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Argus *Hydrogen and Future Fuels*

Market news, analysis and prices

Issue 24-10 | Tuesday 5 March 2024

US has high hopes for subsurface H2

Mining hydrogen promises unprecedentedly low production costs — but potential producers are still calling for initial subsidies, write Emmeline Willey and Stefan Krumpelmann

The US sees large potential for subsurface hydrogen production and is considering subsidising this through its generous production tax credits (PTCs), which could boost investment in the space.

Washington is considering including subsurface hydrogen as an eligible pathway under the Inflation Reduction Act's 45V PTCs, for which the Treasury is currently finalising the guidelines. The Department of Energy (DOE) has provided funding to its Argonne National Laboratory to add a geologic hydrogen emissions calculation pathway to the model used to determine eligibility for 45V, DOE energy research projects director Evelyn Wang told a Senate Energy and Natural Resources committee hearing last week. This process should be completed later this year, Wang said. She expressed high hopes for subsurface hydrogen, noting "it could lower energy costs and increase our nation's energy security and supply chain".

Based on some estimates, subsurface hydrogen could under specific circumstances qualify for the highest tax credit of up to $3/kg, for which lifecycle emissions have to be below 0.45kg of CO_2 equivalent (CO_2e) per 1kg of hydrogen and certain labour standards must be met. The study *Greenhouse gas intensity of natural hydrogen produced from subsurface geologic accumulations* — published in peer-reviewed scientific journal *Joule* last year — modelled production of subsurface hydrogen with a carbon intensity of 0.37kg CO_2e/kg of hydrogen. That said, the study's author, Adam Brandt, cautioned that lifecycle emissions for geologic hydrogen depend on a range of factors, including methane content, the energy sources used to power the production process and the disposal of waste gas.

45V hydrogen tax credit		$/kg
Emissions *kg of CO2e/kg of H2**	Base	Multiplier†
2.5-4	0.12	0.60
1.5 to <2.5	0.15	0.75
0.45 to <1.5	0.20	1.00
<0.45	0.60	3.00

**based on lifecycle emissions; †applies if prevailing wage and apprenticeship requirements are met*

— US government

For companies active in the space, access to the 45V credits could make or break their economic case. Drilling for hydrogen would be economically unappealing in the near term if subsurface production pathways are not included in the credits, US start-up Koloma's chief executive, Pete Johnson, said at last week's hearing. If all other hydrogen production pathways are subsidised but geologic hydrogen is left out of the picture, it will be "very challenging" to garner the private investment needed to get the resource out of the ground, Johnson said.

Subsurface hydrogen has been subject to much scepticism in the face of bold claims it could meet a significant amount of the world's hydrogen demand at unprecedentedly low costs. It has drawn the interest of governments around the globe, but it is uncertain how much can be economically mined.

The US Geological Survey (USGS) recently estimated there could be trillions of tonnes of hydrogen stored underground, but that most of it might be too deep, too far offshore or in concentrations that are too small to be feasibly explored. But just a very small percentage of the potential resource could provide about 500mn t/yr of hydrogen for 200 years, according to USGS research geologist Geoffrey Ellis.

USGS aims to release an initial map of geologic hydrogen prospects by the end of this year. This is "not going to tell you where to drill your wells", but will indicate areas that should be explored, Ellis said.

Meanwhile, other countries are advancing plans to capitalise on subsurface hydrogen deposits. The Philippines' energy department last week opened a tender for exploration in two areas in the north of the country. The provinces of Zambales and Pangasinan have particularly promising geological conditions, the department said. The tender is open to foreign companies and runs until 27 August.

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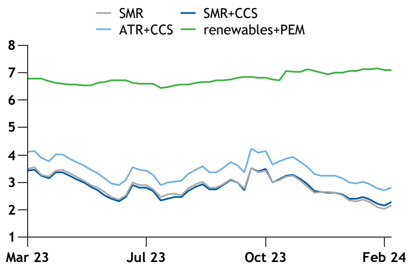
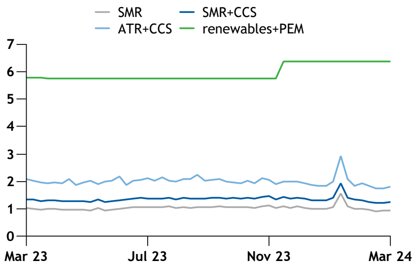
HYDROGEN COSTS

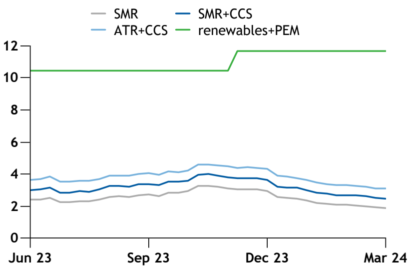
Northwest Europe average cost €/kg



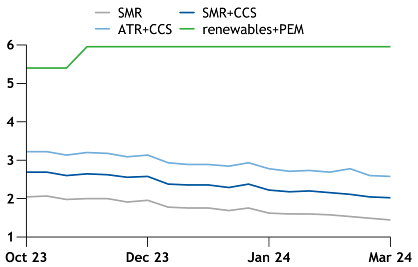
North America average cost $/kg



Northeast Asia average cost $/kg



Exporter average cost $/kg



Regional hydrogen cost markers						5 Mar
			Incl. capex		Excl. capex	
	Process	Unit	Cost	± 27 Feb	Cost	± 27 Feb
Baseline						
Northwest Europe	SMR	€/kg	2.15	+0.13	1.87	+0.12
Northwest Europe	SMR	$/kg	2.33	+0.14	2.03	+0.14
North America	SMR	$/kg	0.93	+0.01	0.62	+0.01
Northeast Asia	SMR	$/kg	1.88	-0.03	1.57	-0.03
Middle East	SMR	$/kg	1.68	-0.03	1.37	-0.03
BAT+						
Northwest Europe	SMR+CCS	€/kg	2.27	+0.11	1.77	+0.11
Northwest Europe	SMR+CCS	$/kg	2.46	+0.12	1.92	+0.12
North America	SMR+CCS	$/kg	1.24	+0.02	0.69	+0.01
Northeast Asia	SMR+CCS	$/kg	2.47	-0.03	1.91	-0.04
Middle East	SMR+CCS	$/kg	2.28	-0.03	1.73	-0.03
Low-C						
Northwest Europe	ATR+CCS	€/kg	2.80	+0.10	2.12	+0.11
Northwest Europe	ATR+CCS	$/kg	3.03	+0.11	2.30	+0.12
North America	ATR+CCS	$/kg	1.81	+0.06	1.08	+0.07
Northeast Asia	ATR+CCS	$/kg	3.09	-0.03	2.34	-0.03
Middle East	ATR+CCS	$/kg	2.87	-0.03	2.11	-0.04
No-C						
Northwest Europe	Island renewable+PEM	€/kg	7.10	-0.01	4.98	-0.01
Northwest Europe	Island renewable+PEM	$/kg	7.69	nc	5.40	nc
North America	Island renewable+PEM	$/kg	6.39	nc	4.14	nc
Northeast Asia	Island renewable+PEM	$/kg	11.67	nc	9.43	nc
Middle East	Island renewable+PEM	$/kg	5.81	nc	3.58	nc
Exporter						
Exporter baseline	SMR	$/kg	1.44	-0.04	1.14	-0.03
Exporter BAT+	SMR+CCS	$/kg	2.02	-0.03	1.47	-0.04
Exporter low-C	ATR+CCS	$/kg	2.57	-0.03	1.82	-0.03
Exporter no-C	Island renewable+PEM	$/kg	5.95	nc	3.60	nc

Argus hydrogen taxonomy			
	Purity	Pressure	tCO_2e/tH_2
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

CO_2e emissions on a gate-to-gate basis

Pump prices, 70MPa			5 Mar
	Unit	Price	± 2 Feb
Japan			
Eneos	¥/kg	1,650.00	nc
Iwatani	¥/kg	1,210.00	nc
Germany			
H2Mobility (stations with “green” H2 supply)	€/kg	11.50	+0.50
H2Mobility (stations with conventional H2 supply)	€/kg	14.05-15.75	+0.35

MARKET DEVELOPMENTS

H2 stakeholders push to change US tax credit rules

One bone of contention is the period over which emissions from hydrogen production are gauged, writes Emmeline Willey

The US' planned rules for the 45V hydrogen production tax credits continue to divide opinion. A recent consultation attracted more than 29,000 written responses, with some stakeholders asking for the regulations to be completely rewritten and others wanting them to be upheld as they are or made even more stringent.

The Treasury's proposed guidance from December established 'three pillars' that electrolytic hydrogen producers would need to erect to apply for the tax credit of up to \$3/kg (*see table*), the full amount of which is only available for hydrogen produced at a carbon intensity of less than 0.45kg of CO_2/kg.

But industry groups used the comment period, which ended on 28 February, to make a last-ditch effort to loosen restrictions. The Fuel Cell and Hydrogen Energy Association (FCHEA), which represents major US hydrogen producers and technology manufacturers, called for the three pillars to be eliminated or only phased in from 2033, with earlier projects grandfathered into less-demanding regulations.

Under the proposed rules, a facility's annual emissions would be averaged across the amount of hydrogen produced that year to determine credit eligibility. But the FCHEA wants sites to be credited for any duration of hydrogen production, at the discretion of the producer. Firms could then elect the credit for set hours when hydrogen is made from low-cost renewable power, while producing hydrogen outside of those hours that would be ineligible.

FCHEA and other stakeholders, including the American Petroleum Institute (API), ExxonMobil and environmental group Clean Air Task Force (CATF), requested that producers be allowed to submit their own data for the upstream emissions and leakage rates of their feedstocks, which aligns with the Environmental Protection Agency's greenhouse gas reporting requirements. Currently, the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (Greet) lifecycle emissions calculator specially designated for determining eligibility for 45V has fixed data assumptions for upstream and leakage emissions.

If the Treasury does not change its rules, hydrogen will become so expensive that a market "will not be catalysed and our project, and possibly others, will not proceed", ExxonMobil said, referring to its Baytown project that will produce low-carbon hydrogen from natural gas with carbon capture and storage. But a group of 77 environmental bodies wants the Treasury to uphold its proposed rules to ensure 45V "does not devolve into a massive giveaway to dirty energy production". The groups opposed the delayed phase-in of hourly matching, and said the Greet model's embedded upstream emissions for natural gas is "far too low".

Renewable gas' role

Many respondents adressed the use of renewable natural gas (RNG) in hydrogen production, as the Treasury gave few details about this in its proposal.

CATF and the Natural Resources Defense Council opposed including RNG with a negative carbon intensity — which could allow gas-based hydrogen production to achieve the highest credit tier. Using a blend of 25pc RNG or even less could allow producers using steam methane reforming with natural gas to obtain the full \$3/kg even without carbon capture, CATF said. Other environmental groups said being allowed to use RNG offsets — rather than having to physically blend RNG into the gas stream — would allow the industry to "co-opt 45V" and encourage more pollution.

But FCHEA pushed to allow offsets, arguing that RNG production is typically not located near hydrogen sites. The API agreed, saying direct-use rules for RNG would "needlessly" require construction of pipelines to service hydrogen plants.

The final rules are expected sometime this summer. The Treasury has scheduled a public hearing in Washington, DC, for 25 March.

Three pillars for renewable H2
1. Hydrogen must be made using electrolysis powered by renewable energy sources built within the last three years
2. Renewable assets must be on the same regional grid as the H2 project
3. Electricity must be matched to hydrogen production on an annual basis until 2028, and on an hourly basis afterwards

— US Treasury

MARKET DEVELOPMENTS

Egypt grows renewable H2 project pipeline further

The Suez Canal Economic Zone remains the destination of choice for developers in Egypt, writes Akansha Victor

Egypt has added seven more renewable hydrogen plants and a green iron and steel plant — worth tens of billions of US dollars in private investment — to its growing pipeline of projects, according to the government.

The Suez Canal Economic Zone (SCEZ) general authority signed preliminary deals for plants to produce renewable hydrogen and derivatives with seven companies, whose projects would entail a combined $12bn investment in their pilot phases, rising to $29bn following the first phases of development, and more than $40bn in total over the next 10 years, the government says.

The firms signing agreements last week were London-based Pash Global, Switzerland's Smartenergy, South Korea's SK Ecoplant, Canada's AmmPower, China-based United Energy Group and Egyptian companies Gila Al Tawakol Electric and Gama Construction.

For most planned projects, no further details were disclosed. But Smartenergy says it is planning a facility that would utilise 1GW of electrolyser capacity and a combined 2.6GW of wind and solar photovoltaic capacity to produce 150,000 t/yr of renewable hydrogen. This would then be turned into 830,000 t/yr of ammonia that could be used for producing fertilisers and as green fuel for the maritime sector, Smartenergy says, adding that it is targeting domestic use as well as exports. Smartenergy says it "started prospecting the market and strengthening ties with local developers and partners in 2022", and notes that the deal with the SCEZ means it "can commence feasibility and engineering studies" for the plant.

Suez Canal Economic Zone

SK Ecoplant says it intends to build a project at the SCEZ that would produce 50,000 t/yr of hydrogen for conversion into 250,000 t/yr of ammonia. Its facility would involve 500MW of solar power generation and 278MW of offshore wind capacity to power a 250MW electrolyser. The solid-oxide electrolyser will be supplied by Canadian company Bloom Energy, which late last year signed a deal to supply 500MW of equipment to SK Ecoplant. The South Korean firm will jointly develop the 2.6 trillion won ($1.9bn) facility with Chinese state-run construction firm CSCEC and the Egyptian government and is targeting a 2029 start date. SK Ecoplant says it is also planning to pursue projects elsewhere in Africa and globally through strategic co-operation with CSCEC.

In addition to the seven preliminary deals, Cairo is also reviewing a proposal from Italian company Danieli for a $4bn integrated industrial complex for clean iron and steel production, which would be fuelled by a renewable hydrogen facility costing $2bn-3bn, the government says. The project includes factories to make sponge iron, seamless steel pipes and flat steel. Prime minister Mostafa Madbouly has asked Danieli to submit a final version of the proposal, defining the needs of European markets to estimate the export volumes, the government says.

In the Zone

Egypt has announced dozens of early-stage deals for hydrogen projects in recent years, some of which it has upgraded into firmer "framework agreements". None has started construction, but several projects could reach final investment decisions in 2024, industry body Hydrogen Egypt said last year. The vast majority of plants has been announced in the SCEZ, where firms are planning to capitalise on favourable economic terms, such as tax and import duty breaks, as well as on the area's ample renewable power capacity and role as a key shipping route.

Egypt has said it aims to capture 5-8pc of the global hydrogen market and last month finalised a package of incentives to attract developers. Cairo recently announced a target to reach 3.2mn t/yr of renewable hydrogen production capacity by 2030, with expected investments of $175bn.

NEWS

Yara signs deal for Acme's renewable ammonia

Norway-based fertiliser producer Yara has signed a binding agreement to buy 100,000 t/yr of renewable ammonia from Indian Acme's planned Omani plant.

The deal follows 18 months of negotiations and a non-binding term sheet that the two firms signed in 2022, Yara says.

"The regulatory framework and certification regime have evolved significantly" during the negotiation period, Yara says, creating "a suitable environment for such long-term contracts". The deal is "possibly the world's first arm's-length contract for renewable ammonia of this scale and tenure", according to Yara, although it did not specify the duration.

Duqm special economic zone

Subsidiary Yara Clean Ammonia will be the sole long-term buyer from the first phase of the Omani project. The contractual commitment starts in 2027, but Acme "will aim to start earlier", the latter's president and director for green hydrogen and ammonia, Ashwani Dudeja, tells *Argus*. Deliveries could begin in 2026, most likely in the second half of that year, Dudeja says.

Dudeja said last year that the Omani project, which will be located at the Duqm special economic zone and use solar power to produce the ammonia, was on track for commercial operations in 2025. On signing a land agreement for the facility in August 2021, Acme had said the first phase could be commissioned by the end of 2022.

The Omani plant's output will comply with the EU definition of renewable fuels of non-biological origin and requirements under the revised renewable energy directive (RED III), Yara says. Acme intends to eventually increase the plant's ammonia output capacity to 1.2mn t/yr through a three-phase development process. At full capacity, the plant would utilise 3.5GW of electrolyser capacity.

Acme in July secured a loan of 40bn Indian rupees ($480mn) from India's state-run Rural Electrification Corporation to finance the project. Norwegian renewables developer Scatec was involved as a co-developer for the site, but pulled out earlier last year to focus on its own activities in Egypt.

By Dinise Chng

IAG signs 14-year offtake agreement for e-SAF

International Airlines Group (IAG) is planning to purchase 785,000t of renewable hydrogen-based sustainable aviation fuels (e-SAF) over a 14-year period from California-based producer Twelve.

Under the binding agreement, Twelve will start supplying e-SAF — made by combining renewable hydrogen with CO_2 — to IAG from next year onwards. The 785,000t would equate to just over 56,000 t/yr of supply over the 14 years. IAG says the deal is the largest commitment for e-SAF offtake signed by any European airline to date.

IAG, which includes British Airways, Iberia, Aer Lingus, Vueling and Level, has set itself a target of using 10pc SAF in its operations by 2030, and last year signed a deal for SAF from Phillips 66's Humber Refinery in the UK.

EU e-SAF mandates*

Time frame	Minimum share
2030-31	On average 1.2%, minimum 0.7% each year
2032-34	On average 2%, minimum 1.2% from 2032 and 2% from 2034
From 2035	5%
From 2040	10%
From 2045	15%
From 2050	35%

**required e-SAF share in overall jet fuel consumption* *— EU*

The EU has set specific targets for SAF use from 2025 and sub-targets for e-SAF that will apply from 2030 (*see table*). Its legislation specifies penalties for non-compliance, which has given impetus to airlines' drive to secure supply.

Twelve is currently building a demonstration plant in Moses Lake, Washington state, which will provide the first supply for deliveries to IAG, although the initial volumes were not disclosed. Other plants could provide some of the e-SAF for IAG at a later stage once they become operational, Twelve said.

By Evelina Lungu

NEWS

Austria sets €400mn to support renewable H2 output

Austria will provide €400mn ($434.3mn) in operating support for domestic renewable hydrogen production projects, probably through the EU hydrogen bank, the country's climate and energy ministry says.

The funds might be added to the hydrogen bank's second auction process, which is scheduled for later this year and which will make more than €2.2bn available for projects across the bloc.

The EU has given member states the option of adding their own contributions to the hydrogen bank in order to strengthen support for domestic ventures. This 'auctions-as-a-service' funding would offer a streamlined way to help Austrian projects — even if they miss out on top places in the EU's scheme — because it saves the government from setting up its own process.

But the government has reserved the right to set up another auctioning process with different specifications, according to a draft of its Hydrogen Promotion Act.

Austria's plans would mirror a move by Germany, which added €350mn to the EU's hydrogen bank pilot auction in December to support German projects.

The initiative aims to "ensure that Austria remains competitive in those areas that need hydrogen for their processes or that are difficult to electrify — such as energy-intensive industry and shipping and air traffic", climate and energy minister Leonore Gewessler said.

By Pamela Machado

Global hydrogen subsidy tender tracker

Argus provides an overview of announced competitive allocation procedures for hydrogen subsidies in a new data and download. Subscribers to the Argus Hydrogen and Future Fuels service can access this here.

Germany passes draft carbon management strategy

Germany's economy and climate ministry has proposed legal changes that will enable the deployment of carbon capture and storage or use (CCS/CCU) and the transport and offshore storage of carbon in the country.

Economic affairs and climate action minister Robert Habeck last week presented draft key points for a future carbon management strategy, along with a draft amendment to the country's carbon storage law. Habeck stressed that public support for CCS/CCU will be focused on emissions that are difficult or impossible to avoid.

Germany's government will also ratify the amendment to the London Protocol, enabling the export of CO_2, Habeck said.

Storing carbon will be permitted in Germany's offshore zone, excluding protected areas, enabling Germany to "catch up" with neighbours such as Norway, Habeck said. "In this way, we face the responsibility instead of shifting it to others," Habeck said. But permanent carbon storage onshore will remain banned.

Habeck called the decisions "pragmatic" and "responsible". Without CCS and CCU, Germany's climate targets will be impossible to reach, he said.

The draft carbon storage law will provide a legal framework for future CO_2 pipeline infrastructure that is expected to be privately funded, but within a state regulatory framework.

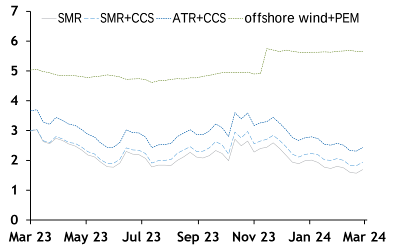
The drafts will now be sent to other ministries, and hearings for the federal states and associations will follow.

The legal changes could help advance plans for low-carbon hydrogen production with CCS or CCU in Germany, although few such projects are currently under consideration. Wintershall Dea aims to produce low-carbon hydrogen at Wilhelmshaven in northern Germany from 2030 onwards, with CO_2 separated off during the process to be shipped for offshore storage in Norway and Denmark. The firm said in 2022 that regulatory changes were key for progressing the plans.

By Chloe Jardine

NEWS

UK H2 costs *£/kg*



SSE, Equinor scrap North Sea H2 production plan

UK utility SSE and Norwegian state-controlled Equinor have scrapped their joint plan to make renewable hydrogen using their Dogger Bank D wind project in the UK sector of the North Sea, SSE says.

Dogger Bank D was announced as the fourth phase of the Dogger Bank wind farm project in February 2023.

The developers had been exploring two options for the 2GW or so of power from Dogger Bank D — delivery to the UK grid in Lincolnshire or a possible renewable hydrogen electrolysis facility in the Humber region.

But the option to make hydrogen has been "retired" by the companies after the project received confirmation for an onshore grid connection from the UK's electricity system operator ESO. The wind farm will now connect to the national grid through a new 400kV substation, Birkhill Wood in East Yorkshire, as part of the transmission system operator National Grid's Great Upgrade Project.

SSE and Equinor had awarded contracts for feasibility studies of a large-scale green hydrogen project in December to London-based firms Genesis and H2GO Power, and German consulting firm Fichtner. "It could become one of the UK's largest green hydrogen projects," SSE said at the time.

Separately, the UK government last week selected seven renewable hydrogen projects to receive a share of £21mn ($26.6mn). The funding is intended to support engineering designs for four larger projects, totalling about 500MW of planned electrolyser capacity, and capital costs for three smaller refuelling projects.

The two largest projects are 200MW plants planned by utilities RWE and EDF. The former plans to start its facility in the "late 2020s" at its Pembrokeshire power plant in Wales, while the latter's project in northeast England would start in 2030 and draw on the company's nuclear and newbuild wind and solar facilities. EDF plans to combine hydrogen with "captured biogenic CO_2" to produce e-methanol for the maritime sector, saying its e-methanol plant could be the UK's first. RWE and EDF have plans to develop smaller projects on their sites first.

London said last week that 250 planned renewable and low-carbon hydrogen plants across the UK could provide a combined 27GW of production capacity by 2030. This puts the country in a good position for its 10GW goal for 2030. But much uncertainty remains about how much of this supply will actually materialise.
By Akansha Victor and Aidan Lea

Engie delays 4GW green H2 goal by five years to 2035

French energy firm Engie says it has pushed back its 4GW renewable hydrogen production target by five years to 2035 because the market has progressed more slowly than envisaged a year ago.

Fewer hydrogen projects reached final investment decisions (FIDs) in 2022 and 2023 than market participants expected, Engie says.

Of Engie's 22 main hydrogen projects outlined in its 2023 report, only the 10MW Yuri project in Australia has reached FID. The firm would not comment on whether two FIDs previously planned for 2024 — for the 100MW HyNetherlands and 200MW Crystal sites in the UAE — are still likely to take place this year.

Even with the delay, Engie says it remains convinced that "hydrogen remains a fundamental factor within the energy transition". And while the electrolyser capacity target has been pushed back, the company's other goals announced in 2021 — for 700km of hydrogen distribution networks, 1TWh of storage and more than 100 operational refuelling stations — remain in place for 2030, it says.
By Roxana Lazar

NEWS

Eni to build €123mn grey H2 plant at Italian refinery

Italian integrated oil firm Eni has commissioned compatriot engineering firm Maire Technimont to build a €123mn ($133mn) methane-based hydrogen plant in Livorno, but it only plans to add carbon capture later, Maire Technimont said.

Eni plans to convert its 88,400 b/d Livorno refinery into a biorefinery and will use the hydrogen in its planned 500,000 t/yr hydrotreated vegetable oil (HVO) unit for making biofuels.

The hydrogen plant will be "designed so that a residual CO_2 capture unit can be implemented at a later stage", Maire Technimont says, implying that the hydrogen plant will release CO_2 emissions in the interim.

Hydrogen made from natural gas with unabated emissions is colloquially referred to as "grey" hydrogen.

Both companies declined to comment on when exactly CO_2 capture could be added, why it would not be added from the start and whether they had considered an electrolytic plant instead.

Italy's plans for carbon storage remain at a very early stage, which could partly explain the decision, although cost is also likely to be a factor.

Other market participants considering hydrogen supply for biofuels production have said the high price of electrolytic hydrogen is a deterrent from using the technology at present.

An HVO unit of this size could require a 60-80 t/d hydrogen plant, depending on what type of biofuel feedstock is being processed, as some variants require more hydrogen than others.

By Aidan Lea

Livorno, Italy

Nel to spin off hydrogen refuelling business

Norwegian electrolyser manufacturer Nel plans to separate its hydrogen refuelling business, creating "two independent pure-play companies", the firm said during its 2023 results presentation last week.

There are "limited synergies" between the electrolyser and refuelling businesses and each division will be better positioned by operating independently, chief executive Hakon Volldal said.

Nel plans to list its refuelling spin-off on the Oslo Stock Exchange and tailor its fuelling station concepts to serve the needs of heavy-duty vehicles. But the final decision to separate the divisions has not been made yet, the company said.

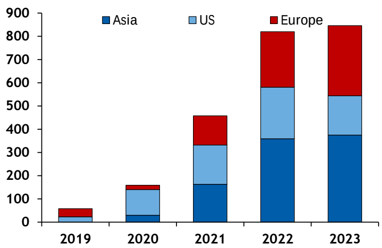
Nel is the latest in a series of electrolyser manufacturers to reconsider its strategy towards refuelling stations. French firm McPhy said in December that it is in negotiations with compatriot hydrogen company Atawey to sell its refuelling station business. UK-based ITM Power completed the sale of its refuelling stations arm in October to private equity fund Hycap.

Nel reiterated last week that it rejects allegations brought forward by Japanese firm Iwatani in a US lawsuit in which Iwatani claimed that Nel had misrepresented the capabilities of its hydrogen refuelling stations. "We will fight the allegations vigorously," Volldal said.

Meanwhile, the company is waiting for more orders to materialise in its electrolyser division. "We need to tick off a couple of large orders to restore faith in the business case," Volldal said, noting that "we acknowledge that it takes more time than we expected". Industry participants face a more financially challenging environment than a year ago and subsidy allocations have been delayed, which is holding back projects, Volldal said.

By Pamela Machado

H2 offtake at refuelling stations manufactured by Nel *t/yr*



ANALYSIS

Japan's Eneos pursues LOHCs to cut H2 transport costs

Eneos' solution could be particularly attractive for companies in the refining and petrochemicals sectors, writes Aidan Lea

The cost of shipping hydrogen over long distances remains a key challenge for connecting low-cost production sites with major demand centres. Japanese refiner Eneos expects liquid organic hydrogen carriers (LOHCs) to offer the most cost-efficient answer for refining and petrochemical companies, but acknowledges that other transport vectors will have a role to play, the firm's deputy general manager, Satoru Otatsume, told *Argus* in a recent interview.

Several companies are backing different LOHC molecules — but they all have in common favourable fossil fuel-like characteristics of comparatively easy storage and handling. Eneos proposes to load up hydrogen molecules — from places such as Australia and Malaysia — onto the aromatic hydrocarbon toluene to temporarily make methylcyclohexane (MCH) for shipment on existing petrochemical or liquid fuel vessels. Shipping this is already possible, so Eneos is waiting for mass production of hydrogen, which could kick off around 2028, Otatsume said.

Today, toluene crosses northeast Asia in 3,000-5,000t ships, but could in future fill ships of 35,000-50,000t, or even larger, according to Otatsume. Toluene can theoretically be recycled indefinitely, and even if it ever deteriorated, it could be sold back into the merchant market, where it is used for refining, paints and adhesives, Otatsume said.

As one of Asia's top suppliers of aromatics, Eneos has skin in the game, but the company argues that adopting LOHCs would also benefit other refining and petrochemical companies. Such firms already have reforming facilities that can retrieve hydrogen from LOHCs, Otatsume said. The resulting hydrogen is about 95pc pure, which is suitable for many uses, although firms would face extra costs if they need to raise purity to the 99pc required for mobility applications. In future, Eneos may employ new "dehydrogenation" technology from compatriot Chiyoda to increase efficiency, but for now using existing reformers is more cost-effective, Otatsume said.

The relatively easy extraction compares favourably with rival transport vector ammonia, where nascent "cracking" technology could take years to reach commercial scale, Otatsume said, adding that MCH is also ahead of transporting hydrogen in liquid form in terms of technological readiness. Capital costs for toluene/MCH facilities could be less than a quarter of those for liquid hydrogen plants while operating costs will also be lower, as MCH is transported at normal temperature and pressure, whereas liquid hydrogen needs cooling to -253°C, he said.

'We selected MCH for the initial stage of development, but do not deny other carriers. We also see promise in liquid hydrogen' — Eneos' Satoru Otatsume

Finding the right formula

But Otatsume concedes that LOHCs would carry less hydrogen on a volumetric basis than liquid hydrogen. And while Eneos sees MCH as its most viable option in the near term, other carriers will have a role to play, he said. "We selected MCH for the initial stage of development, but do not deny other carriers. We also see promise in liquid hydrogen." Other companies could be better placed to handle the toxicity of ammonia, while Eneos decided against using ammonia at mass scale for safety reasons, Otatsume said. "Our plan is to bring hydrogen into our refinery, which is close to residential areas, so safety is key."

Eneos says it could refine its MCH process by harnessing electrolysers' waste heat. Its first hydrogen projects will use technology from US-based Honeywell to add hydrogen from the electrolysers onto toluene to make MCH, but by 2030, Eneos hopes to finish a proprietary technology that would produce MCH directly from the electrolyser, cutting costs by up to 30pc, Otatsume said. The company is operating a "direct MCH" pilot in Australia and last year successfully shipped hydrogen to Japan to refuel a bus. Eneos might allow others to use the technology free of charge to help develop the MCH supply chain quickly and effectively.

IN BRIEF

EU to disburse €1bn for alternative fuels projects

The EU will make €1bn ($1.08bn) in grants available to support alternative fuel infrastructure for transport and has opened a call for project proposals. Eligible projects include hydrogen refuelling stations for road and rail transport, hydrogen supply facilities at airports, and ammonia and methanol bunkering facilities at ports. Infrastructure to supply electricity for transportation is also included. The funds are for "mature investment projects" that already have a financing approval letter from an implementing partner or a financial institution established in the EU. The scheme has three cut-off dates for submissions and grant agreements will be signed within nine months of these deadlines (*see table*).

Cut-off dates for submissions
24 Sep 2024
11 Jun 2025
17 Dec 2025

— European Commission

Large renewable ammonia project in Chile moves forward

Project developer Mejillones Ammonia Energy (MAE) has filed an environmental impact study for a 600,000 t/yr renewable ammonia plant in Chile's northern province of Antofagasta. The $2.5bn project would be delivered in two equally sized phases, with the firm saying the first could start in 2027. MAE will use a 600MW solar park and desalinated residual water to produce about 100,000 t/yr of hydrogen for conversion to ammonia to supply domestic and international markets. The country's hydrogen policies are "moving in the right direction" to make the country competitive, but the cost of using the electrical grid is a challenge that needs to be addressed, MAE general manager Gonzalo Moyano says.

Canada loans $95mn to renewable ammonia project

Export credit agency Export Development Canada (EDC) has agreed to loan C$128mn ($95mn) to developer World Energy GH2 for the 400,000 t/yr first phase of its Nujio'qonik green ammonia plant on the country's east coast. The credit facility will support the project through to the close of long-term financing, World Energy GH2 says. The company hopes to later expand the facility in Newfoundland and Labrador to produce 210,000 t/yr of hydrogen, or about 1.2mn t/yr of ammonia, primarily for export. The loan advances Canada's commitments under the Canada-Germany Hydrogen Alliance signed in 2022, energy and natural resources minister Jonathan Wilkinson says.

S African renewable ammonia site secures power, timeline slips

UK developer Hive Energy has secured a 372MW power supply from wind farm developer Genesis Eco-Energy for a green ammonia export project in South Africa's Eastern Cape, but the start date has been pushed back to 2028 from 2026 initially. Hive still needs to source almost 10 times more electricity, as the first phase requires 3.5GW to feed a 1.2GW electrolyser to produce 900,000 t/yr of ammonia for export and ship bunkering. This is up from projected output of 780,000 t/yr cited when plans for the plant were announced in 2021. Expected costs have also risen — to $5.8bn from $4.6bn. Hive hopes to later expand capacity in three more phases, which would need a further 12GW of power, it says.

Everfuel delays Denmark 20MW electrolyser start again

Denmark's Everfuel has further delayed the start of its 20MW hydrogen plant at Frederica — the project is now two years behind schedule — citing a "quality issue" in the deoxidiser that is part of the electrolyser system supplied by Norwegian firm Nel. Everfuel is now targeting start-up in the second quarter, compared with initial plans for mid-2022. The company is moving ahead with commissioning other high-pressure systems not affected by the deoxidiser. Everfuel had already last year announced delays and a doubling of costs to €45mn ($48.7mn).

COMPLETE HYDROGEN PRODUCTION COSTS

No-C Hydrogen									5 Mar
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 27 Feb	Cost	Cost in $/kg	± 27 Feb
Netherlands	Wind + PEM	Green	€/kg	6.35	6.88	nc	4.26	4.61	nc
Netherlands	Grid + GOO + ALK	Green	€/kg	7.17	7.77	+0.10	5.33	5.77	+0.10
UK	Wind + PEM	Green	£/kg	5.66	7.16	nc	3.89	4.93	nc
UK	Grid + GOO + ALK	Green	£/kg	7.96	10.08	+0.36	6.41	8.11	+0.36
Germany	Wind + PEM	Green	€/kg	7.37	7.99	nc	5.25	5.69	nc
Germany	Grid + GOO + ALK	Green	€/kg	7.44	8.06	+0.23	5.57	6.03	+0.23
France	Wind + PEM	Green	€/kg	7.57	8.20	nc	5.45	5.91	nc
France	Grid + GOO + ALK	Green	€/kg	7.61	8.24	+0.18	5.73	6.21	+0.18
Spain	Diurnal + PEM	Green	€/kg	5.33	5.78	nc	3.23	3.50	nc
Spain	Grid + GOO + ALK	Green	€/kg	5.10	5.53	-0.56	3.18	3.44	-0.56
US west coast	Diurnal + PEM	Green	$/kg	5.70	5.70	nc	3.50	3.50	nc
Canada	Wind + PEM	Green	C$/kg	9.59	7.07	nc	6.47	4.77	nc
Oman	Diurnal + PEM	Green	$/kg	5.80	5.80	nc	3.50	3.50	nc
Saudi Arabia	Diurnal + PEM	Green	$/kg	5.88	5.88	nc	3.58	3.58	nc
UAE	Diurnal + PEM	Green	$/kg	5.64	5.64	nc	3.50	3.50	nc
Qatar	Diurnal + PEM	Green	$/kg	5.90	5.90	nc	3.72	3.72	nc
Namibia	Diurnal + PEM	Green	$/kg	6.47	6.47	nc	3.69	3.69	nc
South Africa	Diurnal + PEM	Green	$/kg	6.41	6.41	nc	3.80	3.80	nc
Japan	Wind + PEM	Green	¥/kg	2,366	15.74	nc	2,015	13.41	nc
China	Diurnal + PEM	Green	Yn/kg	37.06	5.15	nc	22.17	3.08	nc
India	Diurnal + PEM	Green	Rs/kg	477.38	5.76	nc	279.30	3.37	nc
South Korea	Wind + PEM	Green	W/kg	18,806	14.11	nc	15,714	11.79	nc
Vietnam	Wind + PEM	Green	$/kg	8.59	8.59	nc	6.07	6.07	nc
Australia	Diurnal + PEM	Green	A$/kg	8.57	5.59	nc	5.17	3.37	nc
Brazil	Diurnal + PEM	Green	$/kg	5.97	5.97	nc	3.37	3.37	nc
Chile	Diurnal + PEM	Green	$/kg	6.26	6.26	nc	3.96	3.96	nc

Low-C hydrogen									5 Mar
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 27 Feb	Cost	Cost in $/kg	± 27 Feb
Netherlands	ATR + CCS	Blue	€/kg	2.80	3.03	+0.11	2.12	2.30	+0.11
UK	ATR + CCS	Blue	£/kg	2.43	3.08	+0.16	1.86	2.36	+0.16
Germany	ATR + CCS	Blue	€/kg	2.82	3.05	+0.11	2.13	2.31	+0.11
Spain	ATR + CCS	Blue	€/kg	2.72	2.95	+0.09	1.99	2.16	+0.08
France	ATR + CCS	Blue	€/kg	2.79	3.02	+0.13	2.10	2.28	+0.14
US Gulf coast	ATR + CCS	Blue	$/kg	1.72	1.72	nc	0.99	0.99	+0.01
Canada	ATR + CCS	Blue	C$/kg	2.58	1.90	+0.12	1.57	1.16	+0.13
Japan	ATR + CCS	Blue	¥/kg	470	3.13	-0.03	358	2.38	-0.02
South Korea	ATR + CCS	Blue	W/kg	4,065	3.05	-0.03	3,065	2.30	-0.03
Australia	ATR + CCS	Blue	A$/kg	4.31	2.81	-0.07	3.16	2.06	-0.08
Trinidad	ATR + CCS	Blue	$/kg	3.03	3.03	+0.04	1.92	1.92	+0.04
Qatar	ATR + CCS	Blue	$/kg	2.79	2.79	-0.03	2.03	2.03	-0.04
UAE	ATR + CCS	Blue	$/kg	2.94	2.94	-0.03	2.19	2.19	-0.03
Russia west	ATR + CCS	Blue	$/kg	1.83	1.83	nc	0.98	0.98	+0.01
Russia east	ATR + CCS	Blue	$/kg	1.79	1.79	nc	0.94	0.94	+0.01

COMPLETE HYDROGEN PRODUCTION COSTS

BAT+ hydrogen									5 Mar
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 27 Feb	Cost	Cost in $/kg	± 27 Feb
Netherlands	SMR + CCS	Blue	€/kg	2.28	2.47	+0.12	1.78	1.93	+0.11
UK	SMR + CCS	Blue	£/kg	1.94	2.45	+0.15	1.52	1.93	+0.16
Germany	SMR + CCS	Blue	€/kg	2.29	2.48	+0.11	1.78	1.93	+0.11
Spain	SMR + CCS	Blue	€/kg	2.27	2.46	+0.11	1.74	1.88	+0.11
France	SMR + CCS	Blue	€/kg	2.24	2.43	+0.13	1.74	1.89	+0.13
US Gulf coast	SMR + CCS	Blue	$/kg	1.22	1.22	nc	0.68	0.68	nc
Canada	SMR + CCS	Blue	C$/kg	1.70	1.25	+0.03	0.95	0.70	+0.02
Japan	SMR + CCS	Blue	¥/kg	374	2.49	-0.03	290	1.93	-0.04
South Korea	SMR + CCS	Blue	W/kg	3,265	2.45	-0.03	2,519	1.89	-0.04
Australia	SMR + CCS	Blue	A$/kg	3.51	2.29	-0.08	2.68	1.75	-0.08
Trinidad	SMR + CCS	Blue	$/kg	2.46	2.46	+0.05	1.65	1.65	+0.05
Qatar	SMR + CCS	Blue	$/kg	2.28	2.28	-0.03	1.73	1.73	-0.03
UAE	SMR + CCS	Blue	$/kg	2.28	2.28	-0.03	1.73	1.73	-0.03
Russia west	SMR + CCS	Blue	$/kg	1.30	1.30	nc	0.67	0.67	nc
Russia east	SMR + CCS	Blue	$/kg	1.26	1.26	nc	0.63	0.63	nc

BAT+ hydrogen						5 Mar
				Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 27 Feb
Netherlands	SMR + CCS retrofit	Blue	€/kg	1.86	2.02	+0.12
UK	SMR + CCS retrofit	Blue	£/kg	1.56	1.97	+0.15
Germany	SMR + CCS retrofit	Blue	€/kg	1.86	2.02	+0.11
Spain	SMR + CCS retrofit	Blue	€/kg	1.82	1.97	+0.11
France	SMR + CCS retrofit	Blue	€/kg	1.83	1.98	+0.14
US Gulf coast	SMR + CCS retrofit	Blue	$/kg	0.66	0.66	nc
Canada	SMR + CCS retrofit	Blue	C$/kg	1.04	0.77	+0.02
Japan	SMR + CCS retrofit	Blue	¥/kg	287	1.91	-0.03
South Korea	SMR + CCS retrofit	Blue	W/kg	2,506	1.88	-0.04
Australia	SMR + CCS retrofit	Blue	A$/kg	2.64	1.72	-0.08
Trinidad	SMR + CCS retrofit	Blue	$/kg	1.63	1.63	+0.05
Qatar	SMR + CCS retrofit	Blue	$/kg	1.70	1.70	-0.04
UAE	SMR + CCS retrofit	Blue	$/kg	1.70	1.70	-0.04
Russia west	SMR + CCS retrofit	Blue	$/kg	0.65	0.65	nc
Russia east	SMR + CCS retrofit	Blue	$/kg	0.61	0.61	nc

BAT+ hydrogen											5 Mar
					Incl. capex			Excl. capex			
	Process	kcal/kg NAR	Legacy colour	Unit	Cost	Cost in $/kg	± 27 Feb	Cost	Cost in $/kg	± 27 Feb	
Australia	Coal gasification + CCS	5,500	Blue	A$/kg	4.87	3.18	+0.02	3.13	2.04	+0.01	
Australia	Coal gasification + CCS	6,000	Blue	A$/kg	5.18	3.38	+0.04	3.43	2.24	+0.03	
China	Coal gasification + CCS	3,800	Blue	Yn/kg	26.13	3.63	+0.01	17.78	2.47	+0.01	
China	Coal gasification + CCS	5,500	Blue	Yn/kg	25.19	3.50	+0.02	16.91	2.35	+0.02	
Indonesia	Coal gasification + CCS	5,500	Blue	$/kg	3.28	3.28	+0.01	2.06	2.06	+0.02	
Indonesia	Coal gasification + CCS	3,800	Blue	$/kg	3.15	3.15	+0.01	1.92	1.92	nc	
South Africa	Coal gasification + CCS	4,800	Blue	$/kg	3.29	3.29	+0.02	1.87	1.87	+0.02	
South Africa	Coal gasification + CCS	6,000	Blue	$/kg	3.37	3.37	-0.01	1.95	1.95	-0.01	
Russia west	Coal gasification + CCS	6,000	Blue	$/kg	2.86	2.86	+0.02	1.61	1.61	+0.03	
US east coast	Coal gasification + CCS	6,000	Blue	$/kg	3.07	3.07	+0.02	1.96	1.96	+0.03	

COMPLETE HYDROGEN PRODUCTION COSTS

Baseline hydrogen						5 Mar			
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 27 Feb	Cost	Cost in $/kg	± 27 Feb
Netherlands	SMR	Grey	€/kg	2.16	2.34	+0.14	1.88	2.04	+0.14
UK	SMR	Grey	£/kg	1.69	2.14	+0.15	1.46	1.85	+0.15
Germany	SMR	Grey	€/kg	2.16	2.34	+0.13	1.88	2.04	+0.13
Spain	SMR	Grey	€/kg	2.14	2.32	+0.13	1.84	1.99	+0.13
France	SMR	Grey	€/kg	2.12	2.30	+0.14	1.85	2.00	+0.15
US Gulf coast	SMR	Grey	$/kg	0.72	0.72	nc	0.42	0.42	nc
Canada	SMR	Grey	C$/kg	1.53	1.13	+0.02	1.11	0.82	+0.02
Japan	SMR	Grey	¥/kg	281	1.87	-0.03	234	1.56	-0.03
South Korea	SMR	Grey	W/kg	2,519	1.89	-0.03	2,106	1.58	-0.03
Australia	SMR	Grey	A$/kg	2.59	1.69	-0.08	2.13	1.39	-0.07
Trinidad	SMR	Grey	$/kg	1.75	1.75	+0.04	1.30	1.30	+0.04
Qatar	SMR	Grey	$/kg	1.68	1.68	-0.03	1.37	1.37	-0.03
UAE	SMR	Grey	$/kg	1.68	1.68	-0.03	1.37	1.37	-0.03
Russia west	SMR	Grey	$/kg	0.76	0.76	nc	0.41	0.41	nc
Russia east	SMR	Grey	$/kg	0.73	0.73	+0.01	0.37	0.37	nc

Baseline hydrogen						5 Mar			
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 27 Feb	Cost	Cost in $/kg	± 27 Feb
Netherlands	Grid + ALK	Yellow	€/kg	7.06	7.65	+0.12	5.21	5.65	+0.13
Netherlands	Grid + PEM	Yellow	€/kg	7.00	7.58	+0.12	4.98	5.40	+0.12
UK	Grid + ALK	Yellow	£/kg	7.15	9.05	+0.40	5.59	7.08	+0.39
UK	Grid + PEM	Yellow	£/kg	7.01	8.87	+0.36	5.32	6.73	+0.36
Germany	Grid + ALK	Yellow	€/kg	7.33	7.94	+0.25	5.45	5.91	+0.26
Germany	Grid + PEM	Yellow	€/kg	7.25	7.86	+0.24	5.21	5.64	+0.23
France	Grid + ALK	Yellow	€/kg	7.49	8.12	+0.21	5.62	6.09	+0.20
France	Grid + PEM	Yellow	€/kg	7.40	8.02	+0.19	5.37	5.82	+0.20
Spain	Grid + ALK	Yellow	€/kg	4.99	5.41	-0.54	3.06	3.32	-0.54
Spain	Grid + PEM	Yellow	€/kg	5.09	5.51	-0.50	2.99	3.24	-0.50
US west coast	Grid + ALK	Yellow	$/kg	6.77	6.77	-0.64	4.76	4.76	-0.63
US west coast	Grid + PEM	Yellow	$/kg	6.77	6.77	-0.59	4.57	4.57	-0.59
US Midwest	Grid + ALK	Yellow	$/kg	5.67	5.67	+0.19	3.66	3.66	+0.19
US Midwest	Grid + PEM	Yellow	$/kg	5.74	5.74	+0.18	3.55	3.55	+0.18
US east coast	Grid + ALK	Yellow	$/kg	5.87	5.87	+0.16	3.85	3.85	+0.16
US east coast	Grid + PEM	Yellow	$/kg	5.92	5.92	+0.15	3.73	3.73	+0.15
Japan	Grid + ALK	Yellow	¥/kg	1,341	8.92	+0.17	1,032	6.87	+0.17
Japan	Grid + PEM	Yellow	¥/kg	1,318	8.77	+0.16	983	6.54	+0.16

COMPLETE HYDROGEN PRODUCTION COSTS

Hydrogen decarbonisation spreads				5 Mar
	Incl. capex		Excl. capex	
	$/kg	± 27 Feb	$/kg	± 27 Feb
Northwest Europe				
No-C to BAT+	5.23	-0.12	3.48	-0.12
Low-C to BAT+	0.57	-0.01	0.38	nc
BAT+ to baseline	0.13	-0.02	-0.11	-0.02
North America				
No-C to BAT+	5.15	-0.02	3.45	-0.01
Low-C to BAT+	0.57	+0.04	0.39	+0.06
BAT+ to baseline	0.31	+0.01	0.07	nc
Northeast Asia				
No-C to BAT+	9.20	+0.03	7.52	+0.04
Low-C to BAT+	0.62	nc	0.43	+0.01
BAT+ to baseline	0.59	nc	0.34	-0.01
Middle East				
No-C to BAT+	3.53	+0.03	1.85	+0.03
Low-C to BAT+	0.59	nc	0.38	-0.01
BAT+ to baseline	0.60	nc	0.36	nc
Net exporter				
No-C to BAT+	3.93	+0.03	2.13	+0.04
Low-C to BAT+	0.55	nc	0.35	+0.01
BAT+ to baseline	0.58	+0.01	0.33	-0.01

Decarbonisation spreads relevant for subsidy mechanisms							5 Mar
		Incl. capex			Excl. capex		
	Unit	Spread	Spread in $/kg	± 27 Feb	Spread	Spread in $/kg	± 27 Feb
France							
No-C to Baseline[1]	€/kg	5.45	5.90	-0.14	3.61	3.91	-0.15
Germany							
No-C to BAT+[2]	€/kg	5.09	5.51	-0.11	3.47	3.76	-0.11
Netherlands							
No-C to baseline[3]	€/kg	4.19	4.54	-0.14	2.37	2.57	-0.14

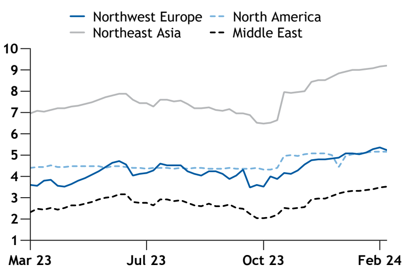
Differentials between the costs of renewable and natural gas-based hydrogen are used in subsidy mechanisms to establish the cost of switching to supply with a lower emissions intensity. The spreads above are relevant for the following:

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

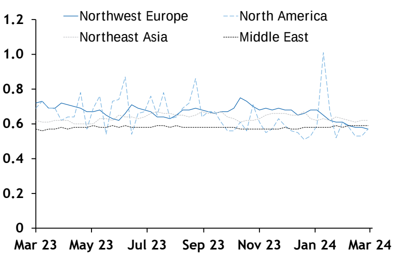
2 Future supply to Thyssenkrupp's direct reduced iron plant in Duisburg

3 Operational support granted to selected projects in Dutch subsidy scheme

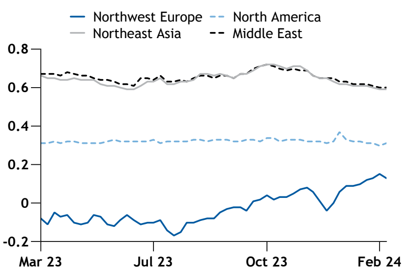
Decarb spread No-C to BAT+ $/kg



Decarb spreads Low-C to BAT+ $/kg



Decarb spread BAT+ to baseline $/kg



COMPLETE HYDROGEN PRODUCTION COSTS

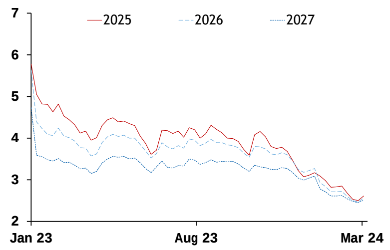
Low-C hydrogen forward — 5 Mar

	Process	Legacy colour	Unit	Incl. capex Cost	Incl. capex Cost in $/kg	Incl. capex ± 27 Feb	Excl. capex Cost	Excl. capex Cost in $/kg	Excl. capex ± 27 Feb
Netherlands									
2025	ATR + CCS	Blue	€/kg	3.06	3.31	+0.11	2.38	2.58	+0.11
2026	ATR + CCS	Blue	€/kg	2.97	3.22	+0.09	2.30	2.49	+0.09
2027	ATR + CCS	Blue	€/kg	2.89	3.13	+0.05	2.22	2.40	+0.05
UK									
2025	ATR + CCS	Blue	£/kg	2.66	3.37	+0.11	2.09	2.65	+0.11
2026	ATR + CCS	Blue	£/kg	2.61	3.31	+0.07	2.05	2.59	+0.07
Germany									
2025	ATR + CCS	Blue	€/kg	3.12	3.38	+0.11	2.04	2.64	+0.11
2026	ATR + CCS	Blue	€/kg	3.04	3.29	+0.09	2.44	2.55	+0.09
2027	ATR + CCS	Blue	€/kg	2.95	3.20	+0.06	2.35	2.45	+0.05
France									
2025	ATR + CCS	Blue	€/kg	3.06	3.32	+0.12	2.38	2.58	+0.12
Spain									
2025	ATR + CCS	Blue	€/kg	3.01	3.26	+0.10	2.28	2.47	+0.10

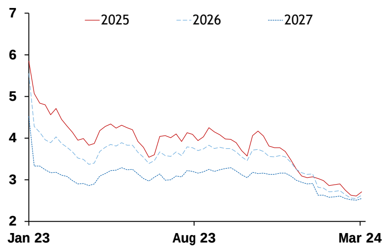
BAT+ hydrogen forward — 5 Mar

	Process	Legacy colour	Unit	Incl. capex Cost	Incl. capex Cost in $/kg	Incl. capex ± 27 Feb	Excl. capex Cost	Excl. capex Cost in $/kg	Excl. capex ± 27 Feb
Netherlands									
2025	SMR + CCS	Blue	€/kg	2.50	2.71	+0.10	2.00	2.17	+0.10
2026	SMR + CCS	Blue	€/kg	2.43	2.63	+0.08	1.93	2.09	+0.07
2027	SMR + CCS	Blue	€/kg	2.35	2.55	+0.04	1.86	2.01	+0.04
UK									
2025	SMR + CCS	Blue	£/kg	2.14	2.71	+0.09	1.73	2.19	+0.10
2026	SMR + CCS	Blue	£/kg	2.11	2.67	+0.07	1.69	2.14	+0.07
Germany									
2025	SMR + CCS	Blue	€/kg	2.55	2.76	+0.10	2.04	2.21	+0.09
2026	SMR + CCS	Blue	€/kg	2.47	2.68	+0.07	1.98	2.14	+0.08
2027	SMR + CCS	Blue	€/kg	2.41	2.61	+0.04	1.90	2.06	+0.04
France									
2025	SMR + CCS	Blue	€/kg	2.46	2.67	+0.10	1.97	2.13	+0.10
Spain									
2025	SMR + CCS	Blue	€/kg	2.48	2.69	+0.10	1.95	2.11	+0.10

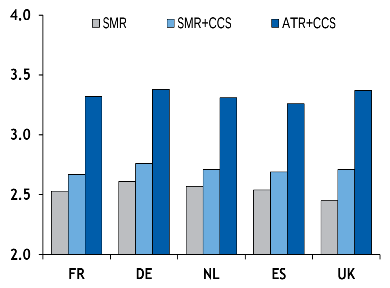
German SMR forward costs *$/kg*



Dutch SMR+CCS forward costs *$/kg*



2025 forward costs *$/kg*



COMPLETE HYDROGEN PRODUCTION COSTS

Baseline hydrogen forward									5 Mar
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 27 Feb	Cost	Cost in $/kg	± 27 Feb
Netherlands									
2025	SMR	Grey	€/kg	2.37	2.57	+0.12	2.10	2.27	+0.12
2026	SMR	Grey	€/kg	2.33	2.52	+0.10	2.05	2.22	+0.10
2027	SMR	Grey	€/kg	2.27	2.46	+0.06	1.99	2.16	+0.06
UK									
2025	SMR	Grey	£/kg	1.94	2.45	+0.10	1.70	2.15	+0.10
2026	SMR	Grey	£/kg	1.92	2.43	+0.08	1.68	2.13	+0.07
Germany									
2025	SMR	Grey	€/kg	2.41	2.61	+0.11	2.13	2.31	+0.12
2026	SMR	Grey	€/kg	2.36	2.56	+0.09	2.09	2.26	+0.10
2027	SMR	Grey	€/kg	2.32	2.51	+0.06	2.04	2.21	+0.07
France									
2025	SMR	Grey	€/kg	2.34	2.53	+0.11	2.06	2.23	+0.12
Spain									
2025	SMR	Grey	€/kg	2.34	2.54	+0.12	2.05	2.22	+0.12

Direct reduction iron costs (1 Mar)		$/t
Specification	Cost	±
Natural gas DRI, ex-works NW Europe	371.64	-6.67
DRI spread No-C hydrogen (renewables+PEM) vs natural gas NW Europe	389.48	+0.15
DRI spread BAT+ hydrogen (SMR+CCS) vs natural gas NW Europe	79.18	-2.75

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

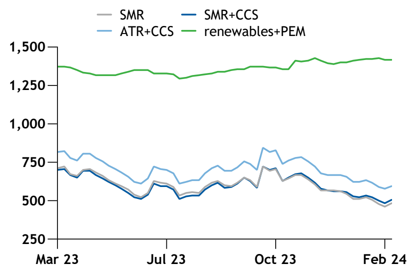
COMPLETE AMMONIA PRODUCTION COSTS

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

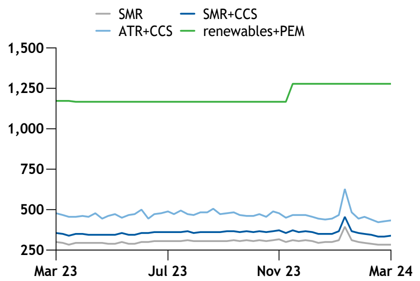
CO2e emissions on a gate-to-gate basis; purity >99.5pc; temperature -33°C

Regional ammonia cost markers						5 Mar
			Incl. capex		**Excl. capex**	
	Process	**Unit**	**Cost**	**± 27 Feb**	**Cost**	**± 27 Feb**
Baseline						
Northwest Europe	SMR	€/t	484	+22	371	+22
Northwest Europe	SMR	$/t	524	+24	402	+24
North America	SMR	$/t	285	+2	162	+2
Northeast Asia	SMR	$/t	434	-5	309	-5
Middle East	SMR	$/t	380	-5	261	-5
BAT+						
Northwest Europe	SMR+CCS	€/t	504	+18	354	+19
Northwest Europe	SMR+CCS	$/t	546	+20	383	+20
North America	SMR+CCS	$/t	338	+3	174	+2
Northeast Asia	SMR+CCS	$/t	535	-5	367	-7
Middle East	SMR+CCS	$/t	483	-5	322	-5
Low-C						
Northwest Europe	ATR+CCS	€/t	594	+17	414	+19
Northwest Europe	ATR+CCS	$/t	644	+20	448	+21
North America	ATR+CCS	$/t	436	+10	240	+12
Northeast Asia	ATR+CCS	$/t	641	-5	440	-5
Middle East	ATR+CCS	$/t	583	-5	387	-6
No-C						
Northwest Europe	Island renewable+PEM	€/t	1,418	-1	986	-1
Northwest Europe	Island renewable+PEM	$/t	1,536	nc	1,068	nc
North America	Island renewable+PEM	$/t	1,280	nc	823	nc
Northeast Asia	Island renewable+PEM	$/t	2,269	nc	1,809	nc
Middle East	Island renewable+PEM	$/t	1,136	nc	681	nc
Exporter						
Exporter baseline	SMR	$/t	358	-6	237	-6
Exporter BAT+	SMR+CCS	$/t	457	-6	295	-5
Exporter low-C	ATR+CCS	$/t	550	-6	354	-5
Exporter no-C	Island renewable+PEM	$/t	1,175	nc	696	nc

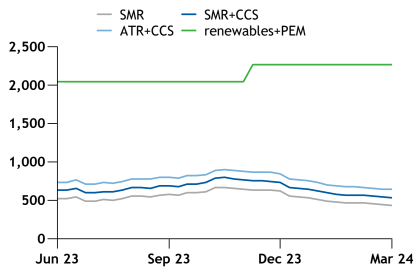
NW Europe ammonia average €/t



North America ammonia average $/t



Northeast Asia ammonia average $/t



COMPLETE AMMONIA PRODUCTION COSTS

No-C ammonia									5 Mar
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 27 Feb	Cost	Cost in $/t	± 27 Feb
Netherlands	Wind + PEM	Green	€/t	1,282	1,389	nc	853	924	nc
UK	Wind + PEM	Green	£/t	1,124	1,423	nc	762	965	nc
Germany	Wind + PEM	Green	€/t	1,462	1,584	nc	1,028	1,114	nc
France	Wind + PEM	Green	€/t	1,508	1,634	nc	1,075	1,165	nc
Spain	Diurnal + PEM	Green	€/t	1,060	1,148	nc	633	686	nc
US west coast	Diurnal + PEM	Green	$/t	1,142	1,142	nc	700	700	nc
Canada	Wind + PEM	Green	C$/t	1,923	1,418	nc	1,283	946	nc
Oman	Diurnal + PEM	Green	$/t	1,135	1,135	nc	665	665	nc
Saudi Arabia	Diurnal + PEM	Green	$/t	1,148	1,148	nc	679	679	nc
UAE	Diurnal + PEM	Green	$/t	1,105	1,105	nc	668	668	nc
Qatar	Diurnal + PEM	Green	$/t	1,155	1,155	nc	711	711	nc
Namibia	Diurnal + PEM	Green	$/t	1,279	1,279	nc	699	699	nc
South Africa	Diurnal + PEM	Green	$/t	1,258	1,258	nc	717	717	nc
Japan	Wind + PEM	Green	¥/t	457,786	3,046	nc	386,098	2,569	nc
China	Diurnal + PEM	Green	Yn/t	7,283	1,012	nc	4,217	586	nc
India	Diurnal + PEM	Green	Rs/t	92,989	1,122	nc	52,545	634	nc
South Korea	Wind + PEM	Green	W/t	3,662,532	2,748	nc	3,028,119	2,272	nc
Vietnam	Wind + PEM	Green	$/t	1,677	1,677	nc	1,150	1,150	nc
Australia	Diurnal + PEM	Green	A$/t	1,726	1,126	nc	1,042	680	nc
Brazil	Diurnal + PEM	Green	$/t	1,173	1,173	nc	636	636	nc
Chile	Diurnal + PEM	Green	$/t	1,218	1,218	nc	752	752	nc

Low-C ammonia									5 Mar
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 27 Feb	Cost	Cost in $/t	± 27 Feb
Netherlands	ATR + CCS	Blue	€/t	599	649	+19	420	455	+19
UK	ATR + CCS	Blue	£/t	504	638	+28	354	448	+27
Germany	ATR + CCS	Blue	€/t	592	641	+19	409	443	+19
Spain	ATR + CCS	Blue	€/t	574	622	+15	380	412	+13
France	ATR + CCS	Blue	€/t	593	643	+22	411	445	+23
US Gulf coast	ATR + CCS	Blue	$/t	421	421	nc	226	226	+2
Canada	ATR + CCS	Blue	C$/t	610	450	+20	343	253	+22
Japan	ATR + CCS	Blue	¥/t	96,787	644	-5	66,429	442	-4
South Korea	ATR + CCS	Blue	W/t	850,326	638	-5	583,766	438	-6
Australia	ATR + CCS	Blue	A$/t	941	614	-12	635	414	-13
Trinidad	ATR + CCS	Blue	$/t	653	653	+7	354	354	+7
Qatar	ATR + CCS	Blue	$/t	572	572	-5	374	374	-7
UAE	ATR + CCS	Blue	$/t	593	593	-5	400	400	-5
Russia west	ATR + CCS	Blue	$/t	416	416	nc	190	190	+1
Russia east	ATR + CCS	Blue	$/t	409	409	nc	183	183	+1

COMPLETE AMMONIA PRODUCTION COSTS

BAT+ ammonia									5 Mar
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 27 Feb	Cost	Cost in $/t	± 27 Feb
Netherlands	SMR + CCS	Blue	€/t	510	553	+20	361	391	+18
UK	SMR + CCS	Blue	£/t	419	530	+26	296	375	+28
Germany	SMR + CCS	Blue	€/t	502	544	+19	349	378	+19
Spain	SMR + CCS	Blue	€/t	497	539	+19	337	365	+19
France	SMR + CCS	Blue	€/t	500	542	+22	350	379	+22
US Gulf coast	SMR + CCS	Blue	$/t	336	336	nc	173	173	nc
Canada	SMR + CCS	Blue	C$/t	460	339	+5	236	174	+3
Japan	SMR + CCS	Blue	¥/t	80,255	534	-5	55,007	366	-6
South Korea	SMR + CCS	Blue	W/t	714,380	536	-5	490,470	368	-7
Australia	SMR + CCS	Blue	A$/t	805	525	-14	553	361	-13
Trinidad	SMR + CCS	Blue	$/t	555	555	+8	308	308	+8
Qatar	SMR + CCS	Blue	$/t	485	485	-5	323	323	-5
UAE	SMR + CCS	Blue	$/t	480	480	-5	321	321	-5
Russia west	SMR + CCS	Blue	$/t	325	325	nc	137	137	nc
Russia east	SMR + CCS	Blue	$/t	318	318	nc	130	130	nc

BAT+ ammonia										5 Mar
					Incl. capex			Excl. capex		
	Process	kcal/kg NAR	Legacy colour	Unit	Cost	Cost in $/t	± 27 Feb	Cost	Cost in $/t	± 27 Feb
Australia	Coal gasification + CCS	5,500	Blue	A$/t	973	635	+4	576	376	+2
Australia	Coal gasification + CCS	6,000	Blue	A$/t	1,026	669	+7	629	410	+5
China	Coal gasification + CCS	3,800	Blue	Yn/t	5,024	698	+2	3,131	435	+2
China	Coal gasification + CCS	5,500	Blue	Yn/t	4,858	675	+3	2,980	414	+3
Indonesia	Coal gasification + CCS	5,500	Blue	$/t	640	640	+2	363	363	+4
Indonesia	Coal gasification + CCS	3,800	Blue	$/t	618	618	+2	339	339	nc
South Africa	Coal gasification + CCS	4,800	Blue	$/t	655	655	+3	331	331	+4
South Africa	Coal gasification + CCS	6,000	Blue	$/t	669	669	-2	344	344	-2
Russia west	Coal gasification + CCS	6,000	Blue	$/t	572	572	+4	288	288	+5
US east coast	Coal gasification + CCS	6,000	Blue	$/t	613	613	+4	360	360	+5

Baseline ammonia									5 Mar
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 27 Feb	Cost	Cost in $/t	± 27 Feb
Netherlands	SMR	Grey	€/t	490	531	+24	378	410	+24
UK	SMR	Grey	£/t	377	477	+26	285	361	+26
Germany	SMR	Grey	€/t	480	520	+22	366	397	+22
Spain	SMR	Grey	€/t	475	515	+23	354	383	+22
France	SMR	Grey	€/t	480	520	+24	367	398	+26
US Gulf coast	SMR	Grey	$/t	250	250	nc	129	129	nc
Canada	SMR	Grey	C$/t	433	319	+4	264	195	+4
Japan	SMR	Grey	¥/t	64,325	428	-5	45,388	302	-5
South Korea	SMR	Grey	W/t	586,432	440	-5	419,832	315	-5
Australia	SMR	Grey	A$/t	648	423	-13	458	299	-12
Trinidad	SMR	Grey	$/t	434	434	+7	248	248	+7
Qatar	SMR	Grey	$/t	382	382	-5	261	261	-6
UAE	SMR	Grey	$/t	377	377	-6	260	260	-5
Russia west	SMR	Grey	$/t	233	233	nc	93	93	nc
Russia east	SMR	Grey	$/t	228	228	+2	86	86	nc

COMPLETE AMMONIA PRODUCTION COSTS

Ammonia decarbonisation spreads				5 Mar
	Incl. capex		Excl. capex	
	$/t	± 27 Feb	$/t	± 27 Feb
Northwest Europe				
No-C to BAT+	990	-20	685	-20
Low-C to BAT+	98	nc	65	+1
BAT+ to baseline	22	-4	-19	-4
North America				
No-C to BAT+	942	-3	649	-2
Low-C to BAT+	98	+7	66	+10
BAT+ to baseline	53	+1	12	nc
Northeast Asia				
No-C to BAT+	1,734	+5	1,442	+7
Low-C to BAT+	106	nc	73	+2
BAT+ to baseline	101	nc	58	-2
Middle East				
No-C to BAT+	653	+5	359	+5
Low-C to BAT+	100	nc	65	-1
BAT+ to baseline	103	nc	61	nc
Net exporter				
No-C to BAT+	718	+6	401	+5
Low-C to BAT+	93	nc	59	nc
BAT+ to baseline	99	nc	58	+1

Argus *Hydrogen and Future Fuels* is published by Argus Media group

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ISSN: 2041-2503

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