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Argus Hydrogen and Future Fuels

Market news, analysis and prices

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Oman advances renewable H2 plans

Oman will launch its third auction round for land as it seeks to become a key renewable hydrogen producer, write Stefan Krumpelmann and Rithika Krishna

Oman is pushing ahead with ambitions to become a key renewable hydrogen producer, having announced a third auction round for plots of land and other mechanisms that could stimulate growth. Besides production, the country is pursuing plans for other infrastructure and domestic equipment manufacturing.

Oman will launch its third licensing round for blocks earmarked for renewable hydrogen production projects by the end of the first quarter of 2025, state-owned company Hydrom said at an investor event on 11 December.

"Our plan is to kick-start round three by March 2025, with an aim to conclude it towards the end of the year, or the beginning of 2026," Hydrom managing director Abdulaziz al-Shidhani said. "We encourage everyone to participate… those who participated in rounds one and two, and those who heard about us after we concluded round two." Al-Shidhani did not disclose the size or estimated value of the blocks. The regions will be determined once "market-sounding" activities are completed, he told *Argus* in an interview on the sidelines of the investor event.

Hydrom is considering tweaks to the auction model, incorporating learnings from the previous two rounds, partly to attract interest from developers that have so far been hesitant, al-Shidhani said.

Hydrom has already awarded eight blocks for renewable hydrogen projects in the Duqm and Salalah areas, partly through the two previous auctions, with prospective developers including BP, Shell, France's Engie and EDF, South Korea's Posco, Australia's Fortescue and Omani firm OQ. Each award is for 47 years, al-Shidhani said — an initial seven-year development and construction phase, and then a 40-year phase for production and operation. The first final investment decisions for these projects are expected in 2026, he said.

The projects could together produce about 1.4mn t/yr of renewable hydrogen using 18GW electrolyser capacity by 2030, according to al-Shidhani. This would be above Oman's 2030 target of 1mn t/yr.

Oman is also considering other measures to stimulate the sector, with al-Shidhani saying at the event that Hydrom could introduce "double-sided auctions". These could be aimed at linking renewable hydrogen producers with downstream industries such as fertiliser producers or green iron projects, according to reports from state-owned Oman News Agency, although details remain limited. Oman has started to attract major industries that are hoping to capitalise on comparatively low-cost renewable hydrogen — such as Indian steelmaker Jindal, which is planning a 5mn t/yr green steel plant in the Duqm region.

Still, most of the output is likely to be geared towards exports. At the investor event, Hydrom and Greece-headquartered Ecolog Hydrogen presented plans to build a centralised terminal for 200,000 t/yr of liquefied hydrogen exports, which could be primarily directed at Europe. The project also involves other partners, including German utility EnBW and the Dutch Port of Amsterdam.

Oman will possibly look to reap the benefits along the hydrogen value chain. Future auctions could give priority to projects that enhance local manufacturing, according to the Oman News Agency, and first steps are being taken towards producing equipment domestically. Germany-based electrolyser maker Thyssenkrupp Nucera signed a deal with Hydrom on the sidelines of the investor event to explore possible locations and opportunities for assembly and servicing in Oman.

Oman renewable H2 targets

Year	Production *mn t/yr*	Electrolysers *GW*	Associated renewable capacity *GW*
2030	1.0-1.5	8-15	16-30
2040	3.25-3.75	35-40	65-75
2050	7.5-8.5	95-100	175-185

— Hydrom

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HYDROGEN COSTS

Updated hydrogen and ammonia production cost models

In line with the *Argus Hydrogen and Future Fuels* methodology, *Argus* has completed its biannual review of modelled production costs.

Costs for electrolysers and other plant equipment have increased further. The model's assumed capital costs have risen by 12pc for electrolysis plants using alkaline technology and by 11pc for proton exchange membrane (PEM) technology — for all countries except China, where capital costs for PEM technology have fallen by 20pc.

Chinese electrolysers and other equipment typically cost less than those manufactured elsewhere and the *Argus* model assumes that capital costs for Chinese electrolysis plants are about 47pc lower than for other locations, but with a lower efficiency and durability.

Argus has raised the assumed capacity factor for diurnal electrolysis plants to 80pc from 70pc and has lowered the capacity factor for electrolysis plants that use offshore wind power to 50pc from 60pc, to better reflect industry views on the utilisation potential for these facilities.

Argus has also updated assumptions on the levelised cost of electricity, cost of debt, cost of equity and the debt-equity ratio.

More information on the assumptions can be found in the *Hydrogen and Future Fuels* methodology here.

For any queries please contact hydrogen@argusmedia.com

Regional hydrogen cost markers						17 Dec
			Incl. capex		Excl. capex	
	Process	Unit	Cost	± 10 Dec	Cost	± 10 Dec
Baseline						
Northwest Europe	SMR	€/kg	3.82	-0.22	3.27	-0.22
Northwest Europe	SMR	$/kg	4.01	-0.25	3.43	-0.25
North America	SMR	$/kg	1.43	-0.01	0.87	nc
Northeast Asia	SMR	$/kg	3.61	-0.15	2.99	-0.14
Middle East	SMR	$/kg	3.23	-0.13	2.67	-0.13
BAT+						
Northwest Europe	SMR+CCS	€/kg	3.88	-0.21	3.23	-0.20
Northwest Europe	SMR+CCS	$/kg	4.07	-0.24	3.39	-0.23
North America	SMR+CCS	$/kg	1.63	nc	0.96	nc
Northeast Asia	SMR+CCS	$/kg	4.42	-0.14	3.68	-0.14
Middle East	SMR+CCS	$/kg	3.61	-0.12	2.94	-0.13
Low-C						
Northwest Europe	ATR+CCS	€/kg	4.96	-0.23	3.76	-0.24
Northwest Europe	ATR+CCS	$/kg	5.20	-0.27	3.95	-0.27
North America	ATR+CCS	$/kg	2.46	+0.02	1.24	+0.01
Northeast Asia	ATR+CCS	$/kg	5.81	-0.15	4.48	-0.15
Middle East	ATR+CCS	$/kg	4.64	-0.12	3.43	-0.13
No-C						
Northwest Europe	Island renewable+PEM	€/kg	7.99	+0.40	5.00	-0.13
Northwest Europe	Island renewable+PEM	$/kg	8.38	+0.37	5.25	-0.16
North America	Island renewable+PEM	$/kg	7.38	+0.74	4.55	+0.40
Northeast Asia	Island renewable+PEM	$/kg	12.12	+0.11	9.34	-0.10
Middle East	Island renewable+PEM	$/kg	6.02	-0.06	3.36	-0.23
Exporter						
Exporter baseline	SMR	$/kg	2.60	-0.04	2.03	-0.04
Exporter BAT+	SMR+CCS	$/kg	3.01	-0.03	2.34	-0.03
Exporter low-C	ATR+CCS	$/kg	4.04	-0.03	2.82	-0.03
Exporter no-C	Island renewable+PEM	$/kg	6.52	+0.19	3.64	+0.03

Argus hydrogen taxonomy			
	Purity	Pressure	tCO2e/tH2
Baseline	99.9%	30 bar	<11.3, >8.0
BAT+	99.9%	30 bar	<2.88, >1
Low-C	99.9%	30 bar	<1, >0.5
No-C	99.99%	30 bar	<0.01

CO2e emissions on a gate-to-gate basis

Pump prices, 70MPa			3 Dec
	Unit	Price	± 1 Nov
Japan			
Eneos	¥/kg	2,200.00	nc
Iwatani	¥/kg	1,650.00	nc
Germany			
H2Mobility (stations with "green" H2 supply)	€/kg	11.50	nc
H2Mobility (stations with conventional H2 supply)	€/kg	15.05-17.75	nc

MARKET DEVELOPMENTS

Dutch H2 transport network faces severe delays

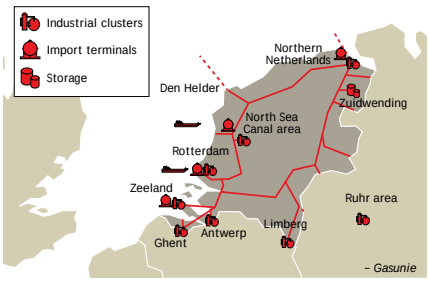
Long lead times and capacity limitations are seriously delaying pipeline and cross-border connection development, writes Stefan Krumpelmann

The Netherlands' plans for a national hydrogen transport network are facing severe delays, with the first major pipeline clusters and cross-border connections expected to become operational several years later than initially envisaged.

State-owned gas transport system operator Gasunie's subsidiary, Hynetwork, expects a 32km pipeline in Rotterdam to be ready by 2026 at the latest — broadly in line with previous estimates — the firm said in an updated roll-out plan put forward for consultation.

But pipeline clusters in other parts of the country might not come on line until 2030. Hynetwork says there is a 50pc chance additional connections in four coastal clusters could be complete by 2029, and a 90pc chance they could be complete by 2030. A northern cluster would include cross-border links with Germany and to storage sites, while a cluster in the southern province of Zeeland would connect to Belgium. In a previous plan from July last year, Hynetwork still expected the first clusters and cross-border connections to be ready by 2027, which was already 1-2 years later than an estimate made in 2022.

Planned Dutch H2 network



The coastal clusters are now set to be connected with each another in 2031-33 — previously, this was expected to be done in 2028-29. A subsequent expansion of the network has also been pushed back and is now only due to take place after 2033, rather than from 2030.

Hynetwork says lead times for project permits are longer than previously anticipated and that there are capacity limitations with regard to contractors, engineering firms and government services. The firm had already cited similar reasons for the delays it outlined last year.

The operator also pointed to substantial delays to the Delta-Rhine Corridor (DRC), which forms a key part of the network and is set to link Rotterdam with the southeast of the Netherlands and establish a connection to the German border. The Dutch government said recently that the DRC is expected to become operational by 2031-32, back from the previously planned 2028 start date.

Hynetwork has also blamed the hydrogen sector's slow development for the delays. "We unfortunately see that the development of the hydrogen market is not going as fast as expected and that market parties are not yet ready to make investment decisions and conclude hydrogen transport contracts with us," it says.

The operator says it included a range of risks in its projections that could lead to delays, including potential legal procedures, nature management measures, limitations on material and an increase in extreme weather events.

Stakeholders can respond to Hynetwork's consultation until 31 January.

For Germany, which wants to have 6,500km of hydrogen pipelines operational by 2030, the Dutch delays are yet another blow with regard to potential imports.

The Danish government said in October that a pipeline connection to Germany will only come on line by 2031 — three years later than previously envisaged. And Norway has scrapped plans for an export pipeline to Germany entirely.

Love me tender

A Dutch tender for just under €1bn ($1.05bn) of renewable hydrogen production subsidies, which closed in late November, was heavily oversubscribed.

More than 30 bidders requested cumulative support of about €3bn, climate and green growth minister Sophie Hermans says, adding that the large number of applications "underlines the enormous interest in electrolysis in the Netherlands".

Hermans separately notes that a Dutch auction under the German H2Global framework to fund imports from outside the EU is expected to be launched in spring. The Netherlands has set €300mn aside for this.

MARKET DEVELOPMENTS

UK offers H2 subsidy CfDs, but barriers remain

Permitting and tariff concerns mean subsidy contracts might not bring the momentum some hoped for, writes Aidan Lea

The UK has offered its long-awaited subsidy contracts to three of the projects in its first hydrogen allocation round (HAR1) and it will issue contracts to the remaining projects in early 2025, it says. But this does not guarantee that all the developers will immediately take investment decisions, as barriers persist, several companies with projects that were selected in the round tell *Argus*.

London did not explain why it staggered sending the contracts for difference (CfDs). Some developers *Argus* has spoken with asked to defer sending until January, so they can start the 20-day clock for their response after Christmas. They say government is encouraging them to sign as soon as possible. But some firms, which have not received contracts, are frustrated and puzzled at being unable to seal them before the holiday period, they say.

UK projects have been waiting since December 2023 for contracts that were delayed — partly by the UK election. The government implied it will issue contracts for all 11 of the projects that it selected 12 months ago. But several of the projects face challenges with permits, offtake or cost inflation, which could mean perhaps 60-70pc of the 125MW electrolytic production capacity initially selected for awards eventually materialises. The UK might still offer contracts to companies that are not fully ready to sign, according to some participants.

This is because companies do not face penalties for pulling out of the contract until they start drawing on grant money, so firms might treat signing as an 'option' and only make a firm decision later, participants say. But firms cannot sign and delay indefinitely since funding is tied to starting works within a certain timeframe after signing, another developer says.

In any event, the signing of the CfDs might not be such a crucial moment as some expected. Firms were waiting to receive the CfDs to shore up other contracts with contractors, customers and financiers, so they might only reach final investment decisions in several months.

Crucially, the UK must clarify whether it will exempt electrolyser projects from environmental taxes it applies to energy used by businesses, developers say. The levy is a serious issue for renewable hydrogen producers as it would raise the cost of their power input and the hydrogen product by about 30pc, firms say.

This would be especially disruptive for projects that agreed to sell their hydrogen at cost parity to customers fuel-switching from natural gas, as the latter are more price-sensitive than applications such as off-grid power generation, according to the developers.

HAR1 developers signed CfD deals with government to close that premium for renewable hydrogen, but the subsidy would be inadequate if it turns out their costs are higher than thought, they say.

HAR1 projects set to receive subsidies

Project name	Lead developer	Capacity *MW*
Barrow Green Hydrogen	Carlton Power	21.0
Bradford Low Carbon Hydrogen	Hygen	24.5
Cromarty Hydrogen	Scottish Power and Storegga	10.6
Green Hydrogen 3	Hyro	10.6
HyBont	Marubeni Europower	5.2
HyMarnham	JG Pears and GeoPura	9.3
Langage Green Hydrogen	Carlton Power	7.0
Tees Green Hydrogen	EDF Renewables Hydrogen	5.2
Trafford Green Hydrogen	Carlton Power	10.5
West Wales Hydrogen	H2 Energy and Trafigura	14.2
Whitelee Green Hydrogen	Scottish Power	7.1

— UK government

When the levy breaks

HAR1 participants were led to believe they would be exempt during the applications, so they did not factor these costs into business plans or subsidy negotiations, the developers say. Some developers are unable to take an investment decision until the exemption is confirmed, they say.

The government will probably fix the problem eventually, but it is unclear how long that might take, according to the companies. The Department for Energy Security and Net Zero (Desnz) supports the exemption, but might need approval from the Treasury and some legislative changes to make it possible, developers say. Desnz was not immediately available for comment.

Desnz says it will announce "in due course" shortlisted projects in the second round (HAR2), through which it aims to subsidise 750MW of production capacity.

NEWS

Germany scraps €350mn EU hydrogen bank subsidies

Germany will not distribute €350mn ($367mn) for domestic renewable hydrogen projects as part of the European Hydrogen Bank's pilot auction owing to flaws with the scheme's design, the economy and climate protection ministry says.

Germany was the only country planning to use the EU's auctions-as-a-service (AAAS) mechanism in the hydrogen bank pilot round for which EU-wide winners were selected in April. The AAAS mechanism allows member states to subsidise domestic projects that miss out in the EU-wide selection.

But none of the German projects that participated in the pilot auction will receive funding from Berlin's AAAS pot, the ministry says. The pilot round suffered from design flaws, the ministry says, noting "very strict" rules on the cumulation of subsidies. Specifically, potential offtake projects for the renewable hydrogen produced by would-be winners in the auction could not receive subsidies themselves through other avenues, the ministry says. This might, for instance, refer to projects selected under the carbon contracts-for-difference mechanism.

The ministry has repeatedly said over the past six months that it was in discussions with potential winners of subsidies from its AAAS pot, but these were seemingly concluded without agreement.

German projects accounted for 20 of 132 bids in the pilot auction, with a planned cumulative renewable hydrogen output capacity of over 100,000 t/yr. But requested subsidies were too high to make the cut in the EU-wide competition, with awards instead going to plants in Finland, Spain, Portugal and Norway.

The ministry says the European Commission has improved the auction design for a second hydrogen bank round that was launched this month. But Germany refrained from earmarking funds under the AAAS mechanism — unlike Spain, Austria and Lithuania, which are all planning to allocate subsidies via this route as part of the ongoing auction. The ministry says it is in talks with the commission to achieve "better conditions" for German projects in future auction rounds.

By Stefan Krumpelmann

AAAS member state funds for second H2 bank auction *€mn*

Country	Earmarked funds
Austria	400
Spain	280-400
Lithuania	36

— European Commission

Switzerland eyes clean H2 imports by mid-2030s

Switzerland expects to import clean hydrogen from about 2035, according to the country's hydrogen strategy, which was published on 13 December.

Pipeline infrastructure for hydrogen imports should be in place by the mid-2030s and imports will be more cost-efficient than domestic production, the government says. The conversion and extension of the Transitgas pipeline, which currently transports natural gas between France, Italy and Germany, is the most important piece of infrastructure work, according to the strategy.

The strategy focuses on hydrogen and derivatives produced from renewable or nuclear power via electrolysis. The document outlines a range of measures through which the government intends to support the nascent clean hydrogen sector, including streamlined permitting, subsidies for domestic production and a guarantee-of-origin system that is expected to be ready next year. But it does not set specific targets for domestic production, imports or consumption.

The government provides estimates for future hydrogen demand, although these vary substantially between scenarios. In the maximum scenario, demand reaches 1.84 TWh/yr by 2030, equivalent to roughly 55,000 t/yr, based on hydrogen's lower heating value of 33.33 kWh/kg. This would initially have to be met through domestic production. Consumption eventually rises to 10.1 TWh/yr, or more than 300,000 t/yr, by 2050 in the maximum scenario.

By Stefan Krumpelmann

Switzerland demand estimates *TWh/yr*

Use for	2030	2040	2050
Road transport	0.11-0.38	0.4-1.3	0.8-2.7
Process heat in industry	0.25-1	0.5-2	2-5
Peak power demand	0	0-0.66	0.75-2.2
Shipping	0-0.03	0-0.1	0.01-1.7
Refinery feedstock	0.43-0.43	0.22-0.22	0.05-0.05
Total	**0.79-1.84**	**1.13-4.28**	**3.61-10.12**

— Swiss government

NEWS

DH2 Energy plans 1.5GW of Spanish green H2 projects

Spanish renewable hydrogen project developer DH2 Energy has announced plans to develop four electrolysis plants with a combined capacity of 1.5GW in the western Spanish region of Extremadura.

The plants are expected to produce a combined 75,000 t/yr of hydrogen and will all be located in Badajoz province, which lies on a junction of the south-western Iberian branch of the planned 2mn t/yr H2Med European cross-border hydrogen pipeline.

Spain's Extremadura region

DH2 Energy's most advanced project is the 25,000 t/yr Raviza plant. The remaining three projects — with capacities of 25,000 t/yr, 17,000 t/yr and 8,500 t/yr — are at the development stage.

The company said it has a pipeline of 15GW of projects at different stages of development in Europe and Latin America, including the 35MW Hysencia project in Aragon, where construction is scheduled to start early next year.

DH2 Energy has joined the five gas grid operators from Portugal, Spain, France and Germany that are promoting H2Med, together with nine other firms involved in the hydrogen value chain in those four countries, to form an alliance with the aim of bringing the planned transport corridor on stream by the "early 2030s".

H2Med is set to be one of Europe's largest and most expensive cross-border infrastructure projects, with the 455km sub-sea section alone expected to cost more than €2.5bn ($2.6bn). The project partners have said the link could come on stream in 2030, but environmentalists and policy makers have voiced doubts about the project's benefits and economic viability, especially in light of uncertainty over the pace of development of a renewable hydrogen industry in Europe.

By Jonathan Gleave

Proteum pauses California ethanol-to-H2 project

A plan to build an ethanol-to-hydrogen plant in California that drew an outcry from environmental groups has gone back to the drawing board as its developer seeks other opportunities in the state.

Proteum Energy, which offers systems to hydrocarbon producers to convert natural gas liquids to hydrogen, had planned to build a $120mn plant in Tulare County in the San Joaquin Valley that would produce hydrogen for trucks. The project also included plans to eventually sequester and store CO_2 through a pipeline network. The project hit multiple obstacles soon after its approval by the county in summer last year, which culminated in Proteum withdrawing its application earlier this year. Finance delays, uncertainty about California's regulation of CO_2 pipeline development and the possibility of producing other low-carbon products in addition to hydrogen were among the factors that Proteum cited as reasons for pausing the Golden State Hydrogen project.

When the county approved the project last year, it exempted it from review under the California Environmental Quality Act because the proposed site was in an existing industrial zone, prompting a lawsuit by an environmental group that argued that the site was not permitted to store "explosive materials". The county rescinded the exemption on 10 December in what environmental advocates hailed as a "significant victory" and agreed to notify parties of the lawsuit if Proteum submits a new application.

Proteum says it remains "bullish" on California's hydrogen market and is also considering an opportunity in the north of the state while it works towards "fuller engagement" with the local community in Tulare County.

By Jasmina Kelemen

NEWS

Australia, US take lead on natural hydrogen

Projects aimed at producing sub-surface natural hydrogen are most advanced in Australia and the US, while in other countries they are held up by a combination of regulatory barriers and lack of investment, delegates heard at French petroleum institute Ifpen's natural hydrogen roundtable in Paris on 13 December.

About 50 exploration projects are under way globally to find sources of natural hydrogen, with many in the US and Australia, and a smaller number in Europe, according to consulting firm NaturalHy chief executive Christophe Hecker. About $700mn has been raised globally for hydrogen exploration, of which $400mn alone has been secured by US firm Koloma, Hecker said.

More than 20 wells are producing natural hydrogen for test purposes in the US, with a high purity of 80-90pc, according to geoscience expert Jean-Claude Lecomte of the French government's mining agency. But the production rates of these wells are not public knowledge. Publishing this information could give investors and governments confidence to support natural hydrogen, Lecomte said.

In other countries, a number of barriers are slowing down developments, including a lack of regulatory systems for providing exploration licences, delegates heard. French firm Engie's project in Brazil has been slowed down by this regulatory gap, although the country in August moved to integrate hydrogen exploration into its mining code, Engie subsidiary Storengy's hydrogen lead, Olivier Lhote, said. The firm also has two projects under way in France and one in Morocco.

France was an early mover in this regard, including the possibility for hydrogen extraction in its mining code in 2022. Of eight requests for permits submitted in the country, one has been granted, with two likely to follow in January, Lecomte said. Timelines for permits are at least 18 months, he said. But Engie has been waiting more than two years for its permits, according to Lhote.

Many start-ups are getting involved in hydrogen exploration, Lhote said, but do not necessarily have access to the capital required to move forward with drilling. Majors have this access, but typically lack the necessary risk appetite. Only one site in the world, in Mali, is currently producing natural hydrogen commercially. It produces about 2-4 b/d of oil equivalent, Lecomte said.

By Rhys Talbot

Japan's KHI mulls Australian coal-to-H2 supply post-2030

Japanese engineering firm Kawasaki Heavy Industries (KHI) plans to continue exploring a coal-to-hydrogen project in Australia after 2030, despite switching to domestic procurement for a liquefied hydrogen shipping demonstration project.

KHI and its partners, domestic refiner Eneos and hydrogen supplier Iwatani, originally aimed to use output from a planned brown coal-to-hydrogen plant with carbon capture and storage in Australia for a project demonstrating large-scale liquefied hydrogen shipping to Japan. But the companies were forced into a rethink as the Australian plans face delays. They will instead procure liquefied hydrogen from within Japan at a smaller scale, so as to be able to complete the demonstration project by 2030-31.

KHI must finish the demonstration by the fiscal year ending March 2031 and begin commercialising hydrogen supply and use in Japan, it said on 17 December, as Japan otherwise risks falling behind in developing a market, including with regard to establishing international regulations. But KHI still considers the coal-to-hydrogen project in Australia as a potential supply source after 2030, when it expects liquefied hydrogen supplies to be commercialised.

By Nanami Oki

ANALYSIS

Dutch hydrogen sector takes aim at mandate plans

Firms say mandates are at odds with the principle of 'better green here than grey elsewhere', writes Stefan Krumpelmann

The Dutch government's proposed legislation for renewable hydrogen consumption mandates has come under fire from industry participants that are warning that the plans put the country's industrial competitiveness at risk.

The Netherlands has proposed a system that combines company-specific obligations with subsidies for production and consumption to comply with EU rules under which 42pc of industrial hydrogen use must come from renewable sources. The exact obligation for individual companies has yet to be decided, with the government considering either 8pc or 24pc by 2030 (*see table*).

But in a consultation on the plans that ended on 12 December, many respondents heavily criticised the plans.

Given that renewable hydrogen is bound to remain considerably more expensive than conventional 'grey' supply, the obligations threaten the competitive position of Dutch industry, especially as no other EU member state has so far announced plans for such mandates, they said.

"An annual obligation... entails the risk of existing hydrogen consumers scaling down or relocating activities," Norwegian state-controlled Equinor said.

The measures would fail to establish a market for renewable hydrogen in the Netherlands and polluting production would merely shift to other countries, the company said. This "goes against the principle of 'better green here than grey elsewhere'", it said.

Energy and water association VEMW agreed. The obligations — whether set at 8pc or 24pc — would "place a disproportionately heavy burden on companies", the group said. They would undermine a level playing field as other EU member states "adopt a wait-and-see approach", it said.

The Port of Rotterdam urged close co-ordination with other member states in order to avoid disadvantaging Dutch industry. It criticised the existing plans for preventing "the transition to other forms of low-carbon hydrogen", such as supply made from natural gas with carbon capture and storage (CCS). Several CCS-based hydrogen projects are planned at the port.

But not every respondent was against the government's approach. "The current proposal sends a strong signal to the market and as such should be kept ambitious at all costs," e-methane project developer Tree Energy Solutions (TES) said. All member states will eventually have to implement the EU rules, and subsidies — plus instruments such as the EU's carbon-border adjustment mechanism (CBAM) — would help prevent the relocation of production abroad, TES said.

Trading firm STX said the Dutch approach is "well-structured", but stressed that measures would have to be taken to mitigate the risks of industry relocating.

Despite a few positive responses, BP's country head for the Netherlands, Cornelis Boot, said the overall conclusions from the consultation were clear. "If almost every company or industry organisation with hydrogen ambitions reacts so sharply, then as a government official you know that something is seriously wrong," Boot wrote on LinkedIn.

VEMW called on the government to "clearly communicate to the European Commission that the 2030 targets [for renewable hydrogen consumption] are not achievable in their current form".

Possible phase-in of Dutch mandates %		
Year	Low variant	High variant
2026	0.2	0.2
2027	1	2
2028	4	8
2029	6	16
2030	8	24

— Dutch government

Penalty shout

Some respondents objected to the government's plans on how companies would be penalised for failing to comply with the obligations.

The government has proposed that Dutch emissions authority Nea decides fines on a case-by-case basis, taking into account factors such as the severity,

ANALYSIS

scope and duration of the non-compliance. Companies would then still have to meet their obligations retrospectively through buying tradeable credits for renewable hydrogen.

This system differs from other systems in similar legislation, such as mandates for hydrogen-based sustainable aviation fuels in the EU and UK, or Finland's proposed obligations for supply of renewable hydrogen and derivatives to the transport sector. In these cases, there are fixed penalties for each unit that companies fall short of for their quotas, effectively constituting a buy-out option for obligated parties.

The Dutch case-by-case approach "does not seem workable" for companies because of the uncertainties involved, sustainable energy association NVDE said. Purchasing tickets retrospectively would hinge on enough having been generated in the first place, it noted.

VEMW sees a buy-out option as preferable to a fine, as it provides more flexibility at a time when availability of renewable hydrogen is uncertain. But the group stressed that ideally neither a fine nor a buy-out penalty should apply because of the concerns over competitiveness.

But utility Eneco, which is planning renewable hydrogen production projects, is against a buy-out mechanism. This would create uncertainty around expected demand "since the obligation can always be bought off", making it more difficult for would-be producers to estimate offtake potential, it said.

TES and STX criticised plans to introduce a system of tradeable credits that could be used to meet obligations for pure hydrogen only, and not for derivatives such as e-methanol or e-methane. All derivatives "must be able to compete on a level playing field" and limiting the tradeability of credits to hydrogen "is in direct conflict with the benefits that derivatives can offer to customers in terms of ease of transport and availability", TES said.

VEMW sees a buy-out option as preferable to a fine, as it provides more flexibility at a time when availability of renewable hydrogen is uncertain

VEMW criticised other aspects of the proposed trading system, including a planned obligation to make prices for the renewable hydrogen credits public, which "raises legal and practical questions".

Spring into action

The Hague has earmarked €767mn ($806mn) for demand-side subsidies, but has yet to detail what these will look like. A consultation on this is overdue, with minister for green growth and climate Sophie Hermans saying last week that this is now expected to happen in spring.

NVDE suggested that the government could introduce a "purchase guarantee" for renewable hydrogen to help production projects along to final investment decisions. This could be done "in analogy" to the Dutch "small field policy" for natural gas. In 1974, the Dutch government obliged state-owned firm Gasunie to purchase output from the country's small fields — all sites other than the giant Groningen field — stepping in as a buyer in the event that there were no other offtakers. This was intended to stimulate exploration of and production from these fields.

NVDE said the government is considering a "purchase scheme" akin to such a guarantee as a preferred route towards a demand-side subsidy.

In order to stimulate domestic production projects, the government should link any potential demand-side subsidies directly to offtake for renewable hydrogen produced in the Netherlands, according to Eneco.

The Netherlands wants to have 3-4GW of electrolysis capacity installed by 2030 and 8GW by 2032, but several reports have suggested that it could fall far short of these targets.

INTERVIEW

CBAM to drive low-carbon NH3 market: Woodside

Australia's Woodside Energy is building a portfolio of clean hydrogen and ammonia projects, including through this year's acquisition of the under-construction Beaumont carbon capture and storage (CCS) ammonia plant on the US Gulf coast. Argus spoke to Woodside's vice president for new energy, Rick Beuttel, about the plant and the outlook for the sector. Edited highlights follow:

How is the Beaumont plant progressing?
Woodside continues to target first ammonia production from 2025 for phase one. Lower-carbon ammonia production is targeted for 2026, following commencement of CCS operations to be provided to Linde by ExxonMobil.

'Beaumont gives us the opportunity to have a balanced portfolio, both geographically and from a contract perspective'

How is the regulatory market shaping up in Europe and what affect does this have on you as a producer?
We believe that Europe's carbon border adjustment mechanism [CBAM] is going to be the driving force that pushes consumers of ammonia or hydrogen to adopt lower-carbon molecules from 2026 onwards as a way to remain compliant and reduce costs. But Europe is not the only end-market. There are tenders for lower-carbon ammonia in Asia, and the OCI team and now Woodside have been active in pursuing those opportunities. In Asia, buyers prefer long-term contracts. European opportunities follow more closely the traditional ammonia market — whether for fertilizer or as a chemical feedstock — and have shorter-term contract durations. Beaumont gives us the opportunity to have a balanced portfolio, both geographically and from a contract perspective.

'For Woodside, phase 1 of the project exceeds our capital allocation targets. And we'd love a huge premium on day one. But you have to be pragmatic'

How achievable are premiums for low-carbon ammonia in the current market and do you expect CBAM implementation will aid this?
For Woodside, phase one of the project exceeds our capital allocation targets. And we'd love a huge premium on day one. But you have to be pragmatic. While there is a great deal of climate sensitivity, people are running businesses and cost is a concern. In our view, the return on investment is there and the premium will increase as the CBAM percentage increases. You also have to consider the underlying ammonia market cycle, global events, Europe's position with respect to gas supply, and the efficiency or competitiveness of existing ammonia assets. All of these will likely cast as long a shadow as CBAM, particularly in the early years.

The Woodside project adds 1.1mn t to the market in 2026. Do you see enough demand from new cases to consume the additional supply?
There is also another project in Texas City, which will come on line soon. Of course, these two new assets coming on stream will have an impact. But if we look at the underlying competitiveness of the Gulf coast, with low-cost gas and these new, large-scale, very efficient assets, we believe they will compete. But we are not going to be running the facility at full rates from day one and we are looking forward more to trading the lower-carbon ammonia. Some of that will go to Europe and some to Asia.

Have you participated in the Japanese or South Korean subsidy tenders?
We are looking at all markets where there is lower-carbon ammonia activity, whether that is power generation, bunkering or other markets. Looking at power generation markets in Asia, Woodside has long-standing relationships with many countries from an LNG perspective. Making lower-carbon ammonia from natural gas and shipping it around the world is very much analogous to shipping LNG.

IN BRIEF

RFNBO quotas in transport		%
Year	Quota	Refinery route share*
2028	1.5	0.5
2029	1.5	0.5
2030	4.0	1.0

this share can be met through RFNBO use at refineries for transport fuel production

— Finnish government

Finland approves renewable H2 transport mandates

Finland's parliament has passed legislation that sets mandates for use of renewable hydrogen and derivatives in the transport sector. Parliament on 13 December approved legal amendments to an existing bill on promotion of renewable fuel use in transport in a second reading that followed a first vote on 4 December. The rules are now scheduled to come into force at the start of next year. The revised legislation will oblige fuel suppliers in Finland to meet quotas for renewable fuels of non-biological origin (RFNBO) — effectively renewable hydrogen and derivatives — in transport from 2028 (*see table*). Suppliers will face penalties of 5.5¢/MJ of RFNBO that they fall short of the mandates, equivalent to about €6.60/kg of hydrogen based on the lower heating value of 120 MJ/kg.

Octopus Energy invests in Finland e-SAF projects

UK utility Octopus Energy's generation arm has invested in Finnish company Nordic Generation Fuels (NGF), which is developing two production plants for hydrogen-based sustainable aviation fuel (e-SAF). Octopus has not disclosed the investment amount. NGF is also backed by Business Finland, the Finnish government's trade and investment agency. Each of the plants, which are currently in the early development stage, are expected to produce about 70,000 t/yr of e-SAF, Octopus tells *Argus*. The companies expect to begin construction "in the next few years" and to start operating one of the plants by 2030.

Germany's Hydrogenious cuts jobs as H2 progress stalls

German hydrogen technology firm Hydrogenious has reduced its workforce by more than 25pc as part of an internal restructuring in response to the sector's slow development. The company, which specialises in liquid organic hydrogen carriers, says it has cut 50 jobs, leaving it with a workforce of 120. No further job cuts are planned for 2025. The redundancies are part of a "transformation process" through which the company wants to focus on a few "flagship projects", such as the Green Hydrogen Blue Danube venture, Hydrogenious says. "Geopolitical crises, higher prices for renewable power and a lack of regulatory frameworks" are slowing down the hydrogen sector's progress, the firm says.

California approves $1.4bn for EV, hydrogen stations

The California Energy Commission (CEC) has approved $1.4bn to expand its network of hydrogen refuelling stations and electric vehicle (EV) charging points. The funding will be disbursed over four years and is part of the state's $48bn Clean Transportation Programme, which includes more than $10bn for zero emission vehicle infrastructure. The programme allocates funding for up to 99 public hydrogen fuelling stations, including 44 that have opened, while it is expected to add 17,000 EV chargers to the existing network of more than 152,000 public and private chargers statewide, CEC says.

South Korea eyes 60MW hydrogen power plant for data centre

South Korean firms and regional governments have announced early-stage plans for a 60MW hydrogen fuel cell power plant, as part of a 2 trillion won ($1.4bn) artificial intelligence and data centre complex. The facility would be located in Gumi in North Gyeongsang province in the south of the country. The consortium aims to start operations in 2028, according to an announcement from Gumi city authorities. The hydrogen plant could only be a partial power supply or backup supply for the 100MW data centre because of its size, but the companies involved did not specify how the bulk of the data centre's power needs would be met.

COMPLETE HYDROGEN PRODUCTION COSTS

No-C Hydrogen									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	Cost	Cost in $/kg	± 10 Dec
Netherlands	Wind + PEM	Green	€/kg	7.84	8.23	+1.07	4.94	5.18	+0.56
Netherlands	Grid + GOO + ALK	Green	€/kg	12.03	12.62	+0.96	9.65	10.13	+0.68
UK	Wind + PEM	Green	£/kg	6.38	8.09	+0.52	3.87	4.91	-0.04
UK	Grid + GOO + ALK	Green	£/kg	10.38	13.16	-0.26	8.36	10.60	-0.56
Germany	Wind + PEM	Green	€/kg	7.88	8.27	-0.01	4.92	5.16	-0.54
Germany	Grid + GOO + ALK	Green	€/kg	11.44	12.00	-0.12	9.02	9.47	-0.41
France	Wind + PEM	Green	€/kg	8.22	8.63	+0.04	5.15	5.40	-0.52
France	Grid + GOO + ALK	Green	€/kg	10.38	10.89	-1.32	7.90	8.29	-1.61
Spain	Diurnal + PEM	Green	€/kg	6.17	6.47	+0.21	3.40	3.57	+0.06
Spain	Grid + GOO + ALK	Green	€/kg	10.45	10.97	-0.07	7.76	8.14	-0.40
US west coast	Diurnal + PEM	Green	$/kg	6.62	6.62	+0.68	4.03	4.03	+0.52
Canada	Wind + PEM	Green	C$/kg	11.54	8.13	+0.80	7.19	5.06	+0.28
Oman	Diurnal + PEM	Green	$/kg	6.30	6.30	-0.03	3.33	3.33	-0.18
Saudi Arabia	Diurnal + PEM	Green	$/kg	6.05	6.05	-0.05	3.38	3.38	-0.22
UAE	Diurnal + PEM	Green	$/kg	5.65	5.65	-0.13	3.22	3.22	-0.29
Qatar	Diurnal + PEM	Green	$/kg	6.07	6.07	-0.05	3.52	3.52	-0.21
Namibia	Diurnal + PEM	Green	$/kg	7.35	7.35	+0.13	3.70	3.70	nc
South Africa	Diurnal + PEM	Green	$/kg	7.04	7.04	+0.13	3.79	3.79	-0.02
Japan	Wind + PEM	Green	¥/kg	2,510	16.39	+0.20	1,996	13.03	-0.39
China	Diurnal + PEM	Green	Yn/kg	32.72	4.50	-0.89	19.77	2.72	-0.37
India	Diurnal + PEM	Green	Rs/kg	560.81	6.61	+0.29	298.65	3.52	+0.14
South Korea	Wind + PEM	Green	W/kg	22,190	15.48	+1.02	17,574	12.26	+0.46
Vietnam	Wind + PEM	Green	$/kg	9.72	9.72	+0.40	5.68	5.68	-0.40
Australia	Diurnal + PEM	Green	A$/kg	9.90	6.30	+0.47	5.78	3.68	+0.30
Brazil	Diurnal + PEM	Green	$/kg	6.85	6.85	+0.29	3.53	3.53	+0.15
Chile	Diurnal + PEM	Green	$/kg	6.48	6.48	-0.10	3.71	3.71	-0.26

Low-C hydrogen									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	Cost	Cost in $/kg	± 10 Dec
Netherlands	ATR + CCS	Blue	€/kg	4.97	5.21	-0.20	3.81	4.00	-0.20
UK	ATR + CCS	Blue	£/kg	4.19	5.31	-0.28	3.16	4.01	-0.29
Germany	ATR + CCS	Blue	€/kg	4.97	5.22	-0.27	3.80	3.99	-0.27
Spain	ATR + CCS	Blue	€/kg	5.13	5.38	-0.26	3.68	3.86	-0.26
France	ATR + CCS	Blue	€/kg	4.93	5.17	-0.33	3.68	3.86	-0.34
US Gulf coast	ATR + CCS	Blue	$/kg	2.65	2.65	+0.03	1.43	1.43	+0.02
Canada	ATR + CCS	Blue	C$/kg	3.21	2.26	nc	1.48	1.04	nc
Japan	ATR + CCS	Blue	¥/kg	908	5.93	-0.12	698	4.56	-0.12
South Korea	ATR + CCS	Blue	W/kg	8,156	5.69	-0.18	6,293	4.39	-0.18
Australia	ATR + CCS	Blue	A$/kg	6.66	4.24	+0.12	4.73	3.01	+0.12
Trinidad	ATR + CCS	Blue	$/kg	5.15	5.15	-0.16	3.29	3.29	-0.17
Qatar	ATR + CCS	Blue	$/kg	4.55	4.55	-0.12	3.30	3.30	-0.13
UAE	ATR + CCS	Blue	$/kg	4.72	4.72	-0.13	3.55	3.55	-0.13
Russia west	ATR + CCS	Blue	$/kg	3.09	3.09	+0.04	1.01	1.01	+0.03
Russia east	ATR + CCS	Blue	$/kg	3.03	3.03	+0.03	0.96	0.96	+0.03

COMPLETE HYDROGEN PRODUCTION COSTS

BAT+ hydrogen									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	Cost	Cost in $/kg	± 10 Dec
Netherlands	SMR + CCS	Blue	€/kg	3.87	4.06	-0.23	3.24	3.40	-0.22
UK	SMR + CCS	Blue	£/kg	3.18	4.03	-0.25	2.61	3.31	-0.26
Germany	SMR + CCS	Blue	€/kg	3.90	4.09	-0.24	3.26	3.42	-0.23
Spain	SMR + CCS	Blue	€/kg	3.99	4.19	-0.24	3.19	3.35	-0.24
France	SMR + CCS	Blue	€/kg	3.88	4.07	-0.25	3.19	3.35	-0.24
US Gulf coast	SMR + CCS	Blue	$/kg	1.73	1.73	+0.03	1.06	1.06	+0.03
Canada	SMR + CCS	Blue	C$/kg	2.17	1.53	-0.03	1.22	0.86	-0.03
Japan	SMR + CCS	Blue	¥/kg	682	4.45	-0.14	567	3.70	-0.13
South Korea	SMR + CCS	Blue	W/kg	6,279	4.38	-0.14	5,246	3.66	-0.14
Australia	SMR + CCS	Blue	A$/kg	4.87	3.10	+0.10	3.80	2.42	+0.09
Trinidad	SMR + CCS	Blue	$/kg	3.91	3.91	-0.16	2.89	2.89	-0.16
Qatar	SMR + CCS	Blue	$/kg	3.60	3.60	-0.13	2.91	2.91	-0.13
UAE	SMR + CCS	Blue	$/kg	3.61	3.61	-0.12	2.96	2.96	-0.13
Russia west	SMR + CCS	Blue	$/kg	1.85	1.85	+0.03	0.70	0.70	+0.03
Russia east	SMR + CCS	Blue	$/kg	1.81	1.81	+0.03	0.66	0.66	+0.03

BAT+ hydrogen							17 Dec
				Excl. capex			
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	
Netherlands	SMR + CCS retrofit	Blue	€/kg	3.56	3.74	-0.23	
UK	SMR + CCS retrofit	Blue	£/kg	2.82	3.58	-0.25	
Germany	SMR + CCS retrofit	Blue	€/kg	3.55	3.73	-0.25	
Spain	SMR + CCS retrofit	Blue	€/kg	3.49	3.66	-0.24	
France	SMR + CCS retrofit	Blue	€/kg	3.51	3.68	-0.25	
US Gulf coast	SMR + CCS retrofit	Blue	$/kg	1.31	1.31	+0.02	
Canada	SMR + CCS retrofit	Blue	C$/kg	1.70	1.20	-0.03	
Japan	SMR + CCS retrofit	Blue	¥/kg	584	3.81	-0.13	
South Korea	SMR + CCS retrofit	Blue	W/kg	5,447	3.80	-0.14	
Australia	SMR + CCS retrofit	Blue	A$/kg	4.16	2.65	+0.09	
Trinidad	SMR + CCS retrofit	Blue	$/kg	3.06	3.06	-0.16	
Qatar	SMR + CCS retrofit	Blue	$/kg	3.12	3.12	-0.12	
UAE	SMR + CCS retrofit	Blue	$/kg	3.16	3.16	-0.13	
Russia west	SMR + CCS retrofit	Blue	$/kg	0.90	0.90	+0.03	
Russia east	SMR + CCS retrofit	Blue	$/kg	0.86	0.86	+0.03	

BAT+ hydrogen											17 Dec
					Incl. capex			Excl. capex			
	Process	kcal/kg NAR	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	Cost	Cost in $/kg	± 10 Dec	
Australia	Coal gasification + CCS	5,500	Blue	A$/kg	6.21	3.95	nc	4.26	2.71	nc	
Australia	Coal gasification + CCS	6,000	Blue	A$/kg	6.87	4.37	-0.01	4.92	3.13	-0.01	
China	Coal gasification + CCS	3,800	Blue	Yn/kg	31.19	4.29	-0.04	21.59	2.97	-0.04	
China	Coal gasification + CCS	5,500	Blue	Yn/kg	30.90	4.25	-0.04	21.30	2.93	-0.04	
Indonesia	Coal gasification + CCS	5,500	Blue	$/kg	4.21	4.21	-0.03	2.72	2.72	-0.03	
Indonesia	Coal gasification + CCS	3,800	Blue	$/kg	4.00	4.00	-0.03	2.51	2.51	-0.04	
South Africa	Coal gasification + CCS	4,800	Blue	$/kg	4.29	4.29	-0.05	2.58	2.58	-0.05	
South Africa	Coal gasification + CCS	6,000	Blue	$/kg	4.52	4.52	-0.05	2.80	2.80	-0.06	
Russia west	Coal gasification + CCS	6,000	Blue	$/kg	4.07	4.07	-0.01	2.19	2.19	-0.01	
US east coast	Coal gasification + CCS	6,000	Blue	$/kg	3.75	3.75	-0.02	2.53	2.53	-0.01	

COMPLETE HYDROGEN PRODUCTION COSTS

Baseline hydrogen									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	Cost	Cost in $/kg	± 10 Dec
Netherlands	SMR	Grey	€/kg	3.81	4.00	-0.24	3.28	3.44	-0.23
UK	SMR	Grey	£/kg	2.96	3.75	-0.26	2.48	3.14	-0.27
Germany	SMR	Grey	€/kg	3.84	4.03	-0.25	3.30	3.46	-0.25
Spain	SMR	Grey	€/kg	3.91	4.10	-0.25	3.23	3.39	-0.25
France	SMR	Grey	€/kg	3.81	4.00	-0.26	3.23	3.39	-0.26
US Gulf coast	SMR	Grey	$/kg	1.35	1.35	+0.02	0.78	0.78	+0.02
Canada	SMR	Grey	C$/kg	2.14	1.51	-0.03	1.35	0.95	-0.02
Japan	SMR	Grey	¥/kg	554	3.62	-0.14	456	2.98	-0.14
South Korea	SMR	Grey	W/kg	5,160	3.60	-0.15	4,286	2.99	-0.15
Australia	SMR	Grey	A$/kg	4.07	2.59	+0.09	3.17	2.02	+0.09
Trinidad	SMR	Grey	$/kg	3.35	3.35	-0.16	2.49	2.49	-0.16
Qatar	SMR	Grey	$/kg	3.22	3.22	-0.13	2.64	2.64	-0.13
UAE	SMR	Grey	$/kg	3.24	3.24	-0.12	2.69	2.69	-0.13
Russia west	SMR	Grey	$/kg	1.40	1.40	+0.03	0.43	0.43	+0.03
Russia east	SMR	Grey	$/kg	1.36	1.36	+0.03	0.39	0.39	+0.03

Baseline hydrogen									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	Cost	Cost in $/kg	± 10 Dec
Netherlands	Grid + ALK	Yellow	€/kg	12.01	12.60	+0.97	9.63	10.11	+0.68
Netherlands	Grid + PEM	Yellow	€/kg	11.68	12.26	+0.94	9.13	9.58	+0.66
UK	Grid + ALK	Yellow	£/kg	10.11	12.82	-0.26	8.10	10.26	-0.56
UK	Grid + PEM	Yellow	£/kg	9.83	12.46	-0.23	7.65	9.70	-0.52
Germany	Grid + ALK	Yellow	€/kg	11.41	11.97	-0.13	9.00	9.44	-0.42
Germany	Grid + PEM	Yellow	€/kg	11.12	11.67	-0.09	8.52	8.94	-0.38
France	Grid + ALK	Yellow	€/kg	10.36	10.87	-1.32	7.87	8.26	-1.62
France	Grid + PEM	Yellow	€/kg	10.16	10.66	-1.20	7.48	7.85	-1.49
Spain	Grid + ALK	Yellow	€/kg	10.44	10.95	-0.07	7.74	8.12	-0.39
Spain	Grid + PEM	Yellow	€/kg	10.26	10.77	-0.04	7.34	7.70	-0.37
US west coast	Grid + ALK	Yellow	$/kg	9.72	9.72	+0.49	7.21	7.21	+0.20
US west coast	Grid + PEM	Yellow	$/kg	9.58	9.58	+0.49	6.87	6.87	+0.20
US Midwest	Grid + ALK	Yellow	$/kg	8.12	8.12	+0.53	5.61	5.61	+0.24
US Midwest	Grid + PEM	Yellow	$/kg	8.09	8.09	+0.52	5.38	5.38	+0.23
US east coast	Grid + ALK	Yellow	$/kg	8.90	8.90	+0.61	6.40	6.40	+0.33
US east coast	Grid + PEM	Yellow	$/kg	8.82	8.82	+0.60	6.11	6.11	+0.31
Japan	Grid + ALK	Yellow	¥/kg	1,711	11.17	+0.69	1,299	8.48	+0.39
Japan	Grid + PEM	Yellow	¥/kg	1,676	10.94	+0.66	1,230	8.03	+0.35

COMPLETE HYDROGEN PRODUCTION COSTS

Hydrogen decarbonisation spreads	Incl. capex		Excl. capex		17 Dec
	$/kg	± 10 Dec	$/kg	± 10 Dec	
Northwest Europe					
No-C to BAT+	4.31	+0.61	1.86	+0.07	
Low-C to BAT+	1.13	-0.03	0.56	-0.04	
BAT+ to baseline	0.06	+0.01	-0.04	+0.02	
North America					
No-C to BAT+	5.75	+0.74	3.59	+0.40	
Low-C to BAT+	0.83	+0.02	0.28	+0.01	
BAT+ to baseline	0.20	+0.01	0.09	nc	
Northeast Asia					
No-C to BAT+	7.70	+0.25	5.66	+0.04	
Low-C to BAT+	1.39	-0.01	0.80	-0.01	
BAT+ to baseline	0.81	+0.01	0.69	nc	
Middle East					
No-C to BAT+	2.41	+0.06	0.42	-0.10	
Low-C to BAT+	1.03	nc	0.49	nc	
BAT+ to baseline	0.38	+0.01	0.27	nc	
Net exporter					
No-C to BAT+	3.51	+0.22	1.30	+0.06	
Low-C to BAT+	1.03	nc	0.48	nc	
BAT+ to baseline	0.41	+0.01	0.31	+0.01	

Decarbonisation spreads relevant for subsidy mechanisms		Incl. capex			Excl. capex		17 Dec
	Unit	Spread	Spread in $/kg	± 10 Dec	Spread	Spread in $/kg	± 10 Dec
France							
No-C to Baseline[1]	€/kg	4.41	4.63	+0.30	1.92	2.01	-0.26
Germany							
No-C to BAT+[2]	€/kg	3.98	4.18	+0.23	1.66	1.74	-0.31
Netherlands							
No-C to baseline[3]	€/kg	4.03	4.23	+1.31	1.66	1.74	+0.79

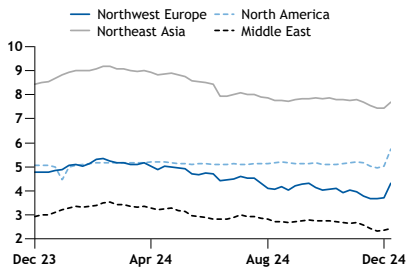
Differentials between the costs of renewable and natural gas-based hydrogen are used in subsidy mechanisms to establish the cost of switching to supply with a lower emissions intensity. The spreads above are relevant for the following:

1 France's planned operational support scheme for renewable hydrogen plants

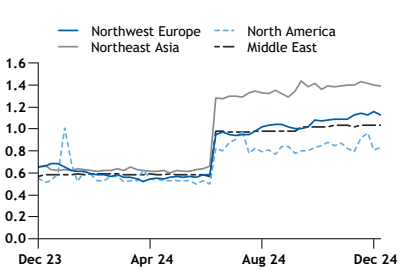
2 Future supply to Thyssenkrupp's direct reduced iron plant in Duisburg

3 Operational support granted to selected projects in Dutch subsidy scheme

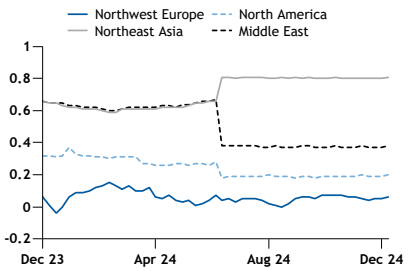
Decarb spread No-C to BAT+ *$/kg*



Decarb spread Low-C to BAT+ *$/kg*



Decarb spread BAT+ to baseline *$/kg*

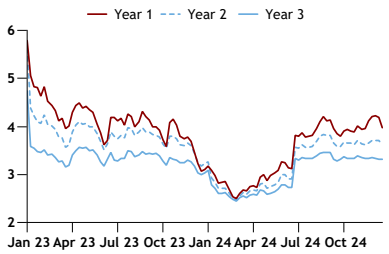


COMPLETE HYDROGEN PRODUCTION COSTS

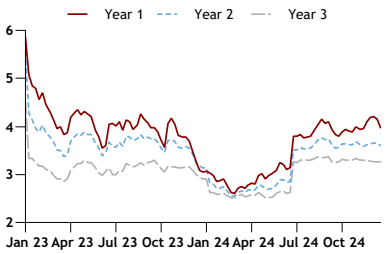
Low-C hydrogen forward									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	Cost	Cost in $/kg	± 10 Dec
Netherlands									
2025	ATR + CCS	Blue	€/kg	4.83	5.07	-0.14	3.68	3.86	-0.14
2026	ATR + CCS	Blue	€/kg	4.42	4.64	-0.01	3.27	3.43	-0.01
2027	ATR + CCS	Blue	€/kg	4.07	4.27	+0.06	2.92	3.06	+0.05
UK									
2025	ATR + CCS	Blue	£/kg	4.08	5.17	-0.22	3.06	3.88	-0.22
2026	ATR + CCS	Blue	£/kg	3.76	4.77	-0.06	2.75	3.48	-0.06
Germany									
2025	ATR + CCS	Blue	€/kg	4.87	5.11	-0.21	3.20	3.88	-0.21
2026	ATR + CCS	Blue	€/kg	4.48	4.70	-0.07	3.70	3.47	-0.07
2027	ATR + CCS	Blue	€/kg	4.14	4.34	nc	3.31	3.11	nc
France									
2025	ATR + CCS	Blue	€/kg	4.77	5.00	-0.24	3.52	3.69	-0.25
Spain									
2025	ATR + CCS	Blue	€/kg	4.95	5.19	-0.18	3.50	3.67	-0.19

BAT+ hydrogen forward									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	Cost	Cost in $/kg	± 10 Dec
Netherlands									
2025	SMR + CCS	Blue	€/kg	3.79	3.98	-0.18	3.16	3.32	-0.17
2026	SMR + CCS	Blue	€/kg	3.43	3.60	-0.05	2.79	2.93	-0.05
2027	SMR + CCS	Blue	€/kg	3.12	3.27	+0.01	2.48	2.60	+0.01
UK									
2025	SMR + CCS	Blue	£/kg	3.12	3.96	-0.20	2.56	3.25	-0.20
2026	SMR + CCS	Blue	£/kg	2.86	3.62	-0.06	2.29	2.90	-0.07
Germany									
2025	SMR + CCS	Blue	€/kg	3.85	4.04	-0.19	3.20	3.36	-0.19
2026	SMR + CCS	Blue	€/kg	3.50	3.67	-0.06	2.85	2.99	-0.06
2027	SMR + CCS	Blue	€/kg	3.18	3.34	-0.01	2.53	2.66	-0.01
France									
2025	SMR + CCS	Blue	€/kg	3.78	3.97	-0.20	3.10	3.25	-0.20
Spain									
2025	SMR + CCS	Blue	€/kg	3.88	4.07	-0.18	3.08	3.23	-0.18

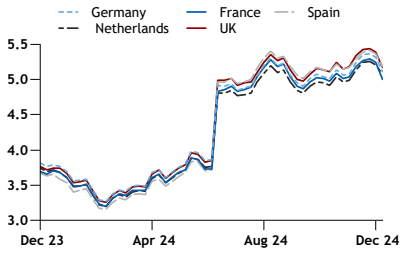
German SMR costs *$/kg*



Dutch SMR+CCS costs *$/kg*



European year 1 ATR+CCS costs *$/kg*



COMPLETE HYDROGEN PRODUCTION COSTS

Baseline hydrogen forward									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 10 Dec	Cost	Cost in $/kg	± 10 Dec
Netherlands									
2025	SMR	Grey	€/kg	3.74	3.92	-0.19	3.20	3.36	-0.19
2026	SMR	Grey	€/kg	3.38	3.55	-0.06	2.85	2.99	-0.06
2027	SMR	Grey	€/kg	3.08	3.23	-0.01	2.54	2.67	nc
UK									
2025	SMR	Grey	£/kg	2.94	3.73	-0.21	2.46	3.12	-0.22
2026	SMR	Grey	£/kg	2.68	3.40	-0.08	2.21	2.80	-0.08
Germany									
2025	SMR	Grey	€/kg	3.78	3.97	-0.21	3.24	3.40	-0.21
2026	SMR	Grey	€/kg	3.45	3.62	-0.08	2.91	3.05	-0.07
2027	SMR	Grey	€/kg	3.15	3.31	-0.01	2.60	2.73	-0.02
France									
2025	SMR	Grey	€/kg	3.72	3.90	-0.21	3.14	3.29	-0.21
Spain									
2025	SMR	Grey	€/kg	3.79	3.98	-0.19	3.12	3.27	-0.19

Direct reduction iron costs (13 Dec)		*$/t*
Specification	**Cost**	**±**
Natural gas DRI, ex-works NW Europe	426.69	-9.53
DRI spread No-C hydrogen (renewables+PEM) vs natural gas NW Europe	376.88	+6.38
DRI spread BAT+ hydrogen (SMR+CCS) vs natural gas NW Europe	162.28	+4.64

Argus Hydrogen and Future Fuels Data & Downloads

Argus Hydrogen and Future Fuels subscribers can access the full range of data available to the service through the Data & Downloads section of Argus Direct or by clicking on the links below.

- Global cross-border offtake agreements for low-carbon hydrogen and derivatives
- H2Global tenders for hydrogen and derivatives
- Global e-Methanol production facilities
- Global electrolyser orders
- Global electrolyser manufacturing capacity
- Global planned ammonia cracking facilities
- Global hydrogen production and electrolyser capacity targets
- Global renewable hydrogen-based SAF production sites
- Global hydrogen production and consumption targets by company
- Global hydrogen subsidy auctions tracker
- Global planned hydrogen DRI steelmaking plants
- Global planned and operational synthetic natural gas plants
- Global LOHC and liquid hydrogen seaborne transport plans

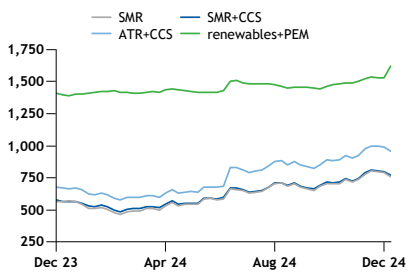
COMPLETE AMMONIA PRODUCTION COSTS

Argus liquid ammonia taxonomy (for calculated costs)	
	tCO2e/tNH3
Baseline	<1.93, >1.37
BAT+	<0.49, >0.17
Low-C	<0.17, >0.09
No-C	<0.01

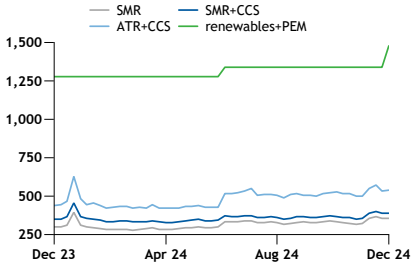
CO2e emissions on a gate-to-gate basis; purity >99.5pc; temperature -33°C

Regional ammonia cost markers						17 Dec
			Incl. capex		Excl. capex	
	Process	Unit	Cost	± 10 Dec	Cost	± 10 Dec
Baseline						
Northwest Europe	SMR	€/t	757	-35	587	-37
Northwest Europe	SMR	$/t	794	-41	616	-42
North America	SMR	$/t	355	+1	181	-1
Northeast Asia	SMR	$/t	726	-22	534	-24
Middle East	SMR	$/t	636	-20	476	-22
BAT+						
Northwest Europe	SMR+CCS	€/t	768	-32	580	-35
Northwest Europe	SMR+CCS	$/t	806	-38	609	-40
North America	SMR+CCS	$/t	390	+2	198	-1
Northeast Asia	SMR+CCS	$/t	869	-22	657	-24
Middle East	SMR+CCS	$/t	702	-19	524	-22
Low-C						
Northwest Europe	ATR+CCS	€/t	957	-35	667	-40
Northwest Europe	ATR+CCS	$/t	1,004	-42	700	-46
North America	ATR+CCS	$/t	538	+5	243	+2
Northeast Asia	ATR+CCS	$/t	1,114	-23	787	-26
Middle East	ATR+CCS	$/t	879	-18	605	-23
No-C						
Northwest Europe	Island renewable+PEM	€/t	1,621	+92	997	-18
Northwest Europe	Island renewable+PEM	$/t	1,701	+88	1,046	-25
North America	Island renewable+PEM	$/t	1,480	+140	902	+75
Northeast Asia	Island renewable+PEM	$/t	2,390	+35	1,799	-14
Middle East	Island renewable+PEM	$/t	1,179	-26	641	-44
Exporter						
Exporter baseline	SMR	$/t	538	-5	371	-6
Exporter BAT+	SMR+CCS	$/t	610	-4	425	-5
Exporter low-C	ATR+CCS	$/t	792	-1	505	-5
Exporter no-C	Island renewable+PEM	$/t	1,287	+17	701	+1

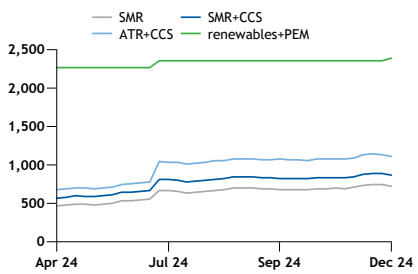
NW Europe ammonia average *€/t*



North America ammonia average *$/t*



Northeast Asia ammonia average *$/t*



COMPLETE AMMONIA PRODUCTION COSTS

No-C ammonia									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 10 Dec	Cost	Cost in $/t	± 10 Dec
Netherlands	Wind + PEM	Green	€/t	1,600	1,679	+223	993	1,042	+114
UK	Wind + PEM	Green	£/t	1,294	1,640	+119	765	969	-2
Germany	Wind + PEM	Green	€/t	1,592	1,670	+16	973	1,021	-97
France	Wind + PEM	Green	€/t	1,673	1,755	+27	1,025	1,076	-92
Spain	Diurnal + PEM	Green	€/t	1,225	1,285	+20	662	695	+5
US west coast	Diurnal + PEM	Green	$/t	1,309	1,309	+109	793	793	+89
Canada	Wind + PEM	Green	C$/t	2,344	1,651	+171	1,434	1,010	+60
Oman	Diurnal + PEM	Green	$/t	1,246	1,246	-21	633	633	-36
Saudi Arabia	Diurnal + PEM	Green	$/t	1,179	1,179	-23	642	642	-43
UAE	Diurnal + PEM	Green	$/t	1,103	1,103	-37	615	615	-57
Qatar	Diurnal + PEM	Green	$/t	1,186	1,186	-23	673	673	-42
Namibia	Diurnal + PEM	Green	$/t	1,474	1,474	+4	702	702	-1
South Africa	Diurnal + PEM	Green	$/t	1,392	1,392	+9	717	717	-4
Japan	Wind + PEM	Green	¥/t	491,947	3,212	+58	383,510	2,504	-68
China	Diurnal + PEM	Green	Yn/t	6,630	912	-165	3,802	523	-67
India	Diurnal + PEM	Green	Rs/t	110,211	1,299	+40	56,421	665	+27
South Korea	Wind + PEM	Green	W/t	4,366,322	3,046	+213	3,395,869	2,369	+93
Vietnam	Wind + PEM	Green	$/t	1,957	1,957	+100	1,083	1,083	-71
Australia	Diurnal + PEM	Green	A$/t	1,965	1,251	+67	1,147	730	+46
Brazil	Diurnal + PEM	Green	$/t	1,358	1,358	+39	669	669	+29
Chile	Diurnal + PEM	Green	$/t	1,263	1,263	-33	705	705	-51

Low-C ammonia									17 Dec
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 10 Dec	Cost	Cost in $/t	± 10 Dec
Netherlands	ATR + CCS	Blue	€/t	954	1,001	-31	676	709	-35
UK	ATR + CCS	Blue	£/t	802	1,017	-46	559	709	-50
Germany	ATR + CCS	Blue	€/t	961	1,008	-42	672	705	-46
Spain	ATR + CCS	Blue	€/t	1,005	1,055	-41	650	682	-46
France	ATR + CCS	Blue	€/t	957	1,004	-53	653	685	-57
US Gulf coast	ATR + CCS	Blue	$/t	565	565	+7	269	269	+4
Canada	ATR + CCS	Blue	C$/t	726	511	+3	307	216	-1
Japan	ATR + CCS	Blue	¥/t	174,448	1,139	-18	122,527	800	-21
South Korea	ATR + CCS	Blue	W/t	1,561,039	1,089	-28	1,108,065	773	-32
Australia	ATR + CCS	Blue	A$/t	1,324	843	+25	848	540	+21
Trinidad	ATR + CCS	Blue	$/t	1,053	1,053	-23	583	583	-28
Qatar	ATR + CCS	Blue	$/t	872	872	-18	584	584	-23
UAE	ATR + CCS	Blue	$/t	886	886	-18	626	626	-23
Russia west	ATR + CCS	Blue	$/t	718	718	+12	189	189	+5
Russia east	ATR + CCS	Blue	$/t	714	714	+10	185	185	+4

Japan and Korea low-carbon ammonia benchmark (JK LAB)			17 Dec
	Unit	Cost	± 10 Dec
CFR Ulsan, South Korea, incl. US 45Q tax credit	$/t	572.55	+7.15
CFR Ulsan, South Korea, excl. US 45Q tax credit	$/t	708.55	+7.15
CFR Niihama, Japan, differential	$/t	+0.26	-0.06

The JKLAB includes the US Gulf coast Low-C ATR+CCS ammonia production cost (with and without the US' 45Q tax credit for carbon sequestration) and freight costs for delivery to Ulsan, South Korea. The Niihama differential reflects the cost difference for delivery to Niihama in Japan, rather than to Ulsan.

COMPLETE AMMONIA PRODUCTION COSTS

BAT+ ammonia										17 Dec
				Incl. capex			Excl. capex			
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 10 Dec	Cost	Cost in $/t	± 10 Dec	
Netherlands	SMR + CCS	Blue	€/t	763	801	-36	582	611	-39	
UK	SMR + CCS	Blue	£/t	626	793	-42	469	594	-44	
Germany	SMR + CCS	Blue	€/t	770	808	-39	584	613	-40	
Spain	SMR + CCS	Blue	€/t	802	842	-39	572	600	-41	
France	SMR + CCS	Blue	€/t	772	810	-39	575	603	-41	
US Gulf coast	SMR + CCS	Blue	$/t	400	400	+7	208	208	+5	
Canada	SMR + CCS	Blue	C$/t	540	380	-3	267	188	-6	
Japan	SMR + CCS	Blue	¥/t	134,627	879	-21	100,932	659	-23	
South Korea	SMR + CCS	Blue	W/t	1,231,343	859	-23	937,483	654	-26	
Australia	SMR + CCS	Blue	A$/t	1,002	638	+18	694	442	+16	
Trinidad	SMR + CCS	Blue	$/t	822	822	-24	517	517	-27	
Qatar	SMR + CCS	Blue	$/t	706	706	-20	520	520	-22	
UAE	SMR + CCS	Blue	$/t	697	697	-19	528	528	-22	
Russia west	SMR + CCS	Blue	$/t	484	484	+9	141	141	+5	
Russia east	SMR + CCS	Blue	$/t	478	478	+8	135	135	+4	

BAT+ ammonia											17 Dec
					Incl. capex			Excl. capex			
	Process	kcal/kg NAR	Legacy colour	Unit	Cost	Cost in $/t	± 10 Dec	Cost	Cost in $/t	± 10 Dec	
Australia	Coal gasification + CCS	5,500	Blue	A$/t	1,222	778	+1	773	492	nc	
Australia	Coal gasification + CCS	6,000	Blue	A$/t	1,335	850	nc	886	564	-2	
China	Coal gasification + CCS	3,800	Blue	Yn/t	6,005	826	-6	3,795	522	-7	
China	Coal gasification + CCS	5,500	Blue	Yn/t	5,961	820	-5	3,751	516	-6	
Indonesia	Coal gasification + CCS	5,500	Blue	$/t	822	822	-4	478	478	-5	
Indonesia	Coal gasification + CCS	3,800	Blue	$/t	786	786	-4	442	442	-7	
South Africa	Coal gasification + CCS	4,800	Blue	$/t	852	852	-7	454	454	-9	
South Africa	Coal gasification + CCS	6,000	Blue	$/t	892	892	-7	492	492	-10	
Russia west	Coal gasification + CCS	6,000	Blue	$/t	829	829	nc	389	389	-2	
US east coast	Coal gasification + CCS	6,000	Blue	$/t	741	741	-2	460	460	-2	

Baseline ammonia										17 Dec
				Incl. capex			Excl. capex			
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 10 Dec	Cost	Cost in $/t	± 10 Dec	
Netherlands	SMR	Grey	€/t	752	789	-39	589	618	-41	
UK	SMR	Grey	£/t	587	744	-43	444	563	-46	
Germany	SMR	Grey	€/t	760	797	-41	590	619	-43	
Spain	SMR	Grey	€/t	787	826	-41	578	607	-44	
France	SMR	Grey	€/t	760	797	-41	581	610	-43	
US Gulf coast	SMR	Grey	$/t	333	333	+6	159	159	+4	
Canada	SMR	Grey	C$/t	534	376	-4	288	203	-6	
Japan	SMR	Grey	¥/t	111,959	731	-21	81,481	532	-23	
South Korea	SMR	Grey	W/t	1,032,092	720	-24	766,902	535	-26	
Australia	SMR	Grey	A$/t	861	548	+17	583	371	+15	
Trinidad	SMR	Grey	$/t	722	722	-24	446	446	-27	
Qatar	SMR	Grey	$/t	640	640	-20	472	472	-22	
UAE	SMR	Grey	$/t	632	632	-20	480	480	-22	
Russia west	SMR	Grey	$/t	403	403	+8	93	93	+5	
Russia east	SMR	Grey	$/t	397	397	+8	87	87	+4	

COMPLETE AMMONIA PRODUCTION COSTS

Ammonia decarbonisation spreads				17 Dec
	Incl. capex		Excl. capex	
	$/t	± 10 Dec	$/t	± 10 Dec
Northwest Europe				
No-C to BAT+	895	+126	437	+15
Low-C to BAT+	198	-4	91	-6
BAT+ to baseline	12	+3	-7	+2
North America				
No-C to BAT+	1,090	+138	704	+76
Low-C to BAT+	148	+3	45	+3
BAT+ to baseline	35	+1	17	nc
Northeast Asia				
No-C to BAT+	1,521	+57	1,142	+10
Low-C to BAT+	245	-1	130	-2
BAT+ to baseline	143	nc	123	nc
Middle East				
No-C to BAT+	477	-7	117	-22
Low-C to BAT+	177	+1	81	-1
BAT+ to baseline	66	+1	48	nc
Net exporter				
No-C to BAT+	677	+21	276	+6
Low-C to BAT+	182	+3	80	nc
BAT+ to baseline	72	+1	54	+1

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