast cluster, potentially attracting a further GBP 8 billion in private funding. Both clusters aim to sequester CO_2 emissions, including from the production of hydrogen from natural gas, transporting the CO_2 through both new and repurposed pipelines to offshore storage facilities. Together, both clusters could store up to 650 million tonnes of CO_2.

Meanwhile, the Industrial Energy Transformation Fund is offering up to GBP 500 million (until 2028) to help industries cut energy consumption and carbon emissions by investing in energy efficiency and low-carbon technologies, including hydrogen fuel switches.

Finally, UK announcements in late 2024 indicate its intention to introduce a subsidy scheme for hydrogen-fired power stations, offering similar support as for CCS-enabled gas-fired power plants. The Hydrogen to Power Business Model (H2PBM) will reduce key deployment barriers, derisk investment and support the deployment of Hydrogen to Power (H2P) plants. In March 2025, the UK government published a call for evidence, seeking feedback on innovative H2P projects that could be deployed pre-2030.

Hydrogen demand

While demand targets remain stable, growth uncertainty has crept into some hydrogen markets

Scaling up low-emissions hydrogen markets will depend on end-user readiness to adopt not only new energy vectors but, in some cases, new technologies across various sectors. Government targets, guidance and incentives will be key to market growth, but relatively few developments in this domain happened in 2024.

Northwest European Hydrogen Monitor countries account for over half of total annual European hydrogen demand

According to IEA data, total European hydrogen demand reached about 7.6 Mt (250 TWh) in 2023, overwhelmingly concentrated in refining (60%) and ammonia production (35%). The production of methanol and other chemicals represents a second (much smaller) hydrogen demand segment.

EU countries accounted for over 80% of European hydrogen demand, totalling about 6 Mt (200 TWh) and split along very similar sub-sectoral lines as in Europe overall. Germany and the Netherlands are the two largest consumers of hydrogen, together accounting for roughly one-third of total EU demand. The remainder is highly distributed among member states.

Meanwhile, Northwest European Hydrogen Monitor countries accounted for over 40% of total European hydrogen demand, representing approximately 3.1 Mt (105 TWh) of consumption.

Supranational hydrogen demand targets remain key, but progress relies on country-level actions.

Hydrogen demand ambitions in the European context remain a key element in the dual objective of cutting the emissions intensity of energy use and reducing reliance on imported energy sources, most notably from the Russian Federation (hereafter, “Russia”). Beyond high-level ambitions, the European Union has introduced specific sector-level targets for hydrogen uptake. While few changes took place in 2024, 2025 is a key year for implementing many mechanisms that have been in development for some time.

RED III, which came into force in November 2023 with a key member state transposition deadline in May 2025, establishes origin requirements for hydrogen used in industry and transport. Thus, at least 42% of hydrogen employed in industry should be from renewable fuels of non-biological origin by 2030. In transport, by 2025, 1% of all fuel consumed in the sector must either fall under the advanced biofuel or biogas classification or comply with RFNBO rules. This share rises to 5.5% by 2030, with at least 1% coming from RFNBOs. In 2024, the European Commission provided guidance on the accounting of hydrogen use in transport, clarifying that use of hydrogen in refining activities could count in reaching the transport sector RFNBO targets.

EU regulations also target the transport sector in carving out a space for low-emissions fuels, including hydrogen. The FuelEU Maritime Regulation, which was adopted in 2023 and came into force in January 2025, sets progressively more stringent caps on the average GHG emissions intensity of fuels used by large ships (above 5 000 gross tonnes). The targets imply a 2% reduction in emissions intensity by 2025 (compared with 2020), climbing to 6% by 2030 and 80% by 2050. The regulation also establishes a potential RFNBO sub-target of 2% in shipping by 2034 in case of insufficient progress before 2031. Although the regulation is technology-neutral, it is expected to spur the uptake of hydrogen and hydrogen-derived fuels in shipping.

The European Union also adopted ReFuelEU Aviation in October 2023 to promote the use of sustainable aviation fuel (SAF) in airborne transport. The first imposed targets come into effect in 2025, with fuel suppliers required to integrate at least 2% SAF into their supply. SAF shares then rise to 6% in 2030 and 70% in 2050. The imposition of a minimum share of synthetic fuels from 2030 onwards (1.2% by 2030 and 35% by 2050) also favours hydrogen-derived fuels.

While targets for emissions reductions and low-emissions fuels are beginning to take effect and will become increasingly strict, many of the associated EU regulations date to 2023 and earlier, indicating that relatively few supranational developments have happened since then. Nationally, advances in hydrogen demand targets and guidelines have also been limited among *Northwest European Hydrogen Monitor* countries.

Austria

There have been no significant updates to hydrogen demand targets and ambitions in Austria since the last edition of this *Monitor*.

Belgium

There have been no significant updates to hydrogen demand targets and ambitions in Belgium since the last edition of this *Monitor.*

Denmark

While Denmark's hydrogen ambitions remain largely unchanged, the Danish energy agency downgraded its expectations in late 2024 for electricity demand in the production of hydrogen and hydrogen-derived fuels by nearly half compared with previous expectations for 2035, suggesting weaker market prospects in Denmark and neighbouring markets.

France

There have been no significant updates to hydrogen demand targets and ambitions in France since the last edition of this *Monitor*.

Germany

Germany's 2024 Import Strategy for hydrogen and hydrogen derivatives reiterates and supplements the country's hydrogen demand ambitions. Germany expects demand for hydrogen and its derivatives to reach between 95 and 130 TWh by 2030, with key demand sectors including industry, aviation, shipping, heavy-duty transport and electricity production.

Nevertheless, the coalition agreement that emerged from Germany's newly formed government in April 2025 announced a rollback in hydrogen demand ambitions in the aviation sector. The government has resolved to abolish the power-to-liquid quota that had been previously imposed above the ReFuelEU Aviation ambitions.

Luxembourg

Luxembourg's updated Integrated National Energy and Climate Plan (PNEC) of 2024 presented specific medium-term hydrogen demand projections. By 2030, total hydrogen demand could reach 230 GWh, split between industry and road transport. Although road transport could catalyse early demand for hydrogen, uptake in heavy industry applications would ramp up more quickly, accounting for over 50% of hydrogen demand by 2030.

Netherlands

The Netherlands is currently Europe's second-largest hydrogen consumer and aims to both decarbonise existing uses and scale up hydrogen demand to decarbonise sectors that are difficult to electrify. However, despite the country's stated ambitions for hydrogen use, in its November 2024 Climate and Energy Outlook, the Dutch Environmental Assessment Agency (PBL) scaled back forecast hydrogen demand in industry significantly, citing increasing electrolyser costs and electricity tariffs, as well as offtaker uncertainty. From a renewable hydrogen demand range of 27-40 PJ (7.5-11 TWh) forecast for 2030 in the 2023 report, expectations fell to just 12-15 PJ (3-4 TWh) in the 2024 edition.

Norway

There have been no significant updates to hydrogen demand targets and ambitions in Norway since the last edition of this *Monitor*.

Switzerland

In December 2024, Switzerland adopted a national hydrogen strategy based on the report Hydrogen: Overview and Options for Action for Switzerland, adopted in November 2023 by the Swiss Federal council. Although the strategy does not define a target for hydrogen demand, it estimates that demand for low-emissions supplies will be 0.8-1.8 TWh in 2030. Cautiously, the strategy clarifies that much uncertainty persists around the uptake of hydrogen and its derivatives.

United Kingdom

In the United Kingdom, hydrogen is considered to have a central role in aiding decarbonisation efforts and achieving the country's Clean Energy Superpower Mission. In this aim, the UK government reiterated its guiding principles for hydrogen (including for demand) in its Hydrogen Strategy Update to the Market: December 2024.

Figuring prominently in the country's hydrogen demand strategy is its role in decarbonising power generation and offering grid flexibility. Thus, the UK government is planning scoping exercises to better understand hydrogen's potential in the sector, including market engagement with industry. The December 2024 Clean Power 2030 Action Plan foresees a potential need for 2-7 GW of dispatchable low-carbon power generation capacity, creating a possible role for H2P technology.

The strategy also names industry as another key potential demand sector, notably industrial clusters for which hydrogen can serve as a feedstock and an energy source. Furthermore, offroad machinery could be a source of hydrogen demand, dovetailing with high uptime transport needs at industrial and port sites.

The transport sector may also boost UK hydrogen demand. While electrification is advantageous for light-duty road vehicles, hydrogen could have a more important role in heavier transport segments such as shipping, aviation and some heavy-goods road transport.

Finally, the UK government intends to assess the latest evidence on hydrogen use in home heating and on blending hydrogen into the gas transmission network, before consulting separately on both topics in 2025. This will help provide clarity on the level of demand associated with these potential uses.

The European Union and all Northwest European countries are promoting H_2-derived fuels for maritime use

The maritime sector is under increasing pressure to reduce its GHG emissions, which contribute approximately 3% of the global total. Hydrogen-derived fuels, including ammonia, methanol and other synthetic fuels have emerged as promising alternatives to traditional fossil fuels, offering pathways to decarbonise shipping operations. In Northwestern Europe, a combination of international regulations, regional policies and national initiatives is driving the adoption of these low-emissions fuels.

The 2023 IMO strategy and EU regulatory advances are paving the way for hydrogen-derived fuel use in shipping

In July 2023, the International Maritime Organization (IMO) adopted a revised strategy to reduce GHG emissions from ships, targeting net zero emissions by or around 2050. The strategy sets indicative checkpoints for 2030 and 2040, emphasising the need for alternative fuels such as hydrogen derivatives to achieve these targets. Hydrogen-based fuels are expected to contribute significantly, with low-emissions fuels anticipated to account for 5-10% of international shipping fuel consumption by 2030. However, the production ramp-up required to meet these targets may present challenges as the 2027 deadline approaches.

Simultaneously, the European Union has also taken steps to integrate low-emissions hydrogen into the maritime sector through targeted policies. Notably, the European Council has adopted a FuelEU Maritime regulation that, while not mandating the use of e-fuels before 2030, sets a potential sub-target of 2% RFNBOs in shipping by 2034. Achieving this aim would require demand of 90-105 kt H_2-eq in that year. The inclusion of shipping in the EU ETS further incentivises the deployment of low-emissions fuels for both domestic and international shipping routes originating or terminating in the region.

National initiatives in Northwestern Europe promote H_2-derived fuels

Countries bordering the North Sea have recognised the region's potential as a hub for renewable energy and hydrogen production. In April 2023, nine countries (Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, and the United Kingdom) signed the Ostend Declaration, setting a collective ambition for 120 GW of offshore wind capacity by 2030 and 300 GW by 2050. This initiative includes plans for offshore renewable hydrogen production and the development of hydrogen transmission infrastructure.

Denmark, leveraging its substantial offshore wind resources, is producing green hydrogen to synthesise e-methanol. One notable facility is the Kassø green methanol plant, which recently commenced production using solar energy and locally sourced biogenic CO_2 to produce up to 42 000 tonnes of e-methanol annually, supplying industry leaders such as Maersk.

Meanwhile, Norway has mandated that cruise ships operating in its World Heritage fjords must be zero emissions as of 1 January 2026, with larger vessels given until 1 January 2032 to comply. This initiative encourages the adoption of alternative fuels, including hydrogen.

In the United Kingdom, the government has announced its intention to include international shipping emissions in its carbon budget and its Nationally Determined Contribution for 2035. The UK government recently released a Maritime Decarbonisation Strategy, which includes new goals of zero emissions by 2050, a 30% reduction in lifecycle GHG emissions by 2030, and an 80% reduction by 2040 (compared with 2008 levels), reflecting the highest level of the IMO 2023 GHG Strategy.

Supporting these aims are a lifecycle well-to-wake GHG marine fuel standard and an emissions pricing mechanism recently approved by the IMO, to be implemented in 2028 (subject to its formal adoption this October). Domestic fuel regulations will accompany these measures to drive the uptake of zero- and near-zero-GHG-emissions fuels and energy sources, with hydrogen derivatives such as ammonia and methanol likely to be very important in decarbonising the maritime sector.

Within the IMO, the United Kingdom also supports the updated targets for improving energy efficiency and will try to play a leading role in the second phase of the IMO review of short-term measures to further incentivise energy efficiency.

These policy advances, along with rising orders for alternative-fuel-ready ships, are driving the transition to a more sustainable, hydrogen-powered maritime sector in Northwestern Europe.

European industry shows momentum with key recent developments

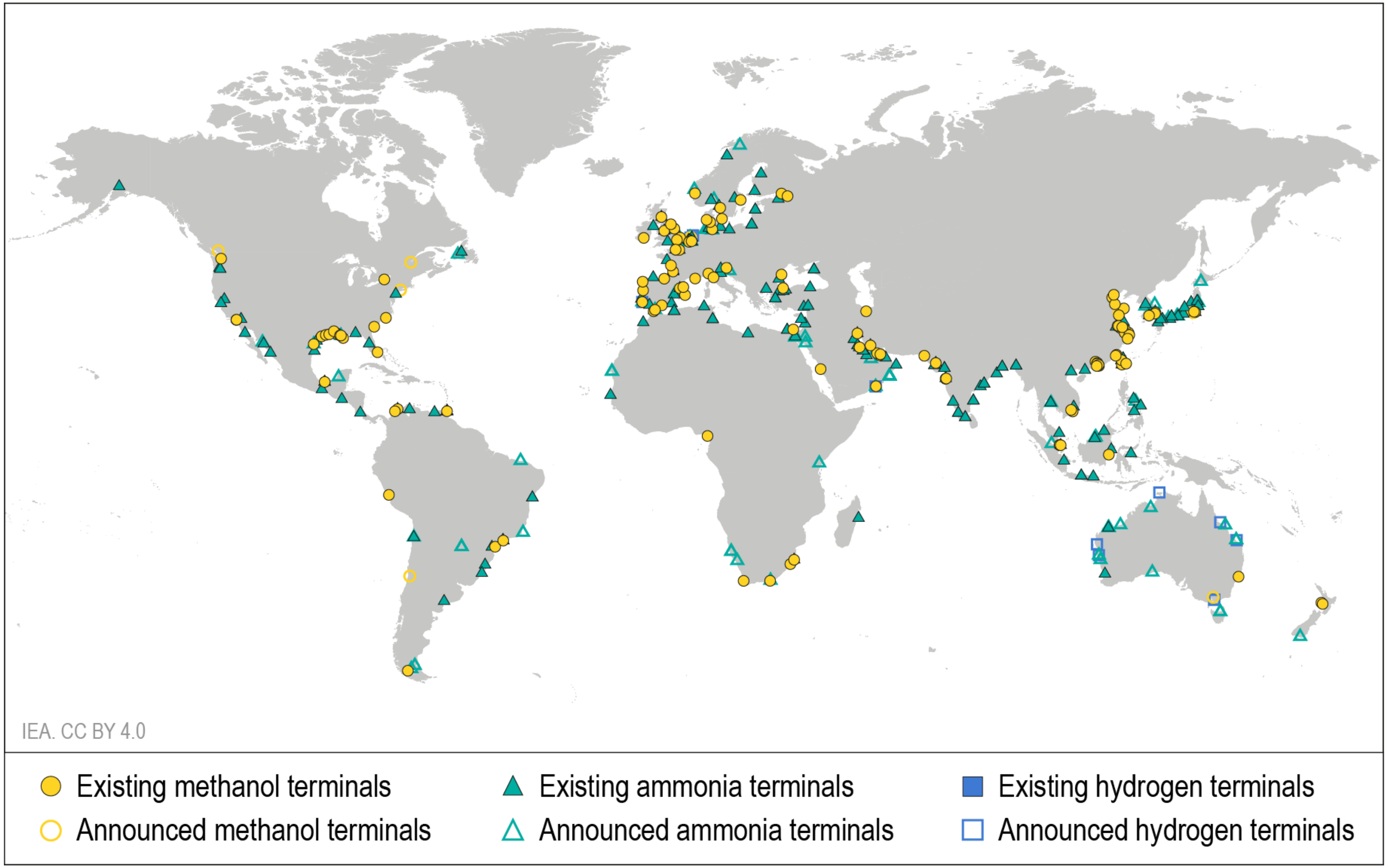
The maritime industry in Northwestern Europe has made notable progress in adopting hydrogen-derived fuels. Recent projects and technological breakthroughs underscore the sector's commitment to sustainable fuel alternatives:

- In February 2025, Norwegian shipping firm Höegh Evi announced plans to make a final investment decision within the year on the ammonia-derived-hydrogen project in Lubmin, aimed at supplying German grids. This initiative involves developing a floating hydrogen import terminal at Lubmin on the Baltic Sea, equipped with a green ammonia cracker integrated into a floating barge system to produce hydrogen for inland distribution. The terminal is to produce around 30 000 tonnes of hydrogen annually, which will be injected into Germany's hydrogen core network through the existing feed-in point at the Deutsche ReGas Terminal in Lubmin. Höegh Evi aims to offer green hydrogen at USD 3-3.5/kg by 2027, significantly lower than the current European market price of USD 8-10/kg.

- In March 2025, WinGD successfully completed full-load testing of its ammonia-fuelled engine at the Engine Research and Innovation Centre in Winterthur, Switzerland. The tests confirmed that ammonia operation can achieve a thermal efficiency comparable to that of diesel fuel, with pilot oil consumption at the targeted 5% of overall fuel use at full load. Additionally, WinGD has secured nearly 30 orders for these engines, including for vessels such as bulk carriers, gas carriers, container ships and oil tankers. Deliveries are scheduled to commence by mid-2025, with initial units designated for ammonia carriers owned by Exmar LPG and bulk carriers operated by CMB.Tech.

Ammonia and methanol bunkering and import infrastructure demonstrate European ambition

Major existing methanol and ammonia terminals and ports with bunkering or export capability



Source: IEA analysis based on IEA (2024), IEA Hydrogen Infrastructure Projects Database.

Hydrogen supply

Low-emissions hydrogen can be produced through many methods

Global hydrogen production is estimated at nearly 100 Mt. More than 99% is produced from unabated fossil fuels, with natural gas alone accounting for approximately two-thirds of global hydrogen supply. Emissions associated with hydrogen production are estimated at around 920 Mt CO_2 – around 2.3% of global CO_2 emissions.

However, low-emissions hydrogen use could reduce the emissions intensity of existing hydrogen supplies significantly, and could furthermore support the future decarbonisation of gas and energy systems. Besides its environmental benefits, using domestically produced low-emissions hydrogen could reduce reliance on fossil fuel imports.

Hydrogen can be produced through a wide variety of technologies, for instance reforming, gasification, electrolysis, pyrolysis, water splitting and many others, from a range of primary and secondary fuels including coal, oil, natural gas and biomass, as well as renewables- and nuclear-based electricity.

There is currently no international agreement on a universal definition for low-emissions hydrogen. Like in the IEA Global Hydrogen Review 2024, in this Monitor low-emissions hydrogen includes hydrogen produced from:

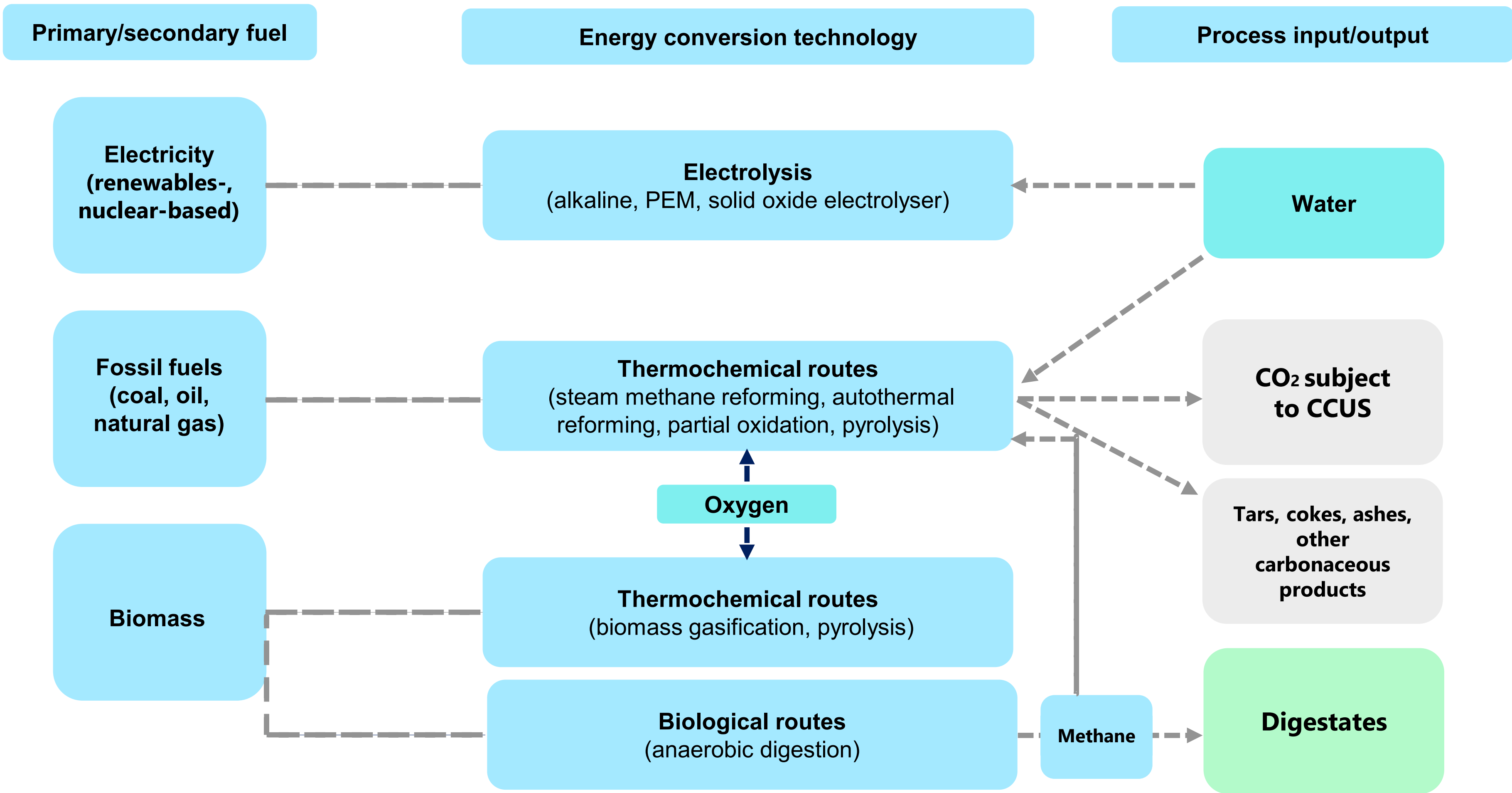
- Renewables-based and nuclear electricity via electrolysis.
- Fossil fuels via steam methane reforming (SMR) or autothermal reforming (ATR) with CCUS. Notably, production from fossil fuels with CCUS is included only if upstream emissions are sufficiently low, if capture – at high rates – is applied to all CO_2 streams associated with the production route, and if all CO_2 emissions are permanently stored to prevent their release into the atmosphere.
- Bioenergy via pyrolysis, anaerobic digestion and other technologies.

The choice of technology will depend largely on the country of production and resource availability. For example, the cost-competitiveness of electrolytic hydrogen will be largely determined by the availability of variable renewable energy sources, while CCUS-based solutions might be more competitive in markets with greater fossil fuel and CO_2 storage potential and/or biomass availability.

Several Northwest European countries have therefore included electrolyser capacity deployment targets in their national hydrogen strategies, while Norway has chosen a technology-neutral approach. Taken together, Northwest European countries target total electrolyser capacity deployment of 30-35 GW by 2030.

Low-emissions hydrogen can be produced through a variety of production routes

Simplified scheme of selected low-emissions hydrogen production routes



Note: PEM = polymer electrolyte membrane.

Unabated fossil fuels currently dominate Northwestern Europe's hydrogen production

The ten countries covered in this Hydrogen Monitor produced just over 3 Mt of hydrogen in 2023, primarily from unabated natural gas. Germany, the Netherlands and Belgium accounted for over 75% of the total hydrogen supply.

Northwestern Europe's electrolytic hydrogen production capacity stood close to 300 MW in 2024, translating into just over 15 kt of low-emissions hydrogen supply. Most of the operating capacity is in Germany, accounting for around 40% of Northwestern Europe's overall supply of low-emissions hydrogen. Although two gas-based hydrogen production projects capture CO_2 for use in industrial and agricultural applications in the Netherlands and in France, they are not classified as producers of low-emissions hydrogen for the purposes of this Monitor (because the use the CO_2 in applications that do not prevent its release back to the atmosphere).

While Northwest European countries are at the forefront of developing low-emissions hydrogen production, the scale and speed of development is expected to vary by country, depending on policy choices, regulatory frameworks and resource endowment.

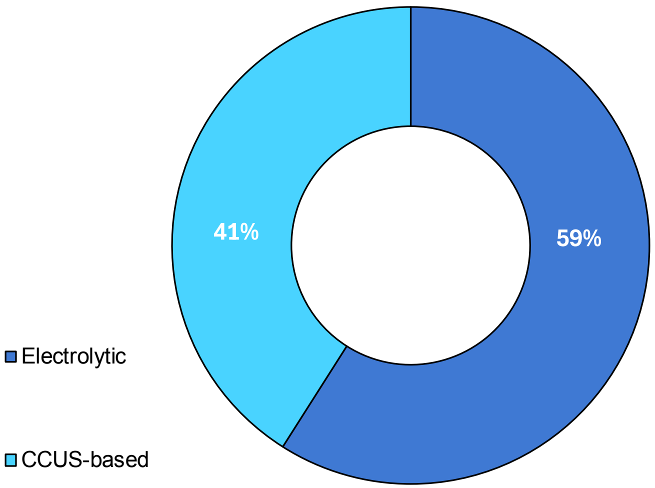
Given their strong potential for wind power generation, several Northwest European countries have included electrolyser capacity deployment targets in their national hydrogen strategies, while Norway has chosen a technology-neutral approach. Based on the latest IEA analysis, if all planned projects become commercially operational and assumptions on efficiency and utilisation factors are accurate, Northwestern Europe's production of low-emissions hydrogen (and derivatives) could reach nearly 8 Mt/yr by 2030. Meanwhile, fossil fuel-based projects equipped with CCUS would account for 41% of total low-emissions hydrogen production, and electrolytic production would make up 59% of the overall low-emissions hydrogen supply.

Less than 8% of the projects underpinning the potential low-emissions hydrogen supply by 2030 have reached FID or are under construction. In fact, over 90% of them are just undergoing feasibility studies or are in the conceptual phase. This highlights the urgent need for policies and support mechanisms to unlock the investments necessary to scale up low-emissions hydrogen production. Demand creation should also be prioritised to stimulate sufficient investment.

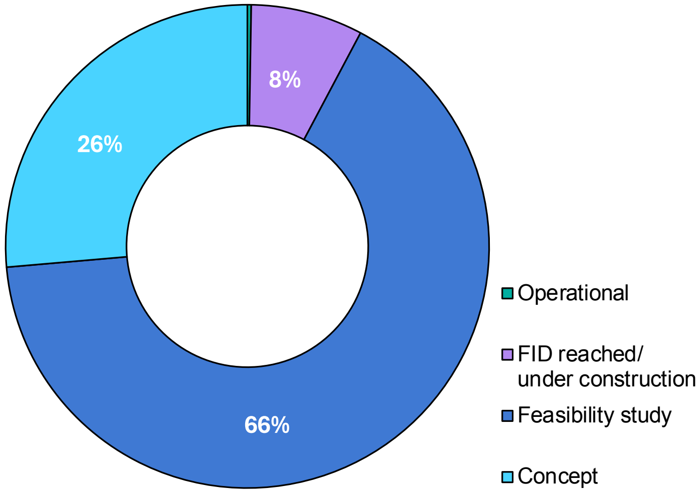
This rest of this section provides an overview of potential low-emissions hydrogen supply sources in Northwestern Europe by technology route and project status, with special attention to. It also includes a special focus on electrolyser manufacturing capacity.

Announced projects indicate that electrolytic production could account for 60% of Northwestern Europe's low-emissions hydrogen supply by 2030

Low-emissions hydrogen supply in Northwestern Europe by type, 2030



Low-emissions hydrogen supply in Northwestern Europe by project status, 2030



Note: FID = final investment decision.

Natural gas-based low-emissions hydrogen projects continue to gain traction

Natural gas-based low-emissions hydrogen production could play an important role in decarbonising Northwestern Europe's hydrogen supply. Projects include hydrogen production from steam methane reforming, autothermal reforming (ATR) and partial oxidation (POx) equipped with CCUS.[2]

In Northwestern Europe, CCUS-based hydrogen plant developments are concentrated along the North Sea owing to its relatively vast natural gas reserves, well-developed gas infrastructure and CO_2 storage ability (depleted reservoirs). If all planned projects become commercially operational (and if assumptions on efficiency and utilisation factors are accurate), Northwestern Europe's production of gas-based low-emissions hydrogen (and derivatives) could reach almost 3.2 Mt/yr by 2030.

The Netherlands, Norway and the United Kingdom together account for more than 85% of this potential low-emissions hydrogen supply, and the remainder of announced projects are in Belgium, France and Germany. However, only 6% of all announced projects have reached FID and/or are under construction, while the remaining 94% are either undergoing feasibility studies or are at the conceptual phase.

The Netherlands

The Netherlands is at the forefront of gas-based low-emissions hydrogen development. While the country's Hydrogen Strategy does not set specific targets for CCUS-enabled low-emissions hydrogen, it notes that hydrogen production plants could become important in coastal regions and that they can receive support through the SDE++ scheme. The country's Hydrogen Roadmap highlights that "hydrogen from natural gas and industrial waste gases will be needed in the transition until at least 2030 […] and at the same time, achieve industrial CO_2 emission targets. CCS can be used to this end."

The Porthos CO_2 transport and storage project received FID in October 2023. Under the project, CO_2 from industry in the Port of Rotterdam will be transported and stored in depleted gas fields under the North Sea, with total storage of about 37 Mt of CO_2 (or around 2.5 Mt of CO_2/yr for 15 years). Construction started in early 2024 and the system is to become operational in 2026.

The Netherlands currently has three CCUS-enabled low-emissions hydrogen projects under construction. Based on the latest IEA analysis, the combined low-emissions hydrogen supply of these projects could total just over 0.2 Mt/yr by 2030.

[2] Low-emissions hydrogen production is estimated from the plant's CO_2 capture capacity, and therefore only includes hydrogen production for which CO_2 is captured and stored.

In November 2023, Air Products announced that it will build, own and operate a state-of-the-art CO_2 capture and treatment facility at its existing hydrogen production plant in Rotterdam. It is to become operational in 2026, and the low-emissions hydrogen it produces will serve ExxonMobil's Rotterdam refinery and additional customers via Air Products' hydrogen pipeline network. The plant will be connected to the Porthos CO_2 transport and storage system.

Similarly, in December 2023 Air Liquide announced that it will build, own and operate a carbon capture unit at its hydrogen production plant in the Port of Rotterdam. The carbon capture unit is to become operational in 2026, and like the Air Products facility, it will be connected to the Porthos CO_2 transport and storage complex.

Both projects will receive a 15-year contract under Sustainable Energy Production and Climate Transition Incentive Scheme (SDE++) under which the government cover the difference between the cost of hydrogen production with CCUS and without.

In November 2023, Yara International signed a binding commercial agreement with Northern Lights, a CO_2 transport and storage service supplier, to transport and store CO_2. Under the agreement, CO_2 will be captured at Yara's Sluiskil ammonia plant, then liquefied and shipped by Northern Lights from the Netherlands for permanent storage on the Norwegian continental shelf. Under the project, Yara Sluiskil will capture approximately 800 000 tonnes of CO_2 from process gas from its ammonia production each year. Operations are expected to start in 2026 for a duration of 15 years. Because the CO_2 is being stored outside the country, the plant was not eligible for an SDE++ contract, but part of its USD 200-million costs will be covered by a USD 30-million grant from the Netherlands.

In addition, several projects are undergoing feasibility studies. If they all become operational, they could supply more than 0.6 Mt of low-emissions hydrogen per year by 2030. This includes the H-Vision project, which aims to reduce carbon emissions in the Rotterdam area. The project partners are Deltalinqs, Air Liquide, BP, Port of Rotterdam, Shell, Royal Vopak and ExxonMobil. The CO_2 abatement strategies of the Municipality Rotterdam, the Province of South Holland, the national government and the European Commission uphold the H-vision concept, and the Dutch government has created a new category in its SDE++ subsidy scheme to support hydrogen production from process gases for industrial heat generation.

Norway

Norway has large natural gas reserves and significant CO_2 storage capabilities, and its Hydrogen Strategy recognises the important part CCS-based technologies could play in decarbonising hydrogen production. It also explains that "CCS is essential for the production of clean hydrogen from natural gas" and that "Norwegian authorities will work to ensure that natural gas reforming combined with CCS can compete on equal terms with hydrogen from water electrolysis in the European energy market."

In September 2024, the Norwegian Minister of Energy officially opened the Northern Lights CO_2 transport and storage facility in Øygarden. It is a joint Equinor, Shell and TotalEnergies venture to enable cross-border CO_2 transport and storage, including from low-emissions hydrogen projects in other Northwest European countries. The first phase of the project has a capacity of 1.5 million tonnes of CO_2 per year and is already fully booked.

Although Norway is advancing several gas-based low-emissions hydrogen projects, all are currently undergoing feasibility studies and have not yet received an FID. Based on the latest IEA analysis, if all these projects become operational they could supply over 0.4 Mt of low-emissions hydrogen per year by 2030.

This includes the Barents Blue project proposed by Horisont Energi, which aims to deliver 1 Mt of clean ammonia from low-emissions hydrogen. The low-emissions hydrogen would be produced from natural gas via autothermal reforming equipped with CCS. The project has received state aid to participate in the Important Projects of Common European Interest Hydrogen programme.

United Kingdom

In its December 2023 Hydrogen Production Delivery Roadmap, the United Kingdom targets 4 GW of CCUS-enabled hydrogen capacity by 2030. Its intermediary target is for 1 GW of CCUS-enabled hydrogen capacity to be in construction or operational by 2025.

The UK has allocated up to GBP 21.7 billion in funding over 25 years to support the carbon capture industry through the HyNet and East Coast Cluster developments.

Several CCUS-based low-emissions hydrogen projects are planned for the United Kingdom – all of which are currently undergoing feasibility studies. Based on the latest IEA analysis, if all projects become operational they could supply more than 1.5 Mt of low-emissions hydrogen per year by 2030.

This includes the 350 MW Hydrogen Production Plant 1 (HPP1) plant, currently in negotiations to connect to the HyNet industrial Cluster, which aims to decarbonise industries located in Northwest England and North Wales by providing low-emission hydrogen produced from natural gas via autothermal reforming subject to CCS. In April 2025, Eni reached financial close with the UK Government's Department of Energy Security and Net Zero (DESNZ) for the Liverpool Bay CCS project, where Eni is the operator of the CO_2 transport and storage system (T&S) of the HyNet industrial Cluster. The construction is set to start later in 2025 and operations are expected to commence from 2028. The first phase of the project will have a storage capacity of 4.5 Mtpa of CO_2, with the potential to increase to 10 Mtpa of CO_2 in the 2030s.

The East Coast Cluster (ECC) reached financial close with the UK Government's Department for Energy Security and Net Zero at the end of 2024, and includes (subject to negotiations) the H2Teesside project led by BP.

The H2H Saltend project, advanced by Equinor, aims to produce CCS-enabled low-emissions hydrogen for use as fuel at Triton Power and Saltend Chemicals Park. In February 2024, the project has been granted planning permission. The planned Humber H2ub is another key CCUS-based low-emissions hydrogen project in the Humber region. The project is advanced by Uniper in partnership with Shell and have proposals to be operational later this decade. Humber H2ub would include a CCUS-enabled low-emissions hydrogen production capability with a capacity of up to 0.72 GW.

Other key CCUS-based hydrogen projects

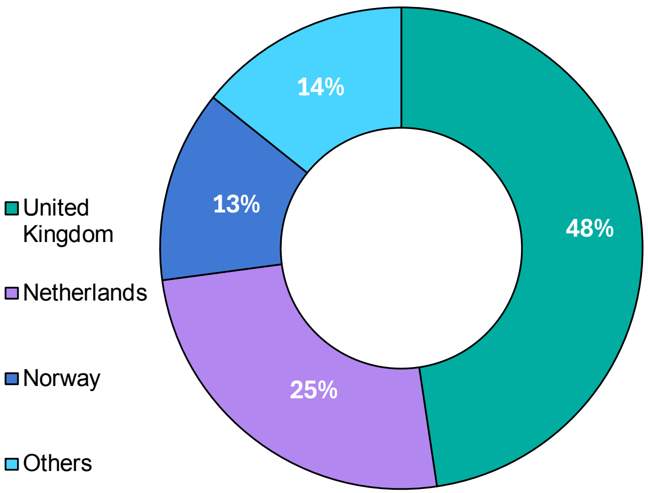
In Germany, VNG and Norway's Equinor are leading the H2GE Rostock project. Under its scheme, Norwegian gas would be converted into low-emissions hydrogen in Germany via methane reforming and subject to carbon, capture and offshore storage (CCOS). The CO_2 emissions would be stored on Norway's continental shelf.

Also in Germany, Wintershall Dea is developing the BlueHyNow project on the North Sea coast at Wilhelmshaven. The project aims to produce 5.6 TWh/yr of gas-based low-emissions hydrogen, with the plant operating on green wind power from the North Sea. CO_2 separated off during hydrogen production will be shipped by sea to offshore locations in Norway and Denmark and stored under the seabed.

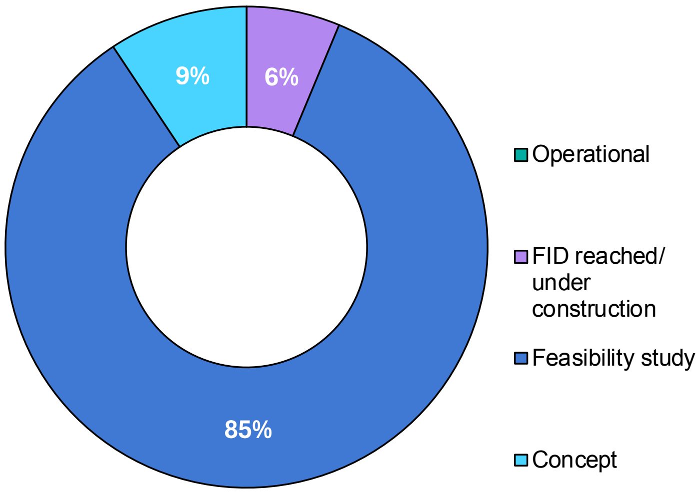
In Belgium, ENGIE and Equinor are advancing the H2BE project, under which CCS-based low-emissions hydrogen would be produced from natural gas in Belgium via autothermal reforming. Although the project is just at the conceptual phase, it could have a low-emissions production capability of up to 1 GW, with operations planned to begin by the end of this decade.

The Netherlands, Norway and the United Kingdom could dominate CCUS-based low-emissions hydrogen project developments in Northwestern Europe

CCUS-based low-emissions hydrogen supply in Northwestern Europe by country, 2030



CCUS-based low-emissions hydrogen supply in Northwestern Europe by project status. 2030



Note: FID = final investment decision.

Electrolytic hydrogen could dominate low-emissions hydrogen supplies in Northwestern Europe

Given their strong wind power generation potential, most Northwest European countries have included electrolyser capacity deployment targets in their national hydrogen strategies. In all, they target electrolyser capacity deployment of 30-35 GW by 2030.

Northwestern Europe's current electrolytic hydrogen production is estimated at just over 15 kt/yr, with around half of the supply concentrated in Germany. Based on the latest IEA analysis, if all planned projects become commercially operational, the region's production of electrolytic hydrogen and derivatives could reach almost 4.65 Mt/yr by 2030 – accounting for almost 60% of low-emissions hydrogen production in the region by the end of the decade.

Based on announced projects, Denmark, France, Germany and the Netherlands together account for more than 70% of Northwestern Europe's potential electrolytic hydrogen supply. However, less than 9% of all announced electrolytic hydrogen projects have reached FID and/or are under construction. Around 53% of them are undergoing feasibility studies and more than 38% are still at the conceptual phase.

Austria

Austria targets 1 GW of electrolyser capacity for renewable hydrogen production by 2030. In fact, the country's National Hydrogen Strategy aims to replace 80% of fossil fuel-based hydrogen with climate-neutral hydrogen in energy-intensive industries by 2030.

Austria had 18.25 MW of installed electrolyser capacity as of February 2025. The largest project is H2FUTURE, equipped with a 6-MW proton exchange membrane (PEM) electrolyser and operational near Linz (Upper Austria) since 2019. The DEMO4GRID project was commissioned in 2022 and has a 3.2-MW alkaline electrolyser. It is intended to supply green hydrogen to the food retail company MPREIS, to replace natural gas for heating. Meanwhile, the Vienna Energy project is equipped with a 3-MW PEM electrolyser and has been operational since 2024 in Simmering in Vienna. It supplies two hydrogen filling stations, which will support the deployment of hydrogen-fuelled buses in Vienna.

Based on the latest IEA analysis, if all planned projects launch commercial operations by 2030, Austria could produce approximately 30 kt of renewable hydrogen per year by 2030. However, only less than 20% of this low-emissions hydrogen potential is underpinned by projects that have already reached FID and/or are under construction.

Belgium

The Belgian Federal Hydrogen Strategy does not specify a low-emissions hydrogen production target. In its National Recovery and

Resilience Plan, Belgium set a target of at least 0.15 GW of electrolysis capacity in operation by 2026.

According to the IEA Hydrogen Projects Database, the country has four operational demonstration facilities to produce low-emissions hydrogen, with a combined capacity of just over 1 MW. Projects that have reached FID and/or are under construction have a total capacity of just over 25 MW.

Several projects are either undergoing feasibility studies or are in their conceptual phase. Based on the latest IEA analysis, if all projects currently under development start commercial operations by 2030, Belgium could produce 0.1 Mt of electrolytic hydrogen per year.

Denmark

Denmark adopted its Power-to-X Strategy in March 2022, targeting 4-6 GW of electrolyser capacity by 2030.

Denmark has an installed electrolysis capacity of near 100 MW. While the majority of this capacity is distributed across small-scale projects. This includes the Port of Aabenraa Methanol project, which is supported by a 50 MW PEM electrolyser. Construction of the facility began in May 2023 and has produced first e-methanol in March 2025. The project will supply low-emissions methanol to shipping companies and fuel retailers. The capacity of projects which reached FID and/or are under construction is over 240 MW.

There are major projects which are either undergoing feasibility studies or are in their conceptual phase. This includes the BrintØ - Hydrogen Island project, which is to be connected to 10 GW of offshore wind. Based on the latest IEA analysis, if all projects currently under development begin commercial operations by 2030, Denmark could produce 1 Mt of electrolytic hydrogen per year.

France

In April 2025, France published its revised National Hydrogen Strategy. While recognising progress made in the hydrogen sector, the Strategy lowered the installed electrolyser capacity target for 2030 to 4.5 GW (from 6.5 GW previously) and adds a 2035 target of 8 GW.

The country has several ongoing small-scale low-emissions hydrogen production projects, with nearly 30 MW of electrolytic hydrogen production capacity in operational status. Projects that have reached FID and/or are under construction could add 285 MW of low-emissions hydrogen production capacity by 2030. Included among them is the Air Liquide Normand'Hy facility, which will have an electrolyser capacity of at least 200 MW and is expected to start operations in 2025. Air Liquide announced an investment of over EUR 400 million for its construction in September 2023.

Several large-scale projects are either undergoing feasibility studies or are in their conceptual phase. Based on the latest IEA analysis, France could produce more than 0.6 Mt of electrolytic hydrogen per year if all the planned projects start commercial operations by 2030.

In addition, early 2024 a major discovery of natural hydrogen was made in France. The discovery is at the early stages: the exact size of the underground reservoir still needs to be determined, as does the potential for extracting it economically.

Germany

Today, Germany accounts for around 40% of Northwestern Europe's operational electrolytic hydrogen production capacity. Distributed among several small-scale projects, the country has a total electrolyser capacity of approximately 120 MW.

As highlighted in last year's Hydrogen Monitor, under its National Hydrogen Strategy Update, Germany doubled its 2030 target for domestic electrolyser capacity from 5 GW to at least 10 GW.

Projects that have reached FID and/or are under construction could add close to 1.3 GW of low-emissions electrolytic hydrogen capacity by 2030. This includes the Clean Hydrogen Coastline project, advanced by EWE in Emden. In July 2024, Siemens Energy was awarded the contract to supply a 280-MW electrolysis system, expected to start operations in 2027.

Another key hydrogen project is RWE's GET H2 Nukleus, which involves developing 300 MW of electrolysis capacity in Emsland in three expansion stages by 2027. The first stage of 100 MW is to start commercial operations in 2025. Meanwhile, the SALCOS project, expected to start operations in the second half of the decade, will initially employ a 100-MW electrolyser.

In addition, there are major projects which are either undergoing feasibility studies or are in the conceptual phase. Based on the latest IEA analysis, if all projects currently under development start commercial operations by 2030, Germany could produce over 0.85 Mt of electrolytic hydrogen per year.

Luxembourg

At the time of writing, Luxembourg had not set quantified targets for low-emissions hydrogen production, but the government had stated that it aims to replace fossil fuel-based hydrogen with renewable hydrogen to reduce GHG emissions by more than 5 kt CO_2/yr.

Netherlands

The Netherlands has set a target of 3-4 GW of electrolyser capacity by 2030, with an intermediate target of 0.5 GW by 2025. At present, it has around 10 MW of operational electrolytic low-emissions hydrogen production capacity installed.

Around 230 MW of electrolyser capacity could be added by 2030 by projects that have reached FID and/or are under construction, including the Holland Hydrogen I project, which will be equipped with 200 MW of electrolyser capacity and is to be operational by 2025. The project will supply low-emissions hydrogen to Shell's Pernis refinery, and the electricity would be sourced from the future Hollandse Kust North offshore wind farm.

In September 2024, Shell and TenneT (the electricity transmission system operators [TSO]) signed a connection and transport agreement to connect the Holland Hydrogen I project to the high-voltage grid. The electrolyser will initially receive a temporary connection to the Maasvlakte high-voltage substation while it awaits commissioning of the Amaliahaven 380-kV high-voltage substation, which is to be completed by the end of 2026 and would give the project a permanent connection.

Several large-scale projects are either undergoing feasibility studies or are in their conceptual phase. If all these projects begin commercial operations by 2030, the Netherlands could produce over 0.8 Mt of electrolytic hydrogen per year, based on the latest IEA analysis.

Norway

While Norway adopted a Hydrogen Strategy in June 2020 and a Hydrogen Roadmap in June 2021, it does not have a specific production target and is taking a technology-neutral approach to low-emissions hydrogen production.

The country currently has 45 MW of electrolytic low-emissions hydrogen production capacity. Projects that have reached FID and/or are under construction are could add over 350 MW of electrolyser capacity by 2030. This includes Project Neptun, which would produce low-emissions ammonia from electrolytic hydrogen in Tromsø, a major Norwegian port and maritime hub.

In addition, there are several projects which are undergoing feasibility studies or are in conceptual phase. Based on the latest IEA analysis, if all these projects start commercial operations by 2030, Norway could produce over 0.55 Mt of electrolytic hydrogen per year.

Switzerland

In Switzerland, the Federal Council adopted a National Hydrogen Strategy in December 2024 to define guiding principles and objectives for hydrogen and hydrogen derivatives. While the strategy does not include specific targets for electrolytic hydrogen production capacity, it projects hydrogen demand of 0.8-1.8 TWh/yr by 2030 and aims to meet this demand through domestic production by the mid-2030s.

Switzerland has several electrolytic hydrogen production projects in operation, with a total capacity of a couple of megawatts. It has been developing hydrogen mobility infrastructure since 2018 through private-sector initiatives, with a focus on heavy-duty transport. Around 50 hydrogen-powered trucks are currently in operation, forming a fully integrated technical ecosystem with refuelling stations and operational infrastructure.

If all projects which are currently undergoing feasibility studies or are in conceptual phase start commercial operations by 2030, Switzerland could produce close to 5 kt/yr by 2030, based on the latest IEA analysis.

United Kingdom

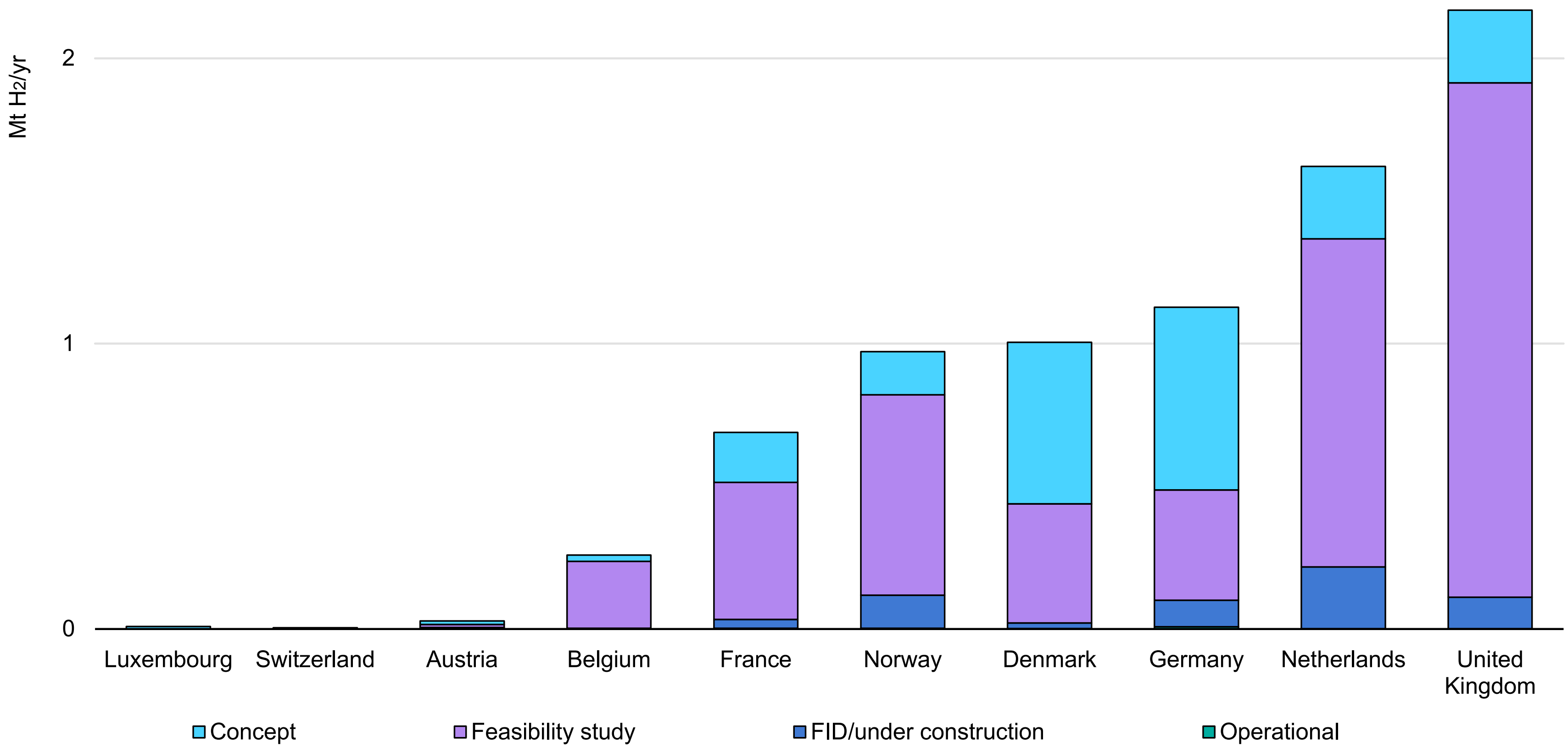
In its British Energy Security Strategy, the United Kingdom doubled its low-emissions hydrogen production ambition to up to 10 GW by 2030, with electrolytic hydrogen accounting for at least half. The Hydrogen Production Delivery Roadmap (published in December 2023) targets 6 GW of electrolytic hydrogen by 2030. The strategy set an intermediary target of 1 GW of electrolytic hydrogen capacity in construction or operational by 2025.

The United Kingdom currently has over 17 MW of electrolytic hydrogen production capacity, mostly in the form of small-scale projects. Projects selected through HAR1 will add up to 125 MW of capacity, with further allocation rounds introducing more.

There are major projects which are undergoing feasibility studies or are in conceptual phase, including giant projects such as the Kintore Scotland Hydrogen project (with a capacity of over 3 GW). If all these projects start commercial operations by 2030, the United Kingdom could produce over 0.6 Mt of electrolytic hydrogen per year, based on the latest IEA analysis.

Less than 9% of the potential production capacity by 2030 has reached FID or is under construction

Potential low-emissions hydrogen production by 2030 based on current project status, by Northwest European country



Note: FID = final investment decision.

Northwestern Europe is at the core of the European electrolyser industry

Today, Northwestern Europe is home to 85% of Europe's electrolyser manufacturing capacity, with Germany, France and Norway accounting for most of the region's electrolyser plants. In terms of technology distribution, more than 90% of European alkaline electrolyser manufacturing capacity (about 4 GW/yr) is in Northwest European countries.

Expanding the region's electrolyser production capacity could support Northwestern Europe's ambition to scale up renewable hydrogen production over the medium term and could strengthen the region's technological leadership in the emerging low-emissions hydrogen value chain. The EU Net-Zero Industry Act, adopted in 2024, aims to scale up manufacturing capacity for key net zero technologies, including electrolysers. Its goal is for at least 40% of EU deployment needs for these technologies to be produced domestically by 2030.

Taking all announced electrolyser manufacturing projects together, total production capacity in Europe could increase eightfold from the 2023 level, reaching more than 36 GW/yr by 2030. Northwestern Europe could have around 70% of this capacity, with Germany, France and Norway remaining in the lead, followed by notable capacity additions in the United Kingdom, Denmark and Belgium.

Alkaline and proton exchange membrane electrolyser technologies are expected to remain dominant, accounting for about 90% of Northwestern Europe's electrolyser manufacturing capacity by 2030. However, as a global leader in low-emissions hydrogen deployment, the region could play a central role in manufacturing new technologies currently under development, such as membrane-free electrolysers (MFE) and membrane electrode assemblies (MEA).

Company expansion plans

A handful of notable electrolyser manufacturing expansion plans across Northwestern Europe underscore the region's continued commitment to scaling up production capacities and investments in the low-emissions hydrogen supply chain. While several companies are aiming to expand their production capabilities, project delays and lower-than-expected orders led certain manufacturers to rationalise their production rates, revise their expansion plans downward and, in some cases, file for in-court restructuring.

In **Germany**, thyssenkrupp nucera plans to expand its electrolyser manufacturing capacity from 1 GW/yr today to 5 GW/yr by 2030. In 2021, the company secured a contract to supply the NEOM low-emissions hydrogen project with large-scale 20-MW alkaline water electrolysis modules. The project's overall capacity is just over 2 GW. At the end of September 2024, thyssenkrupp nucera had delivered about half of the alkaline electrolysers ordered by the NEOM project. The company has also secured several other orders, including from green steelmaker Stegra (750 MW) and from Moeve (300 MW).

However, thyssenkrupp nucera reported a 95% year-on-year decline in new orders for its green hydrogen business in Q1 of the 2024-25 fiscal year.

Thyssenkrupp nucera is central to the German Federal Ministry of Education and Research's hydrogen lead projects initiative, which includes the H2Giga project (manufacturing of large-scale water electrolysers), H_2Mare (the production of synthetic fuels, green ammonia, green methanol and synthetic methane at sea) and TransHyDE (hydrogen transport and conversion technologies such as ammonia cracking). In March 2024, thyssenkrupp nucera and Fraunhofer IKTS launched a strategic partnership to develop and mass-produce solid oxide electrolyser cells (SOECs), aiming to reach 1 GW/yr of capacity by 2030.

Meanwhile, Germany's Quest One (previously H-Tec Systems) inaugurated a PEM electrolyser manufacturing facility in Hamburg in late 2024. The company had planned to expand production capacity to 5 GW/yr, but it is challenged by overcapacity in the electrolyser manufacturing sector and slower-than-expected hydrogen industry ramp-up.

Outside of Germany, the **John Cockerill** company's Franco-Belgian European Gigafactory comprises two operation sites for electrolyser production. The Aspach facility in France has been producing cells since 2023, while the Seraing plant in Belgium assembles them. The company is targeting 1 GW/yr of production capacity in Europe by the end of 2025.

In **Denmark**, Topsoe is building the world's first commercial-scale SOEC manufacturing plant, with operations expected to begin in 2025. The facility will have an initial production capacity of 0.5 GW/yr, but Topsoe is planning to scale up SOEC production to 1.2 GW/yr by 2031, solidifying the company's leadership in high-efficiency electrolyser technology.

Also in Scandinavia, **Norway**'s Nel doubled its annual alkaline electrolyser manufacturing capacity from 500 MW to 1 GW in 2024. The new 500-MW automated production line at the Herøya factory started commercial operations in Q2 2024, but in January 2025 Nel decided to temporarily halt manufacturing at the facility because orders were lower than expected in 2023 and 2024.

Similarly, in **Denmark** the financial performance of electrolyser producer Green Hydrogen Systems deteriorated due to a lack of orders and projects delays. In fact, in April 2025 the company announced it was filing a petition for in-court restructuring of the company, to be prepared under the Danish Insolvency Act.

Meanwhile, the **United Kingdom** is providing support for hydrogen production and related supply chain development to advance its growth mission – creating high-quality jobs, boosting domestic production and reducing carbon emissions. It is home to ITM, a PEM electrolyser manufacturing company. Nearly all the company's current manufacturing is exported, with projects and partnerships in Europe, Asia and North America. At present, around 90% of its sales are exports and it has global partnerships (e.g. Sumitomo in Japan).

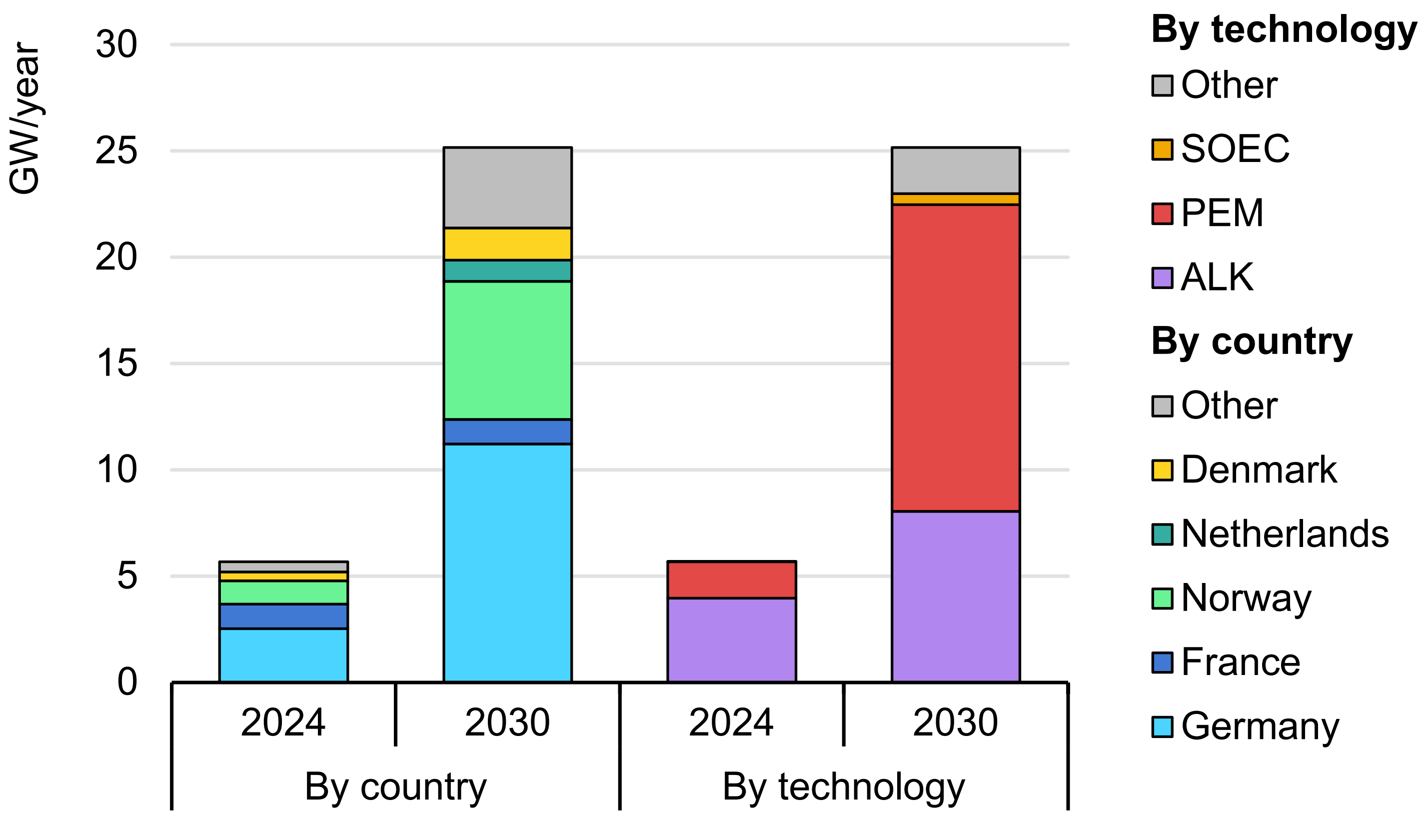
Also headquartered in the United Kingdom, Ceres Power is licensing its SOEC technology to partners in Asia. Agreements are in place with Delta Electronics in Taiwan, DENSO in Japan, and Thermax in India. These agreements support local manufacturing and deployment of SOEC systems in these markets.

Another UK-based company, Oort Energy, supplies containerised PEM electrolysers to international demonstration projects. A recent partnership with Chariot and a Moroccan University is focused on pilot-scale deployment and technology validation in North Africa.

INEOS Inovyn, also based in the United Kingdom, provides industrial-scale electrolysers for chemical production facilities abroad. In India, it has supplied BICHLOR electrolysers for a new chlor-alkali chemical plant in the south of the country and for an expansion project with Tamilnadu Petroproducts in Chennai.

Northwestern Europe has 85% of European electrolyser manufacturing capacity

Electrolyser manufacturing capacity in Northwestern Europe by country and technology based on announced projects, 2024-2030



Notes: ALK = alkaline electrolyser. PEM = proton exchange membrane electrolyser. SOEC = solid oxide electrolyser cell.
Source: IEA analysis based on announcements by manufacturers and personal communications.

Production costs and price discovery

Fossil fuel-based hydrogen production costs continued to decline in 2024…

The reduction of production costs would be crucial to enable the large-scale deployment of low-emissions hydrogen. This section provides an overview of recent Northwest European hydrogen production cost dynamics and initial price discovery, and an outlook to 2030.

Most hydrogen in Northwestern Europe is currently produced via steam methane reforming or autothermal reforming (ATR). Natural gas typically accounts for around 70% of the levelised cost of production and about 80% of operating expenses. The 2022/23 gas supply shock profoundly affected hydrogen production costs, as natural gas prices on TTF – Europe's most liquid hub – surged to all-time highs, averaging USD 41/MBtu (EUR 39/MBtu) in 2022.

In addition, higher carbon prices exerted further upward pressure on unabated gas-based hydrogen production costs. Consequently, the assessed levelised cost of gas-based hydrogen production (LCOH) via unabated SMR rose from USD 2.8/kgH_2 (EUR 2.4/kg/H_2) in 2021 to over USD 5/kgH_2 (EUR 4.8/kgH_2) in 2022. This hike was primarily driven by the surge in natural gas prices,[3] which alone caused almost 90% of the increase in estimated hydrogen production costs.

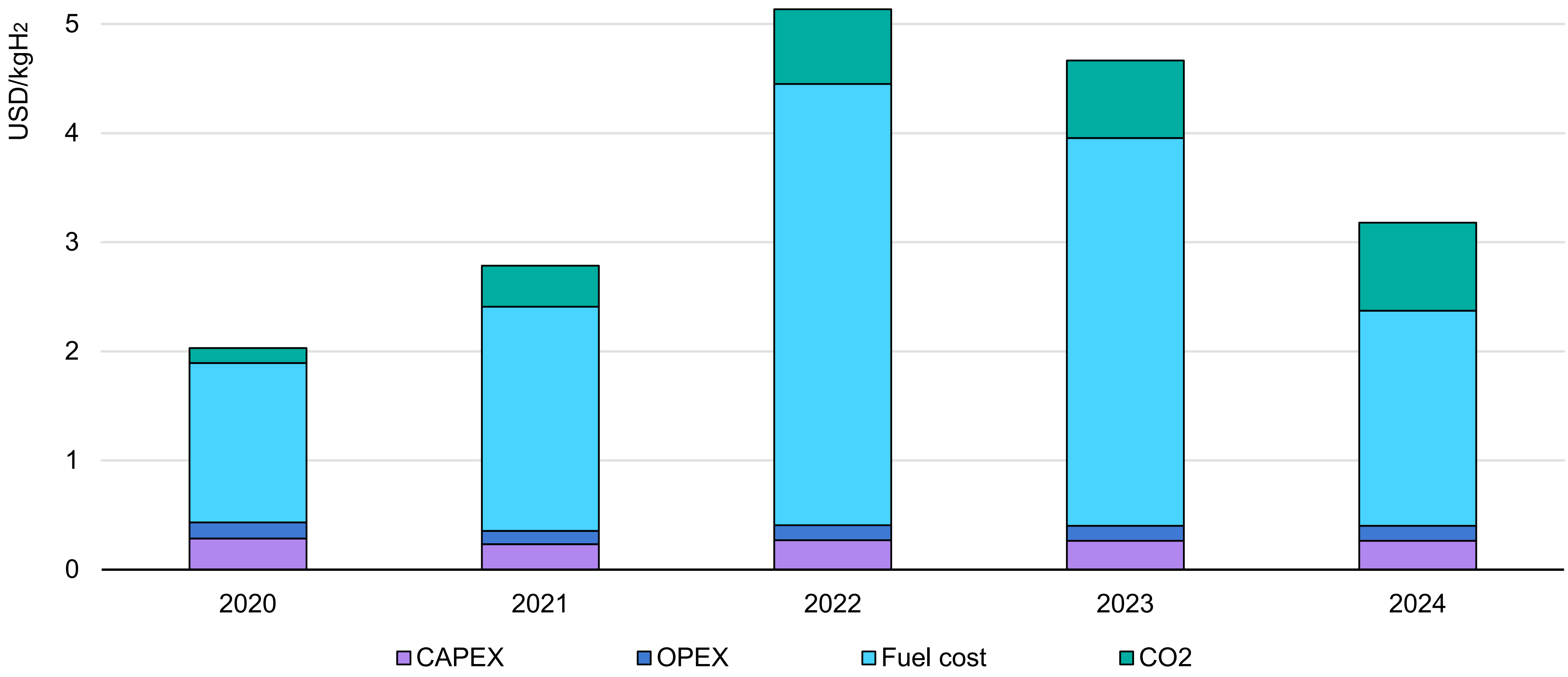
In 2023, TTF prices fell almost 70% from 2022 to average USD 13/MBtu (EUR 12/MBtu) as continued demand reductions, lower storage injections and healthy liquefied natural gas (LNG) inflows altered market fundamentals. Consequently, the assessed LCOH of unabated gas-based hydrogen production declined and averaged just above USD 4.5/kgH_2 (EUR 4.2/kgH_2). This trend continued in 2024, with TTF prices dropping 15% from 2023, to average USD 11/MBtu (EUR 10/MBtu) amid improving supply fundamentals and lower storage injection needs. This in turn weighed on the assessed LCOH of unabated gas-based hydrogen, which dropped to an average of USD 3.2/kgH_2 (EUR 2.9/kgH_2) in 2024 – albeit remaining almost 15% above the 2021 level.

In comparison, the estimated levelised cost of hydrogen production based on solar PV-powered electrolysis prices in 2024 varied within the wide range of USD 8-16/kgH_2 (EUR 7.5-15/kgH_2), while the estimated LCOH using wind power-based electrolysis was USD 5.7-7.6/kgH_2 (EUR 5.3-7/kgH_2). The estimated LCOH for gas-based production with CCUS was just below USD 3.5/kgH_2 (EUR 3.2/kgH_2). Hence, low-emissions hydrogen production routes were still not competitive with unabated production in Northwestern Europe in 2024.

[3] The natural gas prices used for this analysis are based on estimated industrial end-use prices.

…primarily driven by lower fuel costs

Estimated levelised cost of gas-based hydrogen produced via SMR without CCUS, 2020-2024



Notes: SMR = steam methane reforming. CCUS = carbon capture, utilisation and storage. CAPEX = capital expenditures. OPEX = operating expenses.

Low-emissions hydrogen could become cost-competitive by 2030

Initial price discovery for low-emissions hydrogen production is an important foundation for market scale-up and for investment decisions. In Germany in May 2023, the European Energy Exchange launched HYDRIX, a price index for renewable hydrogen. HYDRIX is based on actual price assessments from renowned and established market participants in the industry and is quoted in EUR/MWh. Renewable hydrogen prices on HYDRIX averaged nearly EUR 240/MWh (USD 7.7/kgH_2) in 2024 – close to the May-December 2023 levels. Hence, renewable hydrogen prices were almost 2.5 times the estimated levelised cost of unabated gas-based hydrogen and three times above German power prices. This highlights the need to improve the cost-competitiveness of low-emissions and renewable hydrogen.

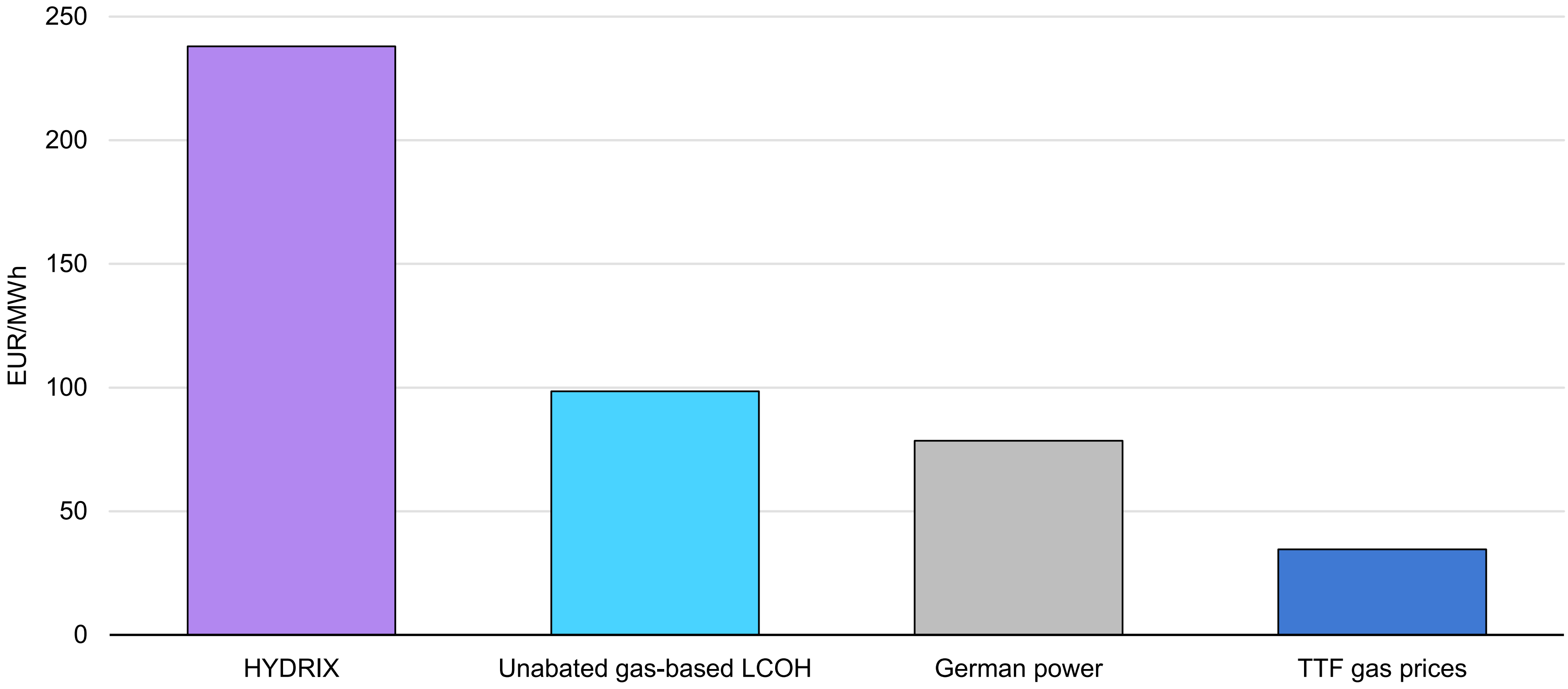
Hydrogen production cost outlook in Northwestern Europe

Hydrogen produced from natural gas with CCUS could become cost-competitive with unabated gas-based hydrogen in Northwestern Europe by 2030. Under the Stated Policies Scenario (STEPS), wind-based electrolytic hydrogen production costs could be in the range of USD 3.6-5.2/kgH_2 (EUR 3.2-4.7/kgH_2). [4] Natural gas with CCUS could be the cheapest source of low-emissions hydrogen at USD 2.1-3.1/kgH_2 (EUR 1.9-2.8/kgH_2), close to the cost of natural gas without CCUS (which we estimate at around USD 2.1-3.5/kgH_2 or EUR 1.9-3.1/kgH_2), assuming that CO_2 prices reach USD 140/t CO_2. Declining electrolysis and renewable technology costs are the key catalyst for the expected drop in low-emissions hydrogen production costs (even though the cost of capital and higher raw material prices led to an upward revision of projected production costs from last year's Hydrogen Monitor). Anticipated carbon price increases would also make low-emissions hydrogen more competitive. For example, the total cost of installing a European- or American-manufactured electrolyser is expected to decline more than 40% over the outlook period, from USD 2 000-2 400/kW in 2024 to USD 1 200-1 400/kW by 2030 in STEPS. The share of CAPEX in the LCOH of offshore wind-based electrolytic hydrogen production is also expected to decline, from almost 40% in 2024 to around 33% in 2030 as electrolyser capital costs decrease. For gas-based hydrogen production, the higher CAPEX and OPEX costs associated with CCUS systems are expected to be more than offset by higher carbon prices. Cost reductions in the STEPS, together with a carbon price of over USD 140/t CO_2-eq, could ensure that the levelised cost of gas-based low-emissions hydrogen approaches (and in certain cases drops below) that of unabated gas-based hydrogen in the region.

[4] At the 15 May 2025 exchange rate.

Renewable hydrogen currently has a significant price premium compared with unabated gas-based hydrogen and alternative energy carriers

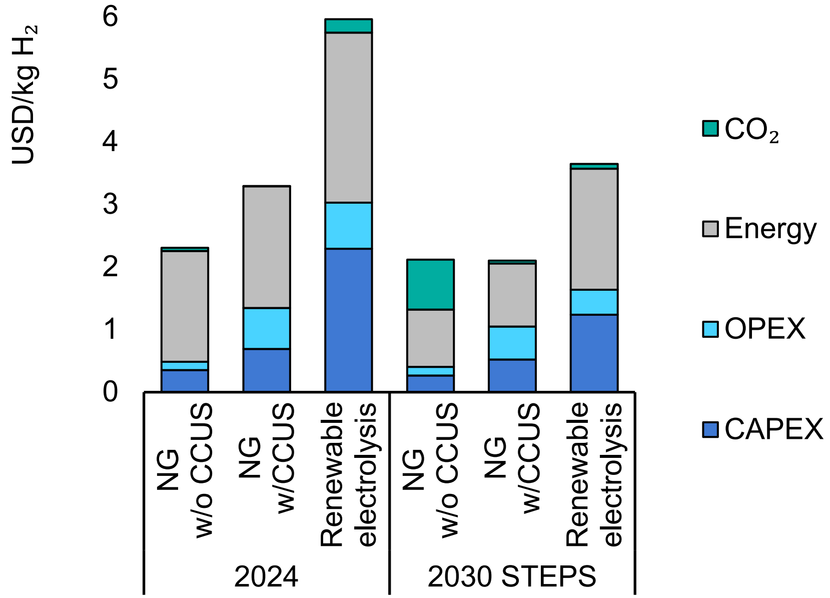
Renewable hydrogen HYDRIX price; German power prices; TTF gas prices; and unabated gas-based LCOH, 2024



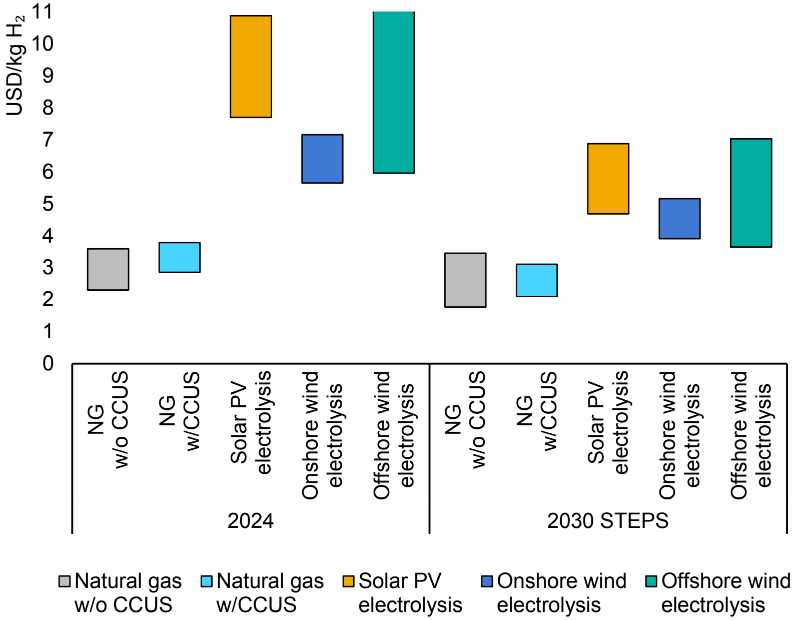
Notes: LCOH = levelised cost of hydrogen. Unabated gas-based LCOH values are estimates.

Low-emissions hydrogen production costs could fall sharply by 2030

Cost-component breakdown for selected technologies, Northwestern Europe, 2024-2030



LCOHs for selected technologies, Northwestern Europe, 2024-2030



Notes: STEPS = States Policies Scenario. NG = natural gas. CCUS = carbon capture, utilisation and storage. w/ = with. w/o = without. CAPEX = capital expenditures. OPEX = operating expenses. Renewable technologies considered include onshore and offshore wind. For electrolysis, CAPEX refers to the installed electrolyser system, while the renewable system cost is factored into the energy-cost component. For techno-economic assumptions, please refer to the Annex of the Global Hydrogen Review 2024.

Hydrogen trade

The low-emissions-hydrogen trade market is developing but remains nascent

Cross-border trading of pure hydrogen is still at a nascent phase and therefore remains limited. In fact, most existing cross-border trade in hydrogen (non-low-emissions) is confined to a few pipelines connecting industrial areas in Belgium, France and the Netherlands, but a few pilot projects have demonstrated the feasibility of transporting hydrogen by ship. In contrast, ammonia and methanol – mostly produced from unabated fossil fuels – are traded globally as a feedstock for the chemical industry. Around 20 Mt of ammonia per year (or 10% of global production) is shipped internationally.

In Northwestern Europe, the Antwerp-Rotterdam-Rhine-Ruhr area is at the centre of hydrogen production and demand. The region accounts for approximately 40% of EU chemical production, for which hydrogen is used as a feedstock. It is also well placed to become a future hub for trading low-emissions hydrogen (and hydrogen derivatives), with its well-developed port infrastructure and access to international routes. Indeed, the ports of Rotterdam, Antwerp and Hamburg, among others, have already been working on strategic plans to position themselves as key import hubs for hydrogen and its derivatives. In addition, several memorandums of understanding (MoUs) have been signed with counterparts in prospective export countries.

Pilot shipments of low-emissions hydrogen derivatives took off in 2023 and 2024

Over the course of 2023 and 2024, several pilot projects completed initial shipments of low-emissions hydrogen-based fuels and derivatives, mainly from the Middle East to destinations in the Asia Pacific region. In North West Europe, Yara commissioned a 24 MW electrolyser at Herøya in Norway, and started supplying fertiliser made from low-emissions ammonia to the Lantmännen agricultural cooperative in Sweden in June 2024.

Based on the announced projects that aim to trade hydrogen or hydrogen-based fuels and its derivatives, 8 million tonnes of hydrogen equivalent (Mt H_2-eq) could be moved around the globe by 2030. Export-oriented projects represent about 20% of the low-emissions hydrogen that could be produced by all the announced production projects by 2030 (41 Mt), indicating that the potential export market is a driver in the development of projects, although very few are at advanced stages. Only a small number of projects for trade have reached final investment decision, all for the trade of ammonia. The share of committed volume, i.e. projects that have at least reached FID or are under construction, is still very low, at less than 5% of the total volume that could be traded by 2030.

About half of the export-oriented projects to 2030 are at early stages of development, while the other half are undergoing feasibility studies. Of this, less than one-third has identified a potential offtaker, and only few have signed a binding offtake agreement. The NEOM Green Hydrogen Company, developer of the homonym project in Saudi Arabia, has signed a 30-year offtake agreement with Air Products for the supply of low-emissions ammonia from 2026 onwards. Securing long-term offtake contracts is a fundamental condition for the projects to move ahead and to guarantee economic sustainability.

Northwestern Europe will be pivotal in the development of low-emissions hydrogen trading

Almost half of the export-oriented projects by 2030 have defined a destination. Countries of the Northwestern European region account for close to 60% of global import volume by 2030 for which a final destination has been identified. The Netherlands, Germany and Belgium, with their industrial activity and the developed port infrastructure, are the preferred destinations for export-oriented projects, and account for the majority of the 2.3 Mt H_2-eq that Northwestern Europe could receive by 2030 according to the announced projects. In fact, this figure has fallen since the last edition of this report. This is largely due to the uncertain outlook for several projects originally intended for export to Northwestern Europe and other regions. Some of these projects have been cancelled, while for others it is not clear whether they will be operational before 2030 as previously expected according to their announcements. In addition, the high share of projects at early stage of development, without a defined destination nor offtake agreements leave high uncertainty about the deployment of trade by 2030.

Of all potential trading regions, intra-European trade accounts for the largest share of projects targeting exports to Northwestern Europe, representing around 20%. This includes projects within Northwestern Europe itself, such as from Denmark or Norway – e.g. the Norwegian Barents Blue project for ammonia exports to the Port of Rotterdam – as well as from Southern Europe, notably the Iberian Peninsula. The Americas, both North and South America, Africa and the Middle East could also be main export regions to supply low-emissions hydrogen and hydrogen-based fuels to Northwest Europe by 2030, based on announced projects.

Northwest European countries are actively investigating low-emissions hydrogen import opportunities

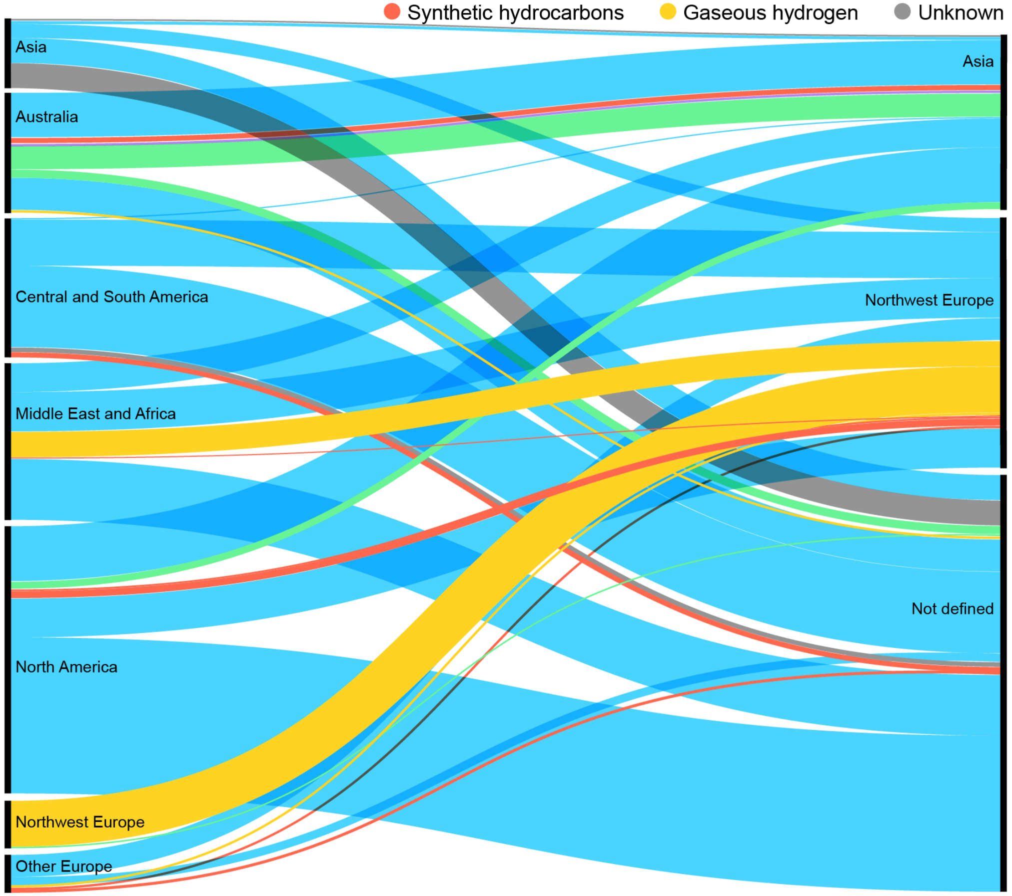
Selected trade-oriented pilot projects in Northwest European countries, 2023-2024

Countries involved	Year	Description
Norway to Sweden	2024	The first batch of low-emissions fertilisers produced from electrolytic ammonia at Yara's plant in Norway has been delivered to Swedish company Lantmannen.
Netherlands to Germany	2023	OCI Global supplied 800 tonnes of bio-ammonia to German chemical company Rohm.
Chile to United Kingdom	2023	Chile's Haru Oni plant has shipped 2 600 litres of synthetic gasoline to England.
Saudi Arabia to European Union	2023	Saudi Arabian Maaden and trading company Trammo have signed an agreement to ship low-emissions ammonia to Europe.

Source: IEA analysis based on company announcements.

Northwestern Europe could become central to hydrogen trade

Potential low-emissions hydrogen trade flows by carrier based on announced projects, 2030



Notes: LOHC = liquid organic hydrogen carrier. "Northwestern Europe" refers to Austria, Belgium, Denmark, France, Germany, Luxemburg, the Netherlands, Norway, Switzerland and the United Kingdom. In million tonnes of hydrogen equivalent, only flows larger than 150 kt H_2-eq/yr are shown.

Source: IEA (2024), Global Hydrogen Review 2024.

Offtake agreements will be key to scale up low-emissions hydrogen trading

Considering the high upfront investment costs for facilities producing trade-oriented low-emissions hydrogen (or derivatives), project developers will understandably try to mitigate investment risks. Long-term offtake contracts essentially function as a risk-sharing mechanism between project developers and buyers, and can be underpinned by a range of mutually agreed commitments:

- **Term commitment**: The duration of the contract, which could be more than a decade, should allow the project developer to recover high initial upfront investment costs through a stable revenue stream.
- **Volume commitment**: The buyer commits to take a certain volume of low-emissions hydrogen (or derivatives) per year over the entire duration of the contract.
- **Price commitment**: The negotiated price (or pricing formula) is usually applicable for the entire duration of the contract.
- **Destination commitment**: The contract typically stipulates a delivery point for the low-emissions hydrogen (or derivatives). A varying degree of destination flexibility can be incorporated into long-term contracts, depending on seller and buyer preferences.

Government support will be required to kickstart the development of low-emissions hydrogen trading

While future costs for low-emissions hydrogen production are expected to decline gradually by the end of the decade, the offtaker may initially face a cost disadvantage compared with traditional unabated fossil fuel-derived hydrogen. Hence, government intervention to bridge the disparity between production costs and purchase price would facilitate the initial deployment of low-emissions hydrogen (and derivatives) trading.

Instruments such as auctions can be used to create bidding competition for contracts and help close the gap between demand and supply prices in a competitive way. Currently, the most developed support programme for hydrogen trading is Germany's H2Global double-sided auction system. Through a market intermediary, HINT.CO, a first auction was held in December 2022 to purchase hydrogen derivatives - renewable ammonia, synthetic methanol and synthetic kerosene - through fixed price 10-year contracts, from suppliers outside the European Union. In parallel, on the demand side, a separate auction will be held to sell the hydrogen derivatives to buyers with shorter contracts of about 1 year. First results were announced in July 2024.

Fertiglobe was awarded the lot to supply renewable ammonia, with the first shipments scheduled to arrive at European ports from Egypt in 2027. Under the contract, Fertiglobe could supply an initial 19 000 tonnes of renewable ammonia in 2027, with total deliveries rising to a cumulative 397 000 tonnes by 2033. The estimated delivered price is EUR 1 000/t NH_3.

In December 2024, the European Commission approved a second round of H2Global auctions with a maximum budget of EUR 3 billion – EUR 2.7 billion from Germany and EUR 300 million from the Netherlands. Hintco launched the second H2Global tender in February 2025, with the supply-side auction organised into five lots. The total budget allocation is EUR 2.5 billion, with the potential to increase it to EUR 3 billion. The regional lots were allocated a minimum of EUR 484 million, while the global lot received a minimum of EUR 567 million. The global lot is funded jointly by the governments of Germany and the Netherlands (see the table below for an overview of the auction lots).

In addition, the European Commission is planning to launch a hydrogen pilot mechanism by September 2025 under the European Hydrogen Bank, aiming to connect international hydrogen producers with European offtakers. The mechanism will gather expressions of demand-side interest from buyers throughout Europe (not just the European Union) and then will allow producers (European and international) to respond with supply offers. The pilot mechanism is expected to enhance transparency, improve market discovery and effectively match prospective supplies of low-emissions hydrogen (and derivatives) with end users. Establishing market structures for demand aggregation is a key step in developing international supply chains to support EU ambitions to import large quantities of low-emissions hydrogen.

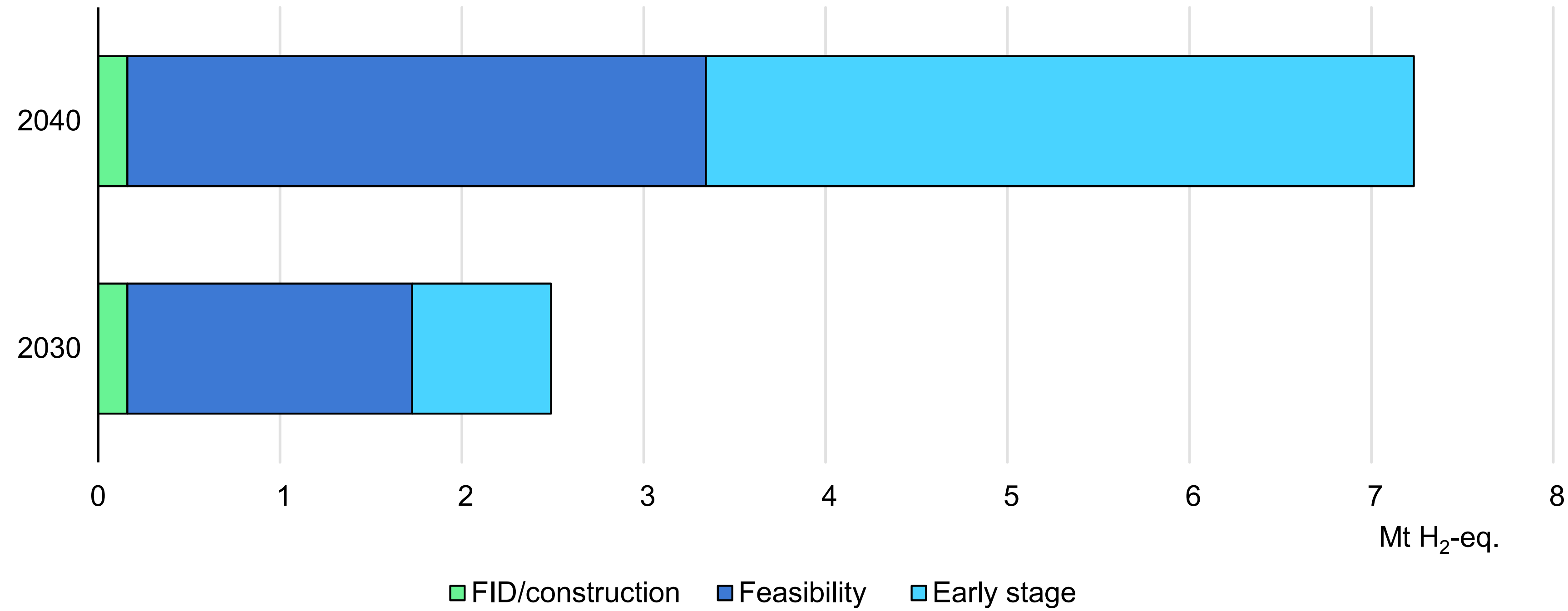
Overview of lots of the second H2Global tender

	Lot	Fund provider for cost gap	Lot type	Delivery point
Regional	• Africa • Asia • North America • South America and Oceania	Germany	Product-open	Germany
Global	Global (projects located in Germany, the Netherlands and in sanctioned countries are ineligible to participate	Germany and the Netherlands	Vector-open	Germany and the Netherlands

Notes:
Product-open lots allow bidders to supply hydrogen, ammonia, or methanol as final products.
Vector-open lots are limited to hydrogen as the final product.
Suppliers are free to choose preferred transport methods (e.g., LOHC, ammonia) in both types of lots, provided that the required final product is extracted or converted back before delivery.

Only a few projects targeting low-emissions hydrogen trade have moved to FID

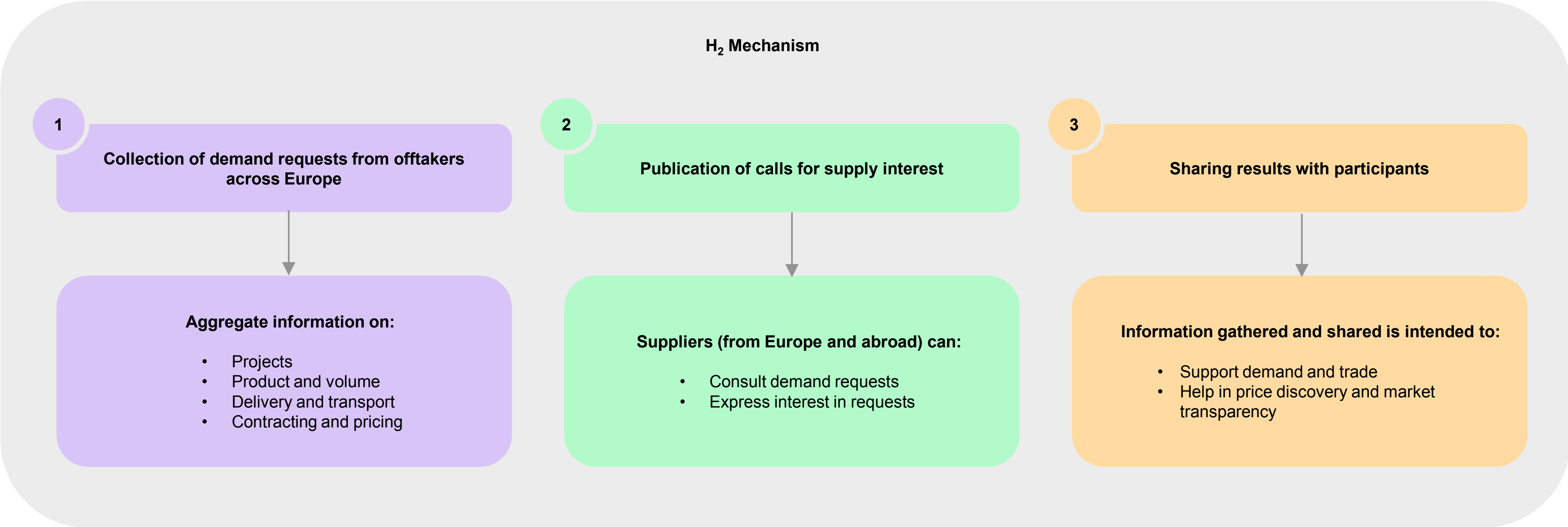
Northwestern European low-emissions hydrogen trade by status, based on announced projects, 2030-2040



Notes: FID = final investment decision. The amount of hydrogen equivalent traded is computed from the capacity of each plant, by considering average capacity factors (reported in the technical documentation of the IEA Hydrogen Projects Database) and by assuming that a certain share of production would be available for trade, in the case of projects aiming at multiple end uses. For each project, a 50% availability factor is assumed for the first year of operation. Only projects with a disclosed start year are included.
Source: IEA (2024), Global Hydrogen Review 2024.

The European Commission's planned pilot hydrogen mechanism aims to connect prospective suppliers and consumers of low-emissions hydrogen (and derivatives)

Simplified scheme of the European Commission's planned hydrogen mechanism



Source: Adapted from the European Commission's presentation, IEA (2025), IEA Low Emissions Gases Day 2025.

Infrastructure

Adequate infrastructure will be essential to scale up the low-emissions hydrogen market

The large-scale use of low-emissions hydrogen will not be possible without an effective and cost-efficient transmission and distribution system to connect supply sources to demand centres. Deployment will also require the development of large-scale, cost-effective, long-term storage solutions. Sufficient storage will be crucial for low-emissions hydrogen to reach its full potential as an energy carrier, allowing it to respond to the evolving flexibility requirements of a more complex energy system. In Northwestern Europe, the development of port infrastructure able to handle hydrogen (and its derivatives) could ensure the scale-up of long-distance, low-emissions hydrogen (and derivatives) imports.

The following section therefore reviews the current state of hydrogen infrastructure and development prospects in Northwestern Europe, with a particular focus on transmission systems and underground storage facilities. For further details on hydrogen infrastructure developments, please refer to the IEA [Hydrogen Infrastructure Projects Database].

The current state of hydrogen infrastructure in Northwestern Europe

Approximately 5 000 km of hydrogen pipelines are currently in operation worldwide, mainly in the United States and Europe. The first hydrogen pipeline, commissioned in 1938 in the Rhine-Ruhr region of Germany, is still in operation. The ten countries considered in the Hydrogen Monitor have approximately 1 600 km of hydrogen pipelines in operation, with over 95% of them located in Belgium, France, Germany and the Netherlands. Most are closed systems owned by large merchant hydrogen producers and are concentrated near industrial consumer centres. The majority of these pipelines were built as dedicated infrastructure for the transport of hydrogen. These pipelines are privately owned, have relatively small diameters, connect refineries and chemical complexes onshore, and operate under constant loads.

According to announcements, future hydrogen pipelines are expected to be significantly larger, connecting countries and even continents, including offshore routes. These new systems would offer greater flexibility, with the ability to handle pressure fluctuations from cyclic loading and provide linepack. Such a hydrogen transmission network would be very different from today's local systems and would more closely resemble today's natural gas transmission, albeit with a more centralised configuration and serving a smaller number of large industrial users.

In addition, several projects aiming to repurpose existing natural gas pipelines to hydrogen are being considered. The first gas pipeline repurposing project was undertaken by the Netherlands, with the 12 km Yara-Dow pipeline, put into commercial hydrogen service in November 2018. In early 2025, Ontras completed the hydrogen filling of a 25 km natural gas pipeline repurposed for hydrogen transport, while Nowega and GASCADE started commissioning activities by initiating the hydrogen filling of 55 km and 400 km, respectively, of mostly repurposed natural gas pipelines.

Hydrogen storage in salt caverns has been used by the petrochemical industry since the early 1970s. In Northwest Europe the only one operational hydrogen salt cavern facility is located in the United Kingdom and commissioned in 1972. Whilst the technology is already available, ongoing research is focused on testing fast cyclic loading and unloading, as well as evaluating the possibility of repurposing salt caverns previously used for natural gas storage for hydrogen. To date, experience of storing pure hydrogen in porous reservoirs such as depleted fields or aquifers remains limited. However, from the 1950s to the 1980s, several porous reservoirs were used commercially to store town gas containing 50-60% hydrogen.

Northwestern Europe has set ambitious targets for hydrogen network development by 2030

Based on pipeline project announcements, the length of the region's hydrogen network could reach around 13 000 km by the early 2030s. However, despite the ambitious targets being assessed by gas transmission system operators, the number of pipeline projects that have reached FID and/or are under construction remains limited.

In fact, according to the IEA Hydrogen Infrastructure Projects Database, only 6% of the hydrogen pipeline projects announced (measured by length) have reached FID, and another 5% are at the front-end engineering design stage. Almost 90% of the hydrogen pipelines being considered remain either at the conceptual phase or are undergoing feasibility studies.

Repurposing existing methane pipelines to transport hydrogen can result in substantial cost savings and shorter lead times compared with new-build hydrogen networks. This could in turn translate into lower transmission tariffs and improve the cost-competitiveness of low-emissions hydrogen. Almost half of the hydrogen pipelines that could be operational by 2030 could be repurposed natural gas pipelines.

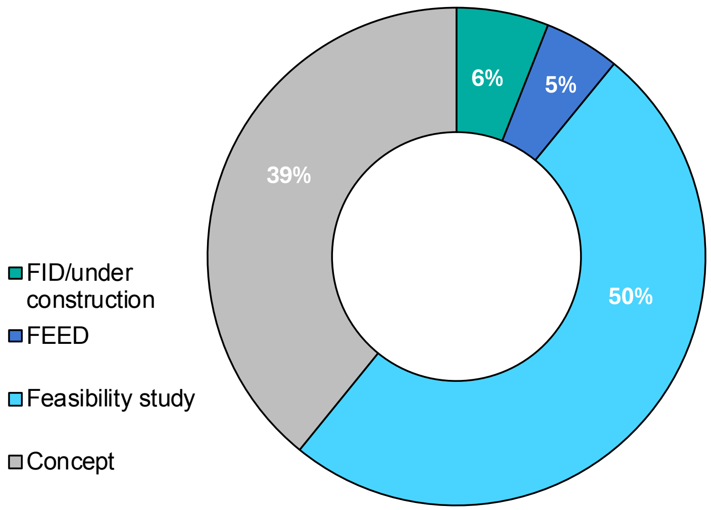
Assuming that hydrogen pipelines have similar lead times as natural gas transmission systems, it could take on average six years from the conceptual phase to the start of commercial operations to develop a new-build hydrogen pipeline. Hence, concentrated and immediate action by all stakeholders would be required to meet the targets set for 2030.

While no specific EU-wide target exists, various support mechanisms are in place to promote hydrogen infrastructure development. In November 2023 the European Commission published a list of Projects of Common and Mutual Interest (PCI/PMI). Of the 166 projects selected, 31 relate to hydrogen pipeline development. The selected projects will benefit from regulatory support (including streamlined permit-granting) and could apply for EU financing from the Connecting Europe Facility (CEF), which provides grant funding to support development studies of cross-border hydrogen infrastructure.

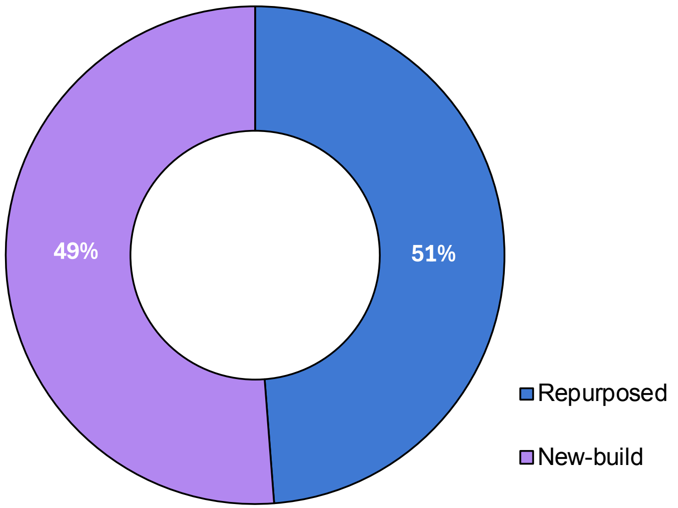
In November 2024, the Commission approved a third Important Project of Common European Interest (IPCEI) to expand hydrogen infrastructure. The IPCEI Hy2Infra project aims to support: 1) the deployment of 3.2 GW of large-scale electrolysers to produce renewable hydrogen; 2) the deployment of approximately 2 700 km of new and repurposed hydrogen transmission and distribution pipelines; 3) the development of large-scale hydrogen storage facilities with total capacity of at least 370 GWh; and 4) the construction of handling terminals and related port infrastructure for liquid organic hydrogen carriers (LOHC) to handle 6 000 tonnes of hydrogen per year.

Most hydrogen pipeline projects are still at early phases of development

Announced hydrogen pipeline projects in Northwestern Europe by 2030, by status



Announced hydrogen pipeline projects in Northwestern Europe in 2030, by origin



Notes: FID = final investment decision. FEED = front-end engineering design.

Austria

Austria's gas market and distribution area manager's (AGGM) Hydrogen Roadmap was updated in 2024 to reflect the most recent developments and expectations.

The Hydrogen Roadmap 2.0 foresees gradual development of Austria's hydrogen network: by 2029, around 150 km of hydrogen distribution lines could be in operation (more than half of them repurposed). In the second phase (2030-2034), over 700 km of hydrogen transmission pipelines could enter into service, complemented by more than 970 km of hydrogen distribution pipelines. Finally, the Hydrogen Roadmap 2.0 expects 730 km of hydrogen transmission pipelines by 2040, with almost 70% repurposed from existing natural gas pipelines.

Austria's key hydrogen transport projects are:

- H2 Collector East: a 100% hydrogen-ready gas pipeline to be built in eastern Austria – partly by adapting existing infrastructure. From 2026, renewable hydrogen is to be transported from northern Burgenland to Lower Austria and Vienna.
- H2 Backbone WAG + Penta-West: a project to create cross-border hydrogen transport possibilities of up to 150 GWh/day between Slovakia and Austria and between Austria and Germany, with hydrogen being transported in both directions. More than 200 km of new pipeline could be built, and 140 km of the existing pipeline could be repurposed. The project has received PCI status.
- H2 Readiness of the TAG pipeline system: a scheme to convert one of the three methane pipelines of the existing Trans Austria Gasleitung (TAG) pipeline system into a hydrogen pipeline. It also intends to create a hydrogen transport corridor between Austria and the neighbouring countries of Italy and Slovakia. The project has received PCI status.

Belgium

Belgium has over 600 km of operational hydrogen pipelines, with junctions around the ports of Ghent (North Sea Port) and Antwerp. Belgium's first hydrogen pipelines were constructed in 1938 and were further developed during the 1960s and 1970s.

As noted in the federal government's October 2021 hydrogen strategy, Belgium is positioning itself as a relevant import and transit hub for low-emissions hydrogen. The government expects the future hydrogen network to connect the ports of Zeebrugge, Ghent and Antwerp with the country's industrial areas and adjacent countries. Central to this strategy is the development of a regulated, open access hydrogen transport network. The government expects this future hydrogen network, which is recognised as an IPCEI project, to connect the ports of Zeebrugge, Ghent and Antwerp, including import terminals, with the country's industrial areas and the adjacent countries.

In April 2024, Fluxys hydrogen was appointed as the hydrogen network operator for the development and management of this regulated hydrogen transmission grid. In March 2025, Fluxys announced the start of construction of the first phase of its hydrogen pipeline network. The first pipelines will be built in the port area of Antwerp and connecting this port with the Ghent area. The first phase is expected to be ready by mid-2026 and the pipelines will be built with multi-purpose technology. The federal government provides support for these initial investments through the European "Resilience and Recovery Fund". A next phase will focus on strengthening the network in and between industrial clusters and interconnecting with the networks of neighbouring countries.

In addition, Belgium's gas TSO, the Port of Antwerp, the Port of Zeebrugge and other relevant partners are part of the Green Octopus 2.0 initiative, which aims to advance the formation of an integrated hydrogen market between Benelux, Germany and France, fostering cross-border co-operation.

Denmark

In May 2023, the Danish government selected Energinet (the TSO) and Evida (the DSO) as the owners and operators of the future hydrogen network. Energinet will have system responsibility for Denmark's hydrogen transmission network and will be responsible for connecting cross-border hydrogen infrastructure and connections to hydrogen storage facilities. Evida will be tasked with connecting domestic hydrogen producers and consumers.

Energinet is considering export options for low-emissions hydrogen. In November 2023 Energinet and Gasunie agreed on the next steps to develop a Danish–German hydrogen network as part of a co-operation agreement.

In February 2025, a broad-ranging hydrogen agreement was reached in Denmark to support the development of a hydrogen pipeline from Esbjerg to the German border. Under the arrangement, the Danish state would provide a loan of EUR 991 million and up to EUR 1.11 billion in operational subsidies to establish the hydrogen pipeline. Booking requirements for the planned pipeline were reduced to 0.5 GW from the initial 1.4 GW, which could facilitate realisation of the project's first phase.

France

France has over 300 km of operational hydrogen pipelines. Based on project announcements, almost 1 000 km of hydrogen pipelines could be developed by 2030, comprising new infrastructure and natural gas network conversions.

Although the European Commission included France's key hydrogen pipeline projects in its November 2023 PCI list, none have yet reached FID:

- The mosaHYc (Moselle Saar HYdrogen Conversion) project is being developed in a partnership of NaTran (formely GRTGaz), Creos Deutschland Wasserstoff GmbH (the hydrogen-focused subsidiary of Creos Deutschland, a

Saarland-based network operator) and SHS - Stahl-Holding-Saar GmbH & Co. KGaA (Germany's third-largest steel producer). The partners will build a 90-km hydrogen pipeline (70 km converted natural gas pipeline) to connect the first industrial consumer – the ROGESA steelmaking factory in Dillingen – to hydrogen producers. The pipeline will have a transport capacity of up to 50 000 tonnes of hydrogen per year. The companies reached an FID in April 2024 and the project is to commence in 2027.

- In April 2022 GRTgaz (now NaTran) announced its RHYn project, which aims to promote hydrogen use in the Upper Rhine region by connecting the Dessenheim area with the Chalampé-Ottmarsheim industrial zone by 2028, as well as the Mulhouse agglomeration for its mobility needs. Of a total 100 km of hydrogen pipelines, at least 60 km will be converted lines.
- NaTran's DHUNE project is planned for the Dunkirk industrial zone, with an extension to Belgium. The initial length of the project would be 10 km, and in early 2024 NaTran launched the front-end engineering and design phase. An investment decision is expected in 2025.
- NaTran's HY-FEN project would run between Fos-Marseille and the Grand-Est region, guaranteeing a connection between geographically distant production and consumption sites. The project could be commissioned in 2030 with a total length of 1 200 km.
- The WHHYN project is being developed jointly by NaTran and Belgium's Fluxys. Its first phase will link the Valenciennes area of France, where both production and consumption projects are located, with the industrial zone of Mons in Belgium. This project received financial support from the Hauts-de-France region and Valenciennes Métropole for the feasibility study. The first phase of the project would be 40 km and could be commissioned by 2030. Interconnector capacity could be around 24 GWh/d.
- NaTran is also advancing the HYnframed project, spanning the Fos-sur-Mer region to Manosque. The total length of the project would be 150 km and an FID is expected by 2025.

Plus, in October 2024, NaTran and Fluxys launched a call for expression of interest in a hydrogen link between the port of Dunkirk and Belgium. The pipeline project would connect the Dunkirk industrial port area with the industrial zones of Ghent and Antwerp and would have a total length of around 150 km.

Germany

Germany has over 370 km of operational hydrogen pipelines, but its National Hydrogen Strategy Update foresees the development of a 1 800-km hydrogen network by 2027/28. Germany's association of supra-regional gas transmission operators (FNB Gas) presented a draft concept of the hydrogen core network in November 2023 and handed in the final application in July 2024. In October 2024 the Federal Network Agency approved construction of the Germany-wide hydrogen core network.

The total length of the approved network is 9 040 km (about 60% repurposed natural gas pipelines), at an investment cost of EUR 18.9 billion. Germany's first network development plan for gas and hydrogen is to be approved by the Federal Network Agency in 2026.

In early 2025, Ontras completed the hydrogen filling of a 25 km natural gas pipeline repurposed for hydrogen transport, while Nowega and Gascade started commissioning activities by initiating the hydrogen filling of 55 km and 400 km, respectively, of mostly repurposed natural gas pipelines.

Several hydrogen pipeline projects are currently being undertaken in Germany, including:

- The H2ercules Project is expected to have a length of around 1 500 km, mostly using repurposed pipelines and is expected to be completed in three stages between 2026 and 2030. The project received PCI status in November 2023.
- Flow – Making Hydrogen Happen, a project to develop a 1 600-km north-south transport route in Germany. Commissioning of the first sections is expected in 2025, with expansion to Baden-Württemberg by 2029. The European Commission included the project in its November 2023 PCI list. In March 2025, initial filling of the first pipeline section began. Around 400 km of natural gas pipelines will be gradually converted to hydrogen transport by the end of 2025.
- The HyperLink Project, advanced by Gasunie to connect low-emissions hydrogen producers and consumers in Germany's northern and western regions. The project is divided into three subprojects and could have a total length of nearly 1 000 km. Completion is targeted for 2032 and repurposed natural gas pipelines could make up around 70% of the network. The European Commission included subprojects 1 and 2 on its IPCI list, while subproject 3 is on the PCI list. According to the project developer, 150 km of natural gas pipeline had already been converted at the end of 2024, and 200 km of pipeline will be hydrogen-compatible by the end of 2025.
- The AcquaDuctus project, being advanced by GASCADE and Fluxys. Its first phase would have an offshore leg of roughly 250 km, transporting offshore wind-based renewable hydrogen from the German North Sea to the mainland. The project received PCI status in November 2023, and its first phase received IPCEI status in February 2024. In April 2024, GASCADE and Norway's Gassco signed a memorandum of understanding to co-operate on coherent planning of offshore hydrogen pipelines in the North Sea.

Luxembourg

In its September 2021 Hydrogen Strategy, Luxembourg states that it will rely primarily on interconnected infrastructure with its neighbouring countries – Belgium, France and Germany – to satisfy its potential green hydrogen needs. At the European level, the country will allow hydrogen to flow from west to east and north to south. In March 2025, Luxembourg adopted the law on hydrogen transport networks. The Law aims to establish an initial legal framework for planning, developing and operating hydrogen transport infrastructure. The law foresees the authorisation of at least one national transport operator.

The HY4Link project is being advanced by Creos Luxembourg together with partner TSOs. The project designed to connect hydrogen demand clusters for industry and transport in France, Germany, and Luxembourg with hydrogen supply centres along the North Sea coast and import hubs in Antwerp, Zeebrugge, Rotterdam and Dunkirk.

Netherlands

The Netherlands is one of the most advanced countries in hydrogen infrastructure development, having a dedicated hydrogen network of around 300 km.

In June 2022, the Netherlands announced the construction of a national hydrogen transport network. Hynetwork Services (a subsidiary of Gasunie) was tasked with building it and subsequently assuming the role of hydrogen network operator in the country. In June 2023, Gasunie took an FID for the first part of the country's planned hydrogen network. The investment associated with this first section exceeds EUR 100 million, and it is being developed by Gasunie's subsidiary, Hynetwork Services. Construction began in October 2023, with King Willem-Alexander performing the official ceremony to start work.

The national hydrogen network would ultimately have a length of 1 200 km and connect the Netherlands' major industrial areas with each other and with Germany and Belgium. The overall cost of developing the network was initially estimated at EUR 1.5 billion , but Gasunie revised this estimate to EUR 3.8 billion in 2025. The increase is partly due to a lower-than-expected share of existing gas pipelines that can be reused - originally estimated at around 85% - as well as higher inflation and rising material and labour costs.

In December 2024, Hynetwork Services published an updated rollout plan for hydrogen network realisation. According to the proposal, the hydrogen network will not be ready by 2030 as originally planned, but by 2033 at the latest. The two main reasons for the delay are: 1) longer-than-expected lead times for project procedures (including permitting); and 2) capacity limitations of the various parties crucial to network rollout (contractors, engineering firms, government agencies, etc.).

The updated rollout plan has four development phases:

- **Rotterdam**: A 32-km hydrogen pipeline will run between the Tweede Maasvlakte industrial area and the village of Pernis. Work on this section started in late 2023 and the pipeline will be ready for operation in 2026.
- **Industrial clusters along the coast**: Hydrogen infrastructure will be developed in coastal industrial clusters, including in the North Sea Canal area, the Northern Netherlands (the HyStock hydrogen storage facility and cross-border connection), and

Southwestern Netherlands (including the first cross-border connection to Belgium). These sections are to be developed by or in 2030.

- **Connections between clusters**: In this phase, connections will be established among the clusters from the previous phase, as well as to the Limburg cluster. These sections are to be developed in 2031-2033.
- **Upgrading:** Once the interconnected hydrogen network is developed, it will be further upgraded, including through the strengthening of cross-border connections. The time frame for this phase has not yet been defined, but it is expected to be after 2033.

Following a consultation process with industry stakeholders, Hynetwork Services sent its proposal to the Ministry of Climate Policy and Green Growth in April 2025.

Norway

In March 2022 Germany and Norway issued a joint statement on co-operation on hydrogen imports, including via offshore pipelines. Then, in November 2023, the German Energy Agency (dena) and Gassco published a feasibility study on a Norway-Germany hydrogen value chain.

In September 2024, Equinor announced its decision to discontinue the hydrogen export pipeline project to Germany due to higher project costs and lack of long-term offtake commitments. Also in September 2024, the Aukra low-emissions hydrogen project in Norway was put on hold due to lack of demand for low-emissions hydrogen. The Aukra Hydrogen Hub was planned to have a capacity to produce around 1 200 metric tonnes of hydrogen per day by 2030.

Switzerland

Switzerland has only minor hydrogen pipelines in industrial areas, but its National Hydrogen Strategy highlights the importance of connecting to Europe’s hydrogen pipeline infrastructure to ensure both imports and transit. According to the Strategy, hydrogen transport and distribution will utilise both converted and new pipelines. Alternative transport modes such as road and rail would also be considered.

In October 2024, five gas TSOs (FluxSwiss, Transitgas, OGE, Fluxys TENP and Snam) signed Memorandum of Understanding to enhance hydrogen supply in Central Europe, particularly in Baden-Württemberg, Germany and northwestern Italy. The partnership would leverage on existing transit gas infrastructure and could facilitate hydrogen imports from North Africa.

United Kingdom

The United Kingdom has approximately 40 km of operational hydrogen pipelines. With its Project Union, National Gas (formerly National Grid) is exploring the development of a UK hydrogen network to connect strategic hydrogen production centres with storage and consumption sites to support creation of a UK hydrogen market. This project will identify potential pipeline routes, assess the readiness of existing natural gas assets and determine a potential transition plan for some of National Gas's transmission pipelines. The existing national transmission system could be repurposed in a phased approach to create a 2 000-km hydrogen network by the early 2030s.

In October 2024, National Gas published its Hydrogen Gas Market Plan, a phased approach to hydrogen network development:

- **Initial connected clusters**: Targeted for 2027, hydrogen use within clusters and transportation between clusters remains limited.
- **Regional expansion**: Targeted for the early 2030s, regional hydrogen networks emerge, facilitating rising hydrogen penetration between clusters and regions.
- **Mature hydrogen backbone**: Targeted for 2035, dispersed hydrogen production and demand sites are connected by networks, with high levels of hydrogen penetration.

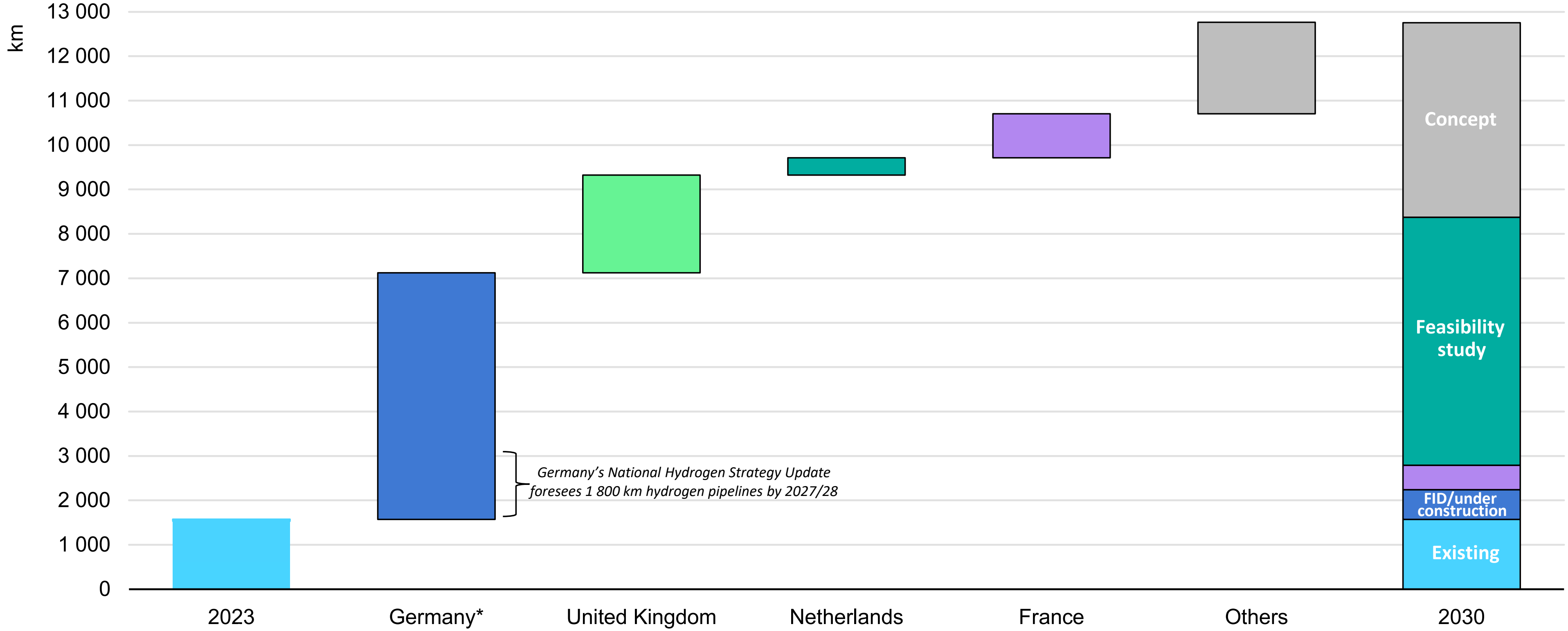
In addition to Project Union, several pipeline projects are being developed across the United Kingdom, for example Cadent's HyNet pipeline and the Northern Gas Networks, National Gas and Cadent projects that form part of East Coast Hydrogen. There is a Humber Hydrogen Pipeline (HHP) project being developed by Equinor, SSE and Centrica.

In December 2023, the UK government published a Hydrogen Transport and Storage Networks Pathway, outlining its approach to enable the buildout of transport and storage infrastructure to develop the hydrogen economy and provide wider energy system benefits. The pathway sets out the strategic ambition for the first allocation rounds of government support for up to two storage projects at scale and associated regional pipelines to be under construction or operational by 2030. The UK also published a Market Engagement Document on the Hydrogen Transport Business Model in December 2023.

Furthermore, a National Energy System Operator (NESO) was formally established in October 2024. The United Kingdom aims for NESO to be responsible for strategic planning of hydrogen transport and storage infrastructure from 2026.

Northwestern Europe's hydrogen network could be nearly 13 000 km long by the early 2030s

Existing and planned hydrogen pipelines in Northwestern Europe, 2023 and 2030



*Germany's National Hydrogen Strategy Update foresees the development of a 1 800-km hydrogen network by 2027/28, while the IEA Hydrogen Infrastructure Projects Database identifies 5 550 km of hydrogen pipeline projects with a startup year of 2030.

Underground storage will be key to enhance low-emissions hydrogen network flexibility

Having access to sufficient underground storage will be crucial to realise hydrogen's full potential as an energy carrier, and to respond to the evolving flexibility requirements of a more complex energy system.

Because low-emissions hydrogen production facilities (SMR plants and electrolysers) will have both flat and volatile supply patterns – especially when fuelled by variable renewables – the extrinsic value of storage will be key in responding to **short-term variability** in both supply and demand. Highly flexible assets, such as salt and hard rock caverns, are best placed to provide such services. Hydrogen storage could also even out **seasonal swings** in hydrogen demand and provide a **security buffer** against supply disruptions and sudden demand peaks.

In addition, ample storage facilities could allow **more optimal hydrogen network development** and improve electrolyser load factors. Moreover, storage could play a key role in market development by facilitating the short-term physical trading of low-emissions hydrogen.

Based on the IEA latest analysis, , Northwestern Europe could develop almost 16 TWh of hydrogen storage capacity by 2030. However, just 3% of it has reached FID and/or is under construction.

Austria

Austria was one of the countries to pioneer research on storing hydrogen in porous reservoirs. From 2013 to 2017, Austria's Underground Sun Storage Project demonstrated the possibility of keeping a blend of up to 20% hydrogen and 80% methane in depleted fields. Currently, the project's extension, Underground Sun Storage 2030, is exploring the possibility of storing pure hydrogen. In April 2023 the facility's testing of pure hydrogen storage in a depleted gas field entered into operation in Gampern, with a capacity of 4.2 GWh of electricity storage (i.e. equal to approximately 2.5 GWh of hydrogen storage).

In January 2024, RAG and its partners launched the EUH_2STARS project to further enhance research on the development of market-ready hydrogen storage in underground gas reservoirs. The process would include storage conversion and the construction of new storage facilities on a larger scale in the central region of Upper Austria.

Denmark

In July 2023, Gas Storage Denmark announced that it is working on plans to convert two of the caverns at the Lille Torup gas storage facility for hydrogen storage. One of the hydrogen caverns is to be dedicated to the Green Hydrogen Hub, while the second is to be offered to customers at ordinary market terms. Commissioning of the hydrogen caverns is expected by late 2028/early 2029.

Meanwhile, the Green Hydrogen Hub project, promoted by Corre Energy, Eurowind Energy and Gas Storage Denmark, is undertaking front-end engineering and design of hydrogen storage in a salt cavern with a working capacity of 200 GWh. In December 2023, Corre Energy agreed to offtake arrangements for the Green Hydrogen Hub.

France

Most of France's several hydrogen storage projects are at early stages of development. They include:

- The HyGreen Provence Project, launched in March 2021 in the salt caverns of the Manosque storage site and expected to be operational in 2028 with a planned working storage capacity of 200 GWh. In June 2024, Géométhane injected 300-350 kg of hydrogen into one of the salt caverns.
- The HyPSTER Storage Project, which started engineering studies in 2021. The salt cavern would have a working capacity of 0.1 GWh during its first stage of development and would operate with multiple annual storage cycles. In September 2023 the demonstration phase was inaugurated, and in October 2024 the first hydrogen molecules were injected into the EZ53 salt cavern, Since then, several more hydrogen injections have been carried out. Following this initial experimental stage, the project could be scaled up until the cavern is at full capacity in 2026.
- The HySOW Project, under which Teréga is planning to develop a hydrogen storage facility in a salt cavern with a capacity of 500 GWh by 2030 and 1 TWh by 2050. In June 2023 Teréga launched a call for expressions of interest.
- The FrHyGe project, launched in March 2024 by a European consortium and co-ordinated by Storengy. The project aims to validate industrial-scale hydrogen storage in underground salt caverns. It will involve deployment of an industrial-scale demonstrator at Manosque, as well as a replication study at the Harsefeld site in Germany. In the commercial phase, which could start after 2030, the two Manosque caverns could store 6 000 tonnes of hydrogen, while the Harsefeld site could have a capacity of 5 200 tonnes.

Germany

Germany's Hydrogen Strategy Update recognises the importance of developing hydrogen storage by both constructing new facilities and successively converting existing natural gas storage for hydrogen use. It also acknowledges that hydrogen storage facilities can provide valuable intermediate storage options as greater amounts of volatile renewable energy are integrated into the power system. Considering the country's considerable gas storage potential, the strategy foresees it playing a central role in the European hydrogen network.

Germany therefore has several hydrogen storage projects under development, including the repurposing of salt caverns previously used for natural gas:

- The HyCAVmobil Project is being developed by EWE, a major German utility, and the German aerospace centre DLR. It involves drilling a 1 000-metre-deep cavern in Rüdersdorf to verify hydrogen quality during and after storage. The project started leaching in 2021 and testing was to begin by the end of 2022. Research was completed in December 2024, and EWE is now transferring the knowledge gained from construction and operation of the 500-m^3 test cavern to large-scale caverns for hydrogen storage.
- The Hydrogen Pilot Cavern (HPC) Krummhörn project started demonstration operations in August 2024. Under the project, the Krummhörn salt cavern (previously used for natural gas storage) was converted to hydrogen service. The project has a storage volume of around 1.8 GWh. In case demonstration operations are successful, the storage capacity is planned to increase up to 250 GWh and by 2030 to around 600 GWh.
- In December 2023, the H_2CAST Etzel project completed the conversion of two large salt caverns previously used for natural gas storage to hydrogen service. Leak tests were successfully completed in the first half of 2024, and in January 2025 the first hydrogen molecules were injected. In February 2025, STORAG ETZEL and EnBW secured a contract to construct and operate new hydrogen cavern storage facilities at the Etzel site, with a geometric volume of over one million cubic metres.
- The Gronau-EPE Salt Cavern Project plans the development of two caverns. The first will be converted and is expected to be operational by 2027 and have a capacity of 135 GWh. The second will be operational by 2028. A market survey for storage capacities was launched by RWE in February 2025.
- The Energiepark Bad Lauchstädt storage project is set to have a capacity of 150 GWh and become operational by 2027.

Netherlands

Gasunie is developing underground hydrogen storage through its HyStock subsidiary. Between April 2021 and the summer of 2022, a borehole into a salt cavern in Zuidwending confirmed potential hydrogen storage. HyStock then held an open season from 15 June to 14 July 2023, offering market participants the opportunity to reserve capacity in its A5 hydrogen salt cavern (216 GWh), and reservation requests far outbid the offered storage capacity. Despite the success of this process, the open season for the first HyStock cavern ended in August 2024 due to project delays and unfinalised subsidy arrangements.

In February 2025, Gasunie and Nobian agreed to co-operate on the development of hydrogen salt caverns in Zuidwending. The first cavern could be ready around 2031, but Nobian must develop the next three before EnergyStock can make them suitable for hydrogen storage.

United Kingdom

The United Kingdom has one operational large-scale hydrogen storage facility, consisting of three salt caverns. It was commissioned in 1972 by Sabic Chemicals and has a storage capacity of approximately 25 GWh.

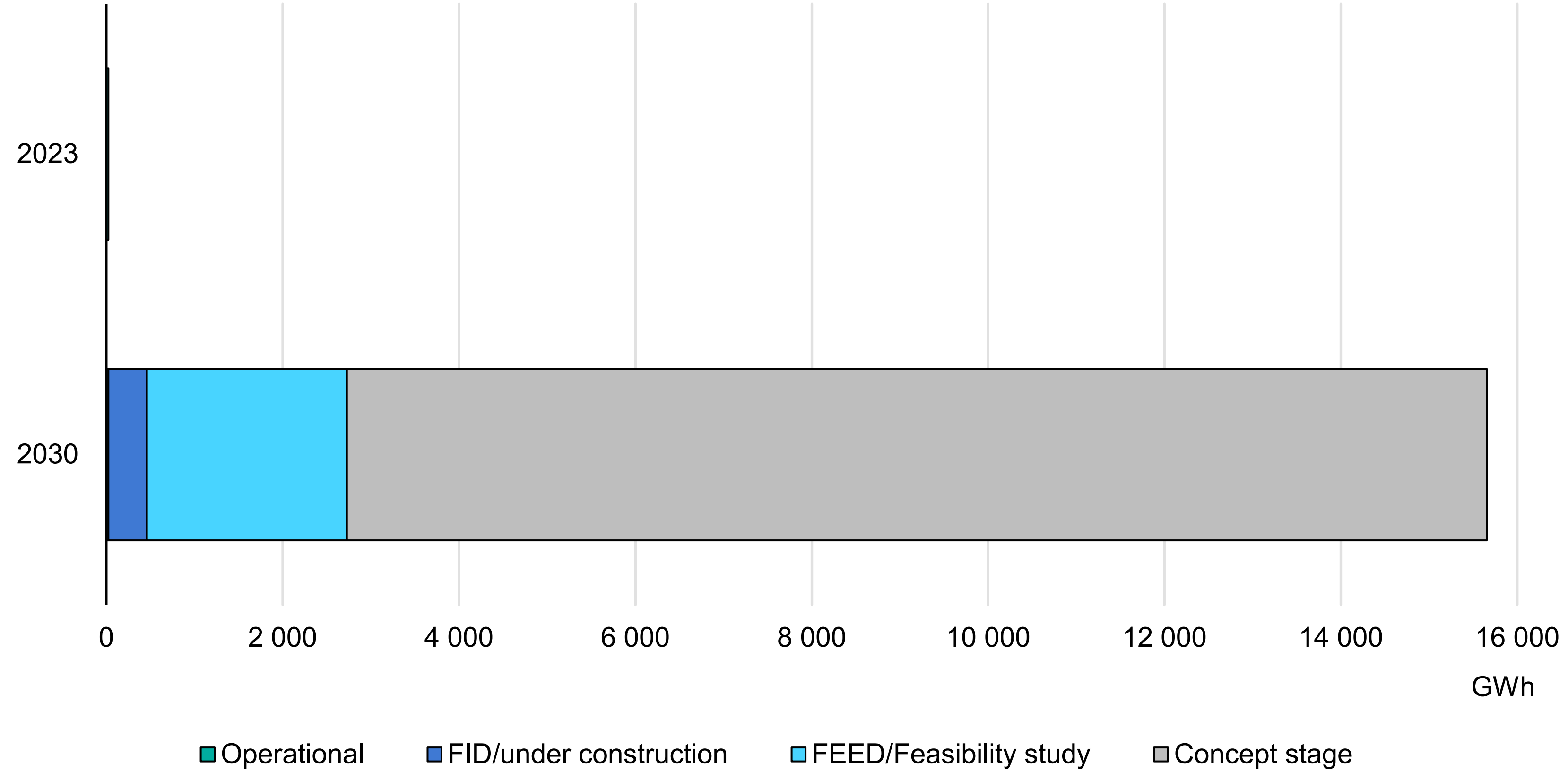
The National Infrastructure Commission's Second National Infrastructure Assessment notes that at least 8 TWh of hydrogen storage capacity will be needed by 2035. The Hydrogen Transport and Storage Networks Pathway sets the ambition to support large-scale hydrogen storage and linked regional pipelines. The pathway indicates that, based on demand analysis, storage infrastructure requirements are likely to increase significantly from 2035 onwards, particularly to enable hydrogen-to-power projects.

The UK government therefore intends to conduct further research into future transport and storage infrastructure needs to determine scale and scope. This will allow it to set ambitions for further allocation rounds of the hydrogen transport and storage business models. The UK published a Hydrogen Storage Business Model market engagement document on the first allocation round in 2023 and is progressing with design of the business model.

Additionally, two salt cavern projects are undergoing feasibility tests for hydrogen storage: Humber Hydrogen Storage (320 GWh) and HyNet (HyKeuper) (1 300 GWh). In March 2024, the UK National Gas Transmission Agency secured public funding to assess the potential of Gravitricity's lined hard-rock-cavern technology, known as H2FlexiStore, which has a capacity of 100 tonnes of hydrogen. In June 2024, Centrica Energy Storage awarded Wood with a front-end engineering and design contract to repurpose the Rough gas field in the North Sea for future hydrogen service.

Most hydrogen storage projects remain at early stages of development

Potential underground hydrogen storage capacity in Northwestern Europe by 2030, based on project announcements



Note: FID = final investment decision.

Ports will play a crucial role in enabling low-emissions hydrogen trade

Port infrastructure will be pivotal to the future trading of low-emissions hydrogen and hydrogen-based fuels. Globally, approximately 150 terminals and ports can handle ammonia, and more than 110 have facilities to deal with methanol. Northwestern Europe has 13 ammonia administration facilities and 16 that handle methanol, mainly concentrated in Germany, France and the Netherlands.

Current facilities are used for trading ammonia (about 20 Mt per year, or 10% of global production) and methanol (about 35 Mt per year, or one-third of global production), while pure hydrogen trade via shipping is essentially non-existent, apart from a few stand-alone pilot projects. Meeting future trade demand for hydrogen-based fuels will thus require both higher utilisation of existing plants and expansions to port infrastructure.

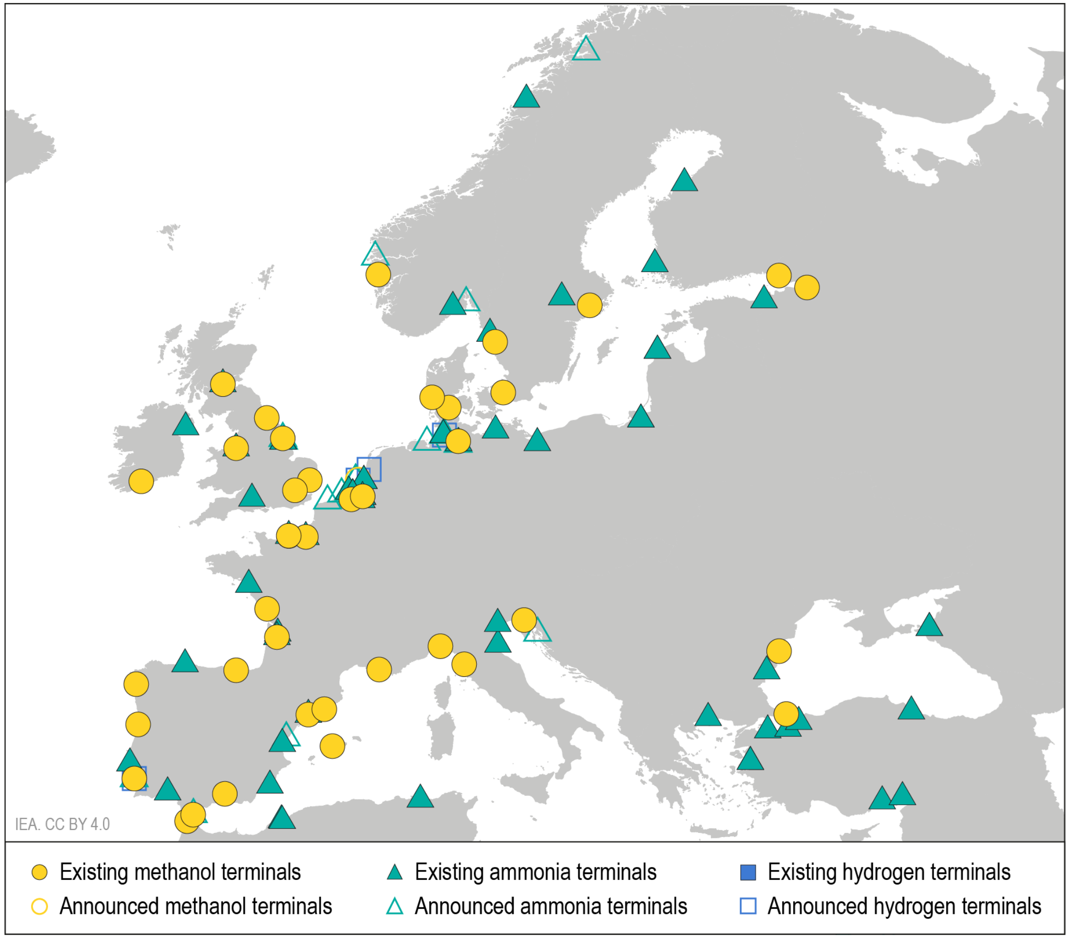
Based on announced projects, around 50 terminals with port infrastructure for trading hydrogen and ammonia could be realised worldwide by the end of the decade. OCI aims to expand its current ammonia import terminal in four phases. In June 2022 OCI reached FID for the first phase, which is new ammonia loading and unloading infrastructure for ships, barges and coasters. In April 2024, the Dutch Environmental Protection Agency granted OCI a permit to construct a new 60 000-tonne ammonia storage tank, based on updated national guidelines (PGS-12) for ammonia storage.

In the same port, new ammonia import terminals are planned by Air Products & Gunvor, GES & Gunvor, ACE, VTTI Amplifhy, Chane and Koole. In addition, there are plans for terminals for importing methanol or liquid organic hydrogen carriers. In October 2024, Yara opened its new 3 Mtpa ammonia import terminal in Brunsbüttel, Germany.

Together with plans for new import terminals, announcements have been made for large-scale ammonia cracking facilities in port areas such as Wilhelmshaven, Rostock and Brunsbüttel (Germany), Antwerp (Belgium), Liverpool and Immingham (United Kingdom), and two in the Port of Rotterdam (Netherlands). In September 2024, Air Liquide started up an ammonia cracking pilot plant in the Port of Antwerp, Belgium, with a nameplate capacity of around 15 ktpa.

Port infrastructure can solidify Northwestern Europe's leading position in hydrogen trade development

Existing and announced port infrastructure for hydrogen and hydrogen-based fuels in Northwestern Europe



Sources: IEA (2024), Global Hydrogen Review 2024 and IEA (2025), Hydrogen Infrastructure Projects Database.

Annex

Terminology

Terminology relating to low-emissions hydrogen

In this report, low-emissions hydrogen includes hydrogen which is produced through water electrolysis with electricity generated from a low-emission source (renewables, i.e. solar, wind turbines or nuclear). Hydrogen produced from biomass or from fossil fuels with CCUS technology is also counted as low-emission hydrogen. Production from fossil fuels with CCUS is included only if upstream emissions are sufficiently low, if capture – at high rates – is applied to all CO_2 streams associated with the production route, and if all CO_2 is permanently stored to prevent its release into the atmosphere. The same principle applies to low-emission feedstocks and hydrogen-based fuels made using low-emission hydrogen and a sustainable carbon source (of biogenic origin or directly captured from the atmosphere). The IEA does not use colours to refer to the different hydrogen production routes. However, when referring to specific policy announcements, programmes, regulations and projects where an authority uses colours (e.g. “green” hydrogen), or terms such as “clean” or “low-carbon” to define a hydrogen production route, we have retained these categories for the purpose of reporting developments in this review.

Terminology for carbon capture, utilisation and storage

In this report, CCUS includes CO_2 captured for use (CCU) as well as for storage (CCS), including CO_2 that is both used and stored, e.g. for enhanced oil recovery or building materials, if some or all of the CO_2 is permanently stored. When use of the CO_2 ultimately leads to it being re-emitted to the atmosphere, e.g. in urea production, CCU is specified.

Regional and country groupings

Africa – Algeria, Angola, Benin, Botswana, Cameroon, Congo, Democratic Republic of the Congo, Côte d'Ivoire, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libya, Morocco, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, United Republic of Tanzania, Togo, Tunisia, Zambia, Zimbabwe and other countries and territories.[1]

Asia Pacific – Australia, Bangladesh, Brunei Darussalam, Cambodia, Chinese Taipei, India, Indonesia, Japan, Korea, the Democratic People's Republic of Korea, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, the People's Republic of China,[2] the Philippines, Singapore, Sri Lanka, Thailand, Viet Nam and other countries and territories.[3]

Central and South America – Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, the Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela and other countries and territories.[4]

Eurasia – Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, the Russian Federation, Tajikistan, Turkmenistan and Uzbekistan.

Europe – Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus,[5,6] the Czech Republic, Denmark, Estonia, Finland, the Former Yugoslav Republic of North Macedonia, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Kosovo,[7] Latvia, Lithuania, Luxembourg, Malta, the Republic of Moldova, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, the Republic of Türkiye, Ukraine and United Kingdom.

European Union – Austria, Belgium, Bulgaria, Croatia, Cyprus,[5,6] the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain and Sweden.

Middle East – Bahrain, the Islamic Republic of Iran, Iraq, Israel,[8] Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, the Syrian Arab Republic, the United Arab Emirates and Yemen.

North Africa – Algeria, Egypt, Libya, Morocco and Tunisia.

North America – Canada, Mexico and the United States.

[1] Individual data are not available and are estimated in aggregate for: Burkina Faso, Burundi, Cape Verde, Central African Republic, Chad, Comoros, Djibouti, Equatorial Guinea, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Niger, Reunion, Rwanda, Sao Tome and Principe, Seychelles, Sierra Leone, Somalia, Swaziland and Uganda.

[2] Including Hong Kong.

[3] Individual data are not available and are estimated in aggregate for: Afghanistan, Bhutan, Cook Islands, Fiji, French Polynesia, Kiribati, the Lao People's Democratic Republic, Macau (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga and Vanuatu.

[4] Individual data are not available and are estimated in aggregate for: Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), French Guyana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, St. Kitts and Nevis, St Lucia, St. Vincent and the Grenadines, Suriname and Turks and Caicos Islands.

[5] Note by the Republic of Türkiye: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. The Republic of Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

[6] Note by all the European Union Member states of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of the Republic of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

[7] The designation is without prejudice to positions on status, and is in line with the United Nations Security Council Resolution 1244/99 and the Advisory Opinion of the International Court of Justice on Kosovo's declaration of Independence.

[8] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Abbreviations and acronyms

ACER	Agency for the Cooperation of Energy Regulators
BMWK	Federal Ministry of Economic Affairs and Climate Action (Germany)
AFC	alkaline fuel cells
ALK	alkaline electrolyser
ATR	autothermal reforming
CAPEX	capital expenditure
CEM	Clean Energy Ministerial (IEA)
CCfD	carbon contract for differences
CCGT	combined-cycle gas turbine
CCS	carbon capture and storage
CCU	carbon capture and use
CCOS	carbon capture and offshore storage
CCUS	carbon capture, utilisation and storage
CHP	combined heat and power
CfD	contract for differences
CO_2	carbon dioxide
CREG	Commission for Electricity and Gas Regulation (Belgium)
DKK	Danish kroner
EC	European Commission
EHB	European Hydrogen Backbone
ENNOH	European Network of Network Operators for Hydrogen
EIB	European Investment Bank
EU	European Union
EU ETS	EU Emissions Trading System
EUR	Euro
FEED	front-end engineering design
EV	electric vehicles
FC	fuel cell
FCEV	fuel cell electric vehicles
FID	final investment decision
FT	Fischer-Tropsch
GBP	British pound
GHG	greenhouse gas
GO	guarantee of origin
H_2	hydrogen
IEA	International Energy Agency
IPCEI	Important Projects of Common European Interest
ITO	independent transmission system operator
LCOH	levelised cost of hydrogen
LHV	lower heating value
LNG	liquefied natural gas
LOHC	liquid organic hydrogen carrier
LOI	letter of intent
LPG	liquefied petroleum gas
MeOH	methanol
MOC	memorandum of collaboration
MOU	memorandum of understanding
NH_3	ammonia
NOK	Norwegian kroner
OPEX	operating expenditure
PCI	Project of Common Interest (EU)
PEM	proton exchange membrane
PMI	Project of Mutual Interest (EU)
PtX	power-to-X
PV	photovoltaic
RED	Renewable Energy Directive (EU)
R&D	research and development
RD&D	research, development and demonstration
RNFBO	renewable fuels of non-biological origin
SMR	steam methane reforming
SOEC	solid oxide electrolysis cell
TSO	transmission system operator
TTF	Title Transfer Facility (Netherlands)
UK	United Kingdom
US	United States
USD	United States dollars

Units of measure

bcm	billion cubic metres
g	gramme
Gt	gigatonnes
GW	gigawatt
GWh	gigawatt-hour
kg	kilogramme
kg H_2	kilogramme of hydrogen
km	kilometres
kt	kilotonnes
kt H_2	kilotonnes of hydrogen
kW	kilowatt
kWh	kilowatt-hour
MBtu	million British thermal units
MJ	megajoule
Mt	million tonnes
Mt CO_2	million tonnes of carbon dioxide
Mt H_2	million tonnes of hydrogen
Mt H_2-eq	million tonnes of hydrogen equivalent
Mtpa	million tonnes per year
MW	megawatt
MWh	megawatt-hour
PJ	petajoule
t CO_2	tonnes of carbon dioxide
tpa	tonnes per year
TWh	terawatt-hour
vol%	volume percentage

See the IEA glossary for a further explanation of many of the terms used in this report.

Acknowledgments, contributors and credits

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For any questions and comments, please contact: Gergely.Molnar@iea.org

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