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Argus *Hydrogen and Future Fuels*

Market news, analysis and prices

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Denmark H2 pipeline and exports delayed

The delay deals a fresh blow to German import plans, following last month's decision to halt work on a link from Norway, write Pamela Machado and Aidan Lea

Plans for a hydrogen pipeline connecting Denmark to Germany have been delayed to 2031 from 2028, Danish state-owned transmission system operator (TSO) Energinet revealed today — a decision that will frustrate export-focused producers in Denmark and hurt Germany's hydrogen import plans.

The TSO now says the Denmark-Germany export pipeline and southern part of the Danish domestic network could be ready by 2031. Energinet says the middle section of the Danish network could be ready by 2032, while the northernmost part that will connect to hydrogen storage sites could be ready by 2033.

"Increased project complexity", the change to a two-step user pledge process, and longer-than-expected planning and environmental processes have all contributed to the setback, according to the TSO. The planning and environmental work could now take 40 months to complete, with Energinet viewing the previous 18-month timeframe as unrealistic.

The delay threatens to slow the hydrogen industry's development in Denmark and calls into question its ambitious target of having 4-6GW of electrolysis capacity by 2030, with both public and private sectors expressing concerns.

The timeline is "not what we expected, and it comes with great risks", Denmark's climate and energy minister, Lars Aagaard says. He adds the government is working to make Energinet's schedule "more secure" and to limit the delay, and highlights the "interaction" between the hydrogen network and Denmark's hopes to scale up its offshore wind industry. Denmark has power generation potential far beyond its own modest needs, but it must massively scale up electricity transmission, hydrogen transport and production of hydrogen derivatives to get this stranded power to customers in distant markets.

The delay is "extremely problematic and downright unacceptable", industry association Hydrogen Denmark's director, Tejs Laustsen Jensen, says. "It is absolutely crucial that everything possible is done, both from the political and administrative side, to speed up the process."

Energinet and the Danish climate and energy ministry will work together towards the 2031 target and will co-operate with their counterpart on the German side, Gasunie Deutschland, to have the connection ready at the same time on both sides of the border.

The delay comes as a further blow to hydrogen import plans in Germany, which has consistently said it cannot meet its own demand with domestic production alone. Berlin has admitted to frustration at last month's announcement by Norway's state-owned Equinor that it is halting development of an export pipeline, in which Germany was to be the main partner.

One step at a time

Energinet's new phased approach to delivering the network could resolve the apparent impasse in financing the pipeline. Copenhagen had demanded a 1.4GW booking commitment from pipeline users, which several Danish companies, such as developer Copenhagen Infrastructure Partners (CIP), said was impossible to meet in the near term.

"Industry has been working together on promoting the idea of the market-driven approach and a section-based buildout so we can break up the large

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commitment of 1.4GW," the company's director of PtX advocacy and regulatory affairs, David Dupont-Mouritzen, told *Argus* recently. He warned that developers desperately wanted to avoid delays to the export pipeline. But developers might take some consolation from the new recognition of the need for the phased approach from the state-owned TSO.

Projects around Denmark are at "significantly different degrees of maturity", Energinet says. It estimates there could be 0.8–4.2GW of user demand for the pipeline network by 2031, but only around 0.8GW of this transportation demand is of a high degree of maturity and this is mostly linked to the southern part of the planned network, it says.

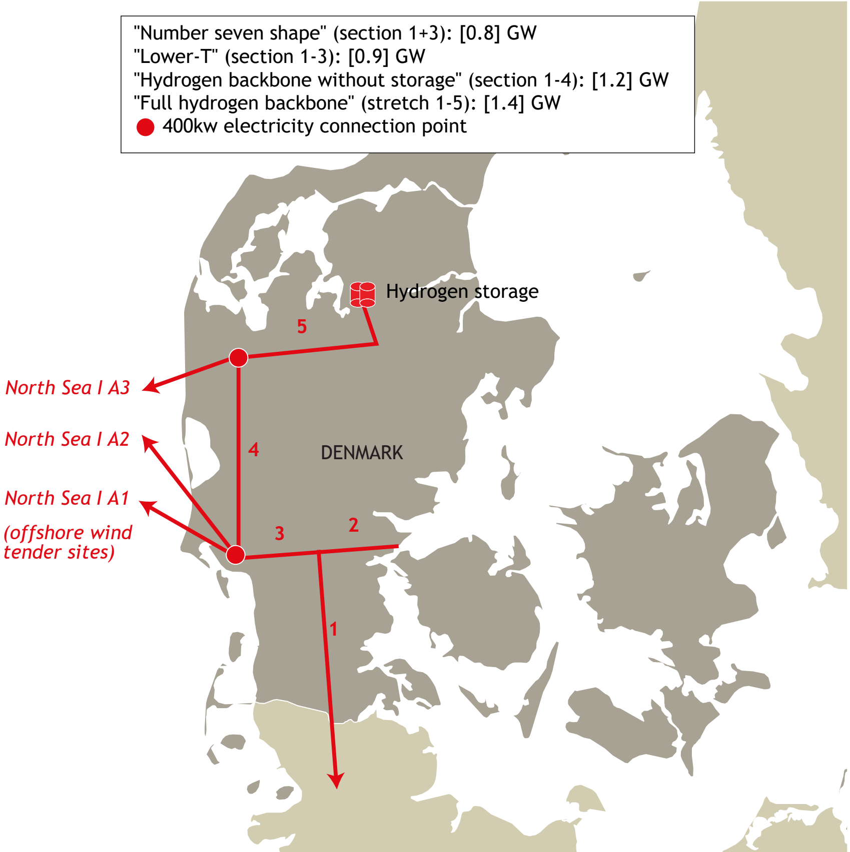
Around 1.3GW of hydrogen transport demand is linked to electrolysis projects connected to ongoing offshore wind tenders, so there can be no further progress here until the tenders are decided, Energinet says.

Energinet has split the user pledge process into two phases, while the capacity sale that it plans to carry out will determine how much of the pipeline network it will be able to seek government financing for. Energinet expects to present the final business case for the project in early 2026.

Copenhagen could finance the southern "Lower T" section if 0.9GW of firm user commitments emerge, while a 1.2GW commitment could unlock an upper connection to Holstebro in northwest Denmark in 2032 and 1.4GW to Lille Torup and possible hydrogen storage in 2033. Energinet envisages that total demand for hydrogen transport could reach 6.9GW in 2050.

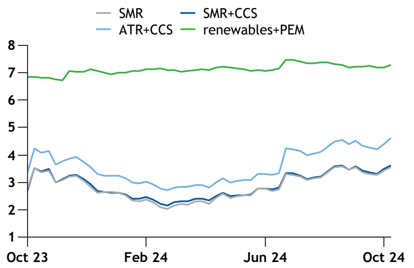
"We are still ready to put state co-financing on the table if the industry leans into the project and commits to capacity," Aagaard says.

Geographical divisions of Denmark's H2 network plan

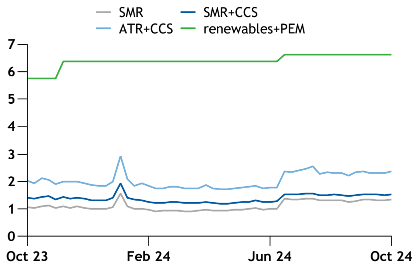


HYDROGEN COSTS

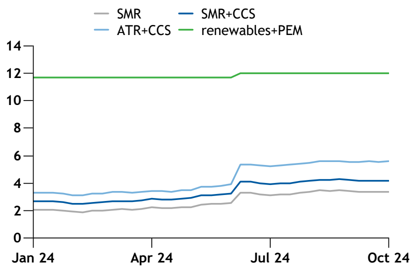
Northwest Europe average cost €/kg



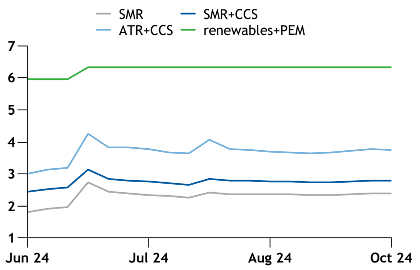
North America average cost $/kg



Northeast Asia average cost $/kg



Exporter average cost $/kg



Regional hydrogen cost markers						8 Oct
			Incl. capex		Excl. capex	
	Process	Unit	Cost	± 1 Oct	Cost	± 1 Oct
Baseline						
Northwest Europe	SMR	€/kg	3.55	+0.11	3.03	+0.11
Northwest Europe	SMR	$/kg	3.91	+0.07	3.33	+0.07
North America	SMR	$/kg	1.35	+0.04	0.79	+0.05
Northeast Asia	SMR	$/kg	3.37	+0.01	2.75	+0.01
Middle East	SMR	$/kg	2.96	+0.01	2.40	+0.01
BAT+						
Northwest Europe	SMR+CCS	€/kg	3.62	+0.13	2.99	+0.12
Northwest Europe	SMR+CCS	$/kg	3.98	+0.09	3.29	+0.09
North America	SMR+CCS	$/kg	1.54	+0.05	0.87	+0.05
Northeast Asia	SMR+CCS	$/kg	4.17	+0.01	3.44	+0.01
Middle East	SMR+CCS	$/kg	3.33	+0.01	2.67	+0.01
Low-C						
Northwest Europe	ATR+CCS	€/kg	4.60	+0.20	3.46	+0.17
Northwest Europe	ATR+CCS	$/kg	5.06	+0.15	3.81	+0.14
North America	ATR+CCS	$/kg	2.37	+0.08	1.16	+0.09
Northeast Asia	ATR+CCS	$/kg	5.58	+0.04	4.24	+0.04
Middle East	ATR+CCS	$/kg	4.35	+0.01	3.15	+0.01
No-C						
Northwest Europe	Island renewable+PEM	€/kg	7.28	+0.10	4.92	+0.07
Northwest Europe	Island renewable+PEM	$/kg	8.01	nc	5.41	nc
North America	Island renewable+PEM	$/kg	6.64	nc	4.15	nc
Northeast Asia	Island renewable+PEM	$/kg	12.01	nc	9.44	nc
Middle East	Island renewable+PEM	$/kg	6.08	nc	3.59	nc
Exporter						
Exporter baseline	SMR	$/kg	2.39	nc	1.82	nc
Exporter BAT+	SMR+CCS	$/kg	2.79	nc	2.12	nc
Exporter low-C	ATR+CCS	$/kg	3.76	-0.01	2.54	-0.02
Exporter no-C	Island renewable+PEM	$/kg	6.33	nc	3.61	nc

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			1 Oct
	Unit	Price	± 3 Sep
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

Australia's Origin exits hydrogen plans

A vicious circle is developing in Australia, as Origin walks away from hub, blaming the sector's slow pace of development, write Tom Major and Akansha Victor

Australia's hydrogen ambitions have suffered another blow as utility and upstream firm Origin Energy has decided not to proceed with its Hunter Valley Hydrogen Hub (HVHH) in the state of New South Wales, despite the promise of considerable government funds, and to no longer pursue any hydrogen developments.

The decision to exit HVHH and turn its back on all hydrogen opportunities was made because of continuing uncertainty about the pace and timing of the industry's development, Origin says. The firm says the capital-intensive project, whose hydrogen was to progressively replace gas as a feedstock in a nearby ammonia plant, carried substantial risks.

HVHH was due to produce some 5,500 t/yr of renewable hydrogen using 55MW of electrolyser capacity in a first phase, with potential to reach 1GW eventually.

Australian chemicals and explosives company Orica had an initial agreement with Origin to take 80pc of the hydrogen produced from the hub for its 360,000 t/yr ammonia facility on Kooragang Island, near the city of Newcastle.

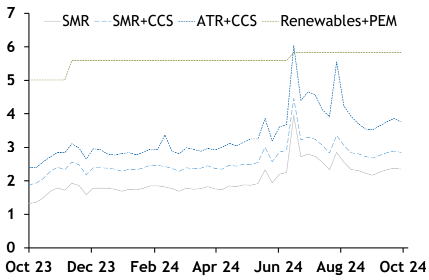
The firm had planned to take a final investment decision on the project by late 2024. But "it has become clear that the hydrogen market is developing more slowly than anticipated, and there remain risks and both input cost and technology advancements to overcome", Origin's chief executive, Frank Calabria, says. "The combination of these factors means we are unable to see a current pathway to take a final investment decision on the project."

This is despite the prospect of more than half of the project's initial costs being covered by public funds. The hub's initial phase was expected to cost A$207.6mn ($143mn) and Origin had been allocated A$115mn in state and federal funding for its development. HVHH had also been shortlisted as one of six projects for the Hydrogen Headstart programme's first round, meaning it would have had a chance of being allocated 10-year operating subsidies, when the final winners are announced later this year.

Origin now aims to prioritise "investments focused on renewables and storage", saying that these "can best support the decarbonisation of energy supply and underpin energy security over the near term".

Orica says it "respects" Origin's decision, but is "disappointed by this development". The firm stressed its ongoing commitment to the region and its desire to keep its manufacturing operations "competitive" in a low-carbon economy, adding that it is open to discussing future hydrogen opportunities with other parties.

Australian H2 costs *t/yr*



Labor pains

The decision is yet another setback for Australia's renewable hydrogen ambitions.

Several projects have been cancelled in recent months, with developers citing a range of reasons, including cost increases and uncertainties over access to renewable power supply, while Australian mining and energy company Fortescue has pushed back its target of producing 15mn t/yr renewable hydrogen by 2030.

In its hydrogen strategy from last month, the Labor government set rather modest production targets for 2030, signalling an implicit recognition that only a small part of the large project pipeline will be realised by then.

The Liberal party used Origin's announcement to attack Labor over its approach to hydrogen. The "development exposes Labor's misguided, all-eggs-in-one-basket renewables-only approach", it says, noting that "if hydrogen is to succeed in Australia, we must be colour blind when it comes to low-emission technologies". Projects have been halted, "despite billions of taxpayer dollars being poured into green hydrogen initiatives" and this puts Australia's energy security at risk, the party says.

MARKET DEVELOPMENTS

UK CCS, H2 hubs get $29bn, but ExxonMobil halts plans

A north-south divide is emerging when it comes to progress in the UK's CCS-based hydrogen sector, writes Stefan Krumpelmann

The UK government has finalised a commitment to provide £21.7bn ($28.5bn) to two planned clusters for carbon capture and storage (CCS) and hydrogen production — a step hailed by one of the beneficiaries as "the launch of the UK's CCS industry". But ExxonMobil has shelved plans to store CO_2 in the English Channel, putting in doubt its ambitions for CCS-based hydrogen output at the Fawley refinery and indicating that endeavours without government backing will struggle to take off.

The Labour government said on 4 October that it has reached a "commercial agreement with industry" for development of the HyNet cluster in northwest England and the East Coast cluster in England's northeastern Humber and Teesside regions. The two projects were selected by the previous Conservative government as 'Track 1' priority clusters in 2021 and could together store some 650mn t of CO_2. They will receive the £21.7bn over 25 years and could attract £8bn of private-sector investment, the government says.

"The allocation of funding marks the launch of the UK's CCS industry," according to Italy's integrated Eni, which leads the development of HyNet's CO_2 transport and storage system. Eni in February gave a start date of 2027 for HyNet.

The East Coast cluster is led by the Northern Endurance Partnership, a joint venture between BP, TotalEnergies and Norwegian state-controlled Equinor.

A range of projects will link to the two hubs to transport and permanently store the carbon, including hydrogen production plants and supporting infrastructure.

HyNet will involve projects developed by EET Hydrogen, a subsidiary of Indian conglomerate Essar, which is planning to bring a 350MW plant for hydrogen production from natural gas with CCS on line by 2027 and another 700MW facility by 2028. The hydrogen will be partly used at EET Hydrogen's sister company, EET Fuels, at its 195,000 b/d Stanlow refinery, but some will also be delivered to industrial consumers in the area. The HyNet cluster includes plans for 125km of new pipelines to transport hydrogen.

For the East Coast cluster, the Track 1 project negotiations included BP's 160,000 t/yr H2 Teesside venture and plans to retrofit CCS technology to an existing steam methane reformer from BOC, which is part of industrial gas firm Linde. Other projects could also be eventually connected to the cluster, specifically Equinor's 600MW H2H Saltend project, German utility Uniper's 720MW Humber H2ub (Blue) project and UK-based Kellas Midstream's 1GW H2NorthEast plant.

Funding confirmation for the hubs 'is a vital step forward, catapulting hydrogen towards long-term certainty'
— Hydrogen Energy Association

The funding confirmation for the CCS hubs "is a vital step forward, catapulting hydrogen towards long-term certainty we need in the UK", industry body the Hydrogen Energy Association's chief executive, Celia Greaves, says. It could help bring the associated hydrogen production sites to FID, with developers previously indicating that the funding was the remaining piece of the puzzle.

The previous government last year picked two Track 2 carbon capture clusters — the Acorn facility in Scotland and the Viking project in northeast England — but these are only due to start up by 2030 and it might be a while before funding agreements for them are finalised.

Going south

London's funding announcement signals progress for the UK's CCS ambitions, but plans in southern England, which missed out on the Track 1 and 2 selection, have hit a dead end.

Shortly after the government announcement, ExxonMobil told *Argus* that it is no longer evaluating opportunities for CO_2 storage in the English Channel and associated transport "at this time" because of a "continued lack of government policy certainty and timelines". The company said its "major investment decisions

MARKET DEVELOPMENTS

are informed by several factors, including the policy, fiscal and market environment", and added that it "will maintain collaboration [with the government] to address the necessary factors".

ExxonMobil planned to transport CO_2 from its Fawley complex, and possibly other industrial facilities in the wider region, to a deep rock formation in the English Channel. A consultation on the proposed Solent CO_2 pipeline project — for which ExxonMobil had identified two preferred routes across the Isle of Wight — ended last month. In the consultation documents, the firm had described the pipeline plans as "the linchpin for establishing CCS technology in southern England", noting that it could transport "millions of tonnes per year of CO_2".

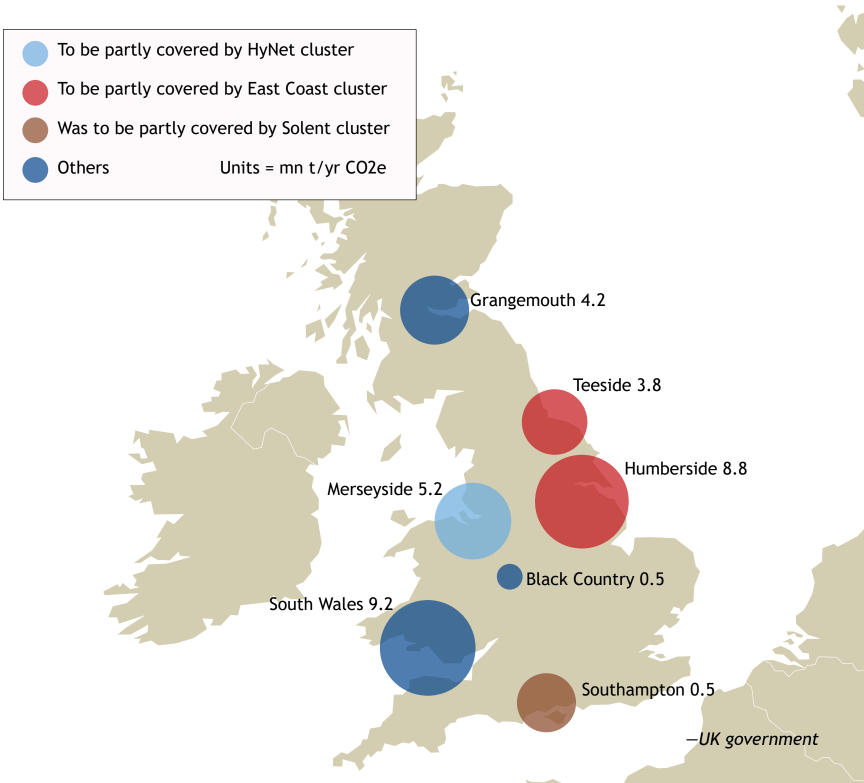
With the CO_2 pipeline and storage developments on hold, ExxonMobil's plans to build a 1.4GW CCS-based hydrogen plant at Fawley might no longer be feasible

With the CO_2 pipeline and storage developments on hold, ExxonMobil's plans to build a 1.4GW CCS-based hydrogen plant at Fawley might no longer be feasible.

ExxonMobil's low-carbon solutions venture executive Michael Foley said in February that the hydrogen plant hinges on the progress of the Solent Cluster for the CO_2 sequestration. Foley said at the time that the company was "keen to move from concept to a more tangible opportunity" and that it was "hopeful to make some progress on that in the near term". But he noted the plans' "complexity" and said that the company had stopped looking at alternative solutions for transporting CO_2 by ship to storage sites because this would be "very expensive".

ExxonMobil did not comment directly on how the scrapped CO_2 storage plans affect the hydrogen facility, but said that it is "committed to reducing emissions from… operated assets" and that it continues "to evaluate a range of emission reductions solutions". Foley had said in February that ExxonMobil sees low-carbon hydrogen as the only option to decarbonise high temperature processes at the 270,000 b/d Fawley refinery, which is the UK's largest.

Major UK industrial cluster emissions from large point sources



—UK government

MARKET DEVELOPMENTS

Electrolyser growth faces slowdown in 2024

Cost increases and technical challenges have put the brakes on electrolyser progress, writes Stefan Krumpelmann

Additions to global electrolyser capacity for hydrogen production could stay far behind expectations this year and will fall compared with 2023, barring a sharp increase this quarter, according to data from Paris-based energy watchdog the IEA.

Only 205MW of new capacity was brought on line globally in January-September, lifting total installed capacity to 1.6GW from 1.4GW at the start of the year, the IEA says in its *Global Hydrogen Review 2024*.

This suggests that installed capacity will stay far below the 5GW that was due to be operational by the end of this year, based on announcements regarding projects that have already reached final investment decisions (FIDs).

Unless additions more than triple in the last few months of the year, the 2024 total will be below the 700MW of new capacity launched last year.

Installed capacity at the end of last year equated to just one sixth of capacity projected by the IEA for 2023 in its first *Global Hydrogen Review*, published in 2021, and a slowdown in growth this year could further widen the gap with previous forecasts.

The EU in 2020 set an interim target for 6GW of installed electrolyser capacity by 2024. But even if all projects slated to start this year were to meet their planned timeline, the bloc's capacity would only reach 700MW.

China continues to dominate in terms of installed capacity. The country accounted for 80pc of capacity additions in 2023 and will again make up the bulk of new capacity this year if projects are realised as planned. But even Chinese growth faces a slowdown this year, barring a sharp rise this quarter.

Renewable hydrogen project plans have faced severe headwinds, including cost increases and technical challenges.

Delayed decisions

Project FIDs have also slipped. Some 6.5GW of capacity reached an FID between September 2023 and September 2024, down from 7.5GW in the previous 12 months, the IEA says. Planned European capacity with an FID rose by over 2GW over this period, compared with less than 500MW over the previous 12 months, while India's ambitions received a boost from AM Green's 1.2GW renewable ammonia project, which reached FID in August. But the increases were offset by slower growth in China and a lack of additions in the Middle East, where Saudi Arabia's Neom project alone had added over 2GW in early 2023.

Globally, 20GW of the electrolyser capacity that is due to come on line by 2030 has now reached the FID stage or progressed further, equivalent to 4pc of all announced projects that have a combined capacity of 520GW, according to the IEA. Another 210GW has progressed to feasibility studies, with the remainder at earlier stages.

In order for all of the announced projects to be realised by the end of the decade, a compound annual growth rate of over 100pc would be needed from this year onwards, the IEA says. This would be "almost twice as high as any growth experienced by solar PV [photovoltaic] in any six-year period during the last two decades", it says.

Overall clean hydrogen production, including through other methods such as from natural gas with carbon capture and storage, could reach 49mn t/yr by 2030, if all announced projects are realised, the IEA says. This is up by 30pc from a year earlier, although the vast majority of announced projects are still in early development stages and it remains to be seen which will be realised.

The watchdog is urging governments to double down on policies to incentivise demand in order to help projects move along.

Renewable H2 project FID share, Aug 23-Sep 24

Region	Share %
China	43
Europe	32
India	20
US	2
Others	3

— IEA

MARKET DEVELOPMENTS

IEA raises 2030 renewable H2 cost estimates

Report notes steep increases in electrolyser manufacturing costs last year, but still sees more favourable conditions ahead, writes Stefan Krumpelmann

Paris-based energy watchdog the IEA has lifted its estimates for future renewable hydrogen production costs and says it expects only Chinese projects to achieve levelised costs of less than $2/kg by 2030.

Over 22mn t/yr of hydrogen production capacity from dedicated wind or solar assets has been announced with a targeted start by 2030, the IEA says in its *Global Hydrogen Review 2024*. But even in the watchdog's net-zero (NZE) scenario — which assumes the steepest reductions in renewable power costs — less than 1mn t/yr of this would be made at a cost below $2/kg and all of this would be in China.

This is based on analysis with German research institute Forschungszentrum Julich, which takes into account specific configurations for all announced projects and "optimal oversizing of the renewable plant in each location".

In its *Global Hydrogen Review 2023*, the IEA had said production costs based on solar photovoltaic (PV) "could fall to $1.60/kg by 2030 in regions with excellent solar irradiation, such as Africa, Australia, Chile, China and the Middle East".

Costs based on solar PV 'could fall to $1.60/kg by 2030 in regions with excellent solar irradiation, such as Africa, Australia, Chile, China and the Middle East' — IEA

Based on the new analysis, a few Latin American projects achieve costs below $2.50/kg by 2030 in the NZE scenario. In total, around 8mn t/yr globally is produced for less than $3/kg, with much of this coming from Australia. But over 9mn t/yr still costs more than $4/kg to produce.

Only around 1mn t/yr of global output is "produced at a cost below the unabated natural gas route [for making hydrogen] by 2030", and some 12mn t/yr is at least $1.50/kg more expensive to make than conventional hydrogen. This highlights the need for "adequate support" to close the cost gap, the IEA says.

In the more downbeat stated policies (STEPS) scenario, less than 500,000 t/yr of global output is produced for under $3/kg, while roughly half of the more than 22mn t/yr of renewable hydrogen produced costs over $5/kg to make.

Argus calculates prevailing renewable hydrogen production costs in northwest Europe at an average of over $8/kg, but costs are close to or below $6/kg in some locations, such as China, India, the Middle East and Australia.

Costs driven up

Capital costs for renewable hydrogen projects have climbed recently as inflation has driven up costs for materials and labour and interest rates have risen.

Costs for an installed electrolysis system of non-Chinese origin reached around $2,000/kW for alkaline technology and $2,450/kW for proton exchange membrane (PEM) equipment in 2023, representing increases of roughly 20pc on the year, the IEA says, although this is partly because the estimates now include "contingency costs". Chinese systems were still much cheaper, at $750-1,300/kW, it says.

The IEA still sees electrolyser costs falling sharply over the coming years, which — with reductions in the price of renewable electricity — will help drive down hydrogen production costs

But the watchdog still expects electrolyser costs to fall sharply over the coming years, which — together with reductions in the price of renewable electricity — will help drive hydrogen production costs down. In the STEPS scenario, installed electrolyser costs fall to $1,250-1,450/kW by 2030, while they dip below $1,000/kW in the NZE scenario.

These cost reductions will be reached through technological progress and economies of scale, the IEA says. Electrolyser manufacturing capacity had reached 25 GW/yr by the end of 2023 "based on the nominal facility size from company announcements", with 60pc of this in China, the IEA says. But only around 10pc of this capacity was utilised last year, with production at 2.5GW.

Based on all announcements, 165 GW/yr of nameplate electrolyser manufacturing capacity could be online by 2030, although 30pc of this "has been announced with a target year for starting operations", the IEA says. Some 50 GW/yr of capacity has already reached a final investment decision, the watchdog says.

NEWS

Germany ‘worried’ about shelved H2 pipe from Norway

The German government is worried about Norwegian state-controlled Equinor’s decision to stop planning for a hydrogen pipeline to Germany, an official from the economy and climate ministry said in Berlin last week, reminding Oslo of its commitments under the Paris agreements.

The decision is “a problem for [Germany’s] hydrogen strategy as well as the hydrogen import strategy”, the ministry’s department head for economic stabilisation, energy security, gas and hydrogen, Philipp Steinberg, said at the Handelsblatt Jahrestagung Gas conference in Berlin on 1 October.

“Of course, there has to be economic profitability for the participants in the longer term,” Steinberg said. But all countries involved have ratified Paris agreement goals, and it is “worrying” that many countries “seem to position themselves in a way that they back the energy transition and hydrogen as long as Germany pays for it and there is a business case for it”, he said. An assumption that gas could easily be sold to Asia-Pacific instead of Europe — thereby negating the need to invest in hydrogen infrastructure — is worrying if it gains traction, he added.

Equinor late last month said it halted development of the pipeline because it lacked a viable business case. “There was no clarity on the regulatory side, there were no customers and there was no supply,” Equinor told *Argus* at the time. The link was intended to primarily carry hydrogen produced from natural gas with carbon capture and storage (CCS) — at least in the short term.

Equinor still has plans to supply CCS-based hydrogen to Germany, but intends to produce this in the Netherlands instead, with the CO_2 to be shipped back to Norway for storage, a company representative said in Berlin. The firm previously announced plans for a 210,000 t/yr CCS-based hydrogen facility in the Eemshaven industrial area on the Netherlands’ northern coast, to be developed with industrial gases firm Linde. But replacing all the direct hydrogen deliveries from Norway that could have been made through the pipeline would require a dozen such facilities.

Other panellists expressed concern about Equinor’s decision. It would be “disastrous” if it were impossible to establish an energy import partnership with Norway in light of the increasing reliance on hydrogen imports through this decade, galvanisation company ZINQ’s chief executive, Lars Baumgurtel, said.
By Till Stehr

ThyssenKrupp Steel weighs decarbonisation plans

German steelmaker ThyssenKrupp Steel Europe is evaluating its decarbonisation plans, partly as a result of increased costs.

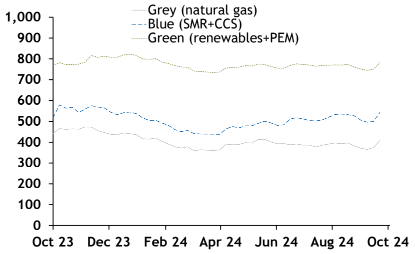
The steelmaker might scrap its plans to build a direct-reduced iron (DRI) plant in Duisburg, a source close to the company told *Argus* last week.

“The situation is currently being reviewed,” a Thyssenkrupp Steel Europe spokesperson says. “We currently assume that the direct reduction plant can be implemented under the given framework conditions.”

Potential cost increases for the planned DRI plant will have no impact on confirmed federal and state subsidies, the steelmaker says.

Germany has allocated up to €2bn to Thyssenkrupp for its decarbonisation efforts in Duisburg. This includes a direct grant of €550mn to build a DRI plant and two melting units and subsidies for renewable hydrogen purchases. If the project is abandoned this would almost certainly mean that this €550mn is forfeited. Thyssenkrupp earlier this year conducted a tender to secure hydrogen produced from renewables or natural gas with carbon capture and storage.
By Carlo Da Cas

Northwest European DRI costs $/t



NEWS

Renewable H2 projects with bank deal				
Project (co-ordinator)	H2 output *t/yr*	Electro. capacity *MW*	Bid price *€/kg*	Funding sought *€mn*
Finland				
eNRG Lahti (Nordic Ren-Gas)	12,200	90	0.37	45.2
Portugal				
Grey2Green-II (Petrogal — part of Galp)	21,600	200	0.39	84.2
MP2X (Madoqua Power2X)	51,100	500	0.48	245.2
Spain				
Hysencia (Angus)	1,700	35	0.48	8.1
Catalina (Renato PtX)	48,000	500	0.48	230.5
Norway				
Skiga (Fuella)	16,900	117	0.48	81.3

— European Commission

Spanish winner of pilot EU H2 bank auction withdraws

Spanish company Benbros Energy will not claim the operating subsidies for its 60MW El Alamillo renewable hydrogen project that it won in the European hydrogen bank pilot auction earlier this year.

Six out of the seven winners — which were first selected in April — signed their final grant agreements for the 10-year subsidies on 7 October, the European Commission says.

But Benbros "decided to withdraw from the grant agreement process", the commission says, without saying whether the project will still go ahead or be halted entirely. The project in Spain was set to receive subsidies of €0.38/kg for 6,500 t/yr of renewable hydrogen, amounting to a total support of €24.6mn.

The forfeited funds will not be allocated to the other projects, suggesting that they could be used to top up future auctions from the EU Innovation Fund.

The six projects with grant agreements will receive a combined €694.5mn and will together produce over 150,000 t/yr of renewable hydrogen (*see table*).

The EU plans to launch a second hydrogen pilot auction in December, with a larger budget of €1.2bn. The commission recently finalised terms and conditions for the second round. These include a rule that limits the share of electrolyser systems from China that developers can use to a maximum of 25pc.

By Akansha Victor

CWP Global joins Angolan 600MW renewable H2 project

Renewables developer CWP Global will join a consortium that is developing a green hydrogen and ammonia plant with 600MW of electrolyser capacity in Angola.

The firm signed an agreement covering co-operation with the consortium's existing members — Angolan state-owned oil and gas firm Sonangol, German engineering firm Gauff and German project developer Conjuncta — on 2 October.

The "current plan" is to convert the hydrogen into ammonia for exports, the partners say. In a first phase, the plant will produce 400,000 t/yr of ammonia, they say. This would require nearly 70,000 t/yr of hydrogen, based on *Argus* estimates.

Projected output appears to have been scaled up from initial plans, with the partners initially targeting 280,000 t/yr of ammonia production.

The facility will use "spare capacity from existing hydroelectric power generation", the partners say. It will be built at the port of Barra do Dande, currently under construction, and could receive power from the 2.07GW Lauca and 520MW Capanda hydroelectric dams, according to German economic development agency GTAI. The consortium signed a deal for electricity supply with national utility RNT in March 2023, GTAI says.

The partners say they are targeting a "rapid development timeline" and note that "Angola is well positioned to become a key supplier of green ammonia before the end of the decade," but did not say exactly when they aim to start the plant. When the project was announced in 2022, the launch had been targeted for 2024.

Other project developers are also hoping to utilise Angola's hydropower for ammonia production. Australian firm Minbos Resources in December 2022 signed a preliminary deal with RNT for 200MW of power over 25 years from the Capanda dam at $4-15/MWh. The company intends to make ammonia for domestic production of fertilisers and mining explosives.

CWP is pursuing projects for renewable hydrogen and derivatives in several other African countries, including Mauritania, Morocco and Djibouti. Conjuncta also has plans for a large renewable ammonia project in Mauritania.

By Stefan Krumpelmann

NEWS

Swiss firm eyes e-fuels for Iberian aviation, shipping

Swiss project developer Smartenergy is planning several plants to produce renewable hydrogen derivatives in southern Europe, primarily targeting the transport sector, business development director Pedro Guedes de Campos told delegates at the World Hydrogen Week in Copenhagen last week.

The company has plans for three renewable hydrogen-based sustainable aviation fuel (e-SAF) projects in Portugal, to serve airports in Lisbon and Porto.

Two of the projects are at the pre-front-end engineering design stage. The Galileu plant, close to Lisbon, will have 500MW of electrolyser capacity, while the Leca facility near Porto will use 250MW. The company expects operations at both plants to start by the end of 2027. The third project, Mondego, is at a later stage of development and will incorporate lessons from the other projects, Campos said. It will be developed in two phases and could eventually reach 1GW.

Smartenergy is targeting the maritime sector with a 180,000 t/yr e-methanol project in Viseu, Portugal, and a 200,000 t/yr e-methanol plant in Spain's Valencia. In Italy's Ravenna, the firm is planning a 168,000 t/yr renewable ammonia plant to supply the local port. The firm is focusing on ammonia in Ravenna because, unlike Spain and Portugal, Italy does not have ample biogenic CO_2, Campos said.

Besides the transport sector, Smartenergy also aims to produce renewable hydrogen for the ceramics and chemical industries in Portugal and Spain. The company has three projects to supply these sectors, two in Portugal and one in Spain, each with planned output capacity of 15,000 t/yr of renewable hydrogen.

These are "complex" projects and none has reached a final investment decision (FID) yet, Campos said. With the EU's e-SAF quotas not starting until 2030, Smartenergy expects the market to take a few more years to mature and developers need to have at least 60pc of offtake secured to get close to FID, Campos said.

Smartenergy is also considering a renewable ammonia production in Egypt.

By Pamela Machado

ZEMBA sees potential maritime e-fuels use by 2026-27

E-fuels made from electrolytic or other low-carbon hydrogen could be deployed by the marine sector from late 2026, with e-methanol set to be the early front-runner, according to a report by the Zero Emission Maritime Buyers Alliance (ZEMBA) and classification society Lloyd's Register.

Based on responses to a request for information (RFI) from ZEMBA — a coalition of retail companies including Amazon, Nike, and Patagonia — 391,000 t/yr fuel oil equivalent of e-fuels could be available by 2027, comprising e-methanol, ammonia and e-methane. About 78pc of that projected supply was reported from suppliers that said the maritime sector is their top target for offtake.

By 2027, there could be 68 containerships capable of running on e-methanol, 27 for e-methane and four for ammonia, which could together provide 985,700 twenty-foot equivalent unit (TEU) capacity, based on responses to the RFI.

Based on its findings, ZEMBA says e-fuels could play a role in a tender next year through which it will seek e-fuel supply from 2027 onwards, with e-methanol the most likely "bid pathway" because of fuel and vessel availability.

But ZEMBA cautioned that "projections do not always equate to deployment," noting that most e-fuel production projects remain in early development stages and that the RFI did not address the issue of costs, which will be key to uptake.

German container shipping company Hapag-Lloyd was awarded ZEMBA's first low-carbon fuel tender, earlier this year.

By Luis Gronda

Expected containership availability

Capable of running on	By 2027	By 2030
E-methane	27	27
E-methanol	68	77
E-ammonia	4	15

— ZEMBA, Lloyds Register

ANALYSIS

Renewable hydrogen development in the Nordic states must overcome a familiar set of challenges to achieve its 'fairytale ending', writes Pamela Machado

Hydrogen industry gloom spreads among Nordics

The Nordics boast highly favourable conditions for clean hydrogen production and could become key suppliers to European demand centres, but delegates at the World Hydrogen Week in Copenhagen on 30 September-4 October expressed frustration over the sector's slow progress.

Industry participants noted that Nordic countries have the key ingredients for competitive renewable production. They can call on inexpensive renewable power, including from hydroelectric sources, and offer easy grid access and ample availability of biogenic CO_2 for e-fuel production, German utility Uniper's vice-president for Nordic green fuels assets, Sebastian Groblinghoff, said.

These favourable conditions are reflected in ambitious goals. Sweden is targeting 5GW electrolysis capacity by 2030, Denmark is aiming for 4-6GW and Finland wants to provide 10pc of the 10mn t/yr of renewable hydrogen that the EU wants to produce by then, which could require over 10GW of electrolysers. Norway could use its vast natural gas reserves to make hydrogen with carbon capture and storage (CCS) and also has a substantial renewable hydrogen project pipeline.

But for all the potential, the reality is that the industry's development might not "live up to our expectations", Denmark's climate and energy minister, Lars Aagaard, said at the conference. Large projects are taking longer than anticipated to materialise and private finance is not picking up as fast as necessary, he said.

Industry participants agreed with the rather gloomy assessment, likening the hydrogen sector's trajectory to Danish fairytales that are full of struggles ahead of a hopefully happy ending. The industry's struggles are well known — rising project costs because of inflation and high interest rates, an absence of firm demand and, especially for renewable hydrogen, a lack of scale and technological maturity.

CCS-based hydrogen has long been touted as key for a transitional phase, as it could be scaled up more easily than renewable supply and is less expensive to produce. But plans were dealt a heavy blow last month, when Norwegian state-controlled Equinor halted development of an export pipeline to Germany, citing the lack of a viable business case. There is no firm demand for CCS-based hydrogen as the EU's focus on renewable hydrogen is a "major restriction" to customers, Equinor's senior vice-president for low-carbon solutions Grete Tveit told delegates in Copenhagen. Regulations should take into account emissions intensity rather than prioritising specific production pathways, Tveit said.

The export pipeline's cancellation shows that current policy support is not sufficient to make projects happen, engineering firm Technip Energies' business development and sales manager, Mika Tienhaara, noted.

Tip of the Esbjerg

Governments must firmly commit to transport infrastructure from the Nordics to European demand centres, especially in Germany, delegates said.

Denmark has "an extraordinary opportunity" to export renewable hydrogen to its southern neighbour for very little investment on its part, considering that Germany is footing most of the bill, H2 Energy Europe's chief executive, Cyril Cabanes, said. The Trafigura majority-owned firm is planning a 1GW project in Denmark's Esbjerg, which has already secured environmental and building permits, but the pipeline's completion is the "crux of the matter", Cabanes said.

But the Danish sector was dealt a blow this week as state-owned operator Energinet said the planned domestic 3GW pipeline network and connection to Germany will be delayed to 2031-32 from 2028 (*see p1*). The news will probably cause knock-on delays for planned Danish hydrogen plants, many of which are export-focused and depend on the pipeline to reach buyers, especially in Germany.

Selected European electrolyser targets

Country	2030 *target, GW*
Spain	12.0
Germany	10.0
France	6.5
Denmark	4-6
Sweden	5.0
Netherlands	3-4
Italy	3.0
Portugal	3.0
Romania	2.1
Lithuania	1.3
Greece	1.2
Austria	1.0
Bulgaria	1.0

IN BRIEF

McPhy electrolyser order nixed as H2 offtaker withdraws

French firm McPhy Energy's recently announced plan to deliver 24MW of electrolyser capacity to an undisclosed renewable hydrogen facility in central Europe will not go ahead because the project has been cancelled. The project was abandoned "due to the unexpected last-minute withdrawal of the offtaker of the green hydrogen", McPhy said only a week after announcing the order with an undisclosed "key player" in the energy sector. The developer had been expected to reach a final investment decision on the project by the end of this year, with plans to commission the equipment by 2026, according to McPhy.

Brazil launches call for funding low-carbon H2 projects

Brazil's energy ministry has launched a call for expressions of interest for low-carbon and renewable hydrogen projects to be considered for funding from the country's potential share of a $1bn industrial decarbonisation programme led by the World Bank-backed Climate Investment Fund (CIF). The CIF programme will be open to projects all over the world, with a focus on developing countries. Brazilian projects should be at commercial scale and can use a variety of production pathways and technologies, including carbon capture and utilisation or storage and ethanol reforming. The call closes on 2 November and winners will be announced on 6 December. Brazil then has until 17 January to submit its portfolio to CIF. Each chosen country could receive $125mn-250mn for projects, the ministry says.

Portugal grants €83mn to renewable H2, gas projects

Portugal's energy ministry has approved €83mn of funding for 22 projects related to the production of hydrogen and other renewable gases. The awards are part of Portugal's EU-funded recovery and resilience plan for decarbonisation of the economy and will facilitate the installation of 178.5MW of production capacity for renewable hydrogen and other gases. They will contribute to Portugal's target of installing some 200MW of additional production capacity for hydrogen and renewable gases by the first quarter of 2026, according to the ministry.

Trammo, Elengy to repurpose French LNG terminal for NH3

Global ammonia trading firm Trammo has signed an agreement with French LNG terminal operator Elengy to repurpose an existing LNG terminal in France for imports of up to 200,000 t/yr of ammonia. Named the Medhyterra project, parts of the 2.2mn t/yr Fos Tonkin LNG terminal will be redeveloped to handle some of the anticipated increase in ammonia imports to Europe as markets for clean ammonia expand. Elengy hopes to offer various distribution solutions, including connecting the terminal to the national rail network and a pipeline to industrial sites in the nearby Fos-sur-Mer industrial port zone. Bunkering facilities will also be considered, given clean ammonia's potential use as a marine fuel.

Yara's 3mn t/yr NH3 import terminal opens in Germany

Norwegian fertiliser producer Yara has officially opened a new 3mn t/yr ammonia import terminal in Brunsbuttel, Germany. Its existing deep-sea export terminal was converted to facilitate imports. The company currently imports 1.3mn-1.5mn t/yr of ammonia into Europe for its downstream operations, most of which is directed towards fertiliser production. But Yara plans to expand its handling of reduced-carbon ammonia as demand increases for the product from hard-to-abate industries. "Ammonia can be delivered directly from the terminal to the point of use, where it could be cracked to low-emission hydrogen," Yara says, indicating that it does not intend to develop a cracking facility at the site.

COMPLETE HYDROGEN PRODUCTION COSTS

No-C Hydrogen									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct	Cost	Cost in $/kg	± 1 Oct
Netherlands	Wind + PEM	Green	€/kg	6.51	7.16	nc	4.20	4.62	nc
Netherlands	Grid + GOO + ALK	Green	€/kg	9.39	10.33	+0.54	7.39	8.13	+0.55
UK	Wind + PEM	Green	£/kg	5.75	7.57	nc	3.76	4.95	nc
UK	Grid + GOO + ALK	Green	£/kg	9.47	12.46	+0.85	7.74	10.19	+0.84
Germany	Wind + PEM	Green	€/kg	7.53	8.28	nc	5.18	5.70	nc
Germany	Grid + GOO + ALK	Green	€/kg	9.58	10.54	+0.57	7.54	8.30	+0.57
France	Wind + PEM	Green	€/kg	7.81	8.59	nc	5.38	5.92	nc
France	Grid + GOO + ALK	Green	€/kg	9.40	10.34	+1.25	7.31	8.04	+1.26
Spain	Diurnal + PEM	Green	€/kg	5.69	6.26	nc	3.19	3.51	nc
Spain	Grid + GOO + ALK	Green	€/kg	8.84	9.72	-0.07	6.56	7.22	-0.07
US west coast	Diurnal + PEM	Green	$/kg	5.94	5.94	nc	3.51	3.51	nc
Canada	Wind + PEM	Green	C$/kg	9.93	7.33	nc	6.48	4.78	nc
Oman	Diurnal + PEM	Green	$/kg	6.33	6.33	nc	3.51	3.51	nc
Saudi Arabia	Diurnal + PEM	Green	$/kg	6.10	6.10	nc	3.60	3.60	nc
UAE	Diurnal + PEM	Green	$/kg	5.78	5.78	nc	3.51	3.51	nc
Qatar	Diurnal + PEM	Green	$/kg	6.12	6.12	nc	3.73	3.73	nc
Namibia	Diurnal + PEM	Green	$/kg	7.22	7.22	nc	3.70	3.70	nc
South Africa	Diurnal + PEM	Green	$/kg	6.91	6.91	nc	3.81	3.81	nc
Japan	Wind + PEM	Green	¥/kg	2,385	16.19	nc	1,977	13.42	nc
China	Diurnal + PEM	Green	Yn/kg	38.03	5.39	nc	21.80	3.09	nc
India	Diurnal + PEM	Green	Rs/kg	530.89	6.32	nc	283.93	3.38	nc
South Korea	Wind + PEM	Green	W/kg	19,361	14.46	nc	15,799	11.80	nc
Vietnam	Wind + PEM	Green	$/kg	9.32	9.32	nc	6.08	6.08	nc
Australia	Diurnal + PEM	Green	A$/kg	8.55	5.83	nc	4.96	3.38	nc
Brazil	Diurnal + PEM	Green	$/kg	6.56	6.56	nc	3.38	3.38	nc
Chile	Diurnal + PEM	Green	$/kg	6.58	6.58	nc	3.97	3.97	nc

Low-C hydrogen									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct	Cost	Cost in $/kg	± 1 Oct
Netherlands	ATR + CCS	Blue	€/kg	4.55	5.01	+0.11	3.45	3.80	+0.10
UK	ATR + CCS	Blue	£/kg	3.90	5.13	+0.17	2.92	3.84	+0.16
Germany	ATR + CCS	Blue	€/kg	4.61	5.07	+0.15	3.49	3.84	+0.15
Spain	ATR + CCS	Blue	€/kg	4.76	5.24	+0.08	3.38	3.72	+0.07
France	ATR + CCS	Blue	€/kg	4.63	5.09	+0.17	3.44	3.78	+0.16
US Gulf coast	ATR + CCS	Blue	$/kg	2.56	2.56	+0.01	1.35	1.35	+0.02
Canada	ATR + CCS	Blue	C$/kg	2.94	2.17	+0.14	1.30	0.96	+0.15
Japan	ATR + CCS	Blue	¥/kg	844	5.73	+0.08	642	4.36	+0.08
South Korea	ATR + CCS	Blue	W/kg	7,257	5.42	nc	5,516	4.12	nc
Australia	ATR + CCS	Blue	A$/kg	5.51	3.76	-0.10	3.71	2.53	-0.10
Trinidad	ATR + CCS	Blue	$/kg	4.95	4.95	+0.06	3.10	3.10	+0.06
Qatar	ATR + CCS	Blue	$/kg	4.26	4.26	+0.01	3.02	3.02	+0.01
UAE	ATR + CCS	Blue	$/kg	4.44	4.44	+0.02	3.27	3.27	+0.01
Russia west	ATR + CCS	Blue	$/kg	3.09	3.09	-0.01	1.02	1.02	nc
Russia east	ATR + CCS	Blue	$/kg	3.03	3.03	-0.01	0.96	0.96	-0.01

COMPLETE HYDROGEN PRODUCTION COSTS

BAT+ hydrogen									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct	Cost	Cost in $/kg	± 1 Oct
Netherlands	SMR + CCS	Blue	€/kg	3.60	3.96	+0.07	2.99	3.29	+0.07
UK	SMR + CCS	Blue	£/kg	2.95	3.88	+0.11	2.41	3.17	+0.11
Germany	SMR + CCS	Blue	€/kg	3.63	3.99	+0.10	3.01	3.31	+0.10
Spain	SMR + CCS	Blue	€/kg	3.72	4.09	+0.06	2.95	3.25	+0.06
France	SMR + CCS	Blue	€/kg	3.64	4.00	+0.10	2.97	3.27	+0.09
US Gulf coast	SMR + CCS	Blue	$/kg	1.65	1.65	+0.01	0.98	0.98	+0.01
Canada	SMR + CCS	Blue	C$/kg	1.94	1.43	+0.09	1.03	0.76	+0.09
Japan	SMR + CCS	Blue	¥/kg	622	4.22	+0.02	510	3.46	+0.02
South Korea	SMR + CCS	Blue	W/kg	5,516	4.12	nc	4,566	3.41	nc
Australia	SMR + CCS	Blue	A$/kg	4.18	2.85	-0.04	3.18	2.17	-0.04
Trinidad	SMR + CCS	Blue	$/kg	3.72	3.72	+0.06	2.70	2.70	+0.06
Qatar	SMR + CCS	Blue	$/kg	3.32	3.32	+0.01	2.64	2.64	+0.01
UAE	SMR + CCS	Blue	$/kg	3.33	3.33	+0.01	2.69	2.69	+0.01
Russia west	SMR + CCS	Blue	$/kg	1.84	1.84	-0.01	0.70	0.70	nc
Russia east	SMR + CCS	Blue	$/kg	1.80	1.80	-0.01	0.66	0.66	nc

BAT+ hydrogen						8 Oct
				Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct
Netherlands	SMR + CCS retrofit	Blue	€/kg	3.30	3.63	+0.06
UK	SMR + CCS retrofit	Blue	£/kg	2.61	3.44	+0.11
Germany	SMR + CCS retrofit	Blue	€/kg	3.30	3.63	+0.10
Spain	SMR + CCS retrofit	Blue	€/kg	3.24	3.56	+0.06
France	SMR + CCS retrofit	Blue	€/kg	3.27	3.60	+0.08
US Gulf coast	SMR + CCS retrofit	Blue	$/kg	1.24	1.24	+0.01
Canada	SMR + CCS retrofit	Blue	C$/kg	1.49	1.10	+0.08
Japan	SMR + CCS retrofit	Blue	¥/kg	526	3.57	+0.02
South Korea	SMR + CCS retrofit	Blue	W/kg	4,740	3.54	nc
Australia	SMR + CCS retrofit	Blue	A$/kg	3.53	2.41	-0.03
Trinidad	SMR + CCS retrofit	Blue	$/kg	2.87	2.87	+0.06
Qatar	SMR + CCS retrofit	Blue	$/kg	2.84	2.84	+0.01
UAE	SMR + CCS retrofit	Blue	$/kg	2.89	2.89	+0.01
Russia west	SMR + CCS retrofit	Blue	$/kg	0.89	0.89	-0.01
Russia east	SMR + CCS retrofit	Blue	$/kg	0.85	0.85	-0.01

BAT+ hydrogen										8 Oct
					Incl. capex			Excl. capex		
	Process	kcal/kg NAR	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct	Cost	Cost in $/kg	± 1 Oct
Australia	Coal gasification + CCS	5,500	Blue	A$/kg	5.69	3.88	-0.01	3.87	2.64	-0.01
Australia	Coal gasification + CCS	6,000	Blue	A$/kg	6.33	4.32	nc	4.52	3.08	nc
China	Coal gasification + CCS	3,800	Blue	Yn/kg	30.83	4.37	-0.02	21.52	3.05	-0.02
China	Coal gasification + CCS	5,500	Blue	Yn/kg	30.62	4.34	+0.01	21.24	3.01	+0.01
Indonesia	Coal gasification + CCS	5,500	Blue	$/kg	4.24	4.24	nc	2.75	2.75	nc
Indonesia	Coal gasification + CCS	3,800	Blue	$/kg	4.04	4.04	nc	2.55	2.55	nc
South Africa	Coal gasification + CCS	4,800	Blue	$/kg	4.32	4.32	+0.03	2.62	2.62	+0.04
South Africa	Coal gasification + CCS	6,000	Blue	$/kg	4.59	4.59	+0.03	2.88	2.88	+0.03
Russia west	Coal gasification + CCS	6,000	Blue	$/kg	4.02	4.02	+0.02	2.14	2.14	+0.02
US east coast	Coal gasification + CCS	6,000	Blue	$/kg	3.70	3.70	+0.02	2.47	2.47	+0.01

COMPLETE HYDROGEN PRODUCTION COSTS

Baseline hydrogen									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct	Cost	Cost in $/kg	± 1 Oct
Netherlands	SMR	Grey	€/kg	3.54	3.89	+0.05	3.02	3.32	+0.04
UK	SMR	Grey	£/kg	2.75	3.62	+0.09	2.30	3.02	+0.10
Germany	SMR	Grey	€/kg	3.56	3.92	+0.08	3.05	3.35	+0.08
Spain	SMR	Grey	€/kg	3.63	3.99	+0.04	2.99	3.29	+0.04
France	SMR	Grey	€/kg	3.56	3.92	+0.07	3.01	3.31	+0.07
US Gulf coast	SMR	Grey	$/kg	1.28	1.28	+0.01	0.71	0.71	+0.01
Canada	SMR	Grey	C$/kg	1.92	1.42	+0.08	1.17	0.86	+0.08
Japan	SMR	Grey	¥/kg	499	3.39	+0.02	405	2.75	+0.02
South Korea	SMR	Grey	W/kg	4,485	3.35	nc	3,669	2.74	nc
Australia	SMR	Grey	A$/kg	3.45	2.35	-0.03	2.59	1.77	-0.04
Trinidad	SMR	Grey	$/kg	3.16	3.16	+0.06	2.30	2.30	+0.06
Qatar	SMR	Grey	$/kg	2.95	2.95	+0.01	2.37	2.37	+0.01
UAE	SMR	Grey	$/kg	2.96	2.96	+0.01	2.42	2.42	+0.01
Russia west	SMR	Grey	$/kg	1.40	1.40	nc	0.43	0.43	nc
Russia east	SMR	Grey	$/kg	1.35	1.35	-0.01	0.39	0.39	nc

Baseline hydrogen									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct	Cost	Cost in $/kg	± 1 Oct
Netherlands	Grid + ALK	Yellow	€/kg	9.35	10.29	+0.54	7.35	8.09	+0.55
Netherlands	Grid + PEM	Yellow	€/kg	9.16	10.08	+0.51	6.98	7.68	+0.51
UK	Grid + ALK	Yellow	£/kg	9.12	12.00	+0.86	7.40	9.74	+0.86
UK	Grid + PEM	Yellow	£/kg	8.88	11.68	+0.80	7.00	9.21	+0.80
Germany	Grid + ALK	Yellow	€/kg	9.54	10.50	+0.57	7.51	8.26	+0.57
Germany	Grid + PEM	Yellow	€/kg	9.34	10.28	+0.53	7.13	7.84	+0.54
France	Grid + ALK	Yellow	€/kg	9.37	10.31	+1.27	7.27	8.00	+1.26
France	Grid + PEM	Yellow	€/kg	9.19	10.11	+1.17	6.90	7.59	+1.17
Spain	Grid + ALK	Yellow	€/kg	8.81	9.69	-0.06	6.53	7.18	-0.07
Spain	Grid + PEM	Yellow	€/kg	8.70	9.57	-0.06	6.21	6.83	-0.06
US west coast	Grid + ALK	Yellow	$/kg	8.55	8.55	+0.58	6.33	6.33	+0.58
US west coast	Grid + PEM	Yellow	$/kg	8.46	8.46	+0.54	6.04	6.04	+0.54
US Midwest	Grid + ALK	Yellow	$/kg	6.68	6.68	+0.13	4.47	4.47	+0.14
US Midwest	Grid + PEM	Yellow	$/kg	6.72	6.72	+0.13	4.30	4.30	+0.13
US east coast	Grid + ALK	Yellow	$/kg	7.16	7.16	+0.22	4.94	4.94	+0.22
US east coast	Grid + PEM	Yellow	$/kg	7.16	7.16	+0.20	4.74	4.74	+0.20
Japan	Grid + ALK	Yellow	¥/kg	1,721	11.68	+1.24	1,370	9.30	+1.24
Japan	Grid + PEM	Yellow	¥/kg	1,681	11.41	+1.16	1,297	8.80	+1.15

COMPLETE HYDROGEN PRODUCTION COSTS

Hydrogen decarbonisation spreads				8 Oct
	Incl. capex		Excl. capex	
	$/kg	± 1 Oct	$/kg	± 1 Oct
Northwest Europe				
No-C to BAT+	4.03	-0.09	2.12	-0.09
Low-C to BAT+	1.08	+0.06	0.52	+0.05
BAT+ to baseline	0.07	+0.02	-0.04	+0.02
North America				
No-C to BAT+	5.10	-0.05	3.28	-0.05
Low-C to BAT+	0.83	+0.03	0.29	+0.04
BAT+ to baseline	0.19	+0.01	0.08	nc
Northeast Asia				
No-C to BAT+	7.84	-0.01	6.00	-0.01
Low-C to BAT+	1.41	+0.03	0.80	+0.03
BAT+ to baseline	0.80	nc	0.69	nc
Middle East				
No-C to BAT+	2.75	-0.01	0.92	-0.01
Low-C to BAT+	1.02	nc	0.48	nc
BAT+ to baseline	0.37	nc	0.27	nc
Net exporter				
No-C to BAT+	3.54	nc	1.49	nc
Low-C to BAT+	0.97	-0.01	0.42	-0.02
BAT+ to baseline	0.40	nc	0.30	nc

Decarbonisation spreads relevant for subsidy mechanisms							8 Oct
		Incl. capex			Excl. capex		
	Unit	Spread	Spread in $/kg	± 1 Oct	Spread	Spread in $/kg	± 1 Oct
France							
No-C to Baseline[1]	€/kg	4.25	4.67	-0.07	2.37	2.61	-0.07
Germany							
No-C to BAT+[2]	€/kg	3.90	4.29	-0.10	2.17	2.39	-0.10
Netherlands							
No-C to baseline[3]	€/kg	2.97	3.27	-0.05	1.18	1.30	-0.04

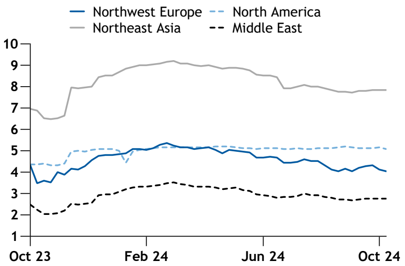
Differentials between the costs of renewable and natural gas-based hydrogen are used in subsidy mechanisms to establish the cost of switching to supply with a lower emissions intensity. The spreads above are relevant for the following:

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

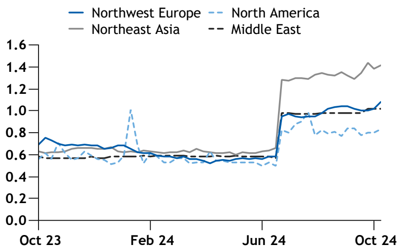
2 Future supply to Thyssenkrupp's direct reduced iron plant in Duisburg

3 Operational support granted to selected projects in Dutch subsidy scheme

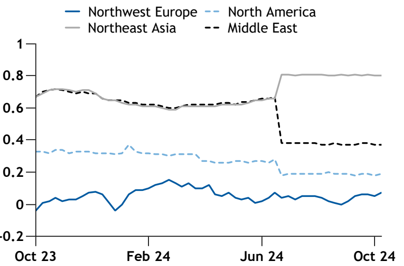
Decarb spread No-C to BAT+ *$/kg*



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



Decarb spread BAT+ to baseline *$/kg*

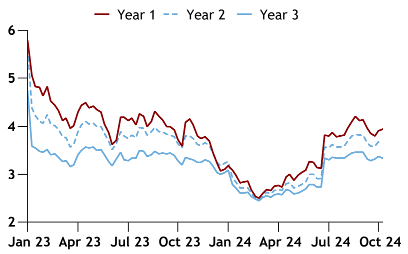


COMPLETE HYDROGEN PRODUCTION COSTS

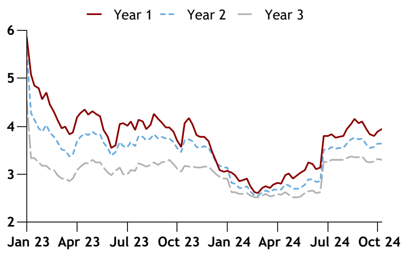
Low-C hydrogen forward									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct	Cost	Cost in $/kg	± 1 Oct
Netherlands									
2025	ATR + CCS	Blue	€/kg	4.52	4.97	+0.06	3.43	3.77	+0.07
2026	ATR + CCS	Blue	€/kg	4.21	4.63	nc	3.12	3.43	+0.01
2027	ATR + CCS	Blue	€/kg	3.87	4.26	-0.02	2.77	3.05	-0.02
UK									
2025	ATR + CCS	Blue	£/kg	3.92	5.16	+0.08	2.94	3.87	+0.08
2026	ATR + CCS	Blue	£/kg	3.66	4.81	+0.01	2.68	3.52	+0.01
Germany									
2025	ATR + CCS	Blue	€/kg	4.61	5.07	+0.06	3.02	3.84	+0.05
2026	ATR + CCS	Blue	€/kg	4.31	4.74	nc	3.49	3.51	nc
2027	ATR + CCS	Blue	€/kg	3.96	4.36	-0.02	3.19	3.13	-0.02
France									
2025	ATR + CCS	Blue	€/kg	4.57	5.03	+0.06	3.38	3.72	+0.06
Spain									
2025	ATR + CCS	Blue	€/kg	4.70	5.17	+0.06	3.32	3.65	+0.06

BAT+ hydrogen forward									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct	Cost	Cost in $/kg	± 1 Oct
Netherlands									
2025	SMR + CCS	Blue	€/kg	3.58	3.94	+0.05	2.97	3.27	+0.05
2026	SMR + CCS	Blue	€/kg	3.30	3.63	nc	2.69	2.96	nc
2027	SMR + CCS	Blue	€/kg	2.99	3.29	-0.03	2.38	2.62	-0.03
UK									
2025	SMR + CCS	Blue	£/kg	3.01	3.96	+0.07	2.46	3.24	+0.06
2026	SMR + CCS	Blue	£/kg	2.78	3.66	+0.01	2.23	2.94	nc
Germany									
2025	SMR + CCS	Blue	€/kg	3.64	4.00	+0.05	3.02	3.32	+0.05
2026	SMR + CCS	Blue	€/kg	3.36	3.70	nc	2.75	3.02	nc
2027	SMR + CCS	Blue	€/kg	3.06	3.37	-0.01	2.45	2.69	-0.01
France									
2025	SMR + CCS	Blue	€/kg	3.59	3.95	+0.05	2.94	3.23	+0.05
Spain									
2025	SMR + CCS	Blue	€/kg	3.67	4.04	+0.05	2.91	3.20	+0.05

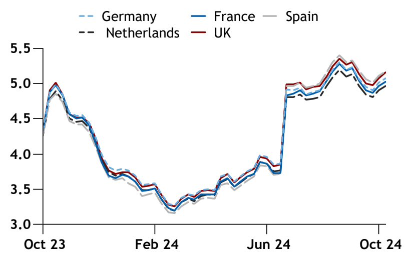
German SMR costs *$/kg*



Dutch SMR+CCS costs *$/kg*



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



COMPLETE HYDROGEN PRODUCTION COSTS

Baseline hydrogen forward									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 1 Oct	Cost	Cost in $/kg	± 1 Oct
Netherlands									
2025	SMR	Grey	€/kg	3.52	3.87	+0.02	3.01	3.31	+0.03
2026	SMR	Grey	€/kg	3.25	3.58	-0.02	2.74	3.01	-0.03
2027	SMR	Grey	€/kg	2.95	3.25	-0.05	2.45	2.69	-0.05
UK									
2025	SMR	Grey	£/kg	2.85	3.75	+0.05	2.39	3.15	+0.05
2026	SMR	Grey	£/kg	2.63	3.46	-0.02	2.17	2.86	-0.02
Germany									
2025	SMR	Grey	€/kg	3.57	3.93	+0.02	3.05	3.36	+0.02
2026	SMR	Grey	€/kg	3.32	3.65	-0.02	2.79	3.07	-0.03
2027	SMR	Grey	€/kg	3.03	3.33	-0.04	2.50	2.75	-0.05
France									
2025	SMR	Grey	€/kg	3.53	3.88	+0.03	2.97	3.27	+0.03
Spain									
2025	SMR	Grey	€/kg	3.59	3.95	+0.03	2.95	3.24	+0.02

Direct reduction iron costs (4 Oct)		$/t
Specification	**Cost**	**±**
Natural gas DRI, ex-works NW Europe	407.40	+33.36
DRI spread No-C hydrogen (renewables+PEM) vs natural gas NW Europe	374.05	-1.92
DRI spread BAT+ hydrogen (SMR+CCS) vs natural gas NW Europe	135.09	+9.68

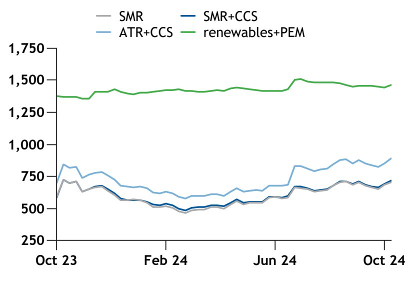
COMPLETE AMMONIA PRODUCTION COSTS

Argus liquid ammonia taxonomy (for calculated costs)	
	tCO_2e/tNH_3
Baseline	<1.93, >1.37
BAT+	<0.49, >0.17
Low-C	<0.17, >0.09
No-C	<0.01

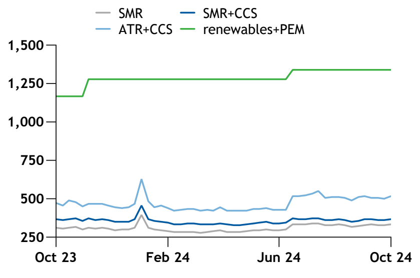
CO_2e emissions on a gate-to-gate basis; purity >99.5pc; temperature -33°C

Regional ammonia cost markers						8 Oct
			Incl. capex		Excl. capex	
	Process	Unit	Cost	± 1 Oct	Cost	± 1 Oct
Baseline						
Northwest Europe	SMR	€/t	704	+19	544	+17
Northwest Europe	SMR	$/t	775	+11	598	+10
North America	SMR	$/t	335	+9	164	+10
Northeast Asia	SMR	$/t	682	+1	492	+1
Middle East	SMR	$/t	588	+2	430	+3
BAT+						
Northwest Europe	SMR+CCS	€/t	716	+23	538	+20
Northwest Europe	SMR+CCS	$/t	788	+15	592	+14
North America	SMR+CCS	$/t	368	+9	179	+10
Northeast Asia	SMR+CCS	$/t	825	+1	615	+1
Middle East	SMR+CCS	$/t	653	+2	478	+2
Low-C						
Northwest Europe	ATR+CCS	€/t	887	+34	614	+30
Northwest Europe	ATR+CCS	$/t	976	+24	675	+23
North America	ATR+CCS	$/t	516	+15	224	+16
Northeast Asia	ATR+CCS	$/t	1,071	+7	747	+7
Middle East	ATR+CCS	$/t	827	+2	558	+2
No-C						
Northwest Europe	Island renewable+PEM	€/t	1,466	+21	974	+14
Northwest Europe	Island renewable+PEM	$/t	1,613	nc	1,071	nc
North America	Island renewable+PEM	$/t	1,340	nc	827	nc
Northeast Asia	Island renewable+PEM	$/t	2,355	nc	1,813	nc
Middle East	Island renewable+PEM	$/t	1,205	nc	685	nc
Exporter						
Exporter baseline	SMR	$/t	500	nc	334	nc
Exporter BAT+	SMR+CCS	$/t	571	nc	388	nc
Exporter low-C	ATR+CCS	$/t	740	-2	457	-3
Exporter no-C	Island renewable+PEM	$/t	1,270	nc	700	nc

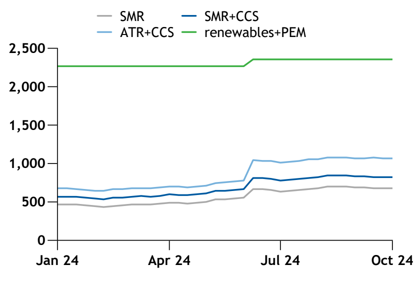
NW Europe ammonia average €/t



North America ammonia average $/t



Northeast Asia ammonia average $/t



COMPLETE AMMONIA PRODUCTION COSTS

No-C ammonia									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in *$/t*	± 1 Oct	Cost	Cost in *$/t*	± 1 Oct
Netherlands	Wind + PEM	Green	€/t	1,324	1,456	nc	844	928	nc
UK	Wind + PEM	Green	£/t	1,156	1,521	nc	738	971	nc
Germany	Wind + PEM	Green	€/t	1,503	1,654	nc	1,016	1,118	nc
France	Wind + PEM	Green	€/t	1,571	1,728	nc	1,062	1,168	nc
Spain	Diurnal + PEM	Green	€/t	1,150	1,265	nc	627	690	nc
US west coast	Diurnal + PEM	Green	$/t	1,200	1,200	nc	704	704	nc
Canada	Wind + PEM	Green	C$/t	2,005	1,480	nc	1,287	950	nc
Oman	Diurnal + PEM	Green	$/t	1,267	1,267	nc	669	669	nc
Saudi Arabia	Diurnal + PEM	Green	$/t	1,202	1,202	nc	685	685	nc
UAE	Diurnal + PEM	Green	$/t	1,140	1,140	nc	672	672	nc
Qatar	Diurnal + PEM	Green	$/t	1,209	1,209	nc	715	715	nc
Namibia	Diurnal + PEM	Green	$/t	1,470	1,470	nc	703	703	nc
South Africa	Diurnal + PEM	Green	$/t	1,383	1,383	nc	721	721	nc
Japan	Wind + PEM	Green	¥/t	464,691	3,154	nc	378,943	2,572	nc
China	Diurnal + PEM	Green	Yn/t	7,599	1,077	nc	4,163	590	nc
India	Diurnal + PEM	Green	Rs/t	105,759	1,259	nc	53,593	638	nc
South Korea	Wind + PEM	Green	W/t	3,793,177	2,833	nc	3,047,396	2,276	nc
Vietnam	Wind + PEM	Green	$/t	1,857	1,857	nc	1,154	1,154	nc
Australia	Diurnal + PEM	Green	A$/t	1,736	1,184	nc	1,003	684	nc
Brazil	Diurnal + PEM	Green	$/t	1,319	1,319	nc	640	640	nc
Chile	Diurnal + PEM	Green	$/t	1,296	1,296	nc	756	756	nc

Low-C ammonia									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in *$/t*	± 1 Oct	Cost	Cost in *$/t*	± 1 Oct
Netherlands	ATR + CCS	Blue	€/t	876	964	+18	614	676	+19
UK	ATR + CCS	Blue	£/t	747	983	+28	516	679	+28
Germany	ATR + CCS	Blue	€/t	889	978	+25	617	679	+24
Spain	ATR + CCS	Blue	€/t	934	1,028	+13	599	659	+13
France	ATR + CCS	Blue	€/t	897	987	+29	610	671	+28
US Gulf coast	ATR + CCS	Blue	$/t	548	548	+3	255	255	+3
Canada	ATR + CCS	Blue	C$/t	656	484	+28	260	192	+28
Japan	ATR + CCS	Blue	¥/t	162,362	1,102	+13	112,858	766	+13
South Korea	ATR + CCS	Blue	W/t	1,391,144	1,039	nc	973,399	727	nc
Australia	ATR + CCS	Blue	A$/t	1,108	756	-17	670	457	-18
Trinidad	ATR + CCS	Blue	$/t	1,014	1,014	+10	549	549	+10
Qatar	ATR + CCS	Blue	$/t	820	820	+2	537	537	+2
UAE	ATR + CCS	Blue	$/t	834	834	+2	578	578	+2
Russia west	ATR + CCS	Blue	$/t	712	712	-2	189	189	-2
Russia east	ATR + CCS	Blue	$/t	710	710	-1	187	187	-1

Japan and Korea low-carbon ammonia benchmark (JK LAB)			8 Oct
	Unit	Cost	± 1 Oct
CFR Ulsan, South Korea, incl. US 45Q tax credit	$/t	557.87	+3.47
CFR Ulsan, South Korea, excl. US 45Q tax credit	$/t	693.87	+3.47
CFR Niihama, Japan, differential	$/t	+0.33	-0.03

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									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 1 Oct	Cost	Cost in $/t	± 1 Oct
Netherlands	SMR + CCS	Blue	€/t	709	780	+11	539	593	+12
UK	SMR + CCS	Blue	£/t	582	766	+19	432	569	+19
Germany	SMR + CCS	Blue	€/t	717	789	+18	541	595	+17
Spain	SMR + CCS	Blue	€/t	748	823	+11	531	584	+11
France	SMR + CCS	Blue	€/t	722	794	+16	535	589	+15
US Gulf coast	SMR + CCS	Blue	$/t	385	385	+2	195	195	+2
Canada	SMR + CCS	Blue	C$/t	476	351	+17	220	162	+17
Japan	SMR + CCS	Blue	¥/t	123,171	836	+2	91,200	619	+3
South Korea	SMR + CCS	Blue	W/t	1,089,886	814	nc	818,084	611	nc
Australia	SMR + CCS	Blue	A$/t	871	594	-6	586	400	-6
Trinidad	SMR + CCS	Blue	$/t	786	786	+11	484	484	+10
Qatar	SMR + CCS	Blue	$/t	658	658	+2	474	474	+2
UAE	SMR + CCS	Blue	$/t	648	648	+2	482	482	+2
Russia west	SMR + CCS	Blue	$/t	479	479	-1	140	140	-1
Russia east	SMR + CCS	Blue	$/t	474	474	-1	135	135	-1

BAT+ ammonia										8 Oct
					Incl. capex			Excl. capex		
	Process	kcal/kg NAR	Legacy colour	Unit	Cost	Cost in $/t	± 1 Oct	Cost	Cost in $/t	± 1 Oct
Australia	Coal gasification + CCS	5,500	Blue	A$/t	1,121	765	-1	704	480	-2
Australia	Coal gasification + CCS	6,000	Blue	A$/t	1,231	840	nc	815	556	nc
China	Coal gasification + CCS	3,800	Blue	Yn/t	5,920	839	-3	3,782	536	-4
China	Coal gasification + CCS	5,500	Blue	Yn/t	5,885	834	+2	3,733	529	+1
Indonesia	Coal gasification + CCS	5,500	Blue	$/t	826	826	nc	483	483	nc
Indonesia	Coal gasification + CCS	3,800	Blue	$/t	791	791	nc	449	449	nc
South Africa	Coal gasification + CCS	4,800	Blue	$/t	856	856	+5	461	461	+7
South Africa	Coal gasification + CCS	6,000	Blue	$/t	902	902	+5	505	505	+5
Russia west	Coal gasification + CCS	6,000	Blue	$/t	819	819	+4	381	381	+4
US east coast	Coal gasification + CCS	6,000	Blue	$/t	731	731	+4	450	450	+2

Baseline ammonia									8 Oct
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 1 Oct	Cost	Cost in $/t	± 1 Oct
Netherlands	SMR	Grey	€/t	698	768	+7	544	599	+7
UK	SMR	Grey	£/t	547	720	+16	412	542	+16
Germany	SMR	Grey	€/t	705	776	+13	546	601	+13
Spain	SMR	Grey	€/t	733	806	+7	535	589	+6
France	SMR	Grey	€/t	709	780	+11	541	595	+11
US Gulf coast	SMR	Grey	$/t	318	318	+1	147	147	+2
Canada	SMR	Grey	C$/t	476	351	+17	244	180	+17
Japan	SMR	Grey	¥/t	101,366	688	+2	72,488	492	+3
South Korea	SMR	Grey	W/t	903,775	675	-1	658,752	492	nc
Australia	SMR	Grey	A$/t	739	504	-7	482	329	-7
Trinidad	SMR	Grey	$/t	686	686	+10	413	413	+10
Qatar	SMR	Grey	$/t	592	592	+2	426	426	+3
UAE	SMR	Grey	$/t	584	584	+2	434	434	+3
Russia west	SMR	Grey	$/t	399	399	-1	92	92	-1
Russia east	SMR	Grey	$/t	393	393	-1	87	87	nc

COMPLETE AMMONIA PRODUCTION COSTS

Ammonia decarbonisation spreads				8 Oct
	Incl. capex		Excl. capex	
	$/t	± 1 Oct	$/t	± 1 Oct
Northwest Europe				
No-C to BAT+	825	-15	479	-14
Low-C to BAT+	188	+9	83	+9
BAT+ to baseline	13	+4	-6	+4
North America				
No-C to BAT+	972	-9	648	-10
Low-C to BAT+	148	+6	45	+6
BAT+ to baseline	33	nc	15	nc
Northeast Asia				
No-C to BAT+	1,530	-1	1,198	-1
Low-C to BAT+	246	+6	132	+6
BAT+ to baseline	143	nc	123	nc
Middle East				
No-C to BAT+	552	-2	207	-2
Low-C to BAT+	174	nc	80	nc
BAT+ to baseline	65	nc	48	-1
Net exporter				
No-C to BAT+	699	nc	312	nc
Low-C to BAT+	169	-2	69	-3
BAT+ to baseline	71	nc	54	nc

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