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Argus *Hydrogen and Future Fuels*

Market news, analysis and prices

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Slow progress dominates Cop 29 H2 talks

The infrastructure needed for key industries to adopt clean hydrogen may not be ready until after 2030, putting climate goals in jeopardy, writes Pamela Machado

Discussions at UN climate summits have in recent years often signalled optimism around the crucial role that clean hydrogen could play in the world's decarbonisation efforts. Delegates at this year's Cop 29 climate conference in Baku have again pointed to hydrogen's potential, but many of the discussions have revolved around how the sector's slow progress could jeopardise global climate targets.

Clean hydrogen plans have been hit by inflation and other challenges that have driven up project costs and led to cancellations and delays, despite ample government support. Meanwhile, in most regions there has been little tangible progress on key elements such as midstream infrastructure.

Optimistic industry participants point to the downward trajectory taken by renewable electricity costs in recent years and decades, seeing potential parallels for hydrogen. Large-scale deployment of solar and wind power was unlocked by supportive policies and renewable hydrogen could take the same path if the right incentives and mandates for demand are put in place, industry group the Hydrogen Council chief executive Ivana Jemelkova said during a hydrogen-focused panel hosted by the World Bank's private-sector investment arm, IFC, at Cop on 16 November.

But in light of the sector's sluggish progress, many in the industry are increasingly questioning these analogies to renewable electricity and are pointing to some of the specific challenges that hydrogen faces. Among these is a need for a much more substantial transformation of infrastructure, including on the side of consumers, where in many cases major investment is needed to adapt to hydrogen use.

The steel sector is a case in point. It is a major emitter of CO_2 and many are relying heavily on hydrogen to help clean up the industry. But steel plants will only "realistically" be able to adopt renewable hydrogen at scale after 2030, because the required infrastructure is not ready yet, according to the head of European steelmaker ArcelorMittal's XCarb innovation fund, Irina Gorbounova.

From a net zero emissions perspective, 2030 might be too late. The steel sector together with the shipping industry — another major polluter — would have to use 10mn-15mn t/yr of clean hydrogen by 2030 to keep the world on track for net zero by 2050, Paris-based intergovernmental group OECD environment directorate policy analyst Joseph Cordonnier said at an event in the run-up to the climate summit.

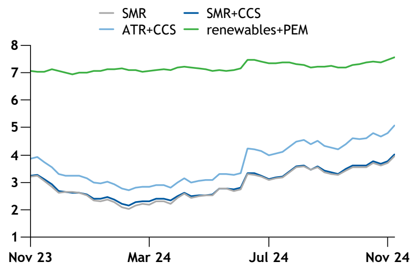
Others at the OECD event agreed. Around 70 commercial-scale green steel plants would be needed by the early 2030s to "stay as close as possible" to the Paris agreement goal to limit the rise in global temperatures to 1.5°C above pre-industrial levels, according to private-sector decarbonisation initiative Mission Possible Partnership chief executive Faustine Delasalle. Around 60 green steel projects have been announced but fewer than 10 have reached a final investment decision.

The Cop 29 presidency was the first to issue a dedicated hydrogen declaration that outlined government commitments, including on demand-side incentives and mandates. The document stressed the need for "financial assistance", especially in developing countries, and panellists at Cop events repeatedly pointed to the enormous efforts required in this regard. Development finance institutions around the world have so far provided around $5bn in concessional financial for hydrogen projects, while estimates suggest that $100bn will be required in the long run, the World Bank's lead climate specialist, Tom Kerr, said at UK group Climate Action's Hydrogen Transition Summit on 15 November in Baku.

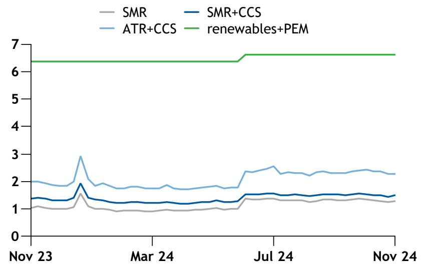
CONTENTS

HYDROGEN COSTS

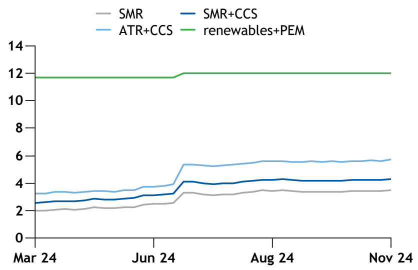
Northwest Europe average cost €/kg



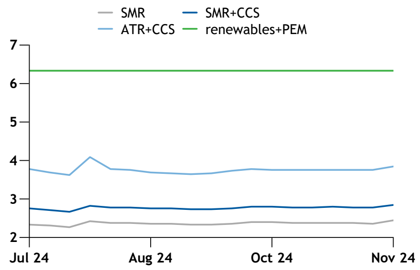
North America average cost $/kg



Northeast Asia average cost $/kg



Exporter average cost $/kg



Regional hydrogen cost markers						19 Nov
			Incl. capex		Excl. capex	
	Process	Unit	Cost	± 12 Nov	Cost	± 12 Nov
Baseline						
Northwest Europe	SMR	€/kg	3.96	+0.25	3.41	+0.24
Northwest Europe	SMR	$/kg	4.19	+0.20	3.60	+0.19
North America	SMR	$/kg	1.28	+0.03	0.72	+0.03
Northeast Asia	SMR	$/kg	3.51	+0.10	2.89	+0.10
Middle East	SMR	$/kg	3.14	+0.11	2.58	+0.11
BAT+						
Northwest Europe	SMR+CCS	€/kg	4.01	+0.24	3.36	+0.23
Northwest Europe	SMR+CCS	$/kg	4.24	+0.19	3.55	+0.19
North America	SMR+CCS	$/kg	1.48	+0.04	0.81	+0.04
Northeast Asia	SMR+CCS	$/kg	4.31	+0.10	3.57	+0.09
Middle East	SMR+CCS	$/kg	3.52	+0.12	2.85	+0.11
Low-C						
Northwest Europe	ATR+CCS	€/kg	5.08	+0.29	3.90	+0.27
Northwest Europe	ATR+CCS	$/kg	5.37	+0.23	4.12	+0.22
North America	ATR+CCS	$/kg	2.27	+0.01	1.06	+0.01
Northeast Asia	ATR+CCS	$/kg	5.71	+0.10	4.37	+0.10
Middle East	ATR+CCS	$/kg	4.54	+0.11	3.34	+0.12
No-C						
Northwest Europe	Island renewable+PEM	€/kg	7.58	+0.12	5.12	+0.08
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	2.44	+0.08	1.88	+0.08
Exporter BAT+	SMR+CCS	$/kg	2.85	+0.08	2.18	+0.08
Exporter low-C	ATR+CCS	$/kg	3.84	+0.08	2.62	+0.08
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 Nov
	Unit	Price	± 1 Oct
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

Bolivia eyes renewable H2 as gas production slumps

Hydrogen-based synthetic fuels could help Bolivia reduce its dependency on transport fuel imports, writes Pamela Machado

Bolivia has traditionally been one of Latin America's largest natural gas producers but the country's output is in decline. The government hopes that renewable hydrogen can help fill the void in the long term and allow Bolivia to continue exporting molecules to its neighbours, especially Brazil, according to its recent hydrogen strategy and roadmap.

Bolivia hopes to capitalise on its solar power potential for large-scale renewable hydrogen production and seeks to leverage its vast gas export infrastructure, according to documents seen by *Argus*. State-owned oil firm YPFB aims to "revert the declining trend in natural gas production and increase production of liquid fuels" including hydrogen-based products, the government says.

Output could serve local demand as well as exports, especially to neighbouring Brazil. Bolivia has been an important source of natural gas for Brazil in recent decades, with supply exported through the more than 3,000km-long Gasbol pipeline. But the country's gas production is in decline and may only suffice for its domestic needs by 2029, prompting the Bolivian government to assess the possibilities for future cross-border hydrogen transport. Bolivia could strike an agreement with Brazil for blending renewable hydrogen with the natural gas that is delivered eastwards and into domestic distribution grids, the strategy document suggests.

Bolivia also plans to assess whether other gas infrastructure could be repurposed for hydrogen. This includes depleted fields that could be used as storage and natural gas liquefaction facilities that could be adapted to liquefy hydrogen.

Supplying overseas demand centres — such as Europe and northeast Asia — could prove more challenging, given that Bolivia is landlocked. But the strategy suggests that Arica port in northern Chile — an important hub for Bolivian and Peruvian trade — could be used for seaborne shipments.

Bolivia also sees opportunities for domestic hydrogen use, such as using derivatives including synthetic fuels to meet its increasing demand for transport fuels and curb the need for imports. The country imports 85pc of the diesel it consumes and 55pc of its gasoline, according to YPFB. But rising imports are straining the national budget. Increasing use of e-fuels could also help reduce the country's CO_2 emissions from diesel and gasoline consumption by 20pc in 2030, 50pc in 2040 and 75pc in 2050, according to the strategy. Making synthetic fuels will require CO_2 to be combined with hydrogen and, while the strategy does not specify where this will come from, Bolivia has ample biomass resources from forestry and agriculture that could provide access to biogenic CO_2.

Gasbol gas pipeline

Off the map

The government's hydrogen roadmap focuses exclusively on renewable hydrogen production and does not consider other pathways such as gas-based production with carbon capture, given its natural gas reserves are in decline. Bolivia wants to produce around 150,000 t/yr of renewable hydrogen by 2030 — of which 85,000 t/yr would be exported — at a levelised cost of $1.76/kg, according to the strategy (*see table*). These cost targets appear ambitious, with Paris-based energy watchdog the IEA recently predicting that only Chinese projects would reach costs below $2/kg by 2030. Bolivia's production goals are also aspirational, with very few projects having been announced so far and none having reached an advanced stage.

The government acknowledges that financing is a challenge for the sector because of project complexity and the industry's nascent state. It aims to establish international partnerships and work with multilateral development banks such as the IDB and the World Bank, and suggests that it could make use of green bonds for projects that have climate and environmental benefits.

Bolivia renewable hydrogen targets

Year	2030	2040	2050
Electrolyser capacity *GW*	1.1	na	24.6
Production *'000 t/yr*	150	1,350	4,150
Exports *'000 t/yr*	85	800	2,650
Levelised cost of H2 *$/kg*	1.8	1.4	1.0

— Bolivian hydrocarbon and energy ministry

MARKET DEVELOPMENTS

Spain, Lithuania to provide subsidies in EU H2 bank

The country-specific budgets could enable projects that miss out in the EU-wide allocation to secure support, write Stefan Krumpelmann and Aidan Lea

Spain and Lithuania will join Austria in providing subsidies to domestic renewable hydrogen projects through the European hydrogen bank's auctions-as-a-service mechanism, during a tender round that starts next month.

Spain will offer subsidies worth a combined €280mn-400mn ($295mn-422mn), with the exact amount dependent on the funds allocated in a separate Spanish subsidy scheme for hydrogen clusters, the European Commission says. Madrid will confirm the amount by spring 2025, after the hydrogen bank auction ends.

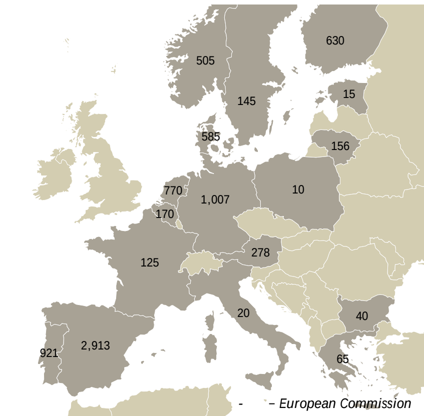
Meanwhile Lithuania has earmarked €36mn for the scheme, with the subsidies intended to help the country reach its 1.3GW electrolysis capacity goal for 2030.

Austria had previously announced plans to make €400mn available in the next European hydrogen bank auction. The country plans to support a maximum of 300MW of electrolysis capacity and will grant up to €200mn to each project, meaning that at least two plants could receive funding, the commission says.

The auctions-as-a-service mechanism allows countries to use the European hydrogen bank tender rounds to provide subsidies to projects in their territory that miss out in the EU-wide competition. Hydrogen bank winners will receive fixed support for each kg of hydrogen produced over a 10-year period and will be picked based on the lowest bids for the amount requested.

In a first round earlier this year, three Spanish projects were among the seven subsidy winners, although one has since withdrawn. The additional domestic budget could increase the number of Spanish projects that receive subsidies in the upcoming round, especially if some are again successful in the EU-wide allocation.

Cumulative electrolyser capacity of submitted bids in H2 bank pilot *MW*



Five Austrian projects with a combined electrolysis capacity of 278MW and three Lithuanian projects for a total of 156MW applied in the first hydrogen bank auction, but these all missed out on receiving subsidies in the EU-wide allocation as their bids were too high. The separate country-specific budgets in the upcoming auction could allow some of these to secure support. The lowest bid submitted by an Austrian project in the first auction was just over €0.50/kg, only slightly above the clearing price of €0.48/kg. The lowest Lithuanian bid was over €1.50/kg.

Only Germany used the auctions-as-a-service mechanism in the first auction, setting aside a €350mn budget. But it has yet to announce the winners, more than six months after selections were made for the EU-wide competition.

The next hydrogen bank auction is due to be launched on 3 December. The EU-wide competition will have a budget of €1.2bn, of which €200mn is earmarked for projects targeting offtake from the maritime sector.

Chinese wall

The commission has further clarified its rule on the exclusion of projects that source more than 25pc of their electrolyser capacity from China.

The EU will judge electrolysers at the stack level — if stacks contain cells that have been made in China, it will consider the whole stack to be sourced from China. It considers cells to be made in China if they contain components from China such as electrodes or membranes, if the assembly takes place in China, or if they have surface treatment in China related to coatings of electrodes, membranes and bipolar plates, the commission says. Developers will have to document the origins of their electrolysers at various stages from application to the start of production.

These details could aid developers as they choose their suppliers, as some manufacturers have international supply chains that could blur the lines about being Chinese-made. Several Chinese equipment makers are looking to expand in the EU, and the new details for the auction may force them to locate more complete production lines in the bloc, rather than just assembling Chinese-made components.

NEWS

Japan's KHI shifts focus to domestic supply for LH2

Japanese engineering company Kawasaki Heavy Industries (KHI) will seek to secure hydrogen from domestic producers rather than imports from Australia for its planned liquid hydrogen and power generation demonstration project. The change in supply source is intended to enable the project to complete on schedule, in the April 2030-March 2031 fiscal year.

KHI and project partners domestic refiner Eneos and hydrogen supplier Iwatani had originally intended to demonstrate large-scale shipments of liquefied hydrogen from Australia to Japan. But the companies have faced delays in receiving approval to build a hydrogen production plant in Australia and are now planning to source the hydrogen domestically, so they can move ahead with the plans on time, KHI says. The firm says it will now buy the hydrogen in gaseous form and liquefy it at a plant that it will build. KHI has not decided where it will source the hydrogen in Japan, or specified the production method through which it will be made.

The liquefied hydrogen will be used for power generation, such as through co-firing with natural gas. But KHI has reduced the expected scope of the project, with hydrogen consumption now expected at around 30,000-70,000 t/yr, down from 100,000 t/yr. With the changes in the procurement plan, KHI has also decided to downsize capacity of the liquid hydrogen carriers it plans to develop and use in the project to 40,000m³ from 160,000m³.

The project is designed to help Japan achieve its ambitious target of reaching a hydrogen supply price of ¥30/Nm³, or around $2.10/kg, by 2030, and ¥20//Nm³, or $1.44/kg, by 2050. KHI had initially planned to bring in supply from Australia made from coal with carbon capture, utilisation and storage, supported by a ¥220bn grant from Japan's state-owned research institute Nedo.

Eneos has also been involved in a project trialling methylcyclohexane production for use as a hydrogen carrier, also supported by Nedo funding. Eneos has been looking into a renewable hydrogen supply source for the project — either Queensland, Australia or Sarawak, Malaysia — and had originally planned to finish the trial by 2030-31. But the project has been delayed by 1-2 years, Nedo says.
By Nanami Oki

Malaysia plans 250,000 t/yr green H2 hub on Borneo

Borneo

A consortium of private and state-owned companies is planning to develop a renewable hydrogen production facility in Kota Mardu in Malaysia's Sabah state, with a target output of 250,000 t/yr.

Malaysian property developer LBS Bina Group has signed a preliminary deal for the project with government-backed Invest Sabah, state environmental agency Sabah Forestry Development Authority and lighting solution provider Midwest Green. LBS will be the "master developer", the firm says.

The project will include an electrolysis facility powered by 10GW of solar and wind sources and an industrial park. It will be situated on a potential site that spans 15,000-30,000 acres (6,000-12,000 hectares) and benefits from some of the highest solar irradiance and consistent wind speeds in Malaysia, making it "ideal for renewable energy production", LBS says. And the site's proximity to seaports supports "efficient export logistics", LBS adds, although it has not specified the countries or sectors to which the consortium plans to sell its output.

Sabah is on the northern part of Borneo, which is politically divided between Malaysia, Indonesia and Brunei. The Malaysian state of Sarawak in northern Borneo could host a centralised hydrogen production hub in Bintulu town.
By Akansha Victor

NEWS

Amercoeur, Belgium

Engie, Carmeuse scrap Belgian e-methane project

French energy firm Engie and Belgian lime producer Carmeuse have abandoned plans to make e-methane in Belgium by combining CO_2 captured from a lime kiln with renewable hydrogen from a 100MW electrolysis plant in Amercoeur.

"The current market does not guarantee the viability of the Columbus project," Engie says. A "European market for hydrogen and its derivatives is still emerging", the firm says. Progress has been "slower than initially envisaged", notably because regulatory frameworks and the synthetic fuels market are not sufficiently mature, it says.

The partners halted the plans despite being selected for an undisclosed amount of funding support from Belgium's Wallonia region under the EU's Important Project of Common European Interest scheme.

The developers had projected total investment costs for the project at €300mn ($316mn) in 2022. They were aiming to reach a final investment decision in 2024, with a view to starting operations in 2026. Belgian technology firm John Cockerill was slated to supply the electrolyser.

The e-methane would have been injected into Belgium's national grid or used as a fuel in industry and transport, allowing for over 160,000 t/yr in CO_2 emissions reductions, according to the developers.

The cancellation is the latest in a string of similar announcements from developers of renewable hydrogen and derivatives projects in Europe and elsewhere. Many have pointed to rising project costs, difficulties in finding offtakers for their potential supply and regulatory uncertainties.

Engie and Carmeuse say the cancellation "does not alter" their decarbonisation strategies. Engie has several projects under development for producing hydrogen or derivatives from renewable power or natural gas with carbon capture and storage, although the company earlier this year pushed back its target to have 4GW of installed electrolysis capacity by 2030, with the firm now aiming for 4GW by 2035. Carmeuse says it is still pursuing plans for CO_2 capture and aims to build on the "significant advances" made while researching for Columbus.

By Stefan Krumpelmann

New Brazil plant to supply green H2 to Germany

Brazilian power utility Eletrobras, German state-owned Securing Energy for Europe (SEFE) and Kuwait-based project developer EnerTech are planning to jointly develop a project in Brazil that could supply 200,000 t/yr of renewable hydrogen to Germany.

The firms have signed an initial study agreement to assess the project plans. Supply would be shipped to Germany as ammonia and deliveries could start by 2030, SEFE says. SEFE will manage transport, logistics and hydrogen sales to German and European customers.

SEFE has not said where the facility will be built but has disclosed that the plant will be connected to the Brazilian power grid, which is almost entirely decarbonised. Eletrobras generates more than 90pc of its power from hydroelectric plants. The three companies all intend to be "long-term co-owners of the production assets", SEFE says.

SEFE said earlier this year that it is considering investing over €1bn ($1.05bn) in hydrogen pipeline and storage infrastructure, following a market survey.

SEFE is also eyeing importing renewable hydrogen from Norwegian developer Gen2 and low-carbon hydrogen from Norwegian state-controlled Equinor.

By Pamela Machado

NEWS

Shipping alliance to launch e-fuels tender in January

Retailer coalition Zero Emission Maritime Buyers Alliance (Zemba) plans to launch a tender in January to procure synthetic marine fuels (e-fuels) from 2027.

The group will accept bids that achieve emissions reductions of at least 90pc compared with conventional fuels and award offtake contracts for 3-5 years, starting in 2027. Through the tender, Zemba aims to reach at least 80bn tonne-miles of demand for container shipping. This could equate to at least 250,000 t/yr of e-methanol or 300,000 t/yr of ammonia, Zemba tells *Argus*. The final volumes are to be confirmed once the group has settled on a commercial agreement with the successful bidder, it says. The tender will open in January and close in March.

The 3-5 year timeframe for offtake contracts is shorter than most new fuel producers need in order to reach a final investment decision for their projects, but "it is multiple times longer than freight buyers normally offer carriers", Zemba says. The initiative is meant to inspire industry participants "to do their part to support e-fuel production through their own longer-term offtake commitments".

Zemba's members include large global retail companies such as Amazon, Ikea and Nike, among others.

E-fuel availability could reach the equivalent of 391,000 t/yr of fuel oil by 2027, comprising e-methanol, ammonia and e-methane, according to a market survey previously carried out by Zemba.

The announcement of the tender came shortly after shipping industry participants called for "faster and bolder action" to accelerate and increase the use of low and zero-emissions marine fuels to "at least 5pc, striving for 10pc, by 2030".

Industry participants asked for stronger efforts to increase e-fuels uptake, investment in zero-emissions vessels and hydrogen infrastructure in a letter co-ordinated by non-profit groups including the Rocky Mountains Institute and the UN Foundation and signed at the UN Cop 29 climate summit in Baku this month. The shipping sector could require at least 5mn t/yr of renewable hydrogen or derivatives by 2030 to align with the Paris Agreement's target to limit the increase in global temperatures to 1.5°C compared with pre-industrial levels, the letter says.
By Pamela Machado

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

Spanish developer auctions renewable H2 supply

Spanish developer DH2 has launched an auction scheme to sell renewable hydrogen produced at its 35MW Hysencia electrolysis plant in Aragon, northeast Spain.

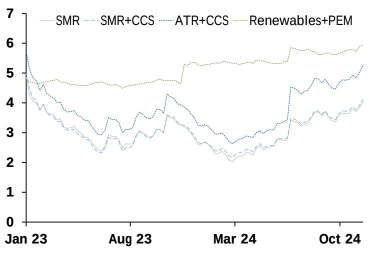
The scheme opened on 15 November and is being carried out in partnership with the Iberian Mibgas gas exchange. The first step of the auction process is a pre-qualification phase, which will be followed by a qualification stage and then final bidding. Companies submitting the most competitive bids will be selected for bilateral negotiations with DH2. Domestic and international companies can apply and there are no restrictions on offtake sectors.

DH2 expects production at Hysencia to start in the first half of 2027. The plant will be powered by 49MW of solar energy and has a planned output of 2,200 t/yr, reaching peak production of 6.5 t/d during the summer months, according to the project description. The plant received environmental approval in July.

Hysencia was one of the winning projects in the European Hydrogen Bank's pilot auction, having requested €8.1mn ($8.77mn) in funding with a bidding price of €0.48/kg of H2.

DH2 is also planning a 75MW electrolyser project in Portugal, where it aims to produce 3,500 t/yr of renewable hydrogen in the Castelo Branco district.
By Pamela Machado

Spanish H2 costs *$/kg*



NEWS

More hydrogen firms face potential insolvency

Many hydrogen start-ups are facing an uncertain future, with two more European companies recently warning of potential insolvency.

Irish electrolyser manufacturer and project developer Fusion Fuel has filed a damages claim against potential investor Hydrogenial for the latter's "failure to fund" the $33.5mn that Fusion Fuel says was committed under a subscription agreement signed by the two companies in August.

Hydrogenial has failed to deliver the funds and, as "a direct consequence of the funding delay, Fusion Fuel has filed for insolvency for its Portuguese subsidiary", through which the company had been carrying out most of its activities, Fusion Fuel says. Fusion Fuel "is actively exploring strategic alternatives" to resolve the situation, including a potential transaction that could "yield significant synergies" with its hydrogen business, the firm says.

Besides electrolyser sales, Fusion Fuel's business model foresees construction of "turnkey hydrogen plants" using its own technology. Planned projects include a large 630MW plant at the port of Sines in Portugal, which is due to be developed with partners and which was selected for state aid under the EU's Important Projects of Common European Interest framework.

Meanwhile, Norway's tax authority has filed a bankruptcy petition against a subsidiary of fuel cell company Teco 2030, for which Teco 2030 provided a guarantee capped at 10mn krone ($900,000), Teco 2030 says. Teco 2030 and its subsidiary are in discussions "to address the situation" but Teco 2030 may face its own bankruptcy proceedings "should negotiations fail to yield a satisfactory resolution", it says.

An increasing number of firms in the US and Europe have signalled difficulties in keeping operations afloat in recent weeks, with many reporting challenges in finalising orders and securing lending commitments.

By Pamela Machado

US firm Plug eyes 1GW sales in 2025, nears DOE loan

US electrolyser maker and hydrogen project developer Plug Power is targeting ambitious electrolyser sales in 2025 and says it is close to finalising a $1.7bn loan from the US Department of Energy (DOE).

Plug has lowered its 2024 revenue guidance to $700mn–800mn from $825mn–925mn, noting that slow hydrogen sector developments have curbed equipment demand, but says it is "positive" about the longer-term outlook.

The company says it could grow electrolyser orders to more than 1GW in 2025, which looks ambitious compared with its orders in the third quarter of this year for just tens of megawatts of capacity. Plug says it hit an "inflection point" in electrolyser sales but expects a rapid increase next year. Plug is helping developers with early design work for around 8GW of potential orders, and it expects "more than a gigawatt" of this will reach a final investment decision that will translate into firm orders next year, chief strategy officer Sanjay Shrestha says.

"We certainly expect a pretty big booking year" for electrolysers in 2025, with orders coming from "Europe and more likely Australia", Shrestha says.

Plug expects to seal a $1.66bn loan from the DOE before US president-elect Donald Trump returns to the White House in January. "We have a clear path with the DOE to close that out before the change in administration," chief executive Andy Marsh says. The DOE's loan programmes office made a conditional commitment for the loan in May, with the funding earmarked for six renewable hydrogen plants in several states, including in Texas and New York.

By Aidan Lea

Plug financial results *$mn*

Period	Net revenue	Net losses
3Q24	173.7	211.2
2Q24	143.4	262.3
1Q24	120.3	295.8

— Plug

INTERVIEW

India's H2e seeks to compete with Chinese electrolysers

Indian firm H2e Power is developing a 1.5 GW/yr electrolyser manufacturing facility in the state of Maharashtra. The company is exploring a range of technologies including solid oxide, proton exchange membrane (PEM) and its proprietary alkaline membrane solid electrolyte equipment, which combines features of PEM and anion exchange membrane designs. Argus spoke with H2e founder Siddharth Mayur about the firm's plans, opportunities and challenges, and the key role of critical components. Edited highlights follow:

What challenges are you facing in India in terms of setting up your electrolyser manufacturing business?

The opportunities are incredibly large and that is why we are investing in this space. But in terms of challenges, there are three major ones. Fundraising is one. It remains a hurdle as we are venturing into uncertain territory, which makes investors hesitant. Secondly, the availability of localised components. Many components are still imported, often with long lead times, which makes it difficult to deliver projects on time or within a timeline that ensures profitability. Thirdly, there is a shortage of skilled manpower.

'Many components are imported, often with long lead times, which makes it difficult to deliver projects on time or within a timeline that ensures profitability'

How can the government help with funding?

The government has a key role to play and it is already doing its bit with its National Green Hydrogen Mission and production-linked incentive (PLI) schemes, but it can still do something similar to what China does. Why are there so many companies in China? Because the Chinese government supports them, providing funding to set up manufacturing facilities and market-linked incentives. I made a submission to India's minister [of new and renewable energy], noting that support for smaller companies is crucial. For example, to qualify for a tender, you often need a five-year-old balance sheet and multi-crore revenue, or a track record of installing several projects. These criteria exclude start-ups and MSMEs [micro, small or medium enterprises] from qualifying for the tender. Winning the tender is a different story. If I'm not competitive, I will not win. But if only large players qualify, then what are we doing to the ecosystem? The other bottleneck is debt funding. As an MSME, if you go to the bank, they tell you that they don't lend to small companies. They often require a profitable balance sheet with at least 3-5 years of profits to even consider lending at workable terms. While banks need to secure their money, small companies face hurdles such as providing bank or performance guarantees [for tender bidding]. If these solutions are implemented, there is no reason why we can't outperform Chinese companies in cost and European companies in terms of technology.

'The other bottleneck is debt funding. As a small or medium enterprise, if you go to the bank, they tell you that they don't lend to small companies'

Could you elaborate on how the availability of components is a challenge?

There are about 390 components that go into an electrolyser. There are certain components on the stack — such as membranes and electrodes — and in the balance of a plant that have long lead times and are expensive currently because there are very few suppliers in the world. But these are being aggressively developed. We are also developing many of these components in-house. By early 2026, as far as H2e is concerned, we should have solved about 80pc of these challenges, reducing inventory times and capital requirements and improving delivery timelines. Delays often occur because certain components are either unavailable, have long lead times or face shipping delays. Last time I imported something, I was promised two weeks but it took several weeks to arrive. Geopolitical issues such as those in Europe, Ukraine, Russia and the Middle East add to these challenges. We are working on developing components, processes and chemical

INTERVIEW

methodologies that will suit India's raw material availability. By 2026 or 2027, we aim to produce electrolysers at a price point comparable to Chinese products delivered in India. That will make a good case for exporting electrolysers. In addition, for challenging components, we are exploring ways to replace or eliminate them altogether through research and development.

'By 2026 or 2027, we aim to produce electrolysers at a price point comparable to Chinese products delivered in India'

What do you think about the restrictions on Chinese electrolysers in the EU's hydrogen bank auction? How could it benefit Indian manufacturers?
Whether there is a rule or not, India definitely has an opportunity. Chinese manufacturers typically offer two types of stacks, one with lower efficiency that is extremely cheap and another with higher efficiency that is more expensive. When you opt for higher efficiency stacks, the cost becomes comparable to those in India or perhaps even Europe. There are many factors that determine whether a stack is good. These include the production rate in kilograms per hour, as well as the production rate in the eighth or ninth year. Also input and output efficiency, the pressure and the temperature conditions, and the required maintenance. For example, how often do you need to replace the catalyst or components in the electrolyser? The stack might be the same type, such as an alkaline or another, but these different factors can impact its performance.

Can you tell us more about H2e's current projects? You announced a 1.5 GW/yr factory in 2022 — what is the progress on that?
The 101.5 MW/yr [electrolyser manufacturing capacity for which] we won a PLI is part of this factory. It's located in Jalgaon and the infrastructure is ready. Some machines are already here, some are being built in-house, and others are in transit. We expect trial production to start around April or May next year. By mid or late next year, we'll begin rolling out commercial-grade electrolysers. Initially, the factory will produce 350 MW/yr and expand in phases as market demand grows. Since we don't have the funding of large corporations, we're taking modest but significant steps. By 2030, we plan to surpass 1.5 GW/yr, aligning with market growth. Separately, we've done several projects with [state-controlled upstream firm] Oil India, including building India's first green hydrogen plant, developing a hydrogen-powered bus, and blending hydrogen with natural gas. We're also working on a project involving liquid organic hydrogen carriers. Recently, we won an Oil India tender to build a MW-scale hydrogen plant in Himachal Pradesh in collaboration with utility Himachal Pradesh Power. We have done important proof-of-concept projects with [state-controlled firms] HPCL, NTPC and IOCL on different types of electrolysers and solutions. A leading public-sector unit is also exploring investing in H2e and is currently conducting due diligence.

'The real bottleneck is supply of round-the-clock renewable energy at a cost that will make green hydrogen or e-fuels cost-effective'

What is your view on India's renewable hydrogen targets for 2030?
On the electrolyser side, yes it can be done. The real bottleneck is supply of round-the-clock renewable energy at a cost that will make green hydrogen or e-fuels cost-effective. Nobody currently has 24/7 renewable energy at an affordable cost. To produce 5mn t/yr of hydrogen, you're looking at 100-140GW of renewable power. India's current renewable capacity is 200GW and it is aiming for 500GW by 2030. The key question is — where should electrolyser plants be located? Do you bring electricity to the plant or move the electrolyser and transport the hydrogen? This logistics issue could delay progress. By 2030, I think we should be able to achieve at least 60-70pc of the target, which will be huge, but as a industry — with support from the government — we are geared up to not just achieve the 500GW renewable power and 5mn t/yr green hydrogen targets, but to surpass them.

IN BRIEF

Strike and reference prices
Strike price
To be based on clean H2 and NH3 costs, factoring in feedstock prices, investment costs, operating expenses, consumer price index adjustments, etc.
Reference price
To be based on the feedstocks or fuels that are replaced, for example Japan's average import costs for LNG (for hydrogen) and coal (for ammonia), as well as environmental costs such as a planned carbon levy on fossil fuels.

— *Japanese government*

Japan to open H2 subsidy scheme on 22 November

Japan will accept applications for its contracts-for-difference (CfD) scheme to subsidise low-carbon hydrogen and ammonia from 22 November. The application window will close on 31 March. Applications submitted by 31 January "will be reviewed in advance", trade and industry ministry Meti says, suggesting that these submissions could be fast-tracked. The process is behind schedule, with Meti having initially planning to accept applications from this summer. Subsidies will be provided under a CfD mechanism, covering the gap between a strike and a reference price over a 15-year period.

Germany's Uniper picks Electric Hydrogen for 200MW electrolyser

German utility Uniper has selected US firm Electric Hydrogen to supply a 200MW proton exchange membrane electrolysis system for its Green Wilhelmshaven project in northern Germany. The electrolyser will be fed by wind power and will be installed on the site of Uniper's former coal-fired power plant in Wilhelmshaven. Electric Hydrogen says its 100MW systems will be available for deployment in Europe in 2026. Uniper has said previously that it could eventually scale up the Wilhelmshaven plant to 1GW. Part of the output from the project has been earmarked for steelmaker Salzgitter, with deliveries of 20,000 t/yr due to begin in 2028.

German firms plan 500MW renewable H2 plant at Stade

A consortium of German firms is planning a renewable hydrogen production plant with 500MW of electrolysis capacity in the city of Stade in northern Germany. The Hanseatic Hydrogen project will entail 100MW of electrolysis capacity in a first phase that is to due to be operational by the end of 2028. This could eventually be expanded to 500MW in a final stage, but the developers have not given a timeline for this. The firms have secured land at the Stade industrial park and have advanced planning for connections to the electricity grid and to water supply. They are targeting a final investment decision on the first 100MW in 2026, with construction to start the same year.

Firms planning Hanseatic Hydrogen project

Company	Description
Buss Group	Developer of port and maritime logistics and energy infrastructure
HAzwei	Joint venture between utilities Avacon Natur and Hansewerk
KE Holding	Investment management firm

Germany's RWE to delay hydrogen investments

German utility RWE said on 13 November that it will delay its investments into hydrogen projects because the market "is not progressing as quickly as expected". RWE will probably invest the funds it had earmarked for hydrogen "later", chief financial officer Michael Muller says. "The ramp-up of the hydrogen economy will take significantly longer" and this could delay "RWE's target of building electrolyser capacity", the company says. Current hydrogen market conditions and "expected delays in the US offshore wind market" have prompted RWE to reduce its investments in these sectors in 2025-26. The company will start a share buy-back scheme worth €1.5bn ($1.59bn) in the fourth quarter.

French firm EDF enters renewable ammonia project in Canada

French energy company EDF has joined Canadian firm Abraxas Power as an equity partner in a planned large-scale renewable ammonia project in Newfoundland and Labrador province, eastern Canada. The Exploits Valley (Evrec) plant will use more than 3GW of wind power to produce about 200,000 t/yr of hydrogen. This will be converted into 1mn t/yr of ammonia for export. The companies plan to reach a final investment decision in 2026, with the plant due to start up in 2030. Abraxas signed a 30-year lease option agreement with the port of Botwood last month, to allow for shipments to Europe and other markets. The Evrec project was awarded access to over 300km² of crown land by the province's government last year.

COMPLETE HYDROGEN PRODUCTION COSTS

No-C Hydrogen									19 Nov
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 12 Nov	Cost	Cost in $/kg	± 12 Nov
Netherlands	Wind + PEM	Green	€/kg	6.77	7.16	nc	4.37	4.62	nc
Netherlands	Grid + GOO + ALK	Green	€/kg	10.57	11.17	+0.49	8.49	8.97	+0.50
UK	Wind + PEM	Green	£/kg	5.97	7.57	nc	3.91	4.95	nc
UK	Grid + GOO + ALK	Green	£/kg	10.22	12.95	+0.46	8.43	10.69	+0.46
Germany	Wind + PEM	Green	€/kg	7.83	8.28	nc	5.39	5.70	nc
Germany	Grid + GOO + ALK	Green	€/kg	10.73	11.34	+0.56	8.61	9.10	+0.56
France	Wind + PEM	Green	€/kg	8.13	8.59	nc	5.60	5.92	nc
France	Grid + GOO + ALK	Green	€/kg	11.27	11.91	+0.49	9.08	9.60	+0.49
Spain	Diurnal + PEM	Green	€/kg	5.92	6.26	nc	3.32	3.51	nc
Spain	Grid + GOO + ALK	Green	€/kg	10.03	10.60	+0.19	7.65	8.09	+0.19
US west coast	Diurnal + PEM	Green	$/kg	5.94	5.94	nc	3.51	3.51	nc
Canada	Wind + PEM	Green	C$/kg	10.28	7.33	nc	6.71	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	2,507	16.19	nc	2,078	13.42	nc
China	Diurnal + PEM	Green	Yn/kg	38.94	5.39	nc	22.33	3.09	nc
India	Diurnal + PEM	Green	Rs/kg	533.57	6.32	nc	285.36	3.38	nc
South Korea	Wind + PEM	Green	W/kg	20,230	14.46	nc	16,509	11.80	nc
Vietnam	Wind + PEM	Green	$/kg	9.32	9.32	nc	6.08	6.08	nc
Australia	Diurnal + PEM	Green	A$/kg	8.99	5.83	nc	5.21	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									19 Nov
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 12 Nov	Cost	Cost in $/kg	± 12 Nov
Netherlands	ATR + CCS	Blue	€/kg	5.02	5.31	+0.21	3.88	4.10	+0.21
UK	ATR + CCS	Blue	£/kg	4.37	5.54	+0.22	3.35	4.25	+0.22
Germany	ATR + CCS	Blue	€/kg	5.08	5.37	+0.23	3.92	4.14	+0.23
Spain	ATR + CCS	Blue	€/kg	5.23	5.53	+0.19	3.79	4.01	+0.19
France	ATR + CCS	Blue	€/kg	5.13	5.42	+0.23	3.89	4.11	+0.22
US Gulf coast	ATR + CCS	Blue	$/kg	2.40	2.40	+0.04	1.18	1.18	+0.04
Canada	ATR + CCS	Blue	C$/kg	3.00	2.14	-0.02	1.30	0.93	-0.02
Japan	ATR + CCS	Blue	¥/kg	897	5.79	+0.11	684	4.42	+0.11
South Korea	ATR + CCS	Blue	W/kg	7,863	5.62	+0.09	6,044	4.32	+0.09
Australia	ATR + CCS	Blue	A$/kg	5.95	3.86	+0.03	4.06	2.63	+0.03
Trinidad	ATR + CCS	Blue	$/kg	5.22	5.22	+0.16	3.37	3.37	+0.17
Qatar	ATR + CCS	Blue	$/kg	4.45	4.45	+0.11	3.21	3.21	+0.12
UAE	ATR + CCS	Blue	$/kg	4.63	4.63	+0.12	3.46	3.46	+0.12
Russia west	ATR + CCS	Blue	$/kg	3.08	3.08	nc	1.00	1.00	-0.01
Russia east	ATR + CCS	Blue	$/kg	3.02	3.02	nc	0.95	0.95	nc

COMPLETE HYDROGEN PRODUCTION COSTS

BAT+ hydrogen — 19 Nov

	Process	Legacy colour	Unit	Incl. capex Cost	Incl. capex Cost in $/kg	Incl. capex ± 12 Nov	Excl. capex Cost	Excl. capex Cost in $/kg	Excl. capex ± 12 Nov
Netherlands	SMR + CCS	Blue	€/kg	3.99	4.22	+0.19	3.36	3.55	+0.19
UK	SMR + CCS	Blue	£/kg	3.36	4.26	+0.19	2.79	3.54	+0.18
Germany	SMR + CCS	Blue	€/kg	4.03	4.26	+0.20	3.39	3.58	+0.20
Spain	SMR + CCS	Blue	€/kg	4.11	4.34	+0.18	3.31	3.50	+0.17
France	SMR + CCS	Blue	€/kg	4.02	4.25	+0.20	3.34	3.53	+0.20
US Gulf coast	SMR + CCS	Blue	$/kg	1.52	1.52	+0.07	0.85	0.85	+0.07
Canada	SMR + CCS	Blue	C$/kg	2.01	1.43	nc	1.07	0.76	nc
Japan	SMR + CCS	Blue	¥/kg	672	4.34	+0.10	554	3.58	+0.10
South Korea	SMR + CCS	Blue	W/kg	5,988	4.28	+0.10	4,981	3.56	+0.09
Australia	SMR + CCS	Blue	A$/kg	4.41	2.86	+0.04	3.36	2.18	+0.04
Trinidad	SMR + CCS	Blue	$/kg	3.98	3.98	+0.16	2.96	2.96	+0.16
Qatar	SMR + CCS	Blue	$/kg	3.51	3.51	+0.12	2.82	2.82	+0.11
UAE	SMR + CCS	Blue	$/kg	3.52	3.52	+0.12	2.87	2.87	+0.11
Russia west	SMR + CCS	Blue	$/kg	1.83	1.83	nc	0.68	0.68	-0.01
Russia east	SMR + CCS	Blue	$/kg	1.79	1.79	nc	0.65	0.65	nc

BAT+ hydrogen — 19 Nov

	Process	Legacy colour	Unit	Excl. capex Cost	Excl. capex Cost in $/kg	Excl. capex ± 12 Nov
Netherlands	SMR + CCS retrofit	Blue	€/kg	3.69	3.90	+0.19
UK	SMR + CCS retrofit	Blue	£/kg	3.01	3.81	+0.18
Germany	SMR + CCS retrofit	Blue	€/kg	3.69	3.90	+0.20
Spain	SMR + CCS retrofit	Blue	€/kg	3.60	3.81	+0.17
France	SMR + CCS retrofit	Blue	€/kg	3.65	3.86	+0.20
US Gulf coast	SMR + CCS retrofit	Blue	$/kg	1.10	1.10	+0.07
Canada	SMR + CCS retrofit	Blue	C$/kg	1.54	1.10	-0.01
Japan	SMR + CCS retrofit	Blue	¥/kg	571	3.69	+0.10
South Korea	SMR + CCS retrofit	Blue	W/kg	5,176	3.70	+0.09
Australia	SMR + CCS retrofit	Blue	A$/kg	3.72	2.41	+0.04
Trinidad	SMR + CCS retrofit	Blue	$/kg	3.13	3.13	+0.16
Qatar	SMR + CCS retrofit	Blue	$/kg	3.03	3.03	+0.12
UAE	SMR + CCS retrofit	Blue	$/kg	3.07	3.07	+0.11
Russia west	SMR + CCS retrofit	Blue	$/kg	0.88	0.88	nc
Russia east	SMR + CCS retrofit	Blue	$/kg	0.84	0.84	nc

BAT+ hydrogen — 19 Nov

	Process	kcal/kg NAR	Legacy colour	Unit	Incl. capex Cost	Incl. capex Cost in $/kg	Incl. capex ± 12 Nov	Excl. capex Cost	Excl. capex Cost in $/kg	Excl. capex ± 12 Nov
Australia	Coal gasification + CCS	5,500	Blue	A$/kg	6.04	3.92	-0.01	4.13	2.68	-0.01
Australia	Coal gasification + CCS	6,000	Blue	A$/kg	6.75	4.38	-0.02	4.84	3.14	-0.02
China	Coal gasification + CCS	3,800	Blue	Yn/kg	31.50	4.36	nc	21.96	3.04	nc
China	Coal gasification + CCS	5,500	Blue	Yn/kg	31.21	4.32	-0.01	21.68	3.00	-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	4.35	4.35	nc	2.64	2.64	nc
South Africa	Coal gasification + CCS	6,000	Blue	$/kg	4.60	4.60	+0.01	2.89	2.89	+0.01
Russia west	Coal gasification + CCS	6,000	Blue	$/kg	4.04	4.04	nc	2.16	2.16	nc
US east coast	Coal gasification + CCS	6,000	Blue	$/kg	3.74	3.74	+0.01	2.51	2.51	nc

COMPLETE HYDROGEN PRODUCTION COSTS

Baseline hydrogen — 19 Nov

				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 12 Nov	Cost	Cost in $/kg	± 12 Nov
Netherlands	SMR	Grey	€/kg	3.94	4.17	+0.20	3.41	3.60	+0.19
UK	SMR	Grey	£/kg	3.16	4.00	+0.18	2.68	3.40	+0.18
Germany	SMR	Grey	€/kg	3.97	4.20	+0.20	3.43	3.63	+0.20
Spain	SMR	Grey	€/kg	4.03	4.26	+0.18	3.36	3.55	+0.18
France	SMR	Grey	€/kg	3.96	4.19	+0.20	3.39	3.58	+0.20
US Gulf coast	SMR	Grey	$/kg	1.14	1.14	+0.07	0.58	0.58	+0.07
Canada	SMR	Grey	C$/kg	1.99	1.42	nc	1.19	0.85	-0.01
Japan	SMR	Grey	¥/kg	544	3.51	+0.10	444	2.87	+0.10
South Korea	SMR	Grey	W/kg	4,911	3.51	+0.10	4,057	2.90	+0.09
Australia	SMR	Grey	A$/kg	3.62	2.35	+0.04	2.74	1.78	+0.04
Trinidad	SMR	Grey	$/kg	3.42	3.42	+0.15	2.56	2.56	+0.16
Qatar	SMR	Grey	$/kg	3.13	3.13	+0.11	2.55	2.55	+0.11
UAE	SMR	Grey	$/kg	3.15	3.15	+0.12	2.60	2.60	+0.11
Russia west	SMR	Grey	$/kg	1.38	1.38	nc	0.41	0.41	-0.01
Russia east	SMR	Grey	$/kg	1.34	1.34	-0.01	0.38	0.38	nc

Baseline hydrogen — 19 Nov

				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 12 Nov	Cost	Cost in $/kg	± 12 Nov
Netherlands	Grid + ALK	Yellow	€/kg	10.55	11.15	+0.50	8.46	8.94	+0.49
Netherlands	Grid + PEM	Yellow	€/kg	10.28	10.87	+0.45	8.01	8.47	+0.46
UK	Grid + ALK	Yellow	£/kg	10.00	12.67	+0.50	8.21	10.41	+0.50
UK	Grid + PEM	Yellow	£/kg	9.70	12.30	+0.46	7.76	9.83	+0.46
Germany	Grid + ALK	Yellow	€/kg	10.71	11.32	+0.56	8.59	9.08	+0.56
Germany	Grid + PEM	Yellow	€/kg	10.44	11.04	+0.52	8.14	8.60	+0.52
France	Grid + ALK	Yellow	€/kg	11.25	11.89	+0.49	9.06	9.58	+0.49
France	Grid + PEM	Yellow	€/kg	10.95	11.58	+0.45	8.57	9.06	+0.45
Spain	Grid + ALK	Yellow	€/kg	10.01	10.58	+0.19	7.63	8.07	+0.19
Spain	Grid + PEM	Yellow	€/kg	9.84	10.40	+0.18	7.25	7.66	+0.18
US west coast	Grid + ALK	Yellow	$/kg	9.64	9.64	-0.07	7.43	7.43	-0.06
US west coast	Grid + PEM	Yellow	$/kg	9.48	9.48	-0.06	7.06	7.06	-0.06
US Midwest	Grid + ALK	Yellow	$/kg	7.01	7.01	+0.16	4.79	4.79	+0.16
US Midwest	Grid + PEM	Yellow	$/kg	7.02	7.02	+0.14	4.60	4.60	+0.14
US east coast	Grid + ALK	Yellow	$/kg	7.44	7.44	+0.22	5.22	5.22	+0.22
US east coast	Grid + PEM	Yellow	$/kg	7.42	7.42	+0.20	5.00	5.00	+0.20
Japan	Grid + ALK	Yellow	¥/kg	1,612	10.41	+0.17	1,243	8.03	+0.18
Japan	Grid + PEM	Yellow	¥/kg	1,583	10.22	+0.16	1,180	7.62	+0.16

COMPLETE HYDROGEN PRODUCTION COSTS

Hydrogen decarbonisation spreads				19 Nov
	Incl. capex		Excl. capex	
	$/kg	± 12 Nov	$/kg	± 12 Nov
Northwest Europe				
No-C to BAT+	3.77	-0.19	1.86	-0.19
Low-C to BAT+	1.13	+0.04	0.57	+0.03
BAT+ to baseline	0.05	-0.01	-0.05	nc
North America				
No-C to BAT+	5.16	-0.04	3.34	-0.04
Low-C to BAT+	0.79	-0.03	0.25	-0.03
BAT+ to baseline	0.20	+0.01	0.09	+0.01
Northeast Asia				
No-C to BAT+	7.70	-0.10	5.87	-0.09
Low-C to BAT+	1.40	nc	0.80	+0.01
BAT+ to baseline	0.80	nc	0.68	-0.01
Middle East				
No-C to BAT+	2.56	-0.12	0.74	-0.11
Low-C to BAT+	1.02	-0.01	0.49	+0.01
BAT+ to baseline	0.38	+0.01	0.27	nc
Net exporter				
No-C to BAT+	3.48	-0.08	1.43	-0.08
Low-C to BAT+	0.99	nc	0.44	nc
BAT+ to baseline	0.41	nc	0.30	nc

Decarbonisation spreads relevant for subsidy mechanisms							19 Nov
		Incl. capex			Excl. capex		
	Unit	Spread	Spread in $/kg	± 12 Nov	Spread	Spread in $/kg	± 12 Nov
France							
No-C to Baseline[1]	€/kg	4.16	4.40	-0.20	2.21	2.34	-0.20
Germany							
No-C to BAT+[2]	€/kg	3.80	4.02	-0.20	2.01	2.12	-0.20
Netherlands							
No-C to baseline[3]	€/kg	2.83	2.99	-0.20	0.96	1.02	-0.19

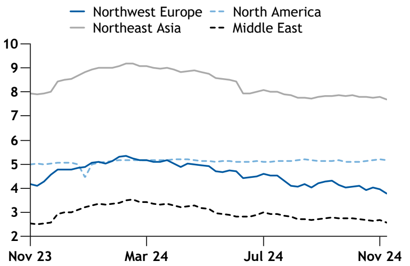
Differentials between the costs of renewable and natural gas-based hydrogen are used in subsidy mechanisms to establish the cost of switching to supply with a lower emissions intensity. The spreads above are relevant for the following:

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

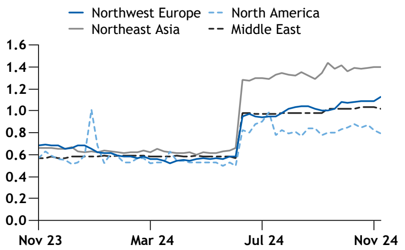
2 Future supply to Thyssenkrupp's direct reduced iron plant in Duisburg

3 Operational support granted to selected projects in Dutch subsidy scheme

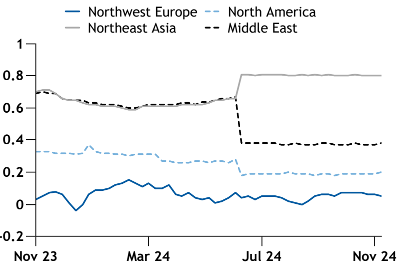
Decarb spread No-C to BAT+ $/kg



Decarb spread Low-C to BAT+ $/kg



Decarb spread BAT+ to baseline $/kg

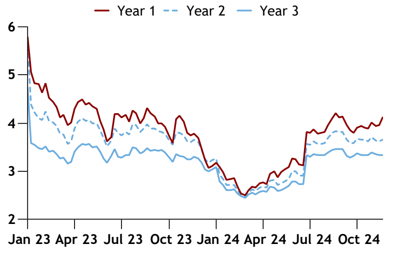


COMPLETE HYDROGEN PRODUCTION COSTS

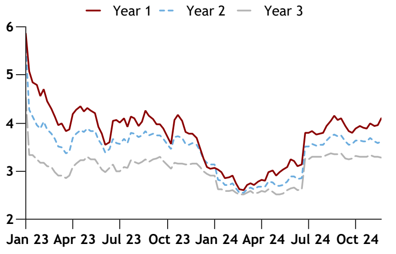
Low-C hydrogen forward									19 Nov
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 12 Nov	Cost	Cost in $/kg	± 12 Nov
Netherlands									
2025	ATR + CCS	Blue	€/kg	4.86	5.14	+0.15	3.73	3.94	+0.16
2026	ATR + CCS	Blue	€/kg	4.36	4.61	+0.02	3.22	3.40	+0.02
2027	ATR + CCS	Blue	€/kg	4.02	4.25	nc	2.88	3.04	nc
UK									
2025	ATR + CCS	Blue	£/kg	4.21	5.34	+0.16	3.20	4.05	+0.16
2026	ATR + CCS	Blue	£/kg	3.79	4.80	+0.03	2.77	3.51	+0.03
Germany									
2025	ATR + CCS	Blue	€/kg	4.97	5.25	+0.17	3.29	4.02	+0.17
2026	ATR + CCS	Blue	€/kg	4.47	4.72	+0.02	3.80	3.49	+0.02
2027	ATR + CCS	Blue	€/kg	4.12	4.35	-0.01	3.30	3.12	-0.01
France									
2025	ATR + CCS	Blue	€/kg	4.90	5.18	+0.14	3.66	3.87	+0.13
Spain									
2025	ATR + CCS	Blue	€/kg	5.00	5.29	+0.12	3.57	3.77	+0.12

BAT+ hydrogen forward									19 Nov
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 12 Nov	Cost	Cost in $/kg	± 12 Nov
Netherlands									
2025	SMR + CCS	Blue	€/kg	3.88	4.10	+0.15	3.24	3.43	+0.14
2026	SMR + CCS	Blue	€/kg	3.42	3.61	+0.02	2.79	2.95	+0.03
2027	SMR + CCS	Blue	€/kg	3.10	3.28	-0.01	2.48	2.62	nc
UK									
2025	SMR + CCS	Blue	£/kg	3.24	4.11	+0.13	2.68	3.40	+0.14
2026	SMR + CCS	Blue	£/kg	2.88	3.65	+0.02	2.32	2.94	+0.02
Germany									
2025	SMR + CCS	Blue	€/kg	3.94	4.16	+0.14	3.29	3.48	+0.14
2026	SMR + CCS	Blue	€/kg	3.49	3.69	+0.03	2.85	3.01	+0.02
2027	SMR + CCS	Blue	€/kg	3.18	3.36	nc	2.54	2.68	nc
France									
2025	SMR + CCS	Blue	€/kg	3.87	4.09	+0.12	3.19	3.37	+0.13
Spain									
2025	SMR + CCS	Blue	€/kg	3.94	4.17	+0.12	3.15	3.33	+0.12

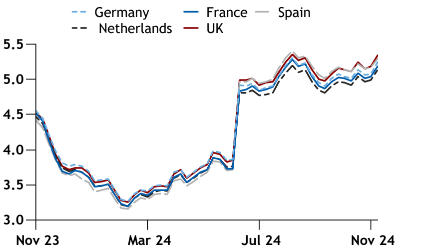
German SMR costs *$/kg*



Dutch SMR+CCS costs *$/kg*



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



COMPLETE HYDROGEN PRODUCTION COSTS

Baseline hydrogen forward									19 Nov
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/kg	± 12 Nov	Cost	Cost in $/kg	± 12 Nov
Netherlands									
2025	SMR	Grey	€/kg	3.83	4.05	+0.15	3.30	3.49	+0.15
2026	SMR	Grey	€/kg	3.39	3.58	+0.03	2.86	3.02	+0.03
2027	SMR	Grey	€/kg	3.08	3.26	nc	2.55	2.70	nc
UK									
2025	SMR	Grey	£/kg	3.08	3.91	+0.13	2.61	3.31	+0.13
2026	SMR	Grey	£/kg	2.73	3.46	+0.01	2.26	2.86	+0.01
Germany									
2025	SMR	Grey	€/kg	3.89	4.11	+0.15	3.35	3.54	+0.15
2026	SMR	Grey	€/kg	3.45	3.65	+0.03	2.91	3.08	+0.03
2027	SMR	Grey	€/kg	3.16	3.34	+0.01	2.61	2.76	nc
France									
2025	SMR	Grey	€/kg	3.82	4.04	+0.14	3.24	3.43	+0.14
Spain									
2025	SMR	Grey	€/kg	3.87	4.09	+0.12	3.20	3.38	+0.12

Direct reduction iron costs (15 Nov)		$/t
Specification	Cost	±
Natural gas DRI, ex-works NW Europe	410.08	+0.67
DRI spread No-C hydrogen (renewables+PEM) vs natural gas NW Europe	370.51	-4.76
DRI spread BAT+ hydrogen (SMR+CCS) vs natural gas NW Europe	140.83	-0.70

Argus Hydrogen and Future Fuels Data & Downloads

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

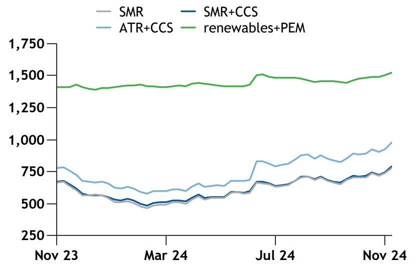
COMPLETE AMMONIA PRODUCTION COSTS

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

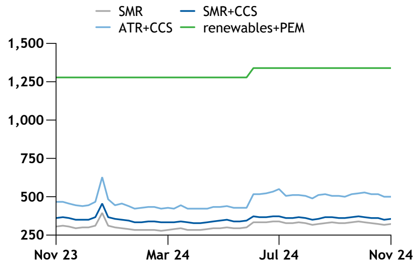
CO2e emissions on a gate-to-gate basis; purity >99.5pc; temperature -33°C

Regional ammonia cost markers						19 Nov
			Incl. capex		Excl. capex	
	Process	Unit	Cost	± 12 Nov	Cost	± 12 Nov
Baseline						
Northwest Europe	SMR	€/t	779	+45	611	+41
Northwest Europe	SMR	$/t	823	+35	646	+34
North America	SMR	$/t	323	+5	152	+5
Northeast Asia	SMR	$/t	706	+16	516	+16
Middle East	SMR	$/t	619	+19	461	+20
BAT+						
Northwest Europe	SMR+CCS	€/t	787	+43	603	+41
Northwest Europe	SMR+CCS	$/t	832	+33	637	+33
North America	SMR+CCS	$/t	358	+6	168	+5
Northeast Asia	SMR+CCS	$/t	849	+17	639	+16
Middle East	SMR+CCS	$/t	684	+19	509	+19
Low-C						
Northwest Europe	ATR+CCS	€/t	974	+51	690	+48
Northwest Europe	ATR+CCS	$/t	1,030	+39	729	+39
North America	ATR+CCS	$/t	500	+1	208	+1
Northeast Asia	ATR+CCS	$/t	1,093	+17	769	+17
Middle East	ATR+CCS	$/t	860	+21	590	+20
No-C						
Northwest Europe	Island renewable+PEM	€/t	1,526	+24	1,013	+16
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	510	+15	344	+15
Exporter BAT+	SMR+CCS	$/t	581	+14	398	+14
Exporter low-C	ATR+CCS	$/t	753	+13	470	+13
Exporter no-C	Island renewable+PEM	$/t	1,270	nc	700	nc

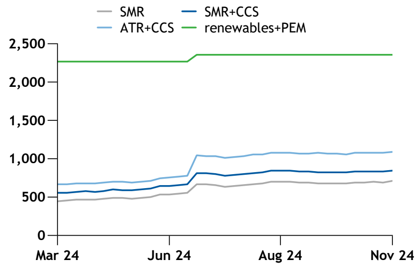
NW Europe ammonia average €/t



North America ammonia average $/t



Northeast Asia ammonia average $/t



COMPLETE AMMONIA PRODUCTION COSTS

No-C ammonia									19 Nov
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 12 Nov	Cost	Cost in $/t	± 12 Nov
Netherlands	Wind + PEM	Green	€/t	1,377	1,456	nc	878	928	nc
UK	Wind + PEM	Green	£/t	1,200	1,521	nc	766	971	nc
Germany	Wind + PEM	Green	€/t	1,565	1,654	nc	1,058	1,118	nc
France	Wind + PEM	Green	€/t	1,635	1,728	nc	1,105	1,168	nc
Spain	Diurnal + PEM	Green	€/t	1,197	1,265	nc	653	690	nc
US west coast	Diurnal + PEM	Green	$/t	1,200	1,200	nc	704	704	nc
Canada	Wind + PEM	Green	C$/t	2,076	1,480	nc	1,333	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	488,400	3,154	nc	398,277	2,572	nc
China	Diurnal + PEM	Green	Yn/t	7,781	1,077	nc	4,263	590	nc
India	Diurnal + PEM	Green	Rs/t	106,291	1,259	nc	53,863	638	nc
South Korea	Wind + PEM	Green	W/t	3,963,441	2,833	nc	3,184,183	2,276	nc
Vietnam	Wind + PEM	Green	$/t	1,857	1,857	nc	1,154	1,154	nc
Australia	Diurnal + PEM	Green	A$/t	1,826	1,184	nc	1,055	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									19 Nov
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 12 Nov	Cost	Cost in $/t	± 12 Nov
Netherlands	ATR + CCS	Blue	€/t	961	1,016	+37	688	727	+37
UK	ATR + CCS	Blue	£/t	832	1,054	+38	592	750	+38
Germany	ATR + CCS	Blue	€/t	974	1,030	+39	692	731	+39
Spain	ATR + CCS	Blue	€/t	1,019	1,077	+32	670	708	+32
France	ATR + CCS	Blue	€/t	987	1,043	+39	689	728	+39
US Gulf coast	ATR + CCS	Blue	$/t	519	519	+6	226	226	+6
Canada	ATR + CCS	Blue	C$/t	675	481	-4	265	189	-4
Japan	ATR + CCS	Blue	¥/t	172,194	1,112	+18	120,164	776	+18
South Korea	ATR + CCS	Blue	W/t	1,502,554	1,074	+16	1,066,058	762	+16
Australia	ATR + CCS	Blue	A$/t	1,192	773	+5	732	475	+6
Trinidad	ATR + CCS	Blue	$/t	1,060	1,060	+27	595	595	+27
Qatar	ATR + CCS	Blue	$/t	853	853	+21	569	569	+20
UAE	ATR + CCS	Blue	$/t	867	867	+21	611	611	+20
Russia west	ATR + CCS	Blue	$/t	711	711	nc	188	188	nc
Russia east	ATR + CCS	Blue	$/t	708	708	nc	185	185	nc

Japan and Korea low-carbon ammonia benchmark (JK LAB)			19 Nov
	Unit	Cost	± 12 Nov
CFR Ulsan, South Korea, incl. US 45Q tax credit	$/t	527.23	+5.22
CFR Ulsan, South Korea, excl. US 45Q tax credit	$/t	663.23	+5.22
CFR Niihama, Japan, differential	$/t	+0.38	+0.07

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									19 Nov
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 12 Nov	Cost	Cost in $/t	± 12 Nov
Netherlands	SMR + CCS	Blue	€/t	780	825	+32	603	637	+31
UK	SMR + CCS	Blue	£/t	655	830	+32	499	633	+32
Germany	SMR + CCS	Blue	€/t	789	834	+33	605	640	+33
Spain	SMR + CCS	Blue	€/t	818	865	+29	592	626	+29
France	SMR + CCS	Blue	€/t	792	837	+34	599	633	+34
US Gulf coast	SMR + CCS	Blue	$/t	362	362	+12	172	172	+12
Canada	SMR + CCS	Blue	C$/t	497	354	nc	230	164	-1
Japan	SMR + CCS	Blue	¥/t	132,707	857	+17	98,950	639	+16
South Korea	SMR + CCS	Blue	W/t	1,175,182	840	+16	892,579	638	+16
Australia	SMR + CCS	Blue	A$/t	917	595	+7	618	401	+7
Trinidad	SMR + CCS	Blue	$/t	830	830	+26	529	529	+27
Qatar	SMR + CCS	Blue	$/t	689	689	+20	505	505	+19
UAE	SMR + CCS	Blue	$/t	679	679	+19	513	513	+19
Russia west	SMR + CCS	Blue	$/t	477	477	-1	138	138	-1
Russia east	SMR + CCS	Blue	$/t	472	472	nc	133	133	nc

BAT+ ammonia										19 Nov
					Incl. capex			Excl. capex		
	Process	kcal/kg NAR	Legacy colour	Unit	Cost	Cost in $/t	± 12 Nov	Cost	Cost in $/t	± 12 Nov
Australia	Coal gasification + CCS	5,500	Blue	A$/t	1,189	771	-2	751	487	-2
Australia	Coal gasification + CCS	6,000	Blue	A$/t	1,311	850	-4	873	566	-3
China	Coal gasification + CCS	3,800	Blue	Yn/t	6,047	837	nc	3,858	534	nc
China	Coal gasification + CCS	5,500	Blue	Yn/t	5,997	830	-2	3,815	528	-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	861	861	nc	464	464	nc
South Africa	Coal gasification + CCS	6,000	Blue	$/t	904	904	+2	507	507	+2
Russia west	Coal gasification + CCS	6,000	Blue	$/t	822	822	nc	384	384	nc
US east coast	Coal gasification + CCS	6,000	Blue	$/t	738	738	+2	457	457	nc

Baseline ammonia									19 Nov
				Incl. capex			Excl. capex		
	Process	Legacy colour	Unit	Cost	Cost in $/t	± 12 Nov	Cost	Cost in $/t	± 12 Nov
Netherlands	SMR	Grey	€/t	772	816	+33	612	647	+33
UK	SMR	Grey	£/t	620	786	+31	479	607	+30
Germany	SMR	Grey	€/t	780	825	+35	614	649	+34
Spain	SMR	Grey	€/t	806	852	+31	601	635	+30
France	SMR	Grey	€/t	782	827	+35	607	642	+35
US Gulf coast	SMR	Grey	$/t	295	295	+12	123	123	+11
Canada	SMR	Grey	C$/t	492	351	-1	253	180	-1
Japan	SMR	Grey	¥/t	109,789	709	+17	79,284	512	+16
South Korea	SMR	Grey	W/t	983,515	703	+16	726,094	519	+15
Australia	SMR	Grey	A$/t	779	505	+7	509	330	+7
Trinidad	SMR	Grey	$/t	731	731	+27	458	458	+27
Qatar	SMR	Grey	$/t	623	623	+19	457	457	+20
UAE	SMR	Grey	$/t	615	615	+19	465	465	+20
Russia west	SMR	Grey	$/t	397	397	nc	90	90	nc
Russia east	SMR	Grey	$/t	391	391	-1	85	85	nc

COMPLETE AMMONIA PRODUCTION COSTS

Ammonia decarbonisation spreads				19 Nov
	Incl. capex		Excl. capex	
	$/t	± 12 Nov	$/t	± 12 Nov
Northwest Europe				
No-C to BAT+	781	-33	434	-33
Low-C to BAT+	198	+6	92	+6
BAT+ to baseline	9	-2	-9	-1
North America				
No-C to BAT+	982	-6	659	-5
Low-C to BAT+	142	-5	40	-4
BAT+ to baseline	35	+1	16	nc
Northeast Asia				
No-C to BAT+	1,506	-17	1,174	-16
Low-C to BAT+	244	nc	130	+1
BAT+ to baseline	143	+1	123	nc
Middle East				
No-C to BAT+	521	-19	176	-19
Low-C to BAT+	176	+2	81	+1
BAT+ to baseline	65	nc	48	-1
Net exporter				
No-C to BAT+	689	-14	302	-14
Low-C to BAT+	172	-1	72	-1
BAT+ to baseline	71	-1	54	-1

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