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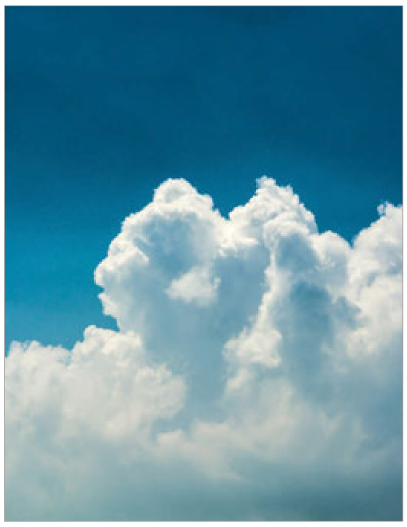

IMAGE: ALEX MACHADO FOR CASALE

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NUMBER 393
JANUARY | FEBRUARY 2025

Long term carbon pricing

Energy storage costs will push up prices over the next 25 years

Advanced materials

Best solutions for the challenging urea environment

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CRU

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Tariff uncertainties cloud the picture

> "Some increases in some tariffs seem to be inevitable ..."

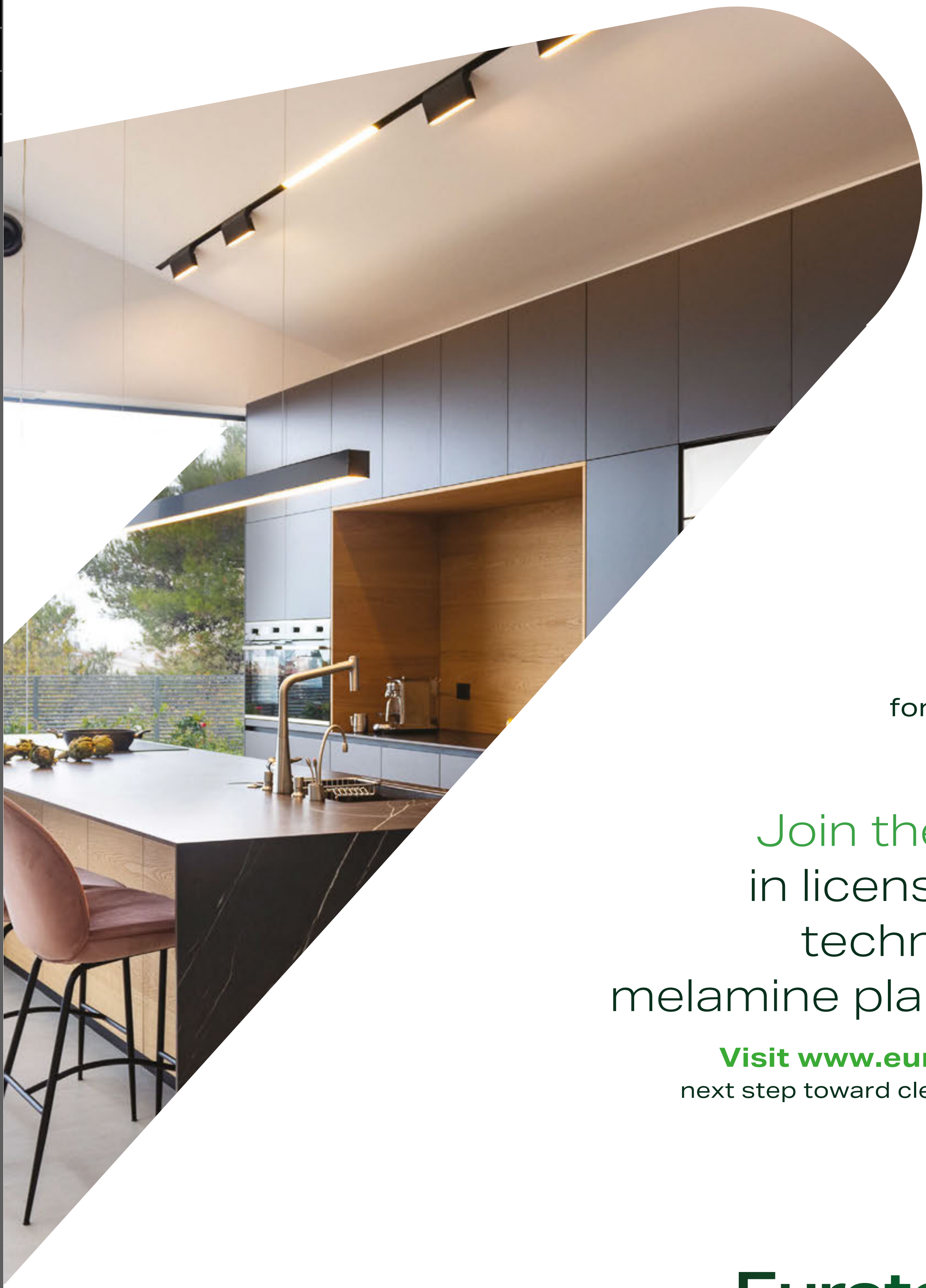
Nitrogen+Syngas went to press just a few days before Donald Trump's swearing-in as the next president of the United States. While it is sometimes difficult to sort the truth from the hyperbole in his public pronouncements, nevertheless, if taken at face value, they would seem to indicate that we may be in for a turbulent four years in commodity markets in particular. While he is an avowed military non-interventionist, on the economic policy side he has emerged as a firm believer in the power of tariffs to alter markets in the favour of the US, and has promised 20% tariffs on all goods entering the US, potentially rising to 25% for Canada and Mexico, and 60% for his particular bugbear, China, sparking a scramble for wholesalers to stock up in the last few weeks of the Biden presidency. Trump previously raised tariffs on Chinese goods entering the US to 20% during his first term, and the Biden administration made no attempt to reverse this, and even added some additional ones, for example 20% on Russian and Moroccan phosphate imports.

It remains uncertain to what extent the president will have the ability to impose all of these tariffs by fiat. Although the president has a wide range of powers at his disposal, some require consultation with Congress – something unlikely to be favoured by the Trump administration – or prior determinations of injury by the US Department of Trade; occasionally a lengthy process. However, lawyers have dug up some more obscure instruments, such as the 1930 Tariff Act, which allows for executive action where a foreign partner has levied an "unreasonable charge, exaction, regulation, or limitation" on US products which is "not equally enforced upon the like articles of every foreign country"; or otherwise discriminated against US goods. There is also a 1977 law called the International Emergency Economic Powers Act (IEEPA) under which the president could declare an 'economic emergency' and impose tariffs unilaterally. However, both of these latter would almost certainly be subject to legal challenge in US courts, and much of their impact might turn upon whether a judge suspended or allowed the measures to continue in the interim while a legal determination was made.

Even so, and even if the threatened measures are intended more as a bargaining chip or opening offer rather than intended to be fully implemented, some increases in some tariffs seem to be inevitable, given that Trump has made them a cornerstone of his economic policy. The question then arises as to what extent reciprocal measures might be put in place. The previous trade war between the US and China, in 2018, ended up spreading into all manner of types of goods worth $100 billion dollars, while the tit for tat steel tariffs with the European Union were not rescinded until 2021. Mexico, Canada and China are the three biggest importers of US agricultural goods, and agriculture is among the US's biggest export engines. The US Department of Agriculture (USDA) estimates 16% of the US corn harvest and 40% of soybeans are exported.

At present, there is too much uncertainty to predict exactly what the effects will be, but there will almost certainly be an impact on both supply and demand in fertilizers both in the US market and globally. CRU's most recent position paper argues that fertilizer imports into the US will become more expensive and that tariffs will reduce the competitiveness of US agriculture, and that these costs will be passed through to the US farmer. Tariffs will likely take a bite out of US fertilizer demand in the second half of 2025.

Richard Hands, Editor



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Price Trends

Ammonia markets saw a slow start to 2025, with further transparency needed on both sides of the Suez to determine the extent to which prices are expected to fall through January amid healthy supply and only limited pockets of demand.

East of Suez, the Middle East appears long, with some producers now heard offering at levels 10-15% below the $400/t FOB mark. That news is likely to be met with positivity by importers in India where, although demand there remains limited for the time being, delivered CFR values do also seem to be easing as phosphate manufacturers deliberate between producing NPKs or DAP/MAP.

Further east, spot demand in East Asia remains on the backburner, with contract prices in the likes of South Korea and Taiwan, China registering no change since the turn of the New Year. Activity was similarly limited in China, where domestic prices registered sizeable declines across the board this week. In keeping with the wider hemisphere, availability out of Southeast Asia remains healthy, with tonnes continuing to move out of Indonesia and Malaysia at a steady rate, though a repeat of the flurry of spot deals seen in December 2024 is yet to emerge.

Urea prices advanced in the second week of the New Year, driven by strong global demand and an absence of exports from China and Iran. China has been out of the export market for 12 months in a bid to keep a lid on domestic prices and this absence of tonnes has been the backdrop to rising urea prices. India's 19 December tender seeking 1.5 million tonnes of prilled/granular urea secured just 187,000 t, and the world's second largest urea importer is expected to return to the market facing import costs that may reach into the $400s/t c.fr, $30/t or more than it achieved in December.

Brazil is still buying to cover the remainder of demand for the second corn crop and there are signs the US is returning to the market after stepping back in the second half of last year. Australia and Mexico also have demand for tonnes. Latest business into Brazil was up $10/t at $380/t c.fr and importers there will need to pay higher still.

China's withdrawal from the export market has forced domestic urea prices down to their lowest in more than seven years, with the export price equivalent now at around $220/t f.o.b., almost half the price for sales from Egypt. The Egyptian granular benchmark climbed to $430/t f.o.b., the highest price since September 2023, with most tonnes heading to Europe. Prices from Egypt have risen $145 since the low of $285/t f.o.b. was reached in May 2024.

In the Middle East, a cargo of 40,000 tonnes from Oman was reported at $380/t f.o.b., likely for late-February loading to the US and in line with a tender award of prills from Qatar. Other sellers are holding until clarity emerges on pricing in India. At New Orleans, urea prices advanced an average of $10/st. February urea barge business at $355/st f.o.b. would equate to a delivered price of $386/t c.fr NOLA.

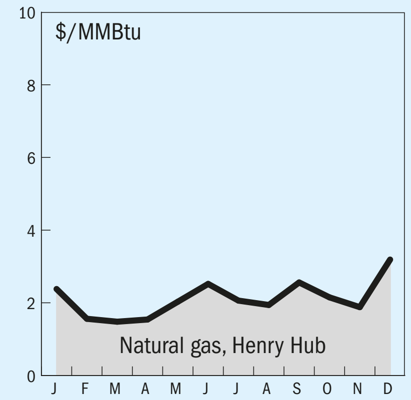
Table 1: **Price indications**

Cash equivalent	mid-Dec	mid-Oct	mid-Aug	mid-Jun
Ammonia ($/t)				
f.o.b. Black Sea	n.m.	n.m.	n.m.	n.m.
f.o.b. Caribbean	530	520	440-500	360
f.o.b. Arab Gulf	350-430	350-430	320-350	320-330
c.fr N.W. Europe	610-620	600-610	550-575	450-460
Urea ($/t)				
f.o.b. bulk Black Sea	305-320	320-330	305-325	340-350
f.o.b. bulk Arab Gulf*	319-358	350-370	290-335	280-350
f.o.b. NOLA barge (metric tonnes)	326-338	330-339	305-316	300
f.o.b. bagged China	n.m.	253-261	n.m.	n.m.
DAP ($/t)				
f.o.b. bulk US Gulf	n.m.	550-570	550-570	550-570
UAN (€/tonne)				
f.o.t. ex-tank Rouen, 30%N	278-280	265-270	240-245	260-265

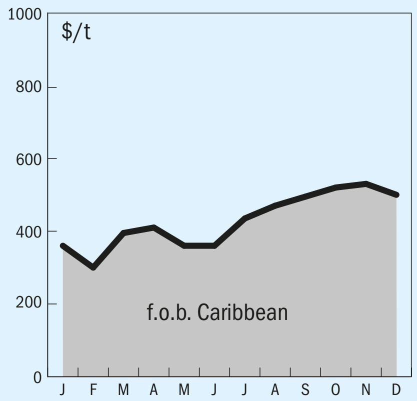
*Notes: n.a. price not available at time of going to press. n.m. no market. * high-end granular.*

END OF MONTH SPOT PRICES

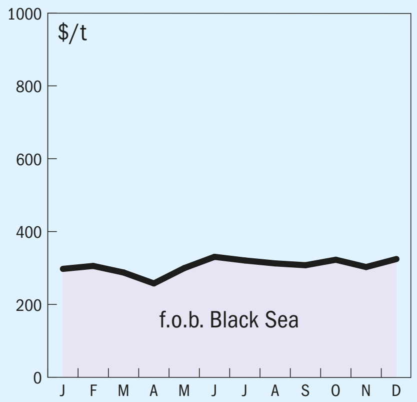
natural gas



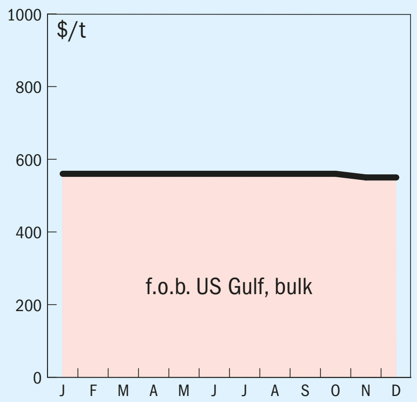
ammonia



urea

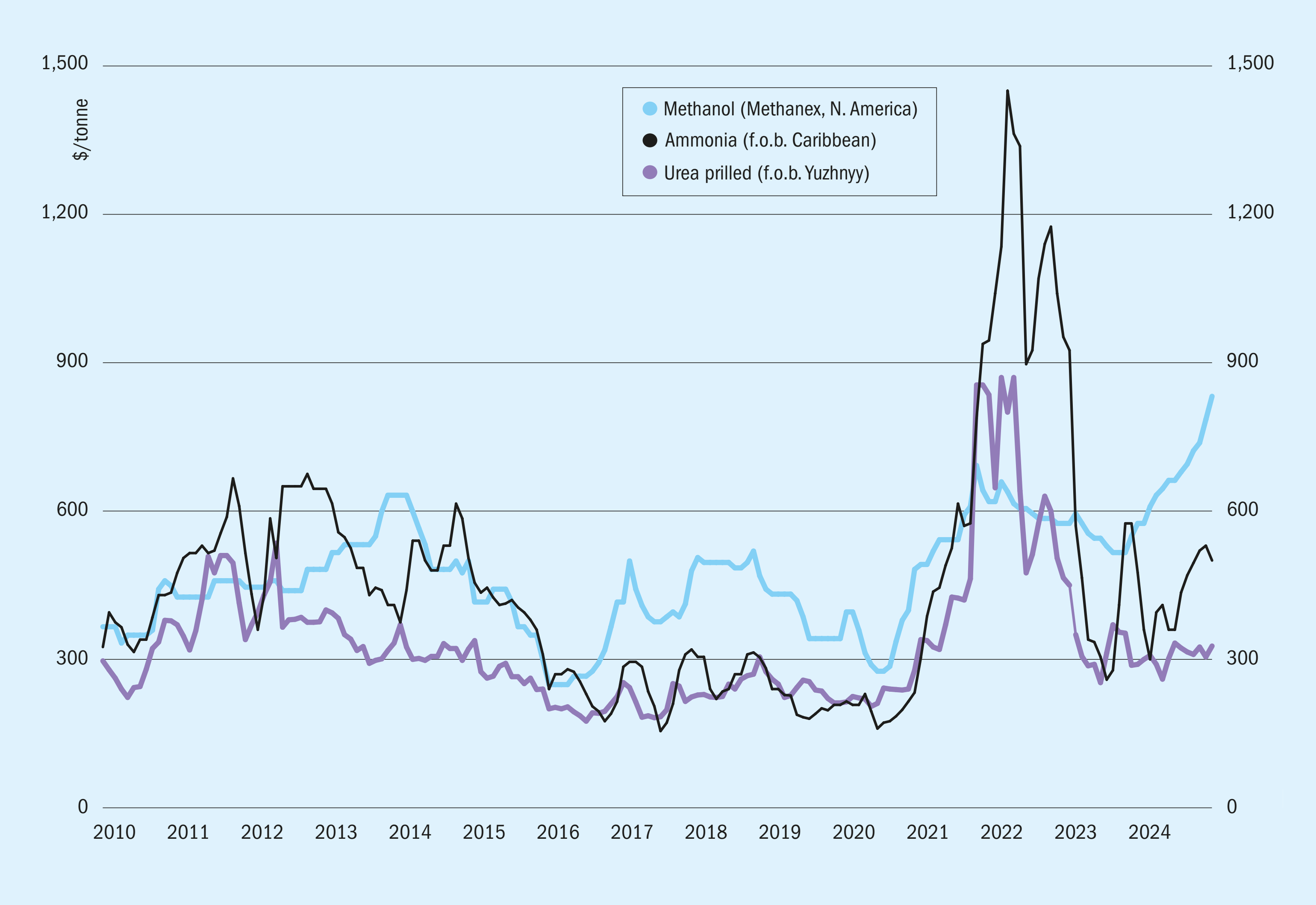


diammonium phosphate



Market Outlook

Historical price trends $/tonne



Source: CRU

AMMONIA

- Prices in most markets should register declines through January, though the extent to which benchmarks will ease is yet unclear. Chinese suppliers have seen significant price declines in recent weeks.
- In Egypt, Abu Qir is said to have no availability before February, though loadings at EBIC's facility on the Red Sea continue.
- Middle Eastern suppliers are seen to be long, and lower prices may tempt Indian DAP producers back into the market.
- European gas prices increased throughout much of 2024, and are expected to continue to rise into 2025, although production cuts remain stable.
- More stable prices for downstream nitrogen fertilizers such as AN, alongside a significant fall in the ammonia price, will pressure European ammonia production and swing the pendulum in favour of imports.

UREA

- There is little relief for urea buyers on the immediate horizon. The near-term outlook is bullish with demand in India, the US, Brazil, Europe and elsewhere and no exports are available from China or Iran.
- Demand in Europe is strong, particularly in Turkey and Italy, although Greece and France are also in the market. Baltic and Black Sea export values increased and are expected to gain more ground when Russia returns from the Orthodox Christmas holiday.
- Chinese urea exports have fallen to a two-decade low, and urea stocks were expected to reach 8 million tonnes by the end of the year.
- There is no indication China will return to the market before the second half of 2025, as it is now heading into the spring application season. Chinese domestic prices are at a seven year low, with exports still halted for now.

METHANOL

- Methanol prices are rising, especially in the Atlantic basin, and there is still a positive industry outlook for 2025. US methanol prices are up 30-40% over 2024, and European prices were up to 60% higher in Q4 2024 than Q1 as a knock on, effect of this as Europe imports methanol from the US.
- Most of this is due to systemic lack of supply, including delays in commissioning Methanex's Geismar 3 plant in the US, Petronas' new facility in Malaysia, and two plants in Iran. There have also been shutdowns in Germany and lost production in Venezuela and the US.
- Supply is likely to ease towards the end of 1Q 2025, but until then demand continues to keep prices at high levels.
- Chinese spot prices are much lower at around $300/t, with ample domestic supply and prices kept in check by MTO affordability levels.

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Nitrogen Industry News

QATAR

Qafco begins construction of blue ammonia-urea plant

A foundation laying ceremony attended by Qatar's Deputy Amir Sheikh Abdullah bin Hamad Al Thani has been held at Qafco's new blue ammonia facility at Mesaieed Industrial City on Qatar's east coast. The plant, which is scheduled to be completed in 4Q 2026, will be the largest blue ammonia facility in the world. Speaking at the ceremony, energy minister Saad Sherida Al-Kaabi said the facility will have a capacity of 1.2 million t/a, along with CO_2 injection and storage facilities with a capacity of 1.5 million t/a. QatarEnergy will also provide the new plant with more than 35 MW of electricity from the solar power plant currently being built in Mesaieed. Completion of the complex will see Qatar become the world's largest exporter of urea, producing 12.4 million t/a, according to Qafco. ■

EGYPT

MOPCO to begin green hydrogen production in 2027

Misr Fertilizers Production Company (MOPCO) is looking to complete two major projects for green hydrogen production, expand its factory, and boost urea production by the end of 2027, according to local press reports. The green hydrogen project will include establishing a new production facility for 150,000 t/a of green ammonia at Damietta port, on Egypt's Mediterranean coast, alongside MOPCO's three existing gas-based ammonia plants. The project is being led by a consortium of companies, including MOPCO, Norway's Scatec, and the Egyptian Petrochemicals Holding Company (ECHEM).

In addition to the green hydrogen project, MOPCO is expanding its production capabilities by increasing the capacity and efficiency of its urea manufacturing operations as well as producing additional melamine.

Another green ammonia project for Egypt

Egypt's General Authority for Investment and Free Zones (GAFI) has announced a partnership with Polish company Hynfra to build a green ammonia production facility with an initial investment cost of $1.6 billion. Hynfra reportedly plans to build five green ammonia plants serving Central and Eastern Europe, with Egypt selected as a flagship location. The first phase of the facility, expected by 2030, will produce 400,000 t/a of green ammonia, with an ultimate goal of increasing production to 1 million t/a, based on wind and solar energy. Surplus electricity will support Egypt's national grid. Hynfra also intends to include energy storage systems and water desalination as part of the project. The project is targeting exports to Europe; the EU has set a goal of importing 6 million t/a of green hydrogen and 4 million t/a of green ammonia by 2030.

MOROCCO

Large scale green hydrogen plans

A UAE-Moroccan private venture says that it is planning to eventually spend $25 billion on a green hydrogen and ammonia project in Morocco. Dahamco has obtained approval from the Moroccan government to set up the project at the Atlantic port of Dakhla on the coast of the disputed Western Sahara region. The first phase would produce 1 million t/a of ammonia at a cost of $4 billion, and Dahamco is targeting first production in 2031, with additional phases coming on stream every 4-5 years thereafter.

INDIA

Topsoe to license ammonia technology for renewable project

Topsoe, has signed an agreement with developer Hygenco, to provide ammonia technology for Hygenco's upcoming green ammonia plant in Gopalpur, Odisha state. Hygenco will use Topsoe's advanced dynamic green ammonia technology, which Topsoe says allows for flexible and efficient operations while optimising overall performance. This technology will support Hygenco's ambition of exporting green ammonia to European markets, aligning with the European Union's Renewable Fuels of Non-Biological Origin (RFNBO) regulations.

Elena Scaltritti, Chief Commercial Officer at Topsoe, said: "We look forward to working with Hygenco on this great project, as green ammonia plays a critical role in reducing greenhouse emissions from energy-intensive industries and long-distance transportation. On a global level, we need to deploy decarbonization at scale, and Hygenco's project will be able to deliver a solid contribution."

Amit Bansal, Co-Founder and CEO of Hygenco, said: "As the world seeks innovative solutions to tackle pressing environmental and energy challenges, Hygenco is making significant progress in advancing the energy transition and decarbonization. We are excited to leverage the cutting-edge technology of a global leader like Topsoe to scale up green ammonia production effectively."

The plant is phase one of a three-phase projects at Tata Steel's Special Economic Zone Industrial Park (GIP) in Gopalpur, Odisha. Phase one of the green ammonia project will have an installed capacity of 750 t/d and is expected to be operational by 2027.

EPC contract for green ammonia project

Belgian based power to X developer Rely has been awarded an EPC contract by AM Green India Ltd for a green ammonia project at Kakinada in Andhra Pradesh state. The project will convert part of the feed to two existing 1,500 ammonia plants owned by NFCL, including two 640 MW pressurised alkaline electrolysers to make hydrogen for the plant. A final investment decision was taken in August 2024. The electrolysers will be powered by a combination of wind, solar power and a pumped hydro-electric storage system. Rely will provide design, detailed engineering, procurement services, construction, management and commissioning services for the entire facility. Rely is a joint venture between Technip Energies and hydrogen producer John Cockerill.

Damien Eyriès, Rely CEO commented: "We are honoured and proud of having been selected by AM Green to engineer and deliver this flagship project that will massively contribute to the decarbonization of the hard-to-abate industries and illustrate that India plays a major role in our global climate goals. This award marks a significant milestone for Rely, less than a year after its creation, and our team is poised to make a substantial impact on the future of clean energy, driving innovation and setting new standards in the industry."

Mahesh Kolli, Group President of AM Green said, "We are excited to partner with Rely to transform our existing Green Ammonia facility into one of the largest in India. Rely's technical expertise will significantly enhance our capabilities in this project. This collaboration not only establishes AM Green as a global leader in energy transition but also plays a crucial role in advancing India's green hydrogen mission and supporting net-zero targets in both India and OECD markets."

SOUTH KOREA

Clean hydrogen auction fails to generate interest

South Korea's first clean hydrogen power auction has resulted in just one company invited for final negotiations: Korea Southern Power (KOSPO), with its bid to co-fire ammonia at the 2.1 GW Samcheok coal-fired power plant. The South Korean government launched the tender in May this year, offering 15-year contracts to support up to 6,500 GWh of annual power generation from 2028. However, only one company was interested and KOSPO's Samcheok Green Power Unit 1 will only generate 750 GWh of power from co-firing ammonia, or 11.5% of the auction target. The result illustrates the difficulty of using expensive green ammonia as a power plant feed to reduce the carbon emissions of coal fired power stations, as planned by Japan, Korea and other east Asian countries.

Samsung partnership for green ammonia shipping fuel

The Korea Institute of Energy Technology (KIER) and Samsung Heavy Industries have announced a strategic partnership to drive the development and commercialisation of green ammonia fuel for the shipping industry. The companies say that they will work together to reduce green ammonia production costs by jointly developing innovative technologies, to make green ammonia a more economically viable fuel option. KIER will leverage its expertise in ammonia synthesis to develop multiple technologies that enable the safe handling and utilisation of ammonia, while Samsung will integrate ammonia operation into its ship designs and operations, helping to drive its commercialisation and adoption. KIER says that it has made significant strides in ammonia synthesis technology, recently achieving successful synthesis of liquid ammonia at low pressures (<50 bars) and temperatures (<400C).

Lee Chang-geun, Head of KIER said that, "Low-cost clean ammonia production and safety utilization technology are essential to meet the IMO's stringent regulations. This collaboration with Samsung Heavy Industries will lay the foundation for a new era of carbon-neutral shipping."

ANGOLA

Amufert selects KBR as technology licensor

KBR has signed an agreement with Amufert for the development of a new ammonia plant in Soyo, Angola. Under the terms of the contract, KBR will provide a technology license, proprietary engineering design, equipment and catalyst solutions for Amufert's 2,300 t/d ammonia plant.

"We are thrilled to be a part of this project and support AMUFERT's efforts in accelerating sustainable agriculture in Angola through our leading ammonia technology," said Jay Ibrahim, KBR President, Sustainable Technology Solutions. "KBR has a proud legacy in Angola, and we look forward to working closely with AMUFERT and our partners to ensure the success of this important project."

RUSSIA

Taman terminal looking to end 2025 for urea exports

Russian media reports say that OTEKO transport holding will commission its new urea export terminal at the port of Taman by the end of 2025. Throughput of nitrogen fertilizers, both ammonia and urea, is eventually planned to rise to 5 million t/a, with warehouses with a capacity of 300,000 tonnes being constructed in ten separate sections. A 2 million t/a terminal for ammonia export is expected to become operational in the next few months, with ammonia export capacity eventually rising to 3.5 million t/a, while the urea terminal will handle 1.5 million t/a. At present the terminal is handling coal and sulphur exports, but fertilizer exports are due to begin next year. Taman is also currently exporting its 100 millionth tonne of coal, a total achieved in five years, and expects to have exported another 100 million tonnes in 2-2.5 years.

NORWAY

Green ammonia supply agreement

Aker Horizons and VNG have signed an agreement for the supply of green ammonia from Norway to Germany. Their joint venture company, Narvik Green Ammonia DA, will be owned and managed by Aker Horizons Asset Development AS, and the Leipzig-based gas trader VNG Handel & Vertrieb GmbH. VNG says that it intends to purchase up to 150,000 t/a of green ammonia from Narvik Green Ammonia DA from 2029 and supply it to its customers directly as ammonia or in the form of hydrogen. The production plant for green ammonia in Narvik, Norway, is expected to produce around 450,000 t/a of green ammonia from 2029.

sProgressing from stated ambitions to firm contracts is what we need to realize industrial-scale production of green hydrogen and ammonia. With VNG signing on as a potential off-taker, distributing our product to clients in Europe's most important energy market, the Narvik Green Ammonia project takes a significant step in this direction," said Knut Nyborg, managing director of Aker Horizons Asset Development. "Aker Horizons appreciates the trust placed in Narvik Green Ammonia and we look forward to continuing the close cooperation with VNG in the year ahead."

ARGENTINA

Study on large scale green ammonia project for Argentina

Austrian renewables developer RP Global says that it aims to install 3 GW of electrolysis capacity as part of the first stage of the "Gaucho Wind to Hydrogen and Green Ammonia" development in Argentina. The electrolysers will be powered by a wind farm of around 4.2 GW, resulting in the production of over 21,340 GWh of electricity and up to 1.7 million t/a of green ammonia in Patagonia, destined mainly for exports to the European market. RP Global secured support for the project in a competitive bidding process conducted by the German Agency for International Cooperation (GIZ) under the International Hydrogen Ramp-up Programme (H2Uppp). This programme aims to promote green hydrogen projects in selected developing and emerging countries in line with the German government's national hydrogen strategy. The first stage of the partnership will involve conducting comprehensive feasibility studies on large-scale green hydrogen and ammonia production and export in Argentina. The findings of these studies will be publicly accessible to support local and national authorities, developers, investors, and other stakeholders in the green hydrogen sector, the Austrian firm stated.

POLAND

Sanctions imposed on NFT

The Polish government has imposed sanctions against Belarussian fertilizer supplier NFT, for breaches of sanctions against Belarussian fertilizer producer Grodno Azot. According to the Polish Ministry of Internal Affairs, NFT has been selling Grodno Azot products in Poland via third countries, in an attempt to bypass the existing sanctions regime. Grodno Azot, one of the largest chemical enterprises in Belarus and a key player in the region in the production of nitrogen fertilizers, was included in the European Union's sanctions list in December 2021, and the export of products to Poland ceased. In addition to the ban on deliveries, the restrictive measures against NFT include freezing all of the company's funds and economic resources in Poland, excluding the company from public procurement or tender procedures, and other measures.

CHINA

Sichuan Lutianhua installs N_2O abatement catalyst

Clariant says that its EnviCat N_2O-S nitrous oxide abatement catalyst is performing successfully at Sichuan Lutianhua's nitric acid plant and is projected to reduce annual emissions by 275,000 t/a of CO_2eq. Sichuan Lutianhua is one of the winners of Clariant's 2021-2022 global Climate Campaign, which offered a free load of the catalyst to nitric acid producers lacking N_2O abatement technology. Located in Sichuan Province, China, the 135,000 t/a nitric acid plant started operating in 2009 with no N_2O removal system in place.

Sun Guang, Assistant General Manager at Sichuan Lutianhua, said; "Our company is committed to sustainable practices and reducing our environmental impact. Partnering with Clariant to install the EnviCat N_2O-S catalyst is an important step towards achieving our emissions reduction goals. We have already measured a significant decrease in N_2O emissions from our nitric acid production and look forward to continued positive results."

PORTUGAL

Partnership to develop floating green ammonia production vessel

An industrial scale floating green ammonia production facility partially powered by wave energy is being developed by Dutch developer SwitcH2, together with Swedish wave energy specialist CorPower Ocean, based on FPSO (floating production, storage, and offloading) technologies. The project is supported by Norway-based BW Offshore and Dutch Oceans Capital, as well as a grant from the Dutch Government's GroenvermogenNL scheme. SwitcH2 aims to begin with a new open-sea project in northern Portugal utilising CorPower Ocean's wave energy technology, plus wind and solar power. CorPower Ocean's wave energy converters turn wave motion into rotation, which is converted into electricity by generators inside a buoy.

SwitcH2 said its NH3-FPSO unit will use a vessel nearly the size of a VLCC (Very Large Crude Carrier), to support a 300 MW electrolysis plant on deck. The produced green ammonia will be temporarily stored

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in pressurised tanks in the vessel and then exported to shore via shuttle carriers. The floating facility is expected to reach an annual production capacity of almost 300,000 t/a of green ammonia when operational from 2029.

CorPower Ocean commercial director Kevin Rebenius said: “Wave energy is one of the largest untapped energy source in the world. It’s renewable, accessible, and abundant. Crucially, it’s also highly consistent bringing greater stability to the clean energy mix, enabling 24/7 renewable electricity supply allowing industrial processes like this to run at high utilisation. We look forward to working with fellow tech pioneer SwitchH2 with a shared vision for a cleaner, brighter future powered by renewables.”

AUSTRALIA

Incitec Pivot to sell Gibson Island plant

Incitec Pivot Ltd (IPL) has announced its decision to sell its Gibson Island site, abandoning earlier plans with Fortescue Future Industries for a green ammonia project. This decision marks a shift from fertilizer production to enhancing their global explosives business. During the company’s annual financial disclosure, Mauro Neves, CEO of IPL, said that the firm is still on track to segregate its fertilizer segment within the next 6-12 months, potentially divesting portions to maximise value.

Gibson Island stopped producing urea in early 2023, since when the site has served as a distribution hub for markets in Queensland and northern New South Wales. The company plans to transition its primary distribution operations to a modern facility managed by Qube at the Port of Brisbane, heralding significant advancements in logistical capabilities. IPL continues to pivot towards exiting fertilizer production and concentrating on its explosives division. The company announced a net loss for the fiscal year, largely due to non-cash impairments and costs associated with business restructuring and the closure of manufacturing sites.

The news is a blow for green ammonia developer Fortescue, which had been planning to build 550 MW of electrolyser capacity at Gibson Island to run the ammonia plant off green hydrogen.

MEXICO

Green ammonia project announcement

Helax, a subsidiary of Copenhagen Infrastructure Partners (CIP), says that it is planning a new $10 billion green hydrogen and ammonia plant in the isthmus of Tehuantepec on Mexico’s southern coast.

The project is currently at a consultative stage with local authorities and residents, and is aiming to begin construction in 2026, assuming acceptance of environmental studies which are ongoing. Plant operation would begin in 2028.

Stamicarbon to license N_2O abatement technology

NextChem subsidiary Stamicarbon has been awarded the licensing and process design package (PDP) for a tertiary abatement unit to be installed at Soluciones Químicas’ nitric acid plant in Minatitlán, Veracruz, Mexico. Stamicarbon will apply its proprietary tertiary abatement technology, to reduce nitrous oxide emissions from the tail gas stream, bringing the plant’s environmental status up to current emission regulations.

Syngas News

CHINA

Long-term green methanol offtake agreement

Hapag-Lloyd has reached an agreement with China's Goldwind for the delivery of 250,000 t/a of green methanol. This will consist of a blend of bio- and e-methanol, ensuring greenhouse gas (GHG) emissions reduction of at least 70%, and compliance with all current sustainability certification requirements, according to Hapag-Lloyd. By 2030, Hapag-Lloyd aims to reduce the absolute GHG emissions of its fleet by around one third compared to 2022, and says that compared to conventional fuels, the contracted volume of green methanol from Goldwind will save a total of up to 400,000 t/a of CO_2e emissions in fleet operations per year. Goldwind is planning to build a new green methanol factory adjacent to its existing project in Hinggan, and will additionally deliver early volumes in 2026.

Hapag-Lloyd and Seaspan are converting five 10,100 TEU charter ships to a methanol dual-fuel propulsion system in 2026 and has additionally made the decision to purchase 24 new container ships with low-emission dual-fuel liquefied natural gas engines.

"With the agreement, we are securing a significant proportion of our requirements for green fuels. This will bring us an important step closer to our goal of achieving net-zero fleet operations by 2045. It is and remains our ambition to play a leading role in the transformation of the liner shipping industry," said Rolf Habben Jansen, CEO of Hapag-Lloyd AG.

"We are grateful for the opportunity to become a strong decarbonisation partner of Hapag-Lloyd… Goldwind highly values this endorsement and looks forward to deepening the collaboration," said Wu Gang, Chairman of Goldwind. "[Our] planned new factory will share technology, utilities, facilities and infrastructures with its neighbouring sister plant, boosting production efficiency. It is still subject to the financial investment decision of the Goldwind Board. We anticipate the completion of a megaton green methanol base in Hinggan League in late 2027."

Clariant catalyst selected for biomass-to-methanol project

Clariant says that its MegaMax catalyst has been selected for China's first commercial biomass gasification-to-green methanol project. The plant will use a combination of farm waste and wind power to produce up to 250,000 t/a of green methanol in two phases by 2027. Construction of the first plant phase began in March 2024 and is expected to start producing methanol in the first half of 2025.

Clariant says that MegaMax is an excellent solution for the project, as it provides enhanced stability and tolerance to the fluctuation of the system required for green methanol production. It also offers high activity even at very low reactor temperatures and pressures. Thanks to the catalyst's enhanced selectivity, methanol yield is low in by-product formation, significantly improving the economics of green methanol synthesis.

Clariant will provide technical service through its Applied Catalyst Technology (ACT) team of engineers and experts. Further support can be provided through the CLARITY™ digital service portal, which offers access to real-time plant data to enhance reliability, safety, and profitability.

China to dominate global acetic acid capacity additions

China is set to dominate acetic acid capacity additions globally through 2028, contributing more than 90% of the total capacity additions from seven new builds and an expansion project, according to GlobalData. China is likely to see acetic acid capacity additions of 6.70 million t/a between 2024 and 2028. Acetic acid has application across multiple industries such as textiles, plastics, and pharmaceuticals. The highest capacity addition is 1.5 million t/a from the new Guangdong Shengyuanda Technology Jieyang acetic acid plant, which is expected to commence production in 2026.

SPAIN

Topsoe to provide technology for e-methanol project

Topsoe says that it has been selected to provide methanol synthesis technology and engineering support for Forestal del Atlántico's Triskelion green methanol in Galicia. A final investment decision (FID) for the project is expected in June 2025, with first operation is planned for January 2028. The Triskelion project will produce 40,000 t/a of green methanol from electrolytically produced hydrogen for applications in the chemical and shipping industries, while capturing and using around 56,000 t/a of CO_2. The project is owned by Spanish shipping and chemicals company Forestal del Atlántico, and was a recipient of a euro 49 million grant from the EU Innovation Fund in 2023.

Kim Hedegaard, CEO Power-to-X at Topsoe, said: "We are excited to be selected as the technology provider for this promising project. e-Methanol will act as a key driver in decarbonising the energy-intensive sectors and may be one of the leading e-fuels used in reducing carbon emissions in industries such as international shipping. Topsoe and Forestal del Atlántico have a shared ambition to make the Triskelion project a European leader in this space, and we look forward to working together to turning these ambitions into reality."

LIBYA

Libya upgrades methanol, urea plants

Sirte Oil Company, a subsidiary of Libya's National Oil Company, has replaced 540 reformer tubes at its First Methanol Plant. The work was completed in less than the anticipated timescale and the plant is set to resume operations and increase production capacity, targeting an output of 1,000 t/d through the implementation of supporting projects and upgrades. Simultaneously, the state-owned Libyan Fertilizer Company (LIFECO) recently restarted its second urea plant after a 16-month shutdown. The restart follows the installation of a high-pressure reactor, relining of the high-pressure washing device and boiler repairs, allowing the plant to achieve 80% of its full capacity of 1,750 t/d. As part of its modernization efforts, LIFECO has also upgraded its logistics infrastructure with the acquisition of a new ship loader from Bruks Siwertell. The equipment, designed for efficient urea handling, incorporates advanced digital technology to enable remote operational support.

Libya's gas valorisation strategy is integral to its efforts to expand its petrochemical sector, with much of this activity concentrated in the Marsa El-Brega industrial zone. This key port hub, managed by Sirte Oil Company, hosts Libya's First Methanol Plant, along with two urea plants and two ammonia plants operated by LIFECO. To enhance petrochemical output, LIFECO has implemented extensive modernization and upgrades across its facilities, focusing on improving efficiency, increasing production capacity, and evaluating the development of new natural gas-based production units.

SAUDI ARABIA

Joint development agreement for low-carbon hydrogen solutions

Saudi Aramco and Topsoe have signed a joint development agreement (JDA) to produce low-carbon hydrogen using Topsoe's eREACT™ technology at the Shaybah Natural Gas Liquids (NGL) recovery plant in Saudi Arabia. Once operational, the plant's 3 MW unit is expected to produce 6 t/d of low-carbon hydrogen daily. This collaboration will further demonstrate the integration of Aramco's innovative palladium-alloy membrane technology ensuring the production of low-carbon hydrogen with simultaneous CO_2 capture, combined with Topsoe's expertise in carbon emission reduction technologies. The companies say that the successful commercialisation of eREACT™ technology will contribute to reducing the carbon footprint of the energy and chemical sectors.

eREACT™ uses an innovative electrified reactor design, which can convert a variety of feedstocks into low-carbon hydrogen or other chemicals and fuels. It is intended to replace fossil fuel used for heating the reformer with electrical heating. Efficiencies gained through the electrified heating has the potential of reducing the gas volumes needed for hydrogen production by up to 30%, as presently demonstrated at pilot scale.

INDIA

Collaboration on green methanol plant

Ohmium International, a designer and manufacturer of proton exchange membrane (PEM) electrolysers, is partnering with the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Breathe Applied Sciences, and Spirare Energy, to build India's first green methanol plant. The project will combine green hydrogen generated by Ohmium electrolysers with CO_2 captured from the Singareni thermal power plant to produce green methanol.

"Converting CO_2 from coal based thermal power to green methanol can significantly advance decarbonization and sustainability," said JNCASR Professor Sebastian Peter, Breathe Applied Sciences co-founder and project leader of the green methanol plant from JNCASR. "We are excited to see our research applied in this pioneering project and looking forward to seeing it scale."

BRAZIL

Petrobras looking at green methanol production

European Energy signed a heads of agreement with state oil and chemical producer Petrobras to develop a commercial-scale green methanol production plant in the state of Pernambuco, building on the memorandum of understanding (MoU) signed between the two companies in November 2023. European Energy will bring experience gained with Denmark's first large-scale commercial e-methanol facility, which is projected to produce 32,000 t/a of green methanol, supported by off-take agreements with several major companies including Maersk.

"The partnership with Petrobras is important for our work in Brazil, which is a key market for us. The abundant resources of the country and the geographic location makes it an ideal hub for green methanol production," said Thiago Arruda, European Energy's Vice President for Latin America.

European Energy has secured a 25-year land lease agreement with the port of Suape for the proposed facility.


PHOTO: CRI

Lava flows near the CRI site.

LATVIA

Green methanol for Latvia

South Korean clean energy firm Plagen has signed a memorandum of understanding (MOU) with Latvia's AE Risinājumi for the production of green methanol in Latvia, commencing in 2028. Plagen's MoU aims to produce 20,000 t/a of green methanol initially. Feasibility studies will begin in the first half of 2025, and full-scale production would begin in 2028, assuming a positive final investment decision. Feedstock would likely be from abundant wood waste; with 53% of Latvia's land area covered by forests, timber production and wood processing make a significant contribution to Latvia's economic production, and generates a large amount of forest residues and wood wastes. In addition, Latvia also has an abundance and low price of renewable electricity from wind power.

"We expect to start producing green methanol in Latvia in 2028, which will reduce greenhouse gas emissions from EU maritime transport vessels and contribute significantly to the revitalisation of the Latvian economy and national energy security" said John Kyung, CEO of Plagen.

ICELAND

Lava encircles carbon-dioxide-to-methanol pilot plant

Carbon Recycling International (CRI), which operates a geothermally powered green methanol plant at Svartsengi, 40km southwest of Reykjavik, had to evacuate its site in late November when a 3km fissure opened in the earth a few kilometres away and lava began spilling across adjacent land. Satellite photos of the area taken on November 24 show a large field of molten and cooled lava to the north, west, and south of Svartsengi, though the plant itself remained undamaged. CRI's Iceland facility runs on CO_2, water, and renewable electricity from the Svartsengi geothermal power station. CRI says the low-carbon energy source allows it to produce 4,000 t/a of methanol with a greenhouse gas footprint just 10–20% that of conventional methanol.

People

The International Fertilizer Association (IFA) elected four new board members to its Board of Directors during the organisation's Strategic General Meeting in London in November. The new board members are: **Fahad Al-Battar**, SABIC Agri-Nutrients Company; **Youssef El Bari**, OCP Nutricrops; **Ahmed El-Hoshy**, Fertiglobe plc; and **Marc Hechler**, EuroChem Group AG. The Strategic General Meeting also re-elected **Marcos Sabelli**, CEO of Profertil Agro for the second term.

IFA CEO/Director General Alzbeta Klein said: "I extend a warm welcome to all our new board members. I look forward to working proactively with the IFA Board of Directors to advance IFA's mission of helping to feed the world sustainably."

IFA also welcomed 19 new members, including two ordinary members, 14 associate members, two affiliate members, and one correspondent member.

The Methanol Institute (MI) has welcomed US-based e-fuels company HIF Global as its newest member. The company's technology produces methanol using green hydrogen through electrolysis and captured CO_2 from atmospheric, biogenic and industrial sources. These components are then synthesised to create e-fuels, including e-methanol for ships. As part of MI's membership, HIF Global is expected to collaborate with other industry leaders, policymakers and stakeholders to promote the adoption of methanol-based solutions and e-fuels in the transition to a low-carbon future.

Greg Dolan, CEO of Methanol Institute, commented: "We are thrilled to welcome HIF Global to the Methanol Institute. HIF Global's work in e-Fuels, particularly e-Methanol, is a crucial contribution to the energy transition. Their innovative approach underscores methanol's potential as a key solution for decarbonizing transportation and industry, and we look forward to collaborating to accelerate this transformation."

Cesar Norton, President and CEO of HIF Global, stated: "e-Fuels are essential to achieving a sustainable future. We applaud the Methanol Institute for their leadership in methanol markets and join them to drive forward the vision to expand e-Methanol based e-Fuels that support our global circular economy. Together we will advance the energy transition by pioneering e-Methanol solutions that utilize existing infrastructure to inspire innovation and reduce costs."

Pivot Bio says that **Melih Keyman** has been elected to the company's board of directors, effective December 1st 2024. Keyman brings to the company more than 40 years of leading expertise in the global fertilizer industry, with significant experience in the broader ag industry.

Pivot Bio CEO Chris Abbott said: "Melih's vast leadership experience with global operations, strategy and M&A will be important to Pivot Bio as we continue our growth trajectory. Additionally, as Pivot Bio continues to build strategic partnerships, including with our fertilizer partners, Melih's deep understanding of the global fertilizer market and commodity fundamentals will be a significant benefit to our team. I am thrilled to have him join the board and confident that his global experience will be a great addition to our dynamic board leadership."

Keyman currently serves as president and chief executive officer, and founder of Keytrade AG, a fertilizer trading companies that caters to the needs of suppliers, distributors, retailers and end users on a worldwide basis and across all fertilizer products. Beside the trading and marketing of conventional fertilizer products, it is engaged in bringing the next generation of fertilizer technologies to market through its subsidiary WeGrow, which provides customers with sustainable crop nutrition solutions. Prior to founding Keytrade, he held leading positions in ENKA Marketing of Turkey and Transammonia. He also has significant board experience, having served on the board of directors for The Fertilizer Institute and as a council member of the International Fertilizer Association. He also served on the board of FertGrow, as well as Transammonia and Ferpro AG, a joint venture between Sinochem and Transammonia. A native of Turkey and a citizen of Switzerland, Keyman has been living in Zurich since 1984. ■

Calendar 2025

JANUARY

26-29
Fertilizer Latino Americano, RIO DE JANEIRO, Brazil
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

30-31
IMPCA Methanol Mini-Conference, ORLANDO, Florida, USA
Contact: International Methanol Producers and Consumers Association
Email: meetings@impca.eu
Web: https://impca.eu/events/11th-impca-conference-amercia-orlando-florida/

FEBRUARY

10-12
Nitrogen+Syngas Expoconference 2025, BARCELONA, Spain
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

MARCH

12
Clean Ammonia Storage Conference, ROTTERDAM, Netherlands
Contact: Stichting NH3 event Europe
Tel: +31 6 10544501
Email: info@nh3event.com

19-20
Gasification 2025, BOLOGNA, Italy
Contact: Mohammad Ahsan – Marketing & Delegate Sales, ACI
Tel: +44 (0) 203 141 0606
Email: mahsan@acieu.net

20-24
11th Annual Gasification Summit, GHENT, Belgium
Contact: Mohammed Ahsan, ACI
Tel: +44 203 141 0606
Email: mahsan@acieu.net

APRIL

1-3
Nitrogen+Syngas Expoconference USA, TULSA, Oklahoma, USA
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

MAY

12-14
IFA Annual Conference, MONTE CARLO, Monaco
Contact: IFA Conference Service, Paris, France.
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

Plant Manager+

How to solve stripper efficiency issues (part 4)

In Part 4 of this series on stripper efficiency issues, we continue to look at the causes of lower stripper efficiency with a discussion on the high delta-P range of liquid dividers.

High delta-P range of liquid dividers

To achieve efficient and satisfactory operation of the stripper it is necessary for the liquid flow and the carbon dioxide (CO_2) flow to be uniformly distributed over the tubes and for the liquid flowing through each tube to be uniformly distributed over the wall. To ensure this, each tube is equipped with a distributor containing flow restrictions in the form of holes for gas and liquid, which have been designed for capacities such that variations in gas density and differences in flow resistance between the gas and liquid in the tube cannot disturb the distribution.

Liquid flow restrictions

Let us first consider the liquid flow restrictions. While there is only one flow restriction for the gas in each tube, there are three liquid restrictions. With three circular holes arranged at equal intervals over the circumference of the tube, uniform distribution of liquid over the wall of the tube is obtained if the liquid flow is large enough.

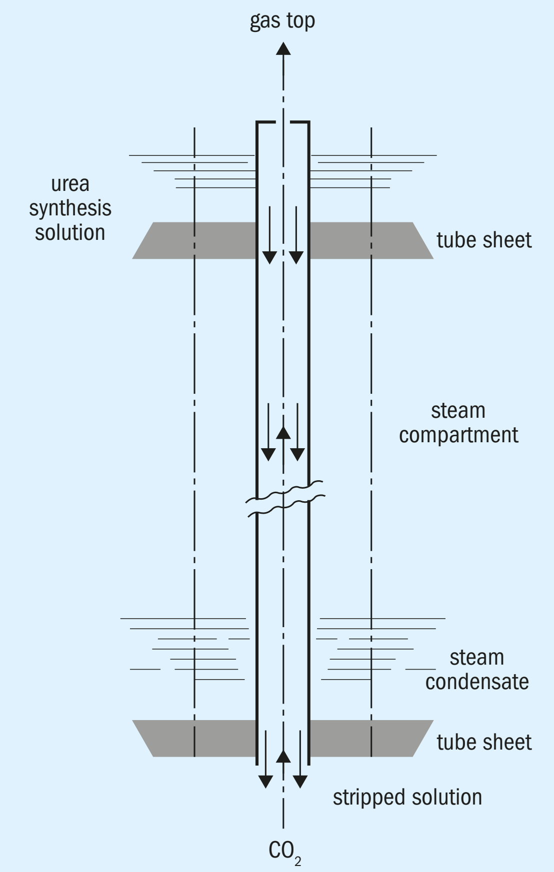
The pressure drop (delta-P) across each liquid hole depends solely on the height of the liquid above the hole (if the gas flow is assumed to be unimpeded). In view of possible deviations from the average liquid load, the following two factors are of importance for any given single tube and for a set of tubes:

- deviations in the diameter of the liquid holes resulting from the tolerance applied in drilling and/or due to corrosion during its lifetime (as a result from cross cut end attack corrosion);
- non-uniformity of the liquid height in the head of the stripper due to a slant of the stripper and/or to the resistance to the liquid flow occurring between the distributors and the gas tubes in the stripper head.

In cases where these factors occur in combination, considerable deviations from the average liquid load may occur. When the diameter of the holes is small, and hence, the level of the liquid high, it is the deviation in diameter of the holes that has the stronger effect, whereas if the holes are large and the liquid level is low, the slant of the stripper and the concavity of the liquid surface are the predominant influences.

The driving force for the gas flow is the difference in pressure between the top and bottom parts of the stripper. As calculations have shown that the pressure drops caused by the friction between the gas flow and the liquid film and by the acceleration of the expelled gas from (downward) liquid velocity to (upward) gas velocity are negligible, the overall pressure difference between top and bottom can be calculated as the sum of the pressure drop over the gas hole and the static head of the gas column in the tube. This head can only be calculated by integration, since the gas density varies over the length of the tube. At every level

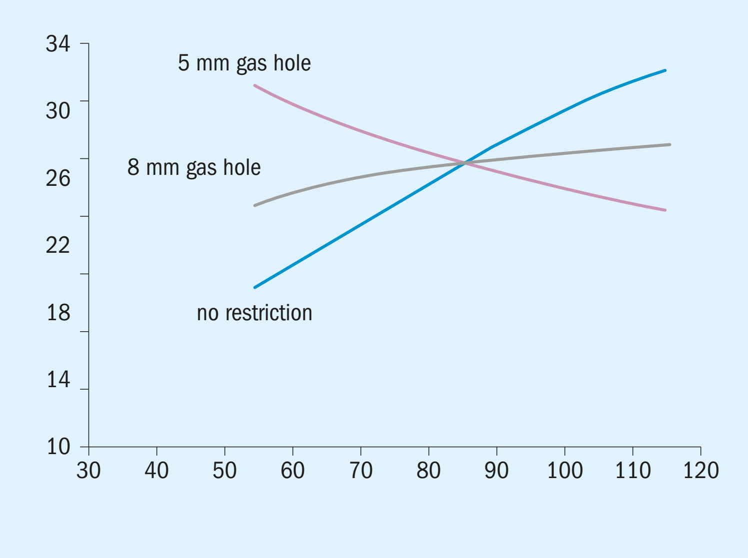
Fig. 1: **Stripper tube (schematic)**



in a tube the gas density depends on the temperature and the ammonia to carbon dioxide ratio and, consequently, on the mass flows of the liquid at the top and the CO_2 gas at the bottom. The pressure difference between top and bottom is equal for all tubes in the stripper. Because of the influence of the amount of liquid on the gas density, not only the liquid flow but also the flow of CO_2 may show a deviation in a limited number of tubes.

If the gas hole is small, say 5 mm, the pressure drop across the gas hole is notable. Enlargement of the flow of liquid to a single tube or to a set of tubes will tend to increase both the flow of gas leaving at the top and the pressure drop across the gas hole. This is counterbalanced by a decrease of the flow of fresh CO_2 gas to the tube(s) under consideration. If there are large gas holes, or if the gas flow is completely unrestricted, the static head of the gas column in the tube will be the decisive factor. An increase of the flow of liquid to a single tube will result in an increased flow of CO_2 so that the gas density in the tube is maintained at a constant value. The liquid/gas ratio remains more or less constant; the risk of flooding of the liquid in a tube due to the upward flow of gas becoming too large is clearly greater than if smaller gas holes are used.

Fig. 2: **Influence of liquid load on CO_2-gas load (vertical axes: amount of CO_2 gas in kg/h/ tube and horizontal axes: amount of liquid in kg/h/tube)**



Deviations from average liquid load

Possible deviations from the average liquid load can be caused, for example, by deviations in the diameter of the liquid holes and by non-uniformity of the liquid height in the head of the stripper.

Diameter of the liquid holes

Deviations in the diameter of the liquid holes can result from the tolerance applied in drilling and/or due to corrosion during its lifetime (as a result of cross cut end attack corrosion).

On top of the stripper tubes distributors are installed to provide proper distribution of the liquid as well as the gas. Typically these distributors are called liquid distributors. To avoid any misunderstanding, these will be referred to as ferrules in this article.

The diameter of the liquid holes increases in time due to cross cut end attack corrosion. The corrosion rates differ per direction as a result of the fabrication process of the ferrules. This means the original round liquid holes become oval over time. It is very important to assure that the delta P over the liquid holes of all installed ferrules fall within a certain range (delta P +/– x% as specified by the licensor) so that all tubes receive the same amount of liquid and can realise a high stripper efficiency. It is good practice to perform a delta-P measurement by means of a certain air flow to measure the delta P of each ferrule. Over time the average delta-P will decrease due to the larger liquid holes and the range of delta-P will become wider.

If a certain number of ferrules have a delta-P which falls outside the acceptable range (average delta P +/– x%), they will need to be replaced by ones with a delta-P that fall within the range. As all liquid holes increase in time it makes sense to rotate the spare ferrules into the set of installed ferrules. Safurex Star ferrules are made according to the Hot Isostatic Pressing (HIP) fabrication process reducing significantly the cross cut end attack issues and realising a longer lifetime of the ferrules.

Non-uniformity of the liquid height

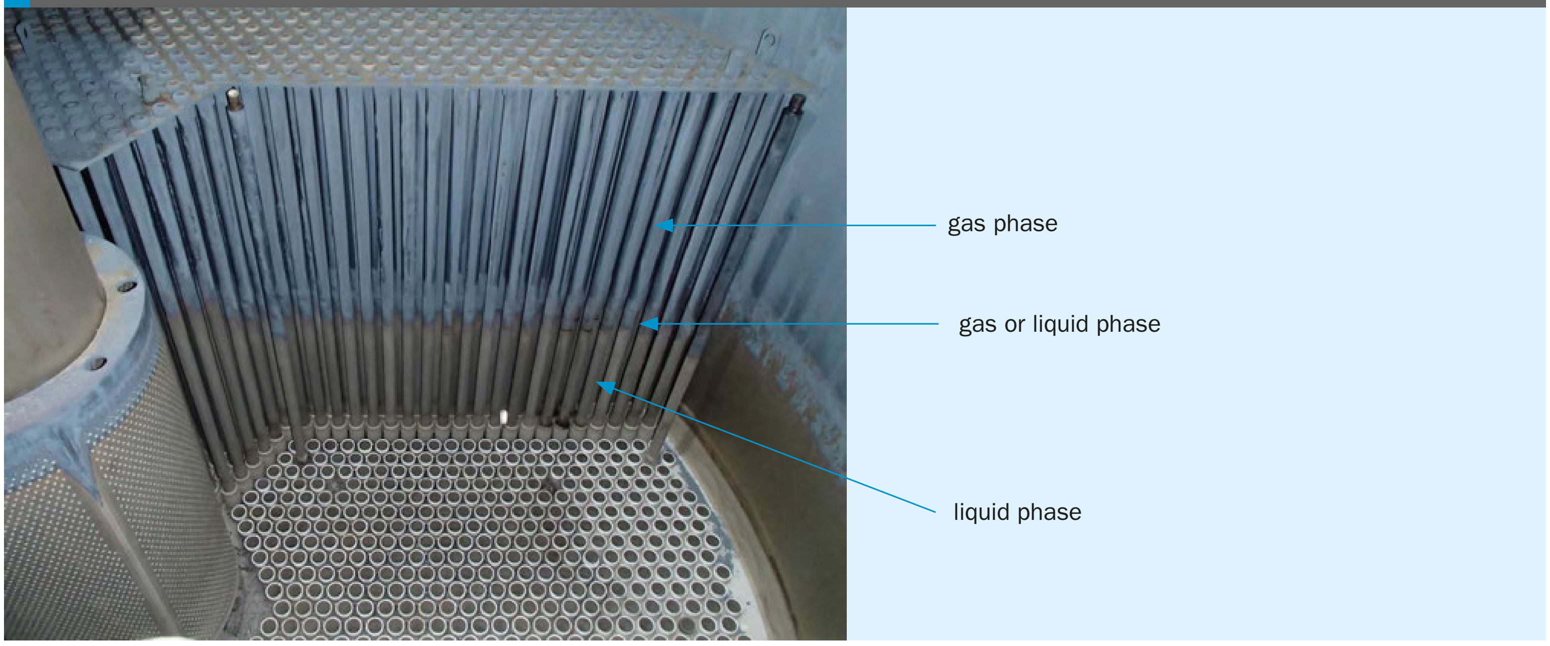
Deviations from the average liquid load can also be caused by non-uniformity of the liquid height in the head of the stripper due to a slant of the stripper (i.e. not perfectly vertical) and to the resistance to the liquid flow occurring between the ferrules in the stripper head.

The Shangdong Hualu Hengsheng Group in China used a caliber to check the slant (verticality) of its CO_2 stripper in their CO_2 stripping urea plant. The urea plant started up in 2007 and operates currently at a capacity of 1,300 t/d. Before the alignment the stripper bottom liquid outlet temperature was some 173-174°C and the stripper efficiency 79% at 100% plant load. After proper alignment the stripper bottom liquid outlet temperature reduced to some 170-171°C and the stripper efficiency increased to 81% at 110% plant load.

It is good practice to check the liquid level in the top of the stripper over the diameter in two directions (north-south and east-west).

In case the liquid level is not equal over the complete diameter, it means that some tubes receive more liquid than others, which leads to a lower stripper efficiency. It is advisable to contact the licensor in that case in order to optimise the design of the liquid distribution in the top of the stripper. ■

Fig. 3: **Visual check of liquid level over diameter**



1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 11 57 12 58 13 59 14 60 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

The future of the European nitrogen industry

Expensive feedstock, overseas competition and tightening environmental regulations all pose potential threats to Europe's nitrogen industry.

The European nitrogen industry has been in a state of turbulence since the 2021 natural-gas price surge and Russia's invasion of Ukraine the following February. Although operating rates have improved drastically from the peak of shutdowns in August 2022, when up to half of all ammonia capacity was idled, producers are still exposed to volatile gas prices, scattered nitrogen demand and increasingly stringent decarbonisation targets and policies. The plight of the industry was emphasised again in October 2024, as Yara announced the closure of its 400,000 t/a ammonia plant in Tertre, Belgium.

Feedstock prices

One of the biggest issues for the European industry in the short term is the price of natural gas feedstock. A surge in gas prices in Europe in 2021-22 led to a wave of capacity shutdowns and curtailments. While lower price volatility since then has resulted in European nitrogen capacity operating at more than 75% utilisation, on average, in 2024, and Dutch TTF gas prices have come down to an average of $10.4/MMBtu for 2024, they remain significantly above the average gas price of $5/MMBtu in 2016–20. Yara, Europe's largest producer, says that it is working on structurally reducing its dependency on Russian raw materials, but high natural gas prices have forced the company to drastically curtail production in Europe. Nevertheless, while high gas prices have lifted the average costs of production in Europe, the industry is thought to have largely adjusted to these higher costs, some of which have been compensated for by the higher than pre-2021 product prices. Even so, Europe's nitrogen industry remains exposed to supply-side disruptions in the gas market, lacklustre demand and competition from lower-cost product elsewhere.

Russian imports

The latter has been a particular concern for EU states on the eastern side of the continent, which have faced increased imports of fertilizer from Russia. Indeed, there is a concern that, while Europe has reduced its dependence on Russian natural gas, in importing fertilizer instead it is merely swapping one dependence for another. Over the past 7 years, fertilizer production in Russia has increased by 33%, and EU imports of Russian fertilizers increased from 2.8 million t/a in 2023 to 3.75 million t/a in 2024. In the first 9 months of 2024, 30% of EU-27 fertilizer imports came from Russia and Belarus. In Poland that figure was 65%, up from 37% in 2022, according to Grupa Azoty figures, and the figure for urea imports was 82%. Russian urea exports to Europe have more than doubled between 2020-21 and 2023-24.

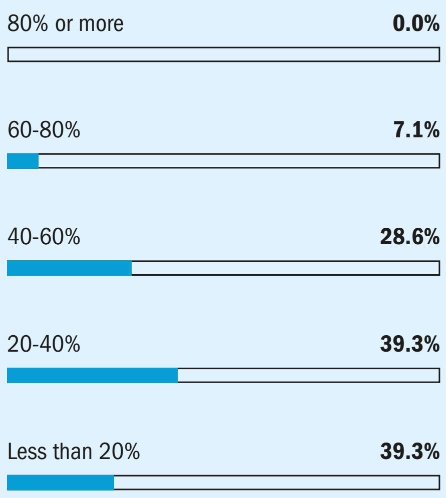
Tariffs

The increase has led to a response by the EU. At the 21st November 2024 EU Trade Council Meeting, Poland together with Estonia, Latvia and Lithuania called on the European Commission to take a decisive action on surging imports of Russian and Belarusian fertilizers to the EU. In parallel,

PHOTO: FLUXYS

Fluxys is building a new ammonia import terminal at Advario's Gas Terminal at Antwerp, part of Europe's projected needs for higher ammonia imports in future.

Fig. 1: **By 2030, what volume of existing European ammonia capacity will be closed**



Source: CRU

Sweden together with 7 other member states called for a Commission proposal on increased tariffs for EU imports of Russian and Belarus products, including fertilizers. The move has been welcomed by Fertilizers Europe, the industry body for European fertilizer producers, and argues that "urgent action is required to stop Russian fertilizers from financing the illegal full-scale invasion of Ukraine, while safeguarding the EU's strategic autonomy in food and fertilizer production." Fertilizers Europe has also stressed that this not only increases dependence on Russia but also cuts across existing environmental goals, as fertilizers produced within the EU are on average 50-60% less carbon intensive than those produced in Russia and Belarus.

European fertilizer producers have also stressed the need for the EU and national governments to put in place a set of short- and long-term measures to ensure the continued competitiveness of Europe's fertiliser industry, in order to strengthen Europe's strategic autonomy, including; ensuring continued access to natural gas for nitrogen production; increasing and earmarking funding for the green transition of the fertiliser industry; removing bureaucratic hurdles for the build-up of renewable power generation capacity; and controlling the inflow of Russian fertilisers into Europe.

Low carbon capacity

The great hope for the European industry has been that, in the longer term, increased use of renewable electricity and recovered nutrients and a transition to more sustainable and resilient fertiliser production, plus the effect of EU measures such as the Carbon Border Adjustment Mechanism, will allow for a low carbon European market for fertilizers which is relatively insulated from the gas price situation. However, this will require a significant investment, and abundant and affordable renewable electricity remains the main bottleneck for large-scale development of green hydrogen and green ammonia production, and there are complexities around certifying green hydrogen which are continuing to act as a drag on this investment.

In the meantime, the EU Renewable Energy Directive part III (RED III) came into force in November 2023, with EU member states given 18 months to institute their own domestic legislation to comply with it. The Directive tightens the target for renewable energy sources in the EU's energy consumption to 42.5% compared to the RED II Directive. EU rules on the promotion of renewable energy sources have evolved significantly: from the original target of 20% of EU energy consumption from renewable energy sources by 2020 to a change in 2018, when the target for 2030 of 32% of EU energy consumption is to come from renewable sources. The draft RED III Directive tightens the target for the share of renewable energy in the EU's energy consumption to 42.5%. The delegated act sets out the main principles for the production of renewable fuels of non-biological origin (RFNBO), together with the criteria for including hydrogen in the calculation of the targets set out in the RED III Directive.

For fertilizer producers this would mean a mandatory target for the share of renewable energy in 2030 at the level of 42.5% (up from 32%) and the share of renewable fuels of non-biological origin in hydrogen used in industry is to be 42% in 2030 and 60% in 2035.

The EU has also recently modified the EU Emissions Trading System (ETS) in June 2023, while the decision on the functioning of market stability reserves came on 1 January 2024. The price of emissions permits for carbon dioxide is forecast to double out to 2030 and triple by 2035, increasing operating costs for producers of 'grey' ammonia. As per CRU estimates, ammonia is expected to be the most exposed to the targets, requiring 1.2 million t/a of green hydrogen alone. While downstream fertilizer nitrates production can be green, the urea industry is likely to face significant hurdles. Europe will likely be seeking outside sources to meet their nitrogen and specifically urea needs. More interest in the low-emitters is likely to arise, keeping in mind the full implementation of Carbon-border Adjustment Mechanism (CBAM) from 2026 affecting final costs to the importers.

CBAM

From 2026 the industry will also have to face the Carbon Border Adjustment Mechanism (CBAM). CBAM is a levy on carbon-intensive goods entering the EU, and the price of CBAM certificates will reflect the EU ETS prices corrected for any free allowances EU producers still receive, and carbon costs incurred during the production process in the producing country. The CBAM aims to mitigate possibly unfair competition from the hydrogen and fertilizer industry outside the EU that doesn't face any carbon-related regulation. This should, in theory, significantly mitigate the eroding competitiveness of the fertilizer industry in Europe versus fertilizer producers from abroad, although it does not affect the loss of the European industry's competitiveness outside Europe in the global nitrogen fertilizer market, and European plants that export substantial volumes outside the EU will lose market share. It is also possible that low carbon capacity outside the EU may be able to export into the EU at a lower price than domestic green/blue ammonia.

Risk of closures

The risk of closure thus continues to hang over European nitrogen capacity. Estimates by a sampling of industry veterans (see Figure 1) are that up to 40% of European ammonia and urea fertilizer producers will need to close in order to meet the targets for renewables. CRU has conducted a capacity risk review for each site across the continent (excluding Ukraine). Within this analysis, production costs, company strategy, import capabilities, and previous operating rates have all been taken into consideration, alongside other evidence, leading to the categorisation of plants as 'high', 'medium' or 'low' risk (Figure 2).

Four plants have been categorised as high risk, and possess very high ammonia

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

production costs and have recorded irregular operations since 2021. Yearly operations at all four facilities are estimated to be less than 15%, while Petrokemija in Croatia and Nitrogenmuvek in Hungary are facing high tax burdens due to high emissions intensity and changes in legislation. Ameropa, owner of the Azomures facility in Romania, is already looking to sell the facility.

Considering the irregular production in the high-risk category since 2021, the main risk to incremental European nitrogen supply lies within the medium-risk category. CRU estimates that 6.9 million t/a of total European capacity ex. Ukraine (17.7 million t/a) falls into the medium-risk category. Plants in the low-risk category are less vulnerable to shutdowns due to relatively better production economics, lower emission intensity or dependability of of domestic demand. Still, the closure of one such plant (Yara-Tertre) hints at a worrying future for European production.

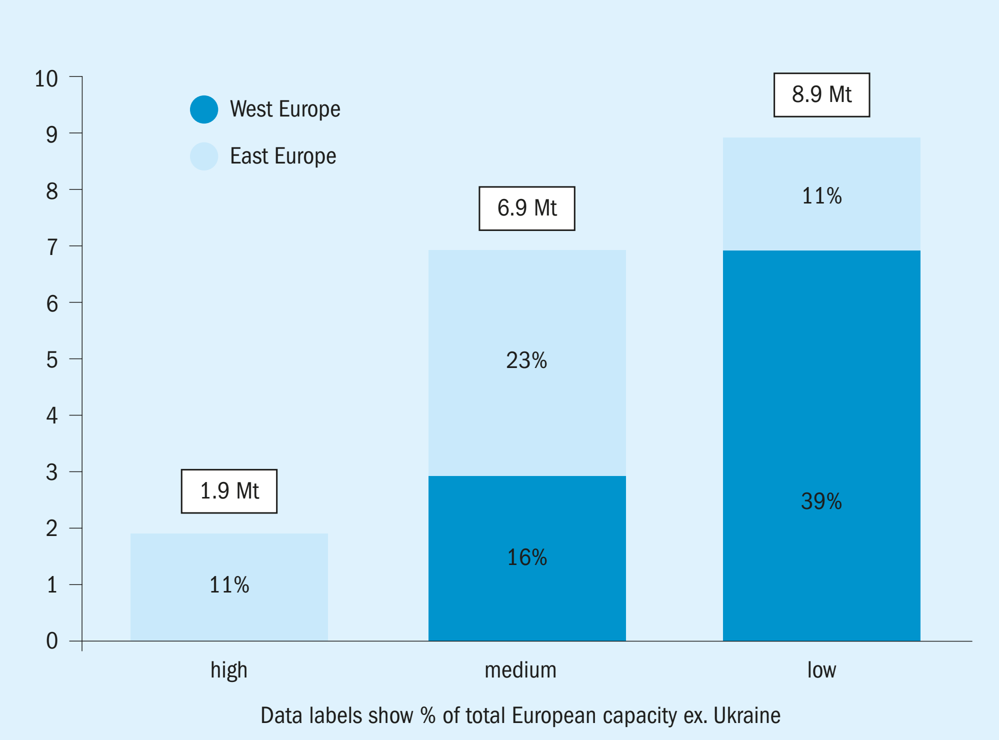
Downstream production

One of the key factors in determining the asset-level ammonia risk is to consider its downstream profitability. Margins for ammonium nitrate, a product which can consume imported ammonia, show relatively similar figures for domestic European production via imported ammonia ($113/t) versus domestically produced ($141/t) ammonia in 2024. As industry prepares for the transition towards the use of low-emissions ammonia for fertilizers, these similar margins add risk to on-site grey ammonia production. Furthermore, the introduction of policies to tax products based on their emissions is likely to incentivise the switch to low-carbon feedstock.

While urea profitability is thought to be break-even, on average, for producers in Europe in 2024, a continued weakness in the global urea prices amid strengthened gas prices is likely to pose extended challenges to production economics. The infeasibility of using imported ammonia to produce urea further questions the future of urea operations in the continent, along with the significant challenges in substituting blue/green ammonia for grey ammonia due to the CO_2 requirements for urea production.

Should medium risk ammonia capacity start to shut, CRU estimates that there is an operations risk to 3.5 million t/a of European urea capacity. This is likely to increase urea import requirements into Europe by approx. 2.8 million t/a, assuming an 80% on-stream factor for the plants, translating to about 230,000 tonnes per month. While this is likely to mark a shift in global urea market sentiment, there is potential to be fulfilled by the abundant urea availability elsewhere.

Fig. 2: **Ammonia plants risk categorisation**



Source: CRU

Ammonia imports

An added layer to the likelihood of ammonia capacity closure is the infrastructure to facilitate that transition. Not all FGAN/CAN capacity has the infrastructure to import ammonia, although CRU estimates that 18.8 million t/a of FGAN/CAN capacity within Europe can import ammonia. Out of this, about 8 million t/a is already dependent on imported ammonia. About 335,000 tonnes per month of ammonia is required to operate the remainder capacity at 100%. Europe typically imports around 400,000 tonnes monthly, including the ammonia requirements of FGAN/CAN production which partially consumes imported ammonia. Reduced industrial production is likely to soften the usual ammonia import demand, but not sufficiently, and CRU estimates that an additional 200,000-250,000 tonnes of ammonia would need to be imported into Europe per month in order to run fertilizer nitrate capacity which is currently dependent on locally produced ammonia.

Currently, Yara possesses the largest and most widespread network of import terminals in Europe. A focus on expanding import terminals by other producers including OCI and Grupa Azoty highlights the increasing reliance on imported ammonia. Grupa Azoty's recent announcement of scaling back domestic production and prioritising ammonia imports along with Yara's decision to shut down the Tertre plant in Belgium strengthens the rising risk on Ammonia operations within Europe.

Major global producers such as Yara, OCI and CF Industries are in the process of setting up low-carbon ammonia production outside Europe, providing added incentive to re-consider grey ammonia production in Europe. Internal offtake opportunities to produce green nitrates will enable them to command a premium and position themselves as the industry leaders in the drive towards decarbonisation.

Nevertheless, a huge amount of investment is still needed for a successful transition to a low-carbon industry. Most producers will be faced with either producing green hydrogen or needing to invest in new import infrastructure, both of which have significant cost implications. Detailed analysis is provided within CRU's latest Low Emissions Hydrogen and Ammonia outlook. ■

Long term carbon pricing

High energy storage costs for renewable-based technologies are likely to make European long term carbon prices considerably higher than their present levels.

Controlling emissions of carbon dioxide and equivalent gases in order to mitigate the worst effects of man-made climate change has become one of the defining issues of the first half of the 21st century. However, actually achieving change on the scale required in a meaningful timescale has been a long and arduous process. Concrete progress came from the United Nations Framework Convention on Climate Change (UNFCCC), which was signed in 1994 by 154 (now 165) countries and other parties such as OPEC and the European Union. The UNFCCC in turn mandated regular annual summits, called the Conference of the Parties (COP) to discuss and ratify agreements. In 1997 the Kyoto meeting first set binding targets on emissions reduction, mainly for developed countries, and created a set of new legal instruments for emissions reductions and removals to be tracked and traded via so-called 'flexibility mechanisms'. The guiding principle was to set a price for carbon emissions which could then be traded via international emissions trading.

Carbon pricing

The aim for carbon pricing mechanisms is to generate a sufficient cost or incentive via carbon credits/penalties to drive investment in less polluting technologies. However, in order to work as intended, the carbon price has to reach a sufficient level. The UN estimates that the carbon price required to cut emissions by 30% by 2030 would be around $40/tonne, and it is estimated that for carbon capture and storage (CCS) to be commercial it requires a carbon price of $60-100/tonne, while existing direct air capture (DAC) processes require up to $200/tonne to break even.

A disparity between the costs required to drive change and the costs that industry was willing to bear emerged in the early days of the European Union's flagship emissions trading scheme (ETS), which has become the model for such schemes worldwide. The EU ETS suffered initially from over-caution by regulators about the

PHOTO: EUROPEAN INVESTMENT BANK

Installing new onshore wind turbines in Denmark.

impact on industry and hence considerable over-allocation of carbon credits and opt-outs, meaning that the EU ETS generated carbon prices of only around €3-5/tonne in the 2010s, easily bearable by carbon intensive industries. It was not until 2016-17 when a subsequent round of credit issuance attempted to correct this by reducing the credits available. This had the desired effect of tightening the market considerably, leading to prices rising to around €25/tonne CO_2e from 2018-2020, and €50/tonne in 2021, rising towards €80/t after the Russian invasion of Ukraine, and staying at a level of €60-80/t since then. Figure 1 shows the development of EU ETS prices since 2010.

Recent developments

As the scheme has matured, European ETS pricing has become primarily driven by the demands of power generators for credits. A higher proportion of renewable energy being generated tends to lead to lower demand for credits and hence lower carbon pricing, while the high gas prices that Europe has endured since the shut off of most Russian gas supplies to the continent conversely has tended to lead to more reliance on coal-based power production, resulting in higher demand for credits and higher carbon pricing.

For example, CRU's recent short term EU carbon price report notes that in November 2024, the EU ETS carbon price dropped to €64 but then increased to €70 by the end of the month. That rise was primarily driven by a decline in renewables output, particularly wind and hydro-electric energy generation, with wind generation decreasing in November. Hydroelectric output decreased compared to October but remained relatively average for the season, and this average level was expected to continue into December. Nuclear power generation in Europe increased in November compared to previous months, exerting downward pressure on the carbon price. Overall, the drop in renewables led to increased use of gas and coal, raising the carbon price. However, despite higher gas prices, there was no particular evidence of gas-to-coal switching; instead, both gas and coal usage increased. Overall, power demand remained lower than historical averages, due to prevailing weak economic conditions in industrial users, especially steel production, though high gas prices continued to provide a risk of more gas to coal switching.

Longer term pricing

Looking to 2030 and even 2050, CRU has also recently published a Long-Term EU Carbon Price Report which provides an in-depth analysis of the European Union carbon pricing forecasts, influenced by shifts in market dynamics, technological advancements, and stringent decarbonisation goals. The report highlights significant adjustments to recent short-, medium-, and long-term carbon price projections, emphasising the critical role of emerging green technologies like hydrogen and renewable energy in meeting climate targets.

As a result, the EU carbon price forecast for 2030 has been adjusted to $134/ tCO_2 (in 2024 terms), reflecting a 1% decrease compared to earlier predictions. This revision stems from an increase in the Total Number of Allowances in Circulation (TNAC), signalling lower-than-anticipated demand for allowances and looser market conditions. This reduced demand is influenced by projections of lower fossil fuel consumption and a general decrease in emissions from major sectors like power, steel, and cement.

By 2050, the carbon price is expected to climb to $206/$tCO_2$, a 3% increase over prior estimates. This upward revision is primarily attributed to the incorporation of hydrogen storage costs into the modelling. Hydrogen is considered a cornerstone of EU decarbonisation efforts, and the additional storage requirements for variable electrolysis have raised abatement costs, particularly for hydrogen-based technologies. The adjustments ensure alignment with the EU's climate neutrality goals for 2050.

In scenarios requiring full decarbonisation by 2050, such as the "Net-Zero by 2050" (NZ '50) scenario, the carbon price forecast has been dramatically revised upward by 31% to $367/$tCO_2$. This reflects the high costs associated with achieving 100% emission reductions, driven by reliance on expensive technologies like green ammonia.

Medium term trends

The medium-term forecast reflects reduced emissions from thermal coal and natural gas consumption, particularly in power generation. This reduction is most notable in Germany, where thermal coal usage has declined significantly. The overall emissions forecast for the period 2024–2028 has been revised downward by ~48 $MtCO_2e$ for thermal coal and an additional ~47 $MtCO_2e$ across the steel and cement sectors. Combined, these reductions have led to a loosening of market conditions and a downward revision of carbon price expectations.

Total Number of Allowances in Circulation forecasts have been revised upward for 2024–2028 due to reduced demand for EU Allowances (EUAs). This reflects a looser carbon market, with allowances remaining plentiful. As a result, carbon prices are unlikely to experience significant upward pressure until the Market Stability Reserve (MSR) mechanism begins withdrawing allowances in 2025. This will tighten supply, leading to steeper price increases through 2028. After 2028, TNAC is expected to fall below the MSR's threshold for releasing allowances, stabilising market conditions. The carbon price is predicted to plateau at $134/$tCO_2$ by 2030, ensuring alignment with the EU's Nationally Determined Contributions (NDCs).

Long-term drivers

Hydrogen storage costs have been a key factor driving long-term price increases. Hydrogen storage, particularly in salt caverns, is essential for ensuring stable supply of hydrogen to industrial processes because of the highly variable output of electrolysis-based systems powered by renewable energy. This storage requirement is calculated to add approximately $0.8/kg to the levelised cost of hydrogen (LCOH) by 2050, raising the costs of producing green hydrogen and ammonia. Consequently, the carbon price forecast for technologies reliant on these fuels, such as marine fuels and steel production, has also risen.

Renewable energy costs, particularly for solar power, are another critical factor influencing long-term forecasts. To better develop our understanding of renewable energy costs CRU gas collected real-world data for solar projects for Europe that became operational between 2020 and 2024. This research confirms that European costs fall in line with the projected costs between our two scenarios. Data from operational solar projects across Europe confirms a steady decline in capital expenditure costs, aligning with previous forecasts. However, the cost reductions vary by country, with German projects

Fig. 1: **EU ETS prices since 2010**

Source: International Carbon Action Partnership

experiencing sharper declines compared to French projects. However, modelling suggests that the optimal solar share for Europe's power grid remains low (10% in Germany) due to high energy storage costs. Countries closer to the equator, such as Spain, exhibit higher optimal solar shares (~17%) due to more consistent solar output. Increasing the share of solar electricity generation beyond these levels would involve significantly higher grid costs. The integration of solar power into the grid also requires substantial energy storage to balance seasonal variability. For Germany, for example, increasing the share of solar based generation from 10% to 25% would necessitate an additional day's worth of storage capacity, highlighting the challenges of balancing renewables with grid stability.

Green ammonia

The displacement of heavy fuel oil (HFO) with green ammonia as a marine fuel is identified as a high-cost abatement action. The increase in green ammonia costs (~$170/t by 2050) due to higher hydrogen costs underscores the financial challenges of achieving full decarbonisation. This drives the upward revision of carbon prices, particularly under the NZ '50 scenario.

Impact of emissions reduction policies

There is some sensitivity to the analysis depending upon emissions reduction policies adopted by EU governments. The base case scenario, which assumes moderate emission reductions aligned with current nationally determined contributions (NDCs), forecasts a carbon price of \$206/tCO_2 by 2050. This reflects a balance between technological advancements and policy-driven reductions. Carbon prices would conversely by lower under the 'stated policies' scenario, which assumes no significant policy changes beyond those already in place. This would put the carbon price at around \$105/tCO_2 by 2050, a slight upwards revision on previous forecasts.

On the other hand, were the EU to determinedly move towards the net-zero scenario ('NZ '50'), requiring full decarbonisation, the steep costs associated with achieving 100% emissions reduction using high cost technologies would make themselves felt in the sharpest price increase, with a forecast of \$367/tCO_2 by 2050. Progressively higher carbon prices are required to drive innovation and adoption of high-cost abatement technologies.

The implication for policymakers is that there needs to be a focus on fostering investment in green hydrogen, renewable energy, and energy storage to bring these prices down and meet long-term climate goals. Achieving cost-effective decarbonisation requires continued advancements in renewable energy and hydrogen technologies. Governments and private sectors should therefore prioritize R&D in low-cost storage solutions and efficient electrolysers. Policymakers must also address the high storage costs associated with solar power integration to ensure balanced renewable energy deployment. While the report highlights the necessity of aggressive targets under scenarios like NZ '50, it also suggests that lower-cost alternatives should be used where possible. Policymakers should consider a mix of strategies to achieve emission reductions without disproportionately burdening industries.

Decarbonisation policies should target high-emission sectors like power generation, steel, and cement. Specific incentives may be needed to promote the transition to green hydrogen and ammonia in these industries. ■

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Biomass as a feedstock

While there is still a considerable push for use of biomass waste as a lower carbon feedstock for chemical production via gasification to syngas, biological processes such as fermentation are increasingly gaining traction as an alternative.

PHOTO: ECOHZ

A biomethane generation site in Germany

As the chemical industry pivots towards lower carbon production, most of the focus has been on hydrogen from electrolysis or using carbon capture and storage to sequester carbon dioxide (‘green’ and ‘blue’ technologies respectively). However, using biomass as a feedstock has also long been another strand of low carbon production. Generally speaking, biomass to chemicals routes focus upon either biological conversion, typically via fermentation, or chemical routes, with gasification the main strand.

Gasification

Gasification is the most versatile technology, as it is able to handle the widest variety of types of biomass, as well as related feeds like municipal solid waste (MSW). While gasification still generates CO_2 during conversion, it is at least in theory from a renewable source which would generate CO_2 and even methane (more damaging in terms of carbon equivalent) during the process of natural decay anyway, and which is presumably also drawing CO_2 from the air as replacement biomass is planted and grown.

Biomass feedstocks are generally classified into four main groups: woody biomass, herbaceous biomass, marine biomass and manures. Woody biomass and herbaceous plants with low moisture contents are the primary choices because they do not require as much energy in drying to remove the moisture; every kilogram of water requires an additional 2.2 MJ of energy to process. Agricultural wastes such as bagasse, sugar cane trash, rice husk, rice straw, coir pith, groundnut shells etc are also potential feedstocks, although pulverisation is needed prior to use as feedstock to enhance their bulk density and reduce transportation cost.

One of the issues for large scale use of biomass gasification is the collection step; generating enough biomass to run a reactor at constant rates. Attention has therefore often focused on the paper processing industry, where large scale collection of trees already occurs. Sweden, Canada and the US, as major pulp and paper producers, have all experimented with gasification of so-called ‘black liquor’, a liquid mixture of pulping residues like lignin and hemicellulose together with inorganic chemicals from the Kraft process such as sodium hydroxide and sodium sulphide, for example. Black liquor is a toxic waste stream which paper producers must treat and dispose of, and so gasification to produce useable products or energy seems a good fit. However, while this remains a promising angle, take-up so far has been limited and only four black liquor gasification plants are currently in operation.

Tar formation

One of the major issues with biomass and waste gasification is tar formation. Ther presence of benzene and other heavier molecular weight compounds in syngas tends to cause problems, leading to incomplete combustion. High molecular weight tars act as promoters of high viscosity, and can cause blockages in fuel pipes and injector lines by condensation. Avoiding tar formation is a key consideration in biomass gasification, and usually requires a fluidised bed gasifier. Feedstock enters the bed and finely ground bed material is fluidised by air or oxidising agent at a temperature of around 700–900°C. Biomass is thermally broken down into gaseous compounds, and char is produced. The hot char and fluidising bed material cause further reactions to break long-chain hydrocarbons or tars into syngas components. Thus, a syngas product with very low tar content is produced with tar content less than 3 g/Nm^3.

An alternative method is plasma gasification, where the extremely high temperatures help to reduce tars and convert all the organic material into syngas. Tar content as is reported to be up to 0.1% of that of an autothermal gasification processes. Arc discharges obtain thermal plasmas from DC or AC current or through radio frequency or microwaves. The oxygen demand in this process is small as compared to conventional gasification as most of the thermal energy is coming from an external energy source rather than exothermic reactions between the fuel and oxygen. However, in spite of considerable lab-scale work on this process, a recent survey of plasma gasification found only four commercial installations operational, all smaller scale and dealing with municipal waste. High costs and occasionally a negative thermal balance remain issues for the technology.

Fermentation

Fermentation is obviously used at a large scale for production of alcohols from some crop types, generally high sugar feeds like sugar beet or sugar cane. However, it is also attracting interest as a potential follow-up step to biomass gasification. So-called gasification-fermentation produces syngas as detailed above, which is then fed to anaerobic microorganisms that convert CO, CO_2 and H_2 to alcohols by fermentation. This process offers advantages such as flexibility of feedstock and syngas composition and lower operating temperatures and pressures compared to other catalytic syngas conversion processes. Bio-catalysts are also cheaper than the catalysts used in thermochemical processes. In comparison to hydrolysis-fermentation, gasification-fermentation can also utilise all of the organic components of biomass, including lignin, leading to higher yields. Overall carbon conversion is around 52%, compared with 41% for conventional gasification. Syngas fermentation microorganisms also do not require strict $CO:H_2:CO_2$ ratios, hence gas reforming is not required.

However, several issues must be addressed for successful deployment of the technology, including conversion efficiency of the gasification and syngas fermentation processes, the effect of some impurities on the bacteria, and the effect of $CO:H_2:CO_2$ ratios on syngas composition.

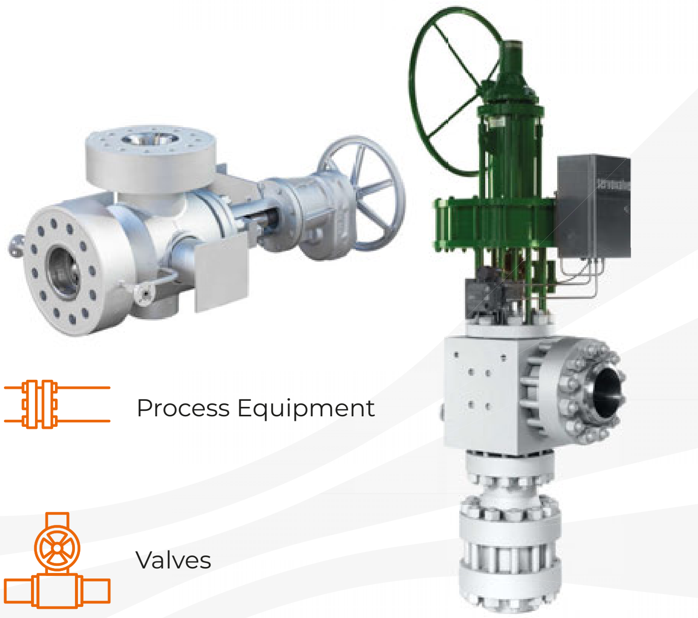
Biomethane

Since current ammonia/methanol processes are geared to use methane as a feedstock, the other major strand of biomass conversion is by using methane generated from biological sources. In this process, biological feeds are broken down by anaerobic bacteria to produce biomethane which can either be fed into a conventional gas grid or used for chemical conversion. Potential nutrient-rich sources can be agricultural waste, food waste, wastewater, and sewage sludge. Biogas production does also generate CO_2 in the feed, which can be scrubbed and sequestered to produce net negative carbon emissions.

Ammonia production from biomethane is in the process of being scaled up from lab demonstration units to pilot and demonstrator plants. In December 2024, Yara announced that it has produced ammonia from biomethane at a demonstrator unit in Brazil, using methane from sugar cane waste. Yara says that by integrating lower-carbon fertilizers into its agronomic expertise, it could for example achieve a reduction of up to 40% in the carbon footprint of harvested coffee beans. In October last year, BASF also launched 'biomass balanced' ammonia which uses biomethane and some green hydrogen to produce a low carbon ammonia for polyamide production, and OCI Global and Rohm also announced a similar demonstrator run of bio-derived ammonia for low carbon methyl methacrylate production.

Cost and scale

As with all green technologies, the key questions remain cost and scale of production. Biomass is a difficult feed to scale beyond small local production, and so does not lend itself to large scale ammonia production might rely instead upon smaller scale, modular reactors. However, in theory it has the potential to be cheaper than other low carbon technologies such as electrolysis. As Europe moves towards higher carbon prices (see elsewhere in this issue) and implements its Carbon Border Adjustment Mechanism from 2026, so the push towards more ammonia production from biomass may grow stronger.



Nitrogen+Syngas Index 2024

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	Deepak Fertilizers inks 15 year LNG supply contract	Mar/Apr	8
	Iffco to launch micronutrient-dosed urea solution	Nov/Dec	10
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	Yara to receive low carbon ammonia from Acme	Mar/Apr	8
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Ireland	Plans for ammonia fuelled power plant	Jan/Feb	10
Japan	Approval in principle for ammonia FSRU	Jan/Feb	8
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Kazakhstan	New ammonia and urea complex for Aktau	Jan/Feb	10
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Mexico	Feasibility study on new urea plant	Sep/Oct	9
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Norway	Electricity supply secured for large scale green NH3	Jul/Aug	11
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Paraguay	Yara signs CAN sales agreement	Sep/Oct	11
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	Plans for additional nitrogen production	Sep/Oct	10
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Senegal	Feasibility study on new urea plant	Jul/Aug	9
South Korea	KBR to partner in floating ammonia plant study	Nov/Dec	11
	Topsoe technology selected for hydrogen project	Mar/Apr	10
	Wartsila to deliver ammonia fuel system for two MGCs	Mar/Apr	10
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Tanzania	New urea plant	Sep/Oct	11
Thailand	PTT to explore low carbon ammonia	Jan/Feb	11
Turkmenistan	Tender for new urea plant	May/Jun	12
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	Notice to proceed for low carbon ammonia plant	Jul/Aug	11
UK	Uhde and JM to offer integrated blue ammonia solution	Jul/Aug	11
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Botswana	Tender issued for coal to liquids project	Jan/Feb	13
Canada	Blue methanol project launched for Medicine Hat	Sep/Oct	12
China	Approval for floating methanol plant design	Jan/Feb	12
	Collaboration on sustainable energy solutions	Mar/Apr	12
	Honeywell selected for methanol to SAF project	Sep/Oct	12
	Methanol engines for Chinese market	May/Jun	13
Denmark	Agreement on methanol storage	Jul/Aug	13
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Egypt	Consortium to develop green methanol plant	Jul/Aug	13
EU	Assessment of biogas rollout	Nov/Dec	14
	EU rules will boost value of methanol in shipping	Nov/Dec	14
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Germany	Biomass balanced ammonia	Nov/Dec	14
	NextChem completes acquisition of GasConTec	Jul/Aug	12
	Shell to build green hydrogen plant for refinery	Sep/Oct	13
	Start-up for electric steam cracking demonstrator	May/Jun	13
Hungary	MOL inaugurates new green hydrogen plant	May/Jun	14
India	CIL and GAIL to build SNG plant	Sep/Oct	13
	Toyo in study on green methanol production	Sep/Oct	13
Italy	Collaboration on Power to X projects	May/Jun	13
	Contract awarded for hydrogen plant	Mar/Apr	12
	Low carbon DME proposal	Jan/Feb	13
	New model for carbon neutral chemistry	Mar/Apr	12
	NextChem/JM to license waste to methanol solutions	Jul/Aug	13
Japan	Agreement on green natural gas	Jan/Feb	13
	Maersk and Yokohama methanol supply agreement	Jan/Feb	13

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Netherlands	Hydrogen import facility for Rotterdam	May/Jun	14
Nigeria	Brass methanol project signs feedstock agreement	Nov/Dec	14
Norway	Eidesvik Offshore launches methanol powered vessel	Mar/Apr	12
	NextChem to supply technology for biofuels plant	Mar/Apr	12
	Solution for large scale green H_2 production	Nov/Dec	12
Singapore	Singapore invites methanol bunker proposals	Jan/Feb	13
Saudi Arabia	Chemanol awards methanol expansion project	Nov/Dec	12
South Africa	Total pulls out of gas project	Sep/Oct	13
South Korea	Ammonia cracking plant for Approtium	Mar/Apr	13
Spain	Plans for green methanol plant	Jan/Feb	13
Sweden	Green methanol project abandoned	Sep/Oct	12
	Permit for green methanol plant	Jul/Aug	13
	Worley to provide FEED for green methanol plant	Nov/Dec	12
T&T	Methanex to switch from Atlas to Titan	Sep/Oct	13
UAE	Feasibility study on waste to fuels plant	Jan/Feb	12
	Masdar and Total to examine methanol to fuel project	Sep/Oct	12
UK	Matthey demonstrates fuel cell recycling technology	Jan/Feb	12
	Topsoe to collaborate on renewable gas and methanol	Jan/Feb	12
US	Fischer Tropsch production for SAF plant	May/Jun	14
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Vietnam	NextChem to upgrade hydrogen plant	Nov/Dec	14

Nitrogen+Syngas 2025 Expoconference

The 38th Nitrogen+Syngas Expoconference will take place in Barcelona, Spain, from 10-12 February 2025. Join us at this industry leading event featuring the most comprehensive agenda to date.

Barcelona cityscape

PHOTO: ALEXANDER PASARIC/PEXELS

The Nitrogen+Syngas Expoconference 2025 returns this year to Barcelona, Spain, with an extensive programme covering the entire nitrogen and syngas value chain. This year there is a strong focus on energy efficiency, carbon capture and GHG emissions, as well as dedicated sessions on digitalisation and future fuels. In addition to the extensive technical programme, the 2025 agenda has been enriched with two new features: a full day of investment and commercial insights from global experts; and a 3-hour certified training programme dedicated to plant safety and reliability.

New for 2025

Certified operator training programme

This three-hour training programme will focus on the theme of hazard identification techniques for risks associated with green ammonia and urea, offering operators the opportunity to learn from real life case studies. Through in-depth presentations and interactive discussions, participants will be able to boost their professional development by exploring critical safety practices and operational insights.

Participants will receive a Certificate of Completion from the Fertilizer Academy, a globally recognised independent training platform dedicated to real-life industry experience, unbound by corporate interests or affiliations with EPC organisations and technology licensors.

Investment in infrastructure

A full day of investment and commercial presentations will take place on 10 February, designed to foster high-impact networking and knowledge-sharing for executives, fund managers, industry infrastructure investors, asset owners and operators, and government representatives. Supported by leading asset owners and industry infrastructure experts, the sessions will delve deep into pivotal topics for 2025 and beyond.

Alongside this, delegates will learn about trade flows, pricing trends, and the latest investment opportunities shaping the nitrogen and syngas landscape from CRU's Head of Fertilizers, Chris Lawson and CRU's Nitrogen & Hydrogen Analysis Lead, Charlie Stephen.

Setting the scene for this year's conference Charlie Stephen comments:

"The European nitrogen and syngas industry remains precariously placed at the beginning of 2025. Natural gas prices remain elevated after steadily climbing through much of 2024 and are expected to be higher on average in 2025. The industry has been sheltered somewhat by high ammonia prices spurred by supply-side interruptions through the back-end of 2024. However, with supply looking healthy at the start of 2025 and the commissioning of new capacity and the re-start of Russian exports from the Black Sea scheduled for later in the year, prices look set to decline, swinging the pendulum to favour the import of ammonia over production and heightening the risk of curtailments and shutdowns.

2025 will be another challenging year, but producers will have their eye keenly on 2026. Commissioning of LNG capacity through the back-end of 2025 and through 2026 is expected to pressure gas prices. Additionally, the commencement of the definitive phase of the EU's Carbon Border Adjustment Mechanism will see imports into the EU subject to equivalent carbon costs that European producers have been incurring for over a decade. Both factors are expected to escalate through to the end of the decade, bringing some structural improvements to European competitiveness.

Longer term, the future of the industry still remains highly uncertain in the face of decarbonisation policy. The latest revision of the Renewable Energy Directive (RED III), requiring 42% of hydrogen consumed to be in the form of a renewable fuel from non-biological origins by 2030, is unlikely to be achieved for nitrogen fertilizers given the current pipeline of low emission ammonia projects.

Given the scale of continuing competitive and policy pressures, the industry must continue to collaborate to pursue improvements in safety, reliability and efficiency while developing and investing in solutions for decarbonisation."

Conference agenda

(Correct at time of going to press)

Monday, 10 February

TRACK ONE

INVESTMENT SESSION
10:00-12:00

Welcome Address
Chris Lawson, *CRU*

Keynote Address: Navigating the global net-zero investment landscape: Outlook for 2025 and beyond
Matti Leppälä, *Pensions Europe*

Investors Panel Discussion
Panellists:
Henry Rushton, *ING Bank, N.V.*
Olivier Musset, *Société Generale*;
Katja Yafimava, *Oxford Energy Institute*;
Nina Fahy, *Rabobank*;
Anny Santodomingo Rojas, *GIZ-NACAG*

Fostering investment in emerging assets – the future of ammonia supply in Europe
Bernd Haveresch, *KBR*

COMMERCIAL AND MARKETS AGENDA
13:50-17:30

Welcome Address, Nicola Coslett, *CRU*
Global nitrogen market outlook, Charlie Stephen, *CRU*
A dose of realism: Assessing the market potential of low emission ammonia and hydrogen, Charlie Stephen and Chris Lawson, *CRU*
Industry Keynote Panel: Chris Lawson, *CRU*; Aviv Bar Tal, *OCI NV*; Richard Holder, *Nutrien*; Joey Dobree, *Nextchem*; Marian Flores Granobles, *Arcelor Mittal*; Ignacio Fernandez Santiago, *FertigHy*
Fertilizer costs and emissions, Halima Abu Ali, *CRU*

TRACK TWO

TECHNICAL SHOWCASES
10:00-12:30

Biogas reforming for sustainable fuel production – Christian Schulz, *BASF*

MethaMaster and MethaDynamics – Digital solution for g-Methanol plant optimum design and operation under VRE
Kei Fukuzawa, *Toyo Engineering Corp.*

2,25 CR1MO enhanced low alloy steel for high pressure ammonia equipment
Diego Lazzari, *Belleli Energy CPE*

BASF OASE® Connect - a digital platform for gas treatment applications, providing resources and a simulation tool for plant operation optimisation
Mohammed Grerifa, *BASF*

Reducing the environmental impact of the nitric acid production
Carmen Perez, *Stamicarbon*

Revolutionary pressure measurement sensor solution for high temperature applications
Christoph Wöber, *WIKA Alexander Wiegand SE & Co. KG*

OMEGA®technology to improve efficiency of stream reformer furnaces Dominique Flahaut, *PARALLOY Group*

Experiences with MicroMist™ and Jet Venturi scrubbing systems
Murad Ismayilov, *Stamicarbon*

Revamping NH_3 plants for CO_2 emission reduction: hybridisation and retrofit for blue/green ammonia production
Sergio Panza, *Casale SA*

Jacob Grose, *Copernic Catalysts*

TRACK THREE

CERTIFIED OPERATOR TRAINING
10:00-12:30

Hazards identification techniques for risk associated with green ammonia and urea

Case studies from electrolysers, ammonia synthesis loops, ammonia storage tanks operation and urea high pressure synthesis sections

- **What is HAZID (HAZardous IDentification)?**
- **Electrolyser technologies to produce hydrogen**
- **Gas (H_2 and O_2) cross over risks in electrolysers**
- **Loss of containment risks in ammonia synthesis loops**
- **Loss of containment risks**
- **Ammonia storage tanks**
- **Release of ammonia during loading/unloading operation**
- **Urea high pressure synthesis sections**
- **Managing leaks**
- **Reliable instrumentation**
- **State-of-the-art ammonia detection technologies**
- **Training tools**
- **New operators**

Speakers:
Dan Cojocaru, *Fertilizer Academy*
Kevin Rouwenhorst, *University of Twente*
Maksym Selianynov, *Fertilizer Academy*
Mark Brouwer, *UreaKnowHow.com*

WELCOME RECEPTION
17:30

Tuesday, 11 February

TRACK ONE

PLANT RELIABILITY & TROUBLESHOOTING
9:00-10:30

Cracking the code: A decade-long journey to enhance plant reliability
Sania Ejaz, *Engro Fertilizers*

MOC – Management of change
Vincent Duponchel, *Yara Belgium S.A./N.V.*

Investigating syngas piping failure – a root cause analysis
Tayyab Ejaz, *Fauji Fertilizer Company Limited*

TRACK TWO

GREEN AMMONIA TECHNOLOGY
9:00-10:30

PEM electrolyser for green NH_3 industrial pilot. Experience and requirements for technology development for full scale applications
Markus Dietzen, *Linde GmbH*

Impact of pressure and temperature variation due to intermittent renewable energy on pressure components in green ammonia facilities
Guglielmo Deodato and Silvia Cincera, *Casale SA*

Beyond the trend: Challenges in green ammonia economy
Bernd Keil, *thyssenkrupp Uhde GmbH*

TRACK THREE

NITRIC ACID: CATALYST AND EQUIPMENT
9:00-10:30

How to achieve higher gauze efficiency and lower costs in nitric acid plants: A practical guide
Florian Knaus and Swetlana Romanenko, *Umicore AG & Co. KG*

Explosion welded applications in nitric acid equipment realise superior safety and reliability levels
Mukesh Ahlavadi, *NobelClad*

Getting the most out of your gauze
Matthew Wilson, *Johnson Matthey*

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Tuesday, 11 February

TRACK ONE

UREA PLANT DESIGN 11:00-13:00

Self-stripping plant revamping with HYPER-U
Matteo Fumagalli, *Casale SA*

Ultra-low energy plant and mechanical design pool condenser/pool reactor
Veronica Ricas, *Stamicarbon*

Enhanced urea production through energy-efficient post combustion carbon capture process for reformer flue gas and installation of bulk flow cooler
Junji Asahara and Yuji Higashi, *Mitsubishi Heavy Industries*

A smart combination of different non-destructive test methods allows quick and reliable on-site assessment of critical process equipment
Manuel Prohaska, *MPC²*

GHG EMISSIONS REDUCTION 14:00-15:40

Membrane-based ammonia purge gas hydrogen recovery units: a fresh look at an established technology
Geir Arne, *Air Products*
Sania Ejaz, *Engro Fertilizers*

Plant and process conditions for effective reduction of N_2O emissions from nitric acid production
Oliver Henkes, *Heraeus Precious Metals GmbH & Co. KG*

The optimum carbon capture rate in H_2 & NH_3 plants: it is not 99%
Klemens Wawrzinek, *Linde GmbH*

Sustainable methanol production powered by novel BASF SYNSPIRE™ Methanol catalysts
Alexander Higelin, *BASF SE*

CO_2 REMOVAL AND CARBON CAPTURE AND UTILISATION 16:10-17:50

Optimisation potential for existing CO_2 removal unit of ammonia plants with BASF's OASE® white LLP flash configuration
Mohammed Grerifa, *BASF*

Effect of maldistribution on CO_2 absorber performance
Simon Weiland, *Optimised Gas Treating Inc.*

Carbon capture energy balance: Can heat pumps solve the equation?
Andrea Orsetti, *NextChem Tech S.p.A.*

Carbon capture and green methanol production potential in the pulp and paper industry
Thor Gallardo, *KBR*

TRACK TWO

AMMONIA, METHANOL AND UREA OPERATIONS 11:00-13:00

Optimising ammonia plant operations: Chemical injection for fouling control to address elevated vacuum pressure
Raymond Gusrinaldi and Winandyo Mangkoto, *PT Pupuk Sriwidjaja Palembang*

Challenges & solutions for ammonia and methanol plants operating beyond full capacity – how we achieved this milestone
Muhammad Imran Idris, OQ Salalah Cluster and Muayad Qatan, *OQBI*

Employing simulation for urea plant to improve operational conditions and reduce utility usageto achieve sustainability goals
Ahmed Hanafi, *Helwan Fertilizers Company*

Lifecycle integrity management of outlet pigtails
Olivia Chung, *Quest integrity*

DIGITALISATION: TECHNOLOGY AND INNOVATION 14:00-15:40

Clariant´s PLUS series and Clarity – Drop-in solutions and digital catalyst insights to enhance the profitability and sustainability of existing syngas assets
Christian Berchthold, *Clariant*

Elevate your plant operations: The future of process monitoring
Ali El Sibai, *Stamicarbon*

Advancements in TOYO's DX-PLANT
Akiko Ushifusa, *Toyo Engineering Corporation*

Access the wealth of knowledge through Topsoe's new digital learning solution
Tommy Allan Jensen, *Topsoe A/S*

AMMONIA PLANT OPERATIONS 16:10-17:25

JGC's green ammonia demonstration project and ammonia cracking development project status update
Kenji Kawabata and Osamu Toyokawa, *JGC*

Reduction in environmental footprint via installation of hydrogen recovery unit
Fauji Fertilizer Company

Development of low temperature ammonia cracking technology utilizing exhaust heat
Ryota Shimura and Seiji Shinoda, *Mitsubishi Heavy Industries*

TRACK THREE

NITRIC ACID AND AMMONIUM NITRATE TECHNOLOGY AND PLANT RELIABILITY 11:00-13:00

Innovating our way to sustainability: 3D printed catalysts for N_2O decomposition in nitric acid production
Marco Kennema, *BASF*

Lesson learned of changing the defected carrying beams for granulator of ammonium nitrate plant
Ahmed Afify, *Abu Qir Fertilizer Company*

Cutting-edge approaches in fertilizer technology: Casale's expanded product portfolio
Iacopo Cerea, *Casale SA*

Optimisation of labyrinth seal design in turbo train 3-in-1 air compressor to address high thrust bearing temperature issues in ammonium nitrate and nitric acid plants
Hendra Novi, *Pupuk Kalimantan Timur*

SUSTAINABLE FERTILIZER PRODUCTION 14:00-15:40

Pioneering sustainable nitrogen technology: from green ammonia to integrated fertilizer plant
Rolf Postma, *Stamicarbon*

Optimising fertilizer processing: Comparative analysis of cooling technologies for enhanced operational efficiency
Igor Makarenko, *Solex Thermal*

High-fidelity operator training simulator for greenfield green fertilizer plants
Mayank Patel, *Siemens*

FERTILIZER FINISHING 16:10-17:50

Production technologies for urea + AS/sulphur fertilizers
Mark Brouwer, *UreaKnowHow.com*

Stamicarbon granulation technology: from Urea to UAS
Bruno Teixeira, *Stamicarbon*

HDAN prill tower gas combined treatment with WESP finishing at Agropolychim unit
Alessandro Gullà, *A.W.S. Corporation SRL*

AN / CAN & enhanced urea finishing technologies
Ken Monstrey, *Casale SA*

NETWORKING RECEPTION 18:00 – 19:00

Wednesday, 12 February

TRACK ONE

UREA PLANT SAFETY AND INTEGRITY 9:00-10:30

Syn turbine casing integrity and operational continuity: addressing cracks in a high-pressure turbine
Khalid Farooq Khattak and Shuja Hameed Butt, *Fauji Fertilizer Company*

Thermowell design and Inspection
Giulio Paci, *Yara*

UREA PRODUCTION: MATERIALS OF CONSTRUCTION 11:00-13:00

Boosting the lifetime of urea HP equipment
Luca Edoardo Viganò, *Saipem S.p.A.*

Advanced material solutions for optimised urea production. A portfolio overview
Oscar Öhlin, *Alleima Tube AB*

Weldability of high performance super-duplex seamless tube material used in classic & modern urea process units
Denise Caspar, *CPI & Energy, DVMV GmbH*

The first successful installation of mechanical plugs in a pool condenser
Shufen Wen and Tareque Iftekhar, *Stamicarbon*

DECARBONISING UREA PRODUCTION 14:00-15:30

Valorisation of excess LP Steam for reduced carbon footprint of urea plants
Damiano Visciotti, *Stamicarbon*

Technical solutions to decarbonise urea plant
Marc Wieschalla, *thyssenkrupp Uhde GmbH*

TOYO decarbonises urea production for modern and vintage urea plants, and next-gen g-Urea® plants
Kazuki Kamikubo, *Toyo Engineering Corporation*

TRACK TWO

FROM GREEN AMMONIA TO GREEN HYDROGEN – THE JOURNEY 9:00-10:30

Ammonia terminal on gravity based structure: a key asset for the energy transition
Andrea Zambianco, *Saipem S.p.A.*

Cracking it back: the most promising technology on the horizon to produce hydrogen from ammonia
Michael Lutz and Laurent Prost, *Air Liquide*

AMMONIA AND METHANOL PLANT OPERATIONS AND OPTIMISATION 11:00-13:00

Accelerating ammonia plant cold start-up by optimising primary reformer heating path
Alfin Ferdiawan, *PT Petrokimia Gresik*

How OQ has improved the reliability of methanol steam methane reformer tubes
Muhammad Faisal Faraz and Abdullah Al Balushi, *OQBI*

Successful decommissioning, inspection and recommissioning of ammonia storage tank – a record-breaking feat
Hassam Khalid, *Engro Fertilizers Limited*

Successful start-up of a European ammonia plant following replacement of obsolete bayonet and fire-tube boilers with Casale-Arvos double-tube design
Marco Mazzamuto Carlucci, *Casale SA*

AMMONIA PLANT OPERATIONS 14:00-15:30

Drying out for success: Engro's experience of effective HTSC dry-out and resuming ammonia production
Mohammad Arslan Qureshi, *Engro Fertilizers Limited*

Excellence in catalyst performance monitoring: Indorama's digital transformation with CLARITY™ prime
Sushansi Agarwal, *Indorama Eleme Fertilizers and Chemicals*, and Muhammad Umar Riaz, *Clariant*

N2C – circulating nitrogen to reduce cooling time of secondary reformer catalyst replacement using LTS Start Up Blower on KBR Purifier Ammonia Plant
Giar Pradipta, *Pupuk Sriwidjaja Palembang*

TRACK THREE

ENERGY TRANSITION AND FUTURE FUELS 9:00-10:30

Unleashing the power of blue hydrogen: Topsoe's innovations for a clean energy future
Adam Samir Kadhim, *Topsoe A/S*

Blue H_2: ROX (Recuperative and Oxidative Reforming)
Pietro Moreo, *Casale SA*

LOW CARBON HYDROGEN PRODUCTION 11:00-13:00

Challenges of hybrid ammonia plants – innovative ways to close the nitrogen gap and cope with fluctuating green hydrogen profiles
Johannes Distler, *thyssenkrupp Uhde GmbH*

Key performance indicators of CPO, SMR and ATR in low carbon hydrogen production
Leonardo Falbo, *NextChem Tech S.p.A.*

Flexible decarbonisation: Navigating energy transition with hydrogen and ammonia
Sayan Dasgupta, *Air Liquide Global E&C Solutions Germany GmbH*

Ammonia cracking catalyst: Optimising fundamentals of ammonia cracking catalyst starting from the support
Adrien Serve, *UNICAT Catalyst Technologies, LLC*

ASSET INTEGRITY 14:00-15:30

Application of Level 3 fitness-for-service assessment for understanding hot collector integrity
Daniel Blanks, *Quest Integrity Group*

Catalyst tubes after 10 years in service: correlation between operating history and remaining lifetime
Rafael Andrade, *ENGEMASA Engenharia e Materiais Ltda*

Increasing process efficiency and service life of syngas reformers, amine and Benfield vessels: Four case studies
Johannes Poth, *IGS Europe*

END OF CONFERENCE 15:30

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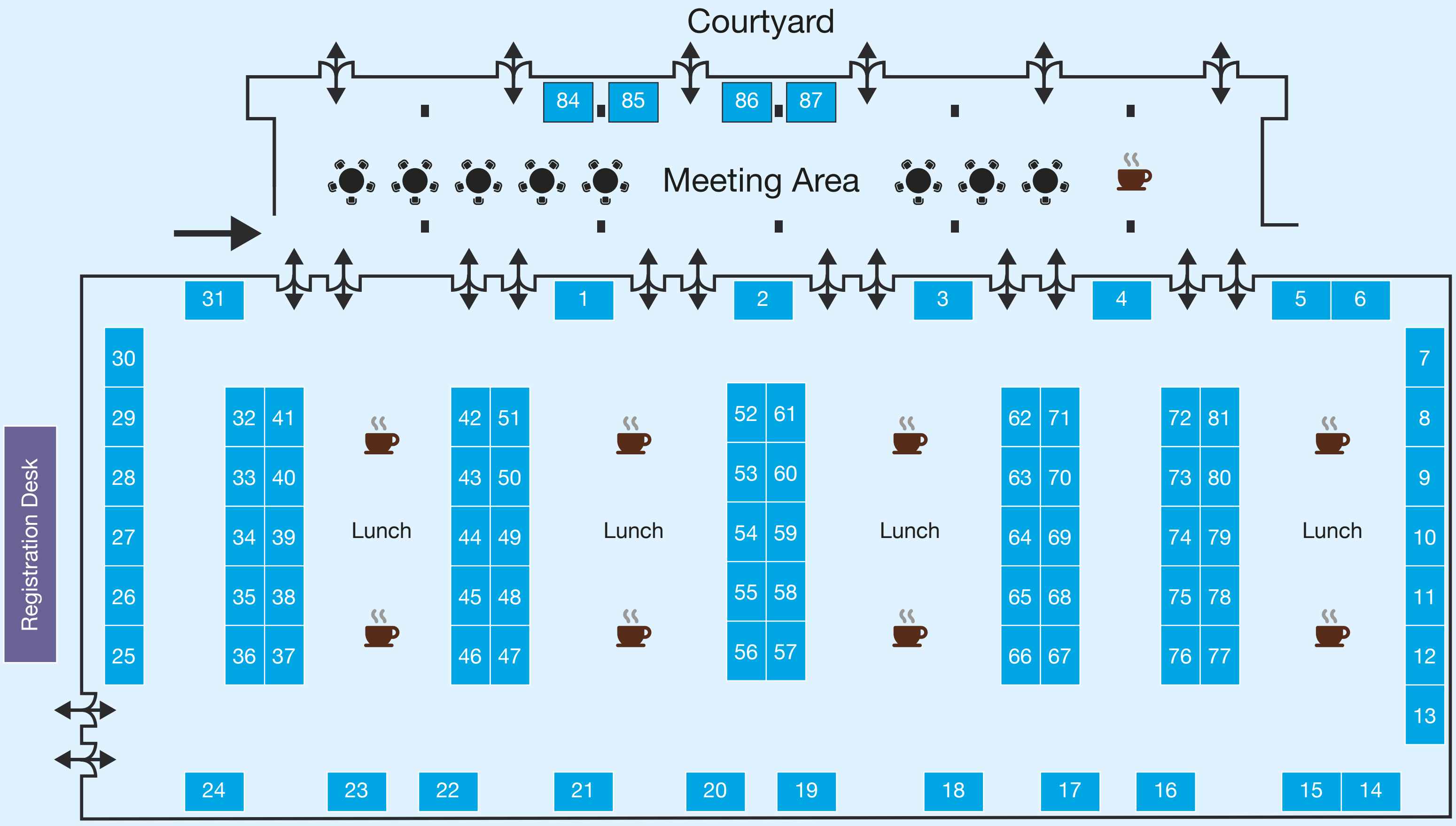
Exhibition plan

(Correct at time of going to press)



EXHIBITOR LIST

- 2 Clariant
- 3 Tema India
- 4 Key Tech Engineering Company
- 5 Gouda Refractories
- 6 Unidense Technology GmbH/Mourik Inc
- 8 Rotex
- 9 AST S.p.A
- 10 Project Materials Energy Services/ SCHMIDT+CLEMENS/ INNOWELD
- 11 Zeeco
- 12 Duiker Clean Technologies
- 13 Benvitec BlueFil®
- 14 Copernic Catalysts
- 15 Tragency Middle East
- 16 TUBACEX
- 17 BHDT
- 18 IPCOS
- 19 BASF
- 20 Blasch Precision Ceramics
- 21 Christof Group SBN
- 22 Paralloy Limited/ Manoir Industries
- 23 Officine LUIGI RESTA S.p.A.
- 24 Integrated Global Services (IGS)
- 25 Uni Abex Alloy Products Limited
- 26 Engemasa
- 27 Quality Engineering
- 29 ITT SPA
- 30 Telus Applications For Industry
- 31 Lointek
- 32 Alleima
- 33 Alleima
- 34 BELLELI ENERGY CPE / WALTER TOSTO / MARALDI
- 35 BREMBANA&ROLLE
- 36 KontrollTechnik
- 37 Johnson Matthey
- 38 thyssenkrupp Uhde GmbH
- 39 Air Products
- 40 WIKA Alexander Wiegand SE & Co. KG
- 41 Linde
- 42 Stamicarbon/Nextchem
- 43 BD Energy Systems
- 44 Kimre/Socrematic
- 45 UNICAT Catalyst Technologies, LLC
- 46 Toyo Engineering Corporation / Metal One Sumisho Tubular Products/ Nippon Steel
- 47 BOLDROCCHI S.R.L.
- 48 KINETICS PROCESS IMPROVEMENTS (KPI)
- 49 Navigance
- 50 Heraeus Precious Metals
- 51 Stamicarbon/Nextchem
- 52 Casale
- 53 LAND®
- 54 BORSIG Process Heat Exchanger GmbH
- 55 CellMark
- 56 Eurotecnica Contractors and Engineers SpA
- 57 Greens Combustion
- 58 Solex Thermal Science
- 59 Ventilatorenfabrik Oelde GmbH
- 60 Begg Cousland Envirotec
- 61 Casale
- 62 Topsoe
- 63 Zwick Armaturen GmbH
- 64 Boustead International Heaters Ltd
- 65 Mitsubishi Heavy Industries, Ltd.
- 66 SCHMIDTSCHE SCHACK | ARVOS GmbH
- 67 Messer SE & Co. KGaA
- 68 QINGDAO NPA
- 69 ALLIA
- 70 Siemens
- 71 Saipem SpA
- 72 Institut Dr. Foerster
- 73 NobelClad
- 74 John Zink
- 75 Mannesmann Stainless Tubes / GEMACO
- 76 Energy Bolting
- 77 SPRANA
- 78 H. Butting GmbH & Co. KG
- 79 Curtiss-Wright EST Group
- 80 AWS CORPORATION SRL
- 81 Umicore AG & Co. KG
- 86 Provalve Armaturen GmbH
- 87 JGC Corporation

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Exhibitor profiles

Alleima — Stand 32/33

Alleima is a leading manufacturer of high value-added products in advanced stainless steels and special alloys as well as products for industrial heating. Based on long-term customer partnerships, Alleima advances processes and applications in the most demanding industries through unique materials that are lightweight, durable, corrosion-resistant, and able to withstand extremely high temperatures and pressures.

Contact: Oscar Johansson
oscar.johansson@alleima.com
www.alleima.com/en/

BASF — Stand 19

BASF is a leading global manufacturer of catalysts for the chemical industry, with solutions across the chemical value chain. The business comprises chemical catalysts and adsorbents, refinery catalysts and custom catalysts. In the process catalysts business, priority is given to developing new and improved products that enable the chemical industry transformation to net-zero emissions.

Contact: Matthias Schwab
matthias.schwab@basf.com
www.basf.com/global/en

BHDT GmbH — Stand 17

BHDT designs and manufacture products in line with the standards of well-known licensors of petrochemical processes, using state-of-the-art engineering tools, high-precision computer-controlled processing machinery and taking customer demands into account at the highest level of technological standards. Its production range contains all of the high pressure products required in a high pressure plant such as high pressure valves, fittings and piping- isometrics with accessories.

Contact: Mr. Michael Simml
michael.simml@bhdt.at
www.bhdt.at/

Casale — Stand 52/61

Established in 1921, Casale greatly contributed to the history of ammonia production and nowadays is a world leading licensor and engineering contractor for the production of ammonia, urea, melamine, methanol, syngas. In 2014, following an acquisition from Borealis (formerly GPN), Casale expanded its portfolio to include also the processes for the production of nitric acid, AN, UAN, and multi-nutrient fertilizer products, including their granulation technology.

Contact: Maria San Antonio
m.sanantonio@casale.ch
www.casale.ch/

Christof Group SBN — Stand 21

Christof Group SBN are specialists in the fabrication of high pressure equipment for the fertilizer industry and particularly for ammonia and urea plants. Comprehensive material knowledge and decades of know-how in the design and production of sophisticated pressure vessels in either monowall or multilayer construction result in optimum implementation of customers' requirements, while focusing on highest possible quality in design and finish as well as on-time delivery.

Contact: Filippo Colucci
f.colucci@christof-group.com
www.christof-group.com/operations/sbn/

Clariant — Stand 2

Clariant Catalysts is a global and independent manufacturer of energy-efficient catalyst technologies shaping a sustainable future for the chemical industry by helping to decarbonise its customers' production processes and scaling up the transition toward zero-emission chemicals and fuels. Through its exceptional R&D and established expertise, Clariant's catalysts and adsorbents provide innovative solutions that range from the oil and gas to the plastic sectors.

Contact: Christian Berchthold
Christian.berchthold@clariant.com
www.clariant.com/catalysts

Eurotecnica Contractors and Engineers — Stand 56

Eurotecnica Contractors and Engineers S.p.A. is known for its leading position as technology provider, designer and implementer of melamine production plants. With 40 years of experience in the melamine, Eurotecnica has transformed this business from a market with few players to a worldwide open market. Urea-melamine easy integration, total-zero-pollution, low energy consumption, superior reliability, are top-notch features of proprietary Euromel® melamine process.

Contact: Roberto Vaghini
r.vaghini@eurotecnica.it
www.eurotecnica.it/en/

Heraeus Precious Metals — Stand 50

Heraeus Precious Metals is a leading provider of precious metals services and products. Its extensive portfolio includes products and services for industrial ammonia oxidation and hydrogen cyanide. Heraeus supplies catalytic gauzes and secondary catalysts for N_2O reduction, as well as supporting its customers in their choice of best catalyst design.

Contact: Oliver Henkes
oliver.henkes@heraeus.com
www.heraeus-precious-metals.com/en/

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Johnson Matthey — Stand 37

Johnson Matthey is a global leader in science that enables a cleaner and healthier world. With over 200 years of sustained commitment to innovation and technological breakthroughs, Johnson Matthey improves the function, performance and safety of its customers' products, in areas such as low emission transport, pharmaceuticals, chemical processing and making the most efficient use of the planet's natural resources.

Contact: Polly Murray
polly.murray@matthey.com
www.matthey.com/en/products-and-markets/chemicals

Linde — Stand 41

Linde Engineering has successfully delivered thousands of gas processing projects around the globe. Favouring trusted, lasting business relationships, Linde collaborates closely with customers to enhance plant lifecycle productivity and streamline process flows. Its proven gas processing technologies and know-how play an indispensable role in the success of customers across multiple industries from oil and gas through petrochemicals to electronics and metal processing.

Contact: Wiebke Mundloch
Wiebke.mundloch@linde.com
www.linde-engineering.com/

Stamicarbon — Stand 42/51

Stamicarbon, the nitrogen technology licensor of NEXTCHEM (MAIRE Group), designs and licenses fertilizer plant technologies, specialising in urea, green ammonia, and nitric acid. Applying 75 years of knowledge and experience, Stamicarbon offers customers tailored solutions and services to maintain, improve and optimise plants in every stage of their life cycle, with a focus on sustainable fertilizer production.

Contact: Vivian Lahaije
Vivian.Lahaije@stamicarbon.com
www.stamicarbon.com/

thyssenkrupp Uhde GmbH — Stand 38

thyssenkrupp Uhde combines unique technological expertise and decades of global experience in the engineering, procurement, construction and service of chemical plants. We develop innovative processes and products for a more sustainable future and thus contribute to the long-term success of our customers in almost all areas of the chemical industry. Our portfolio includes leading technologies for the production of base chemicals, fertilizers and polymers as well as complete value-chains for green hydrogen and sustainable chemicals.

Contact: Tobias Birwe
tobias.birwe@thyssenkrupp.com
www.thyssenkrupp-uhde.com

Toyo Engineering Corporation — Stand 46

Toyo Engineering Corporation (TOYO) is one of the world's leading engineering contractors. Since its foundation in 1961, TOYO has actively deployed Engineering, Procurement, and Construction (EPC) businesses, and successfully delivered large and complex projects in more than 50 countries, focusing on the segment of energy, oil refining, petrochemicals & chemicals, oil & gas development, infrastructure, environment, and other manufacturing facilities.

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Umicore AG & Co.KG — Stand 81

Umicore is a leading circular materials technology company with an extensive expertise in the fields of material science, chemistry and metallurgy. Its overriding goal of sustainable value creation is based on the ambition to develop, produce and recycle materials in a way that fulfils our mission: "materials for a better life", responding to the growing need for advanced materials, and contributing to the pursuit of a global circular economy.

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Uni Abex Alloy Products Limited — Stand 25

Uni Abex Alloy Products Limited, a seasoned leader with over 40 years of expertise, excels in crafting reformer tubes for fertilizer plants, petrochemical plants and gas-based direct reduced iron (DRI) applications. Renowned for its state-of-the-art facility in Dharwad, Karnataka, Uni Abex ensures meticulous manufacturing, assembly, and testing processes. As a premier micro-alloyed manufacturer, Uni Abex specialises in high-performance alloy products, standing out in reformer tubes and catalyst tubes.

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UNICAT Catalyst Technologies, LLC — Stand 45

UNICAT Catalyst Technologies, LLC is an innovative catalyst and process technology partner that collaborates with businesses to find effective solutions to increase efficiency and sustainability. UNICAT's technical expertise is demonstrated through high-quality, award-winning solutions and continuous investment in product development such as its commercialised Magcat® Textured Sphere reformer catalysts, which earned its UK counterpart the Queen's Award for Enterprise – Innovation in 2022, recognising significant technological and performance advancements.

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Blue hydrogen at scale

Blue hydrogen has emerged as a crucial technology for decarbonisation as nations around the world work towards net-zero carbon targets. By decarbonising hydrogen production and exploring clean hydrogen sources we can fully harness the potential of hydrogen in the global energy transition. **Johnson Matthey, Topsoe** and **Casale** report on their strategies and advanced technical solutions for large scale blue hydrogen production.

JOHNSON MATTHEY

Strategies and technological solutions for large-scale blue hydrogen production

Dr Phil Ingram

As nations around the world work towards ambitious net-zero carbon targets, blue hydrogen has emerged as a crucial technology for decarbonisation. Produced from natural gas with integrated carbon capture, utilisation, and storage (CCUS), blue hydrogen offers a scalable solution to reduce emissions across industries while leveraging existing infrastructure.

Hydrogen's role in decarbonisation

Hydrogen's versatility makes it indispensable to the energy transition. It serves as a clean energy carrier and feedstock, supporting a wide range of applications from industrial processes such as ammonia and methanol production to energy storage and hydrogen-powered fuel cells for transport. These capabilities enable hydrogen to play a pivotal role in reducing emissions, particularly in hard-to-abate sectors like steelmaking, refining, and heavy transportation.

While electrolytic (green) hydrogen, derived from water electrolysis powered by renewable energy, will play a crucial role in decarbonising our energy mix, its scalability is currently limited by high costs and infrastructure constraints. Blue hydrogen addresses this challenge by utilising well-established natural gas reforming technologies alongside CCUS to produce low-carbon hydrogen at scale. This allows industries to decarbonise today without waiting for renewable energy infrastructure to fully mature.

Advanced technologies for blue hydrogen production

The production of blue hydrogen relies on two primary reforming technologies: steam methane reforming (SMR) and autothermal reforming (ATR). Both processes convert methane into hydrogen and carbon dioxide, with the latter captured to minimise emissions.

Johnson Matthey's LCH™ technology is a leading example of this process. By combining ATR with gas-heated reformer (GHR) technology, LCH technology achieves CO_2 capture rates of up to 99% while optimising thermal efficiency. The GHR pre-reforms approximately 30% of the natural gas, reducing methane slip and ensuring high hydrocarbon conversion. Operating at elevated pressures, the system also lowers the energy required for CO_2 compression and storage.

Compared to conventional SMR processes, LCH technology consumes 15% less natural gas and reduces operating costs, making it particularly suited for large-scale projects where both economic and environmental considerations are critical.

The essential part of the value chain to decarbonise the industry is CCUS systems. These systems separate CO_2 from reforming processes using advanced materials like solvents and membranes before compressing it for storage or utilisation. Captured CO_2 is typically stored permanently in geological formations, such as depleted oil and gas reservoirs, or used in applications like enhanced oil recovery and building materials production.

In the HyNet initiative, one of the UK's first blue hydrogen projects developed by a consortium including Vertex Hydrogen, CCUS plays a central role. At the Stanlow Manufacturing Complex, hydrogen will be produced using JM's LCH technology, which enables CCUS. The captured CO_2 will be transported via pipelines to Liverpool Bay for permanent storage. This project demonstrates how integrating CCUS with blue hydrogen production can significantly reduce regional emissions.

Infrastructure and hydrogen hubs

One of blue hydrogen's most significant advantages is its compatibility with existing natural gas infrastructure. Pipelines, storage systems, and industrial facilities can be repurposed to transport and store hydrogen, minimising upfront capital costs.

HyNet exemplifies this approach by integrating hydrogen production with a robust distribution network. The project repurposes salt caverns in Cheshire to store up to 35,000 tonnes of hydrogen, ensuring supply reliability while balancing energy demand. Such regional initiatives create hydrogen hubs where production, distribution, and consumption are concentrated, driving economies of scale and fostering collaboration.

H2H Saltend, developed by Equinor and utilising JM's LCH technology, is another notable example. This 600 MW facility blends low-carbon hydrogen into natural gas supplies, reducing emissions at the Saltend Chemicals Park - 0.9 million tonnes of CO_2 per year will be captured and transported through the proposed Humber Low Carbon pipeline to the Northern Endurance Partnership (NEP) storage facility. By supporting industrial operations and energy generation, the project illustrates the scalability and versatility of blue hydrogen in meeting decarbonisation goals.

Economic viability and policy support

Scaling blue hydrogen production requires addressing economic challenges. Government support is essential to bridge this gap. Incentives like carbon pricing, subsidies, and contracts for difference (CfD) stabilise revenue streams, encouraging investment in large-scale projects.

Public-private partnerships, such as those underpinning HyNet, enable resource sharing and risk mitigation, aligning industry efforts with national climate policies. Clear and consistent regulatory frameworks are also crucial. For example, standardised hydrogen certification systems and emissions accounting rules help create a stable market environment that fosters investor confidence.

Efficiency is central to blue hydrogen's competitiveness. Innovations in catalyst design and heat recovery systems are reducing the energy intensity of production processes. LCH technology exemplifies this by recovering heat generated during reforming processes, optimising thermal efficiency and lowering operational costs.

The integration of renewable energy further enhances sustainability. Renewable electricity can power auxiliary systems, such as compressors and preheaters, reducing the carbon footprint of blue hydrogen production. These measures align blue hydrogen with broader decarbonisation goals while ensuring its cost-effectiveness in a competitive energy market.

Conclusion

Blue hydrogen provides an immediate and scalable solution for decarbonising industries while supporting the transition to a low-carbon economy. As demonstrated by initiatives like HyNet and H2H Saltend, regional hydrogen hubs are key to accelerating adoption and creating sustainable industrial ecosystems. By integrating advanced technologies as used in the LCH technology, leveraging existing infrastructure, and aligning with supportive policies, blue hydrogen can deliver significant emissions reductions across critical sectors.

In the next edition of Nitrogen+Syngas Johnson Matthey will explore the use of its LCH technology in the production of blue ammonia. ■

TOPSOE A/S

Unleashing the power of low-carbon hydrogen

Adam Samir Kadhim, Nitesh Bansal, Kim Aasberg- Petersen, Steffen S. Christensen

According to the International Energy Agency (IEA), hydrogen production contributes to a staggering 830 million tons or 3% of global CO_2 emissions annually. This highlights the urgent need to decarbonise hydrogen production. However, the potential of hydrogen extends far beyond reducing emissions in its own production process. It can also serve as a preferred energy carrier, decarbonising multiple sectors, either in its pure form or as converted into ammonia. The Hydrogen Council estimates that hydrogen production will increase eight to ten times by 2050, underscoring the critical importance of decarbonising hydrogen production.

Traditionally, hydrogen is produced through steam methane reforming using fossil-based feedstocks like natural gas, LPG, or naphtha. This type of hydrogen production without CO_2 capture is known as "grey hydrogen". To address this, one promising approach to decarbonise hydrogen production is through water electrolysis powered by renewable energy. The resulting hydrogen is completely green, leaving no CO_2 footprint throughout its production and use. Companies like Topsoe have successfully commercialised electrolysis solutions that can be used as standalone hydrogen units or in hybrid setups, combining them with traditional hydrogen production. However, a major challenge in deploying green hydrogen at a large scale is the limited availability of renewable power capacity.

To unlock the full potential of hydrogen in reducing CO_2 emissions, it is crucial to supplement green hydrogen with other clean hydrogen sources known as "low-carbon hydrogen" often referred to as "blue hydrogen." Low-carbon hydrogen can be produced by integrating traditional production methods with innovative clean technologies. This can involve revamping existing grey hydrogen plants or constructing new low-carbon hydrogen plants from scratch.

By decarbonising hydrogen production and exploring a range of clean hydrogen sources, we can fully harness the potential of hydrogen in the global energy transition, leading to significant reductions in CO_2 emissions. This article presents options to further optimise the existing low carbon hydrogen technology to increase natural gas efficiency, reduce cost and increase CO_2 capture even further.

SynCOR™ reforming

SynCOR™ reforming is an advanced autothermal reforming process, but unlike other ATR processes, SynCOR™ operates at a significantly lower steam-to-carbon ratio and takes place within a single reactor. In the SynCOR™ reactor, process gas enters and combines with oxygen and additional steam, undergoing combination of oxygen combustion and steam reforming simultaneously.

Among the various low-carbon intensity (CI) hydrogen technologies, the SynCOR™ process demonstrates the lowest opex. Its

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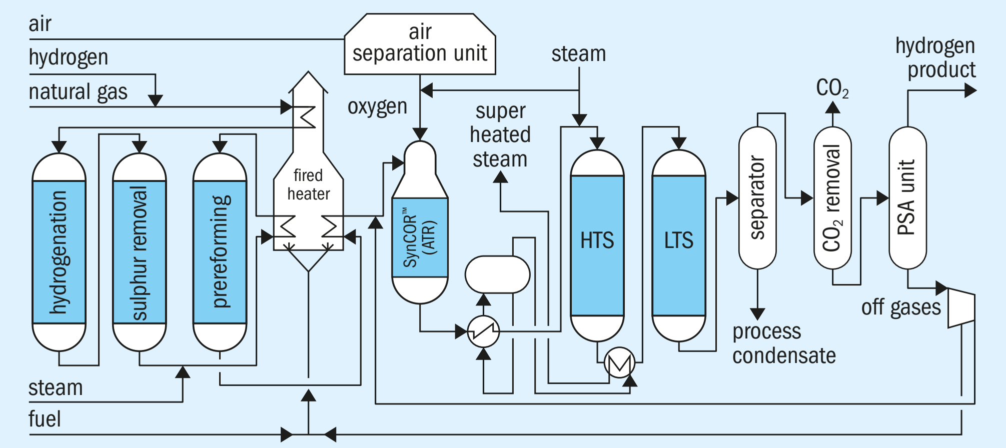
Fig. 1: **SynCOR™ layout for production of low-carbon intensity hydrogen**



Source: Topsoe

Table 1: **Key parameters for production of low-carbon fuel grade hydrogen with and without fired heaters**

Technology	SynCOR™ with fired heaters	SynCOR™ without fired heaters
Natural gas consumption, index	100	94
Oxygen consumption, index	100	104
CO_2 emitted, kg CO_2/kg H_2	0.60	0.53
Capex, index	100	97
Levelised cost of hydrogen, index	100	96

Source: Topsoe

steam-to-carbon ratio of 0.6 is 3-5 times less than SMR or conventional ATR systems, meaning smaller equipment and piping sizes, which is particularly advantageous at larger scales where standard size ranges can be maintained even at high capacities.

External fuel demand is exceptionally low, enabling a high carbon-recovery rate of over 99% inside the process plant without the need for capturing carbon in the flue gas. This makes SynCOR™ highly suitable for low-carbon hydrogen production, and for deployment in mega-scale plants.

Topsoe's SynCOR™ technology has undergone 70 years of development, with the first generation SynCOR™ (ATR) released in 1958. Subsequently, Topsoe has developed a second generation SynCOR, which operates at low S/C ratio. Since then, many large capacity plants have been set up using SynCOR™ for the different applications, such as GTL (gas-to-liquid), TIGAS™ (natural gas to gasoline), syngas. Topsoe SynCOR™ has gained over 300 years of cumulative operational experience, which makes it the most mature technology for low-carbon hydrogen and low-carbon ammonia projects. Currently, the largest operational SynCOR™ reactor produces 510 kNm³/hour of hydrogen, with a single-train capacity limit of 825 kNm³/hour.

Topsoe can integrate the hydrogen plant with numerous globally recognised CO_2 capture technologies to achieve the ultra low-carbon hydrogen at low cost of production.

SynCOR™ without fired heater

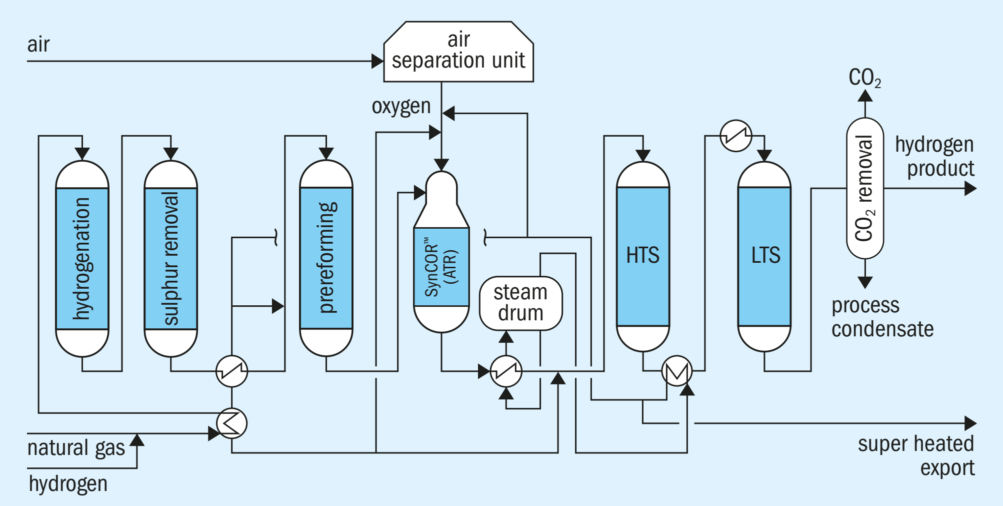
In some cases, the target product of a plant is fuel-grade hydrogen which may contain limited amounts of contaminants such as N_2, CO, and CH_4. As no final hydrogen purification is needed, this simplifies the overall process by avoiding the cost intensive PSA unit. On the other hand, no PSA off-gas is available as fuel for fired heaters. This fuel could then come from either imported natural gas or by increasing the size of the plant and use the product hydrogen as fuel.

An alternative is to avoid the use of fuel entirely by not including fired heaters in the process lineup. Such a process is illustrated schematically in Fig. 2. The required preheating for the individual units is carried out by using steam as the heating medium. All reactors can easily accept a wide range of feed temperatures.

The advantage of this layout is low capex and especially a higher efficiency and consequently a lower opex. Furthermore, essentially all CO_2 formed in the plant may be captured from the process gas as there are no flue gas emissions.

The product contains minor amounts of CO and CH_4 which will be converted into CO_2 when the fuel grade hydrogen is combusted. These carbon molecules in the product hydrogen are also considered as part of the CO_2 emission. In Table 1, a comparison of key parameters for a fuel grade hydrogen plant is provided with and without fired heaters for a case study for production of 200,000 Nm³/hr of fuel grade hydrogen. In both cases no PSA is used. The advantage of not including fired heaters in the plant is evident both from an opex and capex perspective. The oxygen consumption is as expected higher in the case without fired heaters due to the lower

Fig. 2: **SynCOR™ layout for production of fuel grade hydrogen without PSA and fired heaters. Essentially all CO_2 formed in the plant can be captured in this layout**



Source: Topsoe

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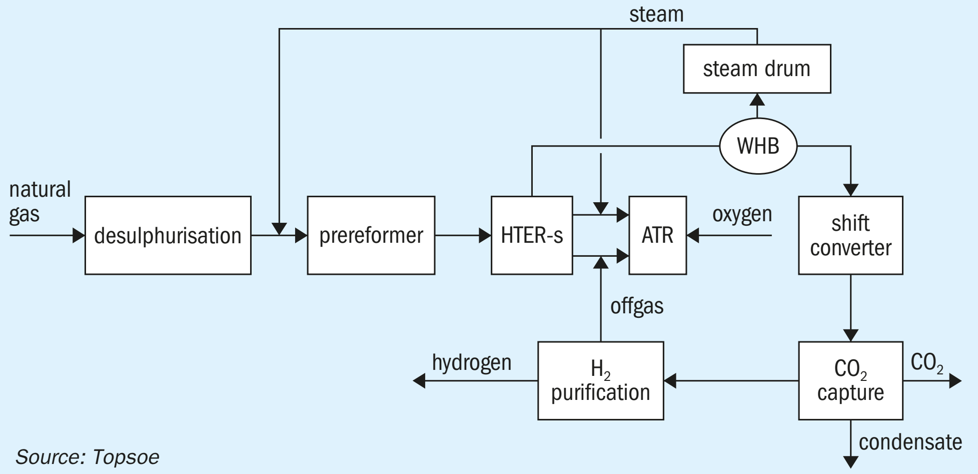
Fig. 3: SynCOR™ with a heat exchange reformer (HTER-s) layout for production of low-carbon intensity hydrogen production



Source: Topsoe

Table 2: Production of pure hydrogen with and without HTER-s

Technology	SynCOR™	SynCOR™ with HTER-s
Natural gas consumption, index	100	95.6
Oxygen consumption, index	100	88
CO_2 emitted, kg CO_2/kg H_2	0.08	0.05
Capex, index	100	99
Levelised cost of hydrogen, index	100	95

Source: Topsoe

preheat temperature to the SynCOR™ ATR reactor. However, in this case, this is more than offset by the reduced natural gas consumption and lower capex with a net result of a lower levelised cost of hydrogen.

SynCOR™ with HTER-s

The SynCOR™ for production of low-carbon hydrogen offers both low capex and opex as well as high utilisation of the feedstock with corresponding very low CO_2 emissions per unit of hydrogen produced. The SynCOR™ solution is already the technology with the highest reformer efficiency compared to market alternatives. However, building upon this platform, an alternative solution with an even higher efficiency has been developed by Topsoe.

The process solution is illustrated in Fig. 3. The scheme combines the SynCOR™ technology with a heat exchange reformer (HTER-s) upstream and in series with the autothermal reformer (ATR). The HTER-s has been developed utilising the basis of a number of other Topsoe heat exchange reformers which for decades have been in operation for example in hydrogen, synthesis gas and ammonia plants. These heat exchange reformers have been developed to operate at aggressive conditions to minimise capital and operating costs while still avoiding metal dusting. In a similar fashion, the novel HTER-s has been designed to operate at relatively low steam-to-carbon ratios compared to alternatives thus reducing the size and duty of the reactor. The new SynCOR™ solution with HTER-s also enables very high carbon recovery rates in excess of 99% inside hydrogen plant.

A comparison of the key parameters for a case of production of blue hydrogen with and without HTER-s is provided in Table 2.

Table 2 illustrates that the introduction of HTER-s enables even further optimisation of the SynCOR™ scheme for production of blue hydrogen. The efficiency is higher while the oxygen consumption, the CO_2 emissions, and the capex are all reduced. The net result is a reduction of the levelised cost of hydrogen from what is already a small number.

eREACT™ in low-carbon hydrogen production

Another approach is to use electrified reactor technology known as eREACT™ for steam methane reforming for example for production of low-carbon hydrogen. In this approach, the steam reforming reactions take place within a catalytic reactor heated by power preferable from renewable sources. This eliminates the need for hydrocarbon fuel as a heat source thus avoiding flue-gas emissions from the reformer. The energy density of the eREACT™ process allows for a significantly smaller reactor size compared to traditional SMR units. The eREACT™ process is mostly targeted towards low and moderate low-carbon hydrogen production at sites where adequate renewable power is available.

Almost all of the CO_2 formed in an eREACT™ based process can be economically recovered using a CO_2 removal unit. More than 99% of the CO_2 can be captured making eREACT™ an excellent choice for low-carbon hydrogen production in scenarios where electricity prices are favourable. The eREACT™ based process has been successfully demonstrated and is currently under commercialisation in a number of plants.

eREACT™ offers a significant advantage in energy efficiency, enabling a 30-40% reduction in natural gas consumption for hydrogen production compared to traditional SMR, which is achieved through the high efficiency of the eREACT™ technology. This makes eREACT™ a highly efficient electric reforming technology.

Conclusion

The SynCOR™ technology with the high single line capacity and carbon recovery in combination with the lowest opex and capex is unmatched by other solutions for production of low-carbon hydrogen. The proven track record with SynCOR™ at high capacities makes it an ideal choice for low-carbon intensity hydrogen production. Nevertheless, Topsoe has continued to develop and optimise solutions for decarbonisation at scale. The new technologies together with SynCOR™ will provide an even stronger suite of solutions for meeting different requirements in the market.

eREACT™ is pushing this innovation step even further, by taking a leap into electrification of low and moderate capacity low-carbon hydrogen production with the help of renewable power.

The new technologies have been presented for production of low-carbon hydrogen. However, all the described solutions are ideally suited also for production of synthesis gas for a range of fuels and chemicals synthesis such as ammonia and methanol. Many such plants based on SynCOR™ are in operation today at high capacities and the new solutions will also be employed to produce low-carbon methanol and ammonia.

CASALE

ROX® by Casale: Redefining low-carbon hydrogen production

As global initiatives to mitigate climate change intensify, hydrogen has emerged as a cornerstone of the transition to a low-carbon economy. Among the various hydrogen production methods, blue hydrogen – derived from hydrocarbon feedstocks with integrated carbon capture and storage (CCS) – has gained significant attention due to its potential to serve as a cleaner energy source while leveraging existing fossil fuel infrastructure.

The ROX® process

Casale, with over a century of experience in the design, licensing, and provision of proprietary equipment for syngas plants producing ammonia and methanol, has integrated its most advanced technologies into a cutting-edge flow scheme that addresses the stringent requirements of ultra-low-carbon blue hydrogen production for the energy transition:

- Casale's auto-thermal reforming (ATR) technology generates hydrogen through oxidative reforming, forming the cornerstone of the ROX® flow scheme.
- Technip Energies' Technip Parallel Reformer® (TPR) provides supplementary reforming, eliminating the need for external steam export by utilising recuperative reforming.

The combination of ATR and TPR technologies forms the foundation of the ROX® (Recuperative OXidative Reforming) scheme, offering a scalable solution with exceptional operational flexibility.

Key features and advantages

The ROX® scheme boasts a hydrogen production capacity of up to 600,000 Nm³/h (2 GW) in a single train and supports customisable carbon capture rates of up to 99%, achieving a carbon intensity of less than 0.1 kg CO_2 per kg of hydrogen (Scope 1).

The process can be tailored to meet each client's specific needs based on factors such as decarbonisation goals, feedstock availability, and operational requirements. By optimising design parameters, ROX® achieves the lowest possible levelised cost of hydrogen (LCOH).

Hydrogen and syngas generation

Hydrogen plays a pivotal role in refining and chemical processes. Steam methane reforming (SMR) has long been the dominant method for converting fossil feedstocks, such as natural gas and refinery fuel gases, into high-purity hydrogen at capacities ranging from a few thousand Nm³/h to over 250,000 Nm³/h.

When aiming to expand capacity and/or reduce carbon emissions, an ATR-based plant offers a superior solution, providing higher conversion efficiency and facilitating near-complete CO_2 capture. This technology is already widely used in various industrial applications, including ammonia and methanol production, gas-to-liquid processes (e.g., Fischer-Tropsch), and oxo-processes (e.g., hydroformylation). It is now gaining increased relevance due to the evolving targets driven by the need for energy transition.

Innovative process flow

Fig. 1 shows a schematic flow diagram of the ROX® process. The main steps are outlined below:

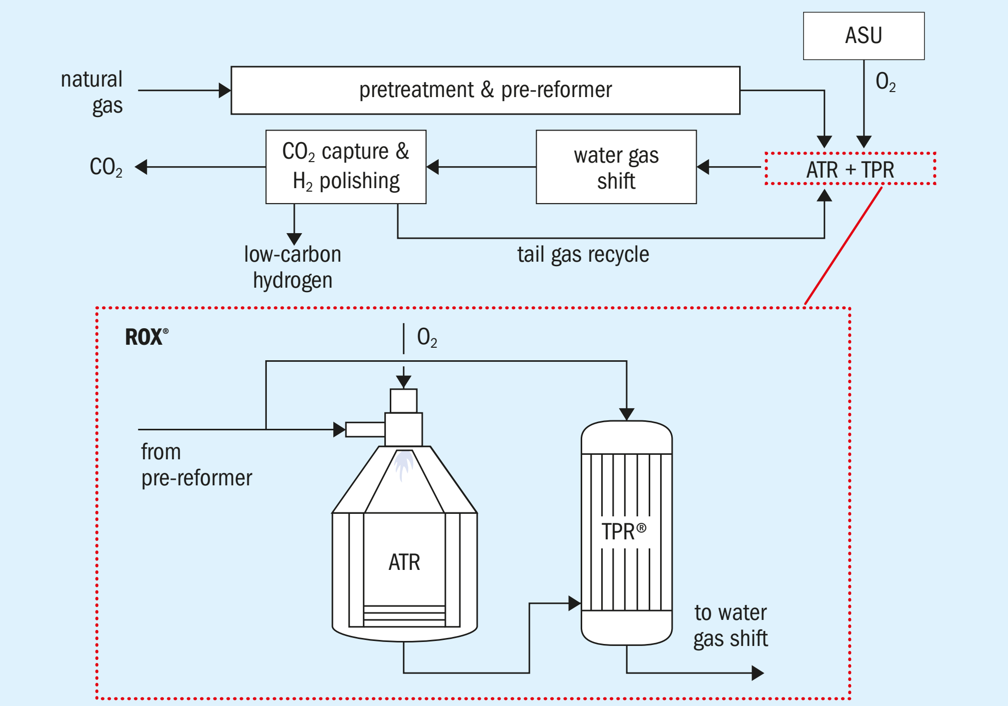
Feedstock preparation and pre-reforming

- Primary feedstocks, such as natural gas or higher hydrocarbons, undergo pretreatment to remove impurities (e.g., sulphur, chlorine, and mercury).
- The pretreated feed is introduced into a pre-reformer, where higher hydrocarbons are converted into methane. This stage enhances operational safety by minimising coking risks and allows for higher preheating temperatures, lower steam-to-carbon (S/C) ratios, and reduced oxygen consumption. The pre-reformer reactor with axial-radial design (Fig. 2) is one of the technologies available in Casale's portfolio and has 9 industrial references.

Reforming section

- The primary feed gas is preheated in a fired heater designed specifically for Casale's ATR process.
- In the ATR reactor, feed gas and oxygen are mixed in a turbulent diffusion flame, enabling optimal combustion and catalytic reforming. The proprietary water-cooled ATR burner ensures stable performance and extended equipment lifespan.
- The TPR reactor operates in parallel with the ATR, further reforming the gas and using heat recuperation to achieve efficient methane conversion and balanced steam generation.

Fig. 1: **ROX® schematic flow diagram**



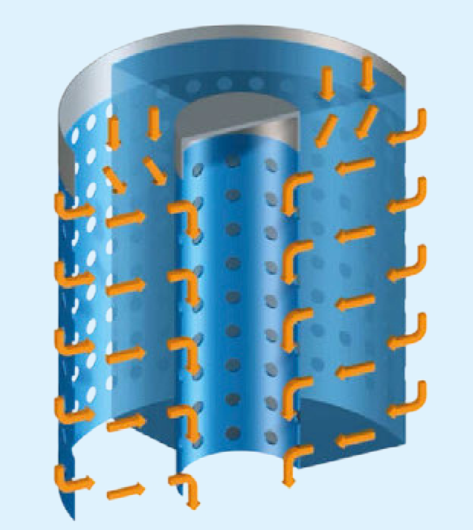
Source: Casale

Table 1: Performance comparison for a 590 MW HHV hydrogen plant

Metric	SMR*	SMR with CCU*	ATR	ROX®
Feed gas, MW HHV	730	800	721	666
Energy efficiency, HHV, %	80.5	73.8	81.8	88.5
CO_2 emitted, kt/year	1,185	427	15	15
CO_2 capture rate, %	0	67	98.7	98.6
Power consumed, MW	2.0	3.8	11.3	11.0
H_2 Scope 1 Carbon Intensity, kg CO_2/kg H_2	9.0	3.3	0.1	0.1

* *Source: IEAGHG Technical Report, Techno-Economic Evaluation of SMR Based Standalone (Merchant) Hydrogen Plant with CCS, February 2017*

Fig. 2: Casale unique axial radial design for pre-reformer and shift reactors



Source: Casale

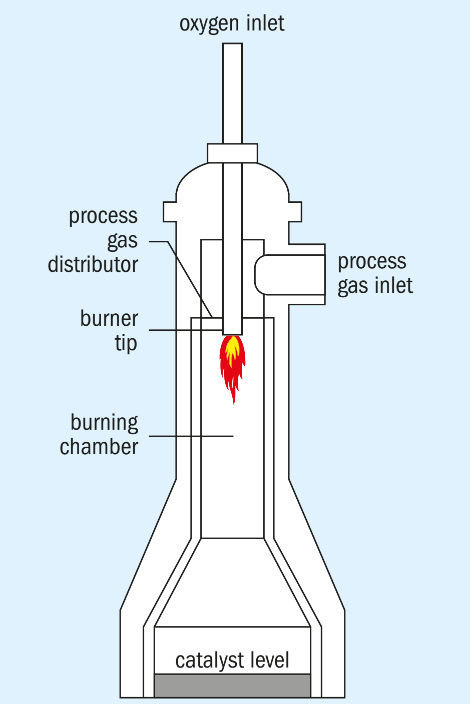
Shift conversion and CO_2 capture

- The syngas passes through high temperature shift (HTS) and low temperature shift (LTS) reactors to maximise hydrogen production. These technologies are available with Casale axial-radial flow path, with more than 40 reactors in operation.
- Heat recovery from exothermic reactions supports steam generation, while CO_2 is separated using amine-based absorption or cryogenic fractionation, depending on the plant's design and size.

Hydrogen purification

- The purified hydrogen stream, with a purity exceeding 99.9%, is ready for industrial applications. CO_2 captured during the process can be compressed and transported for sequestration or utilisation.

Fig. 3: Casale ATR



Source: Casale

Technical differentiators

Auto-thermal reforming (ATR)

Casale's ATR design incorporates a refractory-lined pressure vessel and proprietary water-cooled burners. The system ensures uniform temperature distribution, enhancing catalyst performance while mitigating thermal stresses (Fig. 3).

- Proven operation across 15 industrial plants with capacities ranging from 30,000 Nm³/h to 630,000 Nm³/h.
- Soot-free combustion and an advanced fluid dynamics design prevent refractory hot spots and maximise catalyst longevity.
- Patented water-cooled burner that assures solid performance, safe operation and a lifespan of more than ten years, as demonstrated in the industrial references (Fig. 4).

Performance benchmarks

Compared to traditional SMR and standalone ATR schemes, the ROX® flow scheme demonstrates significant efficiency improvements, as shown in Table 1 for a case study for a 590 MW HHV hydrogen plant.

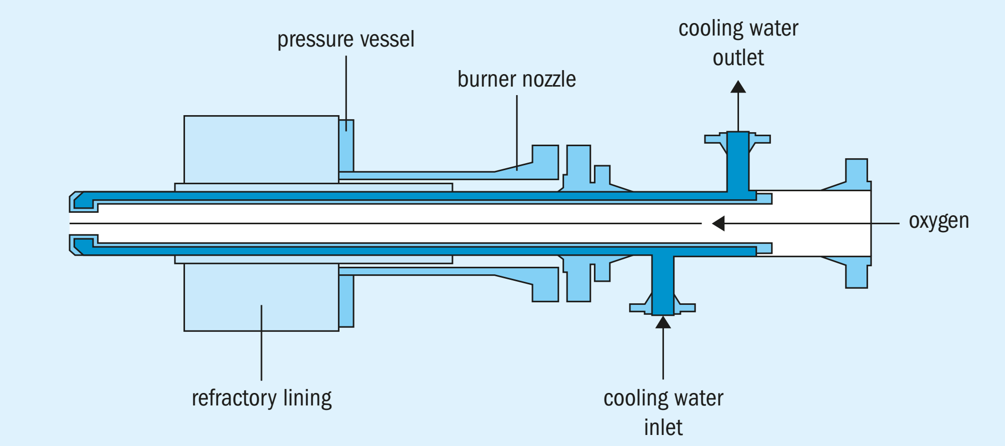
Key highlights:

- 25% reduction in oxygen demand compared to standalone ATR processes, lowering air separation unit (ASU) costs and power consumption;
- 6% feed gas savings;
- near-zero CO_2 emissions from flue gases, achieved through low-carbon fuel utilisation and PSA purge gas recycling.

Sustainability and scalability

The modular design of the ROX® process enables rapid deployment and seamless integration with renewable energy sources, further reducing carbon intensity. By combining proven technologies with innovative flow schemes, Casale delivers a robust solution for blue hydrogen production, supporting global decarbonisation goals. ■

Fig. 4: Casale water-cooled burner design



Source: Casale

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47 48 49 50 51 52 53 54 55 56 57 58 59 60

Advanced material solutions for urea production

The production of urea, a critical component in the fertilizer industry, involves highly corrosive environments, particularly in the high-pressure sections of the process. This necessitates the use of advanced materials that can withstand such aggressive conditions to ensure long life and efficiency of urea production plants. Alleima, Stamicarbon, Saipem and TOYO report on their advanced material and equipment solutions for the urea industry.

ALLEIMA

Advanced materials of construction for urea production

Oscar Öhlin & Daniel Gullberg

Alleima, a renowned manufacturer of advanced stainless steels and special alloys, has been at the forefront of developing corrosion-resistant alloys tailored for the urea industry since the 1970s. This article describes the key products developed by Alleima, their applications, and the benefits they offer to the urea production industry.

The corrosive challenge in urea production

Urea production involves the synthesis of ammonia and carbon dioxide under high pressure and temperature, resulting in a highly corrosive environment due to the presence of ammonium carbamate. Equipment failure due to corrosion can lead to costly downtime and maintenance, making the selection of appropriate materials crucial for ensuring the durability and efficiency of urea production plants.

Alleima's advanced material solutions

Alleima's extensive experience and broad portfolio of tailored material solutions for urea plants enable effective corrosion mitigation, regardless of process design and material preferences. The key products developed by Alleima for the urea industry include:

- Alleima® 3R60 Urea Grade (UNS S31603)
- Alleima® 2RE69 (UNS S31050)
- SAF™ 2906 (UNS S32906)
- Bimetallic Tubing (Alleima® 2RE69 with Zirconium 702)

The key products include both austenitic and duplex alloys that are extensively used in urea plants. The chemical composition of the alloys can be seen in Table 1.

Alleima® 3R60 Urea Grade (UNS S31603)

Alleima® 3R60 Urea Grade is an enhanced version of AISI 316L, characterised by higher purity and higher alloying content than standard 316L. These features make the microstructure of Alleima® 3R60 Urea Grade very austenite stable, preventing the formation of ferrite. As a result, the grade is highly resistant to both general and intergranular corrosion in the process solutions used in urea manufacturing.

In urea plants, Alleima® 3R60 Urea Grade is typically used for high-pressure piping or in equipment where the temperatures are relatively low. The grade requires passivation air to not actively corrode in the carbamate solution. Depending on the temperature, different corrosion rates can be expected.

Alleima® 2RE69 (UNS S31050)

Alleima® 2RE69 is an austenitic material specifically developed for use in the most severe conditions in urea plants. The grade is characterised by excellent corrosion resistance to ammonium carbamate and

Table 1: **Nominal alloy compositions, weight %**

Alloy	UNS Number	C	Si	Mn	P	S	Cr	Ni	Mo	N
Alleima® 3R60 Urea Grade	S31603	≤0.020	0.4	1.7	≤0.015	≤0.010	17.5	14	2.6	
Alleima® 2RE69	S31050	≤0.020	≤0.4	1.7	≤0.015	≤0.010	25	22	2.1	0.12
SAF™ 2906	S32906	≤0.030	0.3	1.0	≤0.030	≤0.015	29	7	2.3	0.35

Source: Alleima

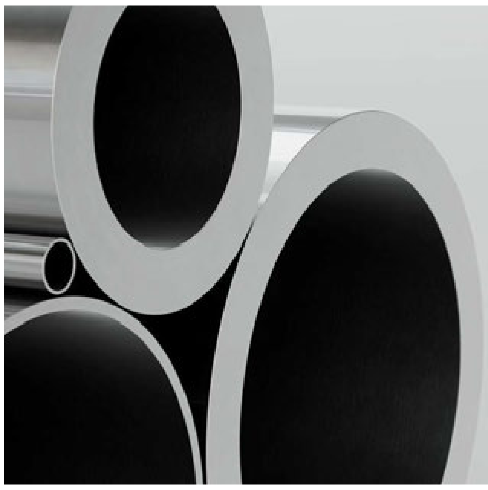


PHOTO: ALLEIMA

Fig. 1: Example of tubular products.

outstanding resistance to intergranular corrosion, owing to its well-balanced chemical composition. The grade has high purity with very low or zero ferrite content.

Alleima® 2RE69 can be used successfully in the high-pressure section of urea plants, where its use as stripper tubes, carbamate condenser tubes, and high-pressure piping is common, see Fig. 1. Despite the advantages of Alleima® 2RE69, it relies on passivation air and may be susceptible to stress corrosion cracking (SCC) if the boiler feed water or process steam contains chlorides. Nevertheless, Alleima® 2RE69 has a solid track record, with installations in the stripper section lasting for more than 35 years, confirming the grade's optimal properties.

SAF™ 2906 (UNS S32906)

SAF™ 2906 is an austenitic-ferritic stainless steel developed for use in the urea synthesis process. The grade has been optimised for superior corrosion resistance against carbamate solutions with low oxygen content, enhancing both plant safety and productivity.

SAF™ 2906 has excellent resistance to general corrosion, intergranular corrosion, pitting corrosion, and chloride-induced stress corrosion cracking (SCC). Its resistance to general corrosion makes SAF™ 2906 suitable for the construction of the high-pressure synthesis section of a urea plant, as it does not corrode actively in the carbamate solution, even with extremely low concentrations of oxygen in the system. Moreover, SAF™ 2906 is immune to condensation corrosion, which can be a problem for equipment constructed from 316 UG and 25-22-2 type materials.

The combination of outstanding corrosion resistance and high mechanical strength of SAF™ 2906 offers significant design advantages compared to Alleima® 2RE69 and Alleima® 3R60 Urea Grade, allowing equipment to be designed with thinner wall thicknesses. SAF™ 2906 can be used successfully in the high-pressure section of the urea plant for all components, including stripper tubes, condenser tubes, high-pressure piping, valves, and liner plates.

Bimetallic tubing (Alleima® 2RE69 with Zirconium 702)

In certain urea production processes, the conditions and design temperatures of the urea stripper can be particularly high, where neither Alleima® 2RE69 nor SAF™ 2906 can be used effectively due to increased corrosion rates. Under these conditions, reactive metals like zirconium or titanium are normally preferred to have acceptable corrosion rates. However, titanium is prone to erosion problems which can limit the lifetime of the urea stripper. Zirconium exhibits excellent corrosion properties in carbamate solutions. The drawback with zirconium is the high cost and low mechanical strength making a mono tube solution non-feasible for the high-pressure stripper in a urea plant.

Bimetallic tubing using a Zirconium 702 inner tube and Alleima® 2RE69 outer tube enables the use of zirconium where it is needed and is a well-proven concept for the HP strippers, see Fig. 2. The outer component in Alleima® 2RE69 provides the mechanical strength, and ease of vessel fabrication, with a stainless-steel cladded tube sheet and welding being pure stainless-to-stainless. The zirconium acts as a corrosion barrier and is only used where it is needed, as the tube inner layer, giving a cost-effective solution. The bimetallic tube is a premium solution for the most demanding environments.

Fig. 2: Alleima® 2RE69/Zr702 bimetallic tube for use in urea high pressure strippers.

Innovation and sustainability at Alleima

Alleima's origins date back to 1862 when the company was founded as Sandvikens Jernverk by Göran Fredrik Göransson, a pioneer in using the Bessemer method for steel production on an industrial scale. The manufacturing of stainless steel began in 1921, and in 1924, the first seamless stainless-steel tubes were introduced to the market, marking the beginning of Alleima's journey.

Today, Alleima is a leading manufacturer and developer of high value-added products in advanced stainless steels and special alloys. The company's product offerings cover a wide range of industries and applications, including seamless tubes and products in advanced stainless steels, industrial heating elements and heating systems, wire for medical devices, as well as a wide range of strip steel and strip-based products. Innovation is key to Alleima's success, with a portfolio of over 900 active alloy compositions and more than 850 patents.

Alleima's fully integrated value chain, from R&D to end-product, ensures industry-leading technology, quality, sustainability, and circularity. For example, Alleima's stainless steel contains 80% recycled steel and uses fossil-free energy sources. The company is also investing a large and increasing share of its strategic R&D budget in the green transition and is committed to the UN Sustainability Goals (SDGs) and Science Based Targets initiative (SBTi).

The urea production industry faces significant challenges due to the highly corrosive nature of the process environment. Alleima's extensive experience and broad portfolio of tailored material solutions for urea plants enable effective corrosion mitigation, ensuring the longevity and efficiency of urea production plants. By staying at the forefront of material science, Alleima aims to support the urea industry in achieving higher efficiency, safety, and sustainability in its operations. The company's ongoing investments in research and development, coupled with its dedication to quality and customer satisfaction, position Alleima well to address future challenges and opportunities in the industry.

STAMICARBON

Advanced materials and equipment for fertilizer production

Stamicarbon, the nitrogen technology licensor of NEXTCHEM (MAIRE Group), has a long history of innovation with the application of technology in mind. These applications have often required experience with and expertise in materials. Reliability has always been an important value for Stamicarbon as it is applied to equipment supply, communication, and actions. As the company ventured into different technologies, such as ammonia and nitrates, new equipment based on different applications and varied materials was needed, but with the reliability and expertise of Stamicarbon.

Stamicarbon continuously enhances its material and high-pressure equipment portfolio to meet the evolving demands of modern fertilizer production, ensuring unmatched performance throughout a plant's lifecycle. For grassroots plants or revamp projects, regardless of the plant licensor, Stamicarbon sets the standard for advanced materials and equipment, ensuring efficient, reliable operations with minimal environmental impact.

The super duplex revolution

The urea production process operates under extreme conditions of high temperature and pressure, requiring the condensation of ammonium carbamate as an intermediate compound. This leads to highly corrosive circumstances unless proper alloys are applied and passivating conditions are created. Addressing these challenges requires advanced materials and high-quality equipment capable of withstanding such aggressive environments while delivering long-term reliability and efficiency.

In the 1990s, Stamicarbon, in partnership with Sandvik (now Alleima), revolutionised urea equipment production materials with the development of Safurex®, a proprietary super duplex stainless steel. Safurex® was specifically designed to eliminate corrosion in fertilizer plants, effectively resisting active ammonium carbamate corrosion, chloride-induced stress corrosion cracking, and other challenges unique to high-pressure urea synthesis equipment.

The super duplex steel, now offered as E-type material, provides a wide range of advantages that make it an indispensable material in urea synthesis. It provides exceptional resistance to key types of corrosion, ensuring durability and reliability in aggressive chemical environments. Its independence from passivation air simplifies plant operations, reducing block-in length, operational complexity, costs, and risks. With improved mechanical properties and superior weldability, E-type steel enhances durability while minimising the risk of structural failures.

Thanks to its superior strength compared to conventionally used materials, less material is needed for the same functionality. The consequently reduced weight facilitates not only savings but also easier handling and installation, while its durability significantly minimises the need for frequent inspections and maintenance, leading to substantial operational cost savings. It has also demonstrated exceptional reliability, with over 2 million combined on-stream hours achieved without a single tube rupture, proving its capability to ensure safe and uninterrupted performance.

Stamicarbon equipment material extends the lifespan of equipment, improves overall plant process performance, and offers higher operational flexibility. This includes the ability to withstand extended block-in times and resilience to upset conditions, making it a versatile and robust solution for demanding urea production environments. Additionally, Stamicarbon's collaboration with specialist steel mills has allowed for continuous material innovations, including the development of tailor-made chemical compositions to

Fig. 1: Pool Reactor (NX STAMI Urea™) made with Stamicarbon's E-type super duplex stainless steel.

meet specific challenges in urea synthesis, ensuring superior corrosion resistance and mechanical performance.

Tailored solutions for every application

Urea production demands materials that combine durability and ease of maintenance. Stamicarbon addresses these needs with advanced materials that eliminate the need for passivation air, simplifying operations and reducing complexity.

As Stamicarbon's business has expanded beyond urea in recent years, the need for different materials for different applications has increased. That's why Stamicarbon Equipment, SEQ, has been introduced. It brings together the innovation expertise, material knowledge and materials categorised into three classes based on their application within the nitrogen fertilizer industry:

- U-Class: Designed for urea applications, with particular tailoring to high temperature/pressure and corrosive environments, such as in urea synthesis equipment.
- A-Class: Tailored for ammonia applications, with particular tailoring to high temperature and embrittling environments, such as in ammonia converters.
- N-Class: Developed for nitrate applications, with particular tailoring to corrosive environments.

This diversity allows Stamicarbon to offer highly specific solutions that align with the unique requirements of different processes, further enhancing the efficiency and reliability of fertilizer production facilities.

Proprietary equipment

The market increasingly demands innovative solutions to reduce operational expenses, energy consumption, and emissions. By leveraging decades of expertise, Stamicarbon offers clients reliable, high-performance equipment tailored to specific applications using various specialised materials classes.

Stamicarbon combines advanced materials know-how with unparalleled expertise to deliver high-quality proprietary equipment for urea production, including:

- High-pressure strippers – efficiently recovering ammonia and carbon dioxide while maintaining exceptional durability.
- High-pressure carbamate condensers – designed for energy-efficient heat exchange.
- Urea reactors (Fig. 1) – featuring high-efficiency trays and U-Class steel internals for maximum conversion efficiency.
- High-pressure piping and valves – engineered for reliability in extreme operating conditions.
- Liquid dividers and mixing tees – optimised for uniform performance and reduced operational complexity.

Stamicarbon maintains a solid span of control over its supply chain, working with top-tier fabricators. With thorough supply chain monitoring and quality checks at every critical stage, Stamicarbon ensures that each piece of equipment meets the highest standards. This approach ensures the quality and availability of critical equipment and spare parts made from proprietary U-class super duplex stainless steel. Moreover, the extension of Stamicarbon's supplier base provides clients with maximum flexibility and access to multiple sources of qualified and reliable suppliers, ensuring optimal solutions for every need.

Stamicarbon's materials have been successfully installed in numerous urea plants worldwide. The equipment has consistently demonstrated unmatched reliability, helping operators achieve long-term efficiency while reducing maintenance requirements.

Full life cycle support

Stamicarbon's full life cycle support offered to fertilizer producers includes plant troubleshooting and equipment inspections required to ensure that customers' equipment remains in optimal condition and performs reliably. These inspections can help detect issues like stress corrosion cracking and condensation, allowing for timely recommendations for repairs, operational adjustments, and procedural improvements. Accurate forecasting of equipment longevity and maintenance needs further ensures seamless operation and minimises unexpected downtimes.

In addition, to address unexpected emergencies like unplanned shutdowns, Stamicarbon provides 24/7 support through its dedicated emergency response team, ready to react immediately and ensure the plant's operations remain safe and uninterrupted.

By incorporating these advanced reliability measures, Stamicarbon not only addresses current operational challenges but also establishes a solid foundation for long-term sustainable, high-efficiency performance across the lifecycle of its equipment.

Recent cases

Stamicarbon's proprietary equipment made with Safurex® super duplex steel has been integral to most of its urea projects, demonstrating customers' trust in its reliability and efficiency in urea production. Some of the recent applications include:

- North America: An urgent relining of a urea reactor was completed using super duplex steel, marking the first full reactor relining from zirconium to this advanced material.
- China: For the Ultra-Low Energy urea plant of Jiangsu Huachang Chemical Company, the customer has selected high-pressure equipment made of super duplex stainless steel. Stamicarbon will design and supply this proprietary equipment, enhancing the plant's energy efficiency and operational reliability.
- Sub-Saharan Africa: A world-scale integrated ammonia and urea complex will utilise super duplex steel for high-pressure equipment, with Stamicarbon set to supply these components for the plant.
- Egypt: A state-of-the-art urea melt and granulation plant for El-Nasr Company for Intermediate Chemicals will feature high-pressure equipment made of super duplex stainless steel. Stamicarbon will design and deliver this equipment to ensure superior reliability and operational efficiency.

These cases highlight the versatility and reliability of super duplex steel, chosen by customers for its unmatched performance in diverse projects.

Driving the future of urea production

Stamicarbon's expertise in material science and equipment design underscores its commitment to advancing the fertilizer industry. By combining innovative materials with decades of engineering experience, the company delivers solutions with Stamicarbon Equipment that enhance safety, performance, and sustainability for fertilizer producers worldwide. ■

SAIPEM

SATURN31™ - the new material for urea applications from Saipem and Tubacex

Saipem is a global leader in the engineering and construction of major projects for the energy and infrastructure sectors, both offshore and onshore. As such Saipem is committed to supporting its clients on the energy transition pathway towards net zero, with increasingly digital means, technologies and processes geared for environmental sustainability.

As licensor of its Snamprogetti™ Urea Technology, Saipem offers its clients state of the art services aimed at prolonging equipment life and improving performances and product quality.

The urea environment is one of the most challenging for materials due to the severe operating conditions to which they are exposed. In the Snamprogetti™ urea process, the high-pressure section due to the operating temperatures, pressures and relatively high content of carbon dioxide faces the most critical conditions.

To cope with these demanding conditions, Saipem provides end users with state-of-the-art high-pressure equipment. Initially, Saipem's focus has been on ensuring proper manufacturing through stringent quality controls, reviews, and qualifications. In this phase AISI 316L UG and 25/22/2 Cr/Ni/Mo, materials readily available on the market, were selected as they ensured satisfactory performance. In particular, non-ferrous materials such as titanium and zirconium, were also applied for the urea stripper thanks to their strong resistance to corrosion phenomena at even harsher operating conditions.

PHOTO: SAIPEM AND TUBACEX

Fig. 1: Microstructure of SATURN31™

Having set the foundations for manufacturing quality, the following step was the development of SATURN31™ a new material with higher performances. Tubacex, fostering the development of advanced materials capable of significantly improving energy efficiency and of operating in the most demanding corrosion and pressure environments, was selected as the ideal partner.

SATURN31™

The development of SATURN31™ was dealt with a multi-optimum approach due to the need to simultaneously satisfy corrosion, manufacturing and constructability requirements.

The new material had to have better corrosion resistance than 25/22/2 Cr/Ni/Mo, and consequently of AISI 316L UG, with lower corrosion rates even in absence of oxygen; the intent being the minimisation of the overall quantity of air circulating in the urea unit and avoiding the need of a dedicated feed of oxygen to the stripper bottom.

To grant smooth manufacturing activities, the new material was required to have excellent weldability and machining properties, thus ensuring the quality of high-pressure equipment so far achieved. In addition, better mechanical properties than those of the materials available on the market were also looked for to allow a reduction of the overall weight laying on structures and foundations.

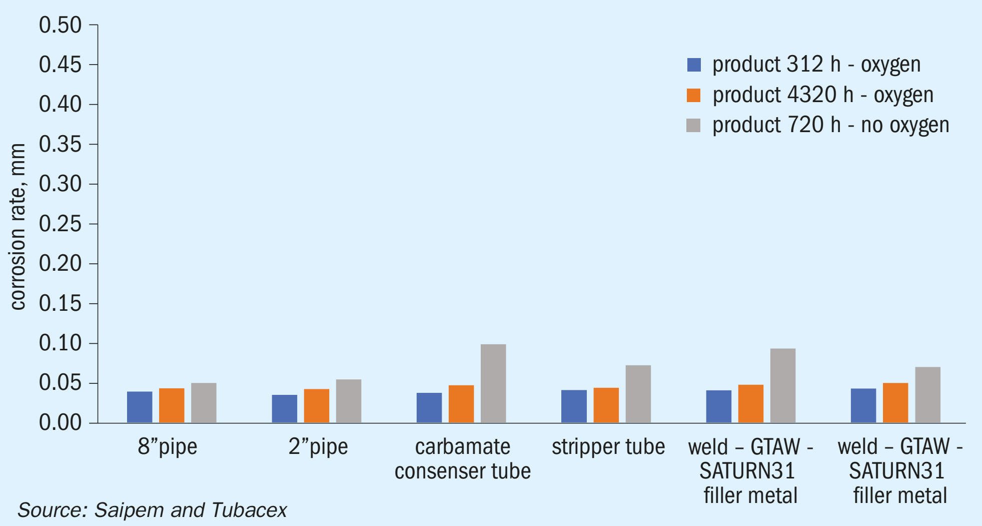
Having the goal to achieve different simultaneous optimums, the development started from numerical simulations to identify the most promising options in terms of chemical composition which were then tested by means of laboratory heats; industrial heats were then performed on the composition finally selected.

The new highly alloyed super duplex steel, SATURN31™, has high chromium and nitrogen contents and moderate additions of molybdenum, tungsten, and cobalt. The well-balanced chemical composition and an optimum solution annealing treatment ensure a final microstructure having a homogeneous distribution of austenite and ferrite bands free from intermetallic phases and precipitates (Fig. 1). This combination of alloying elements has excellent resistance to urea solutions with or without oxygen and, furthermore, guarantees a very high resistance to localised corrosion, such as pitting and crevice corrosion.

Corrosion properties

The corrosion resistance of SATURN31™ at high temperature and in a solution even more aggressive than that of the urea stripper bottom has been studied by immersion

Fig. 2: **Corrosion rates of SATURN31™**



Source: Saipem and Tubacex

tests in an autoclave. Corrosion tests have also been performed on samples installed in industrial strippers.

SATURN31™ has shown outstanding corrosion resistance in both the presence and absence of oxygen (see Fig. 2).

Mechanical properties

SATURN31™ possesses very high mechanical strength (Fig.3). Having a yield strength of double that of AISI 316L UG and 25/22/2 Cr/Ni/Mo materials, significant reductions in pipe and tube thicknesses can be foreseen with beneficial impacts on equipment and bulk weight and on the total cost of the plant. The ductility of SATURN31™ is also high, making the new super duplex steel readily formable through fabrication processes such as bending or expansion.

Welding

The weldability of the new highly alloyed super duplex steel has also been tested: in urea environments, also in the welds, high mechanical properties and excellent corrosion resistance are achieved.

Trials have also been successfully conducted to assess the weldability of SATURN31™ with 25/22/2 Cr/Ni/Mo, confirming the possibility to combine the two materials; this could be useful, for example, in case of re-lining interventions on high pressure equipment.

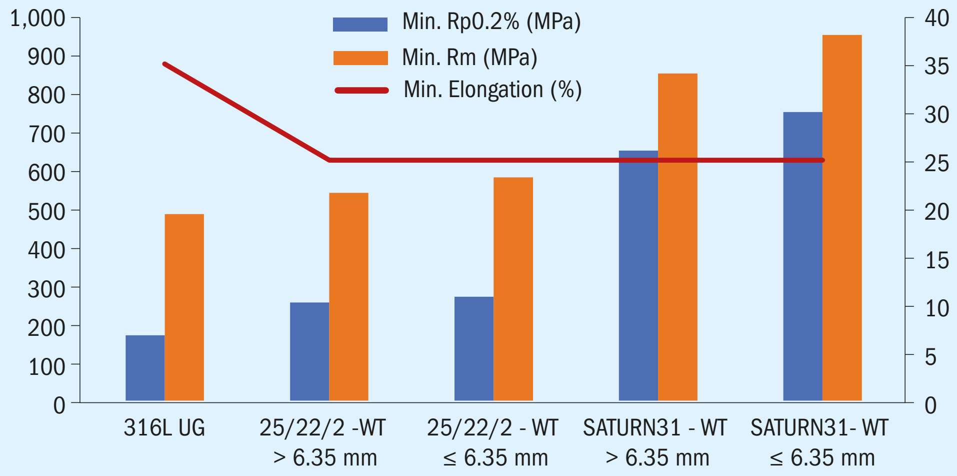
Updates on SATURN31™

After its official presentation in 2022, SATURN31™ has been adopted as a material of construction for the internals of high-pressure equipment. A few sets of urea stripper ferrules (Fig. 4) have been installed as first industrial applications. Considering the accurate and delicate design of this kind of internal, these have been workshop trials confirming its excellent machining and weldability properties.

Next to come are high pressure equipment linings and other internals, for which SATURN31™, thanks to its characteristics opens up new possibilities to achieve better operating performances.

With the completion of ASME code certification, SATURN31™ will also be used in the manufacturing of pressure parts, such as tubing for urea strippers and carbamate condensers, piping and relevant fittings.

Fig. 3: Mechanical properties of SATURN31™ compared to 316L UG and 25/22/2 Cr/Ni/Mo



Source: Saipem and Tubacex

PHOTO: SAIPEM AND TUBACEX

Fig. 4: Urea stripper ferrules in SATURN31™.

Conclusions

SATURN31™, the new material for urea applications by Saipem and Tubacex, has been developed to ensure high corrosion resistance, mechanical strength and weldability. After comprehensive tests, SATURN31™ has demonstrated excellent qualities under all the above aspects, resulting in an ideal material for the aggressive environment of the urea high pressure section granting longer equipment life.

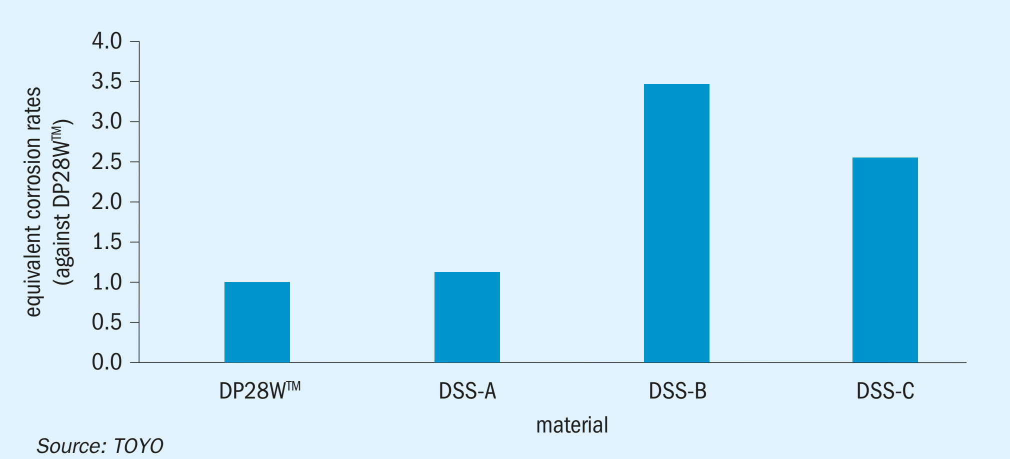
Following the first industrial application of SATURN31™ in urea stripper ferrules, the next application will be as a liner material and for the fabrication of other internals of high-pressure equipment such as SuperCups.
Following ASME code certification, SATURN31™ will also be used in the manufacturing of pressure resistant components for equipment and piping. This step will open the way to design and manufacture the complete range of high-pressure equipment in SATURN31™. ■

TOYO ENGINEERING CORPORATION

Latest advancements in duplex stainless steels for TOYO urea plants

Toyo Engineering Corporation (TOYO) has been using duplex stainless steels (DSSs) for high pressure synthesis equipment of urea CO_2 stripping process since the early 1980s. DP28W™, a DSS developed based on years of accumulated knowledge, has demonstrated excellent corrosion resistance through its successful track record. This article discusses the performance of DP28W™ in a commercial urea plant, along with the latest process, ACES21-LP™, from the perspective of corrosion resistance.

Fig. 1: Equivalent corrosion rates in a urea reactor (ACES21™)



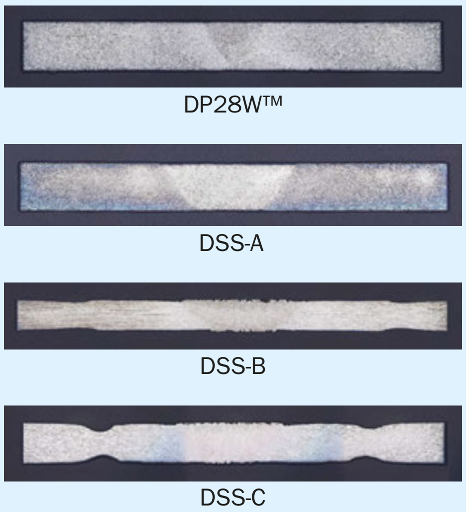
Source: TOYO

Three-year immersion test at one of TOYO's urea plants

The use of advanced materials possessing high corrosion resistance in a urea environment is especially important to enhance the long-term reliability of facilities in a urea plant. The corrosion resistance of welded joints is degraded, especially in the heat affected zone (HAZ), compared with base metal due to the formation of harmful precipitations from welding heat input.

DP28W™, developed specially for urea plant applications, has an optimised chemical composition considering the effects of heat input in welding to ensure excellent corrosion resistance of welded joints. To compare the corrosion resistance of DP28W™ with various commercial grades of 25Cr DSSs (DSS-A, DSS-B, DSS-C), an immersion test was carried out in a commercial urea plant over three years. Welded test coupons of those DSS were mounted in the top and bottom sections of the ACES21™ urea reactor.

Fig. 2: Macroscopic observation



Source: TOYO

Fig. 1 shows the equivalent corrosion rates of those test coupons against DP28W™ and Fig. 2 shows macroscopic photos of those cross-sections. Equivalent corrosion rates of DSS-A, DSS-B, and DSS-C were higher than 1, indicating that the corrosion resistance of DP28W™ is superior to the other DSS.

Macroscopic photos of the cross-sections showed that no remarkable corrosion was observed at the HAZ of DP28W™. DSS-B showed significant corrosion in both base metal and weld metal.

The corrosion resistance of DSS-C base metal was better than that of DSS-B, but significant localised corrosion was observed at the HAZ. DSS-A shows good corrosion resistance both in the base metal and the HAZ.

As mentioned above, there is considerable variation in the corrosion resistance of 25Cr DSS including its welded joints even with a similar chemical composition. This suggests that the selected grade, in this case DSS-A, can be used in urea carbamate solution depending on the corrosiveness of the environment.

TOYO and Nippon Steel Corporation are jointly developing a new grade of DP28W™ with the aim of further improving the corrosion resistance at the HAZ by optimising the alloying elements and by applying strict microstructural control in the manufacturing process. This will contribute to improved reliability of facilities in urea plants.

Material selection concept for TOYO's latest ACES21-LP™ process

ACES21-LP™, TOYO's new generation urea process, has enhanced features such as lowest synthesis pressure, highest CO_2 conversion, further energy savings, and lighter weight of high-pressure equipment in the synthesis section[1]. The amount of passivation air introduced into the CO_2 has also been reduced. This requires the risk of active corrosion under such severe conditions to be accurately determined and the appropriate materials to be selected accordingly.

The dissolved oxygen concentration in the urea carbamate solution is at its lowest in the stripper and the operating temperature is at its highest in the synthesis section. Therefore, the stripper has the most corrosive environment in this section. The stripper outlet gas stream is also expected to be extremely corrosive in case it is condensed.

For this reason, it is necessary to select materials with superior passivation properties, specifically DSSs instead of austenitic stainless steels. DP28W™ which has excellent corrosion resistance and is easily passivated even with less dissolved oxygen in ammonium carbamate solution, and is considered the first choice among DSSs.

As previously reported[2], TOYO has promoted the application of online corrosion monitoring, called AOCM™ (advanced online corrosion monitoring), in urea plants. TOYO is considering the application of AOCM™ in the synthesis section of ACES21-LP™

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PHOTOS: TOYO

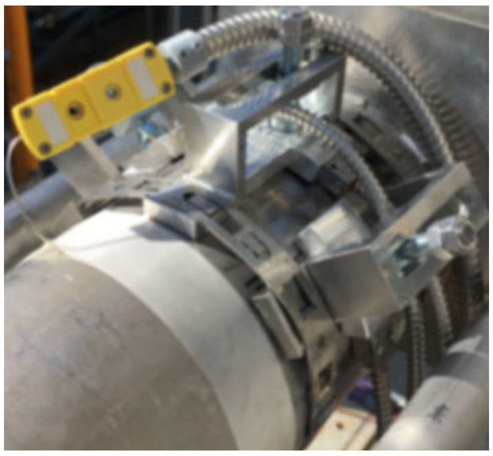


Fig. 3: AOCM™ system.

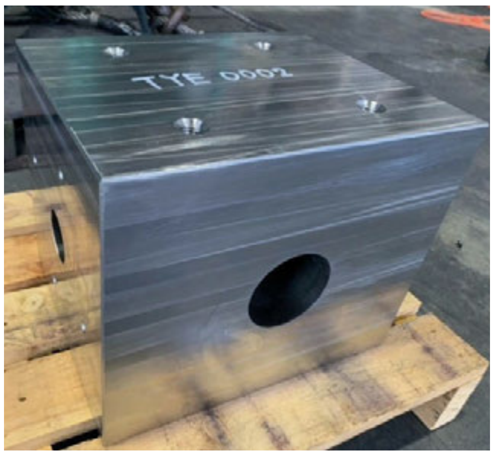


Fig. 4: 12 inch valve body made of 25Cr DSS.

to further improve the long-term reliability of the equipment as well as the selection of appropriate materials according to the corrosive environment.

In fact, the application of AOCM™ has already begun in an existing commercial urea plant. As shown in Fig. 3, the wall thickness of a DSS pipe is continuously measured online. It has been demonstrated from the data on the wall thickness that the measurement accuracy of AOCM™ is sufficient for corrosion risk assessment. ACES21-LP™ can be realised without the risk of unexpected severe corrosion through optimising material selection in combination with using AOCM™.

A more competitive and economical design

The addition of chromium is essential to enhance the corrosion resistance of stainless steels used in urea carbamate solution but it also promotes the precipitation of harmful phases and worsens workability in hot working. In DSSs, the tendency is accelerated when the chromium content is higher than 25%. Especially for large size components, such as thick piping or valves, difficulty in temperature control to avoid precipitation and poor workability lead to low yield rate of products, which results in a higher unit price. Among high chromium DSSs, such negative effects are minimised for DP28W™ by the addition of tungsten instead of molybdenum which keeps its excellent corrosion resistance.

Meanwhile, as a competitive and economical option, TOYO is developing a 25Cr DSS for large components (see Fig. 4), which shows less precipitation and good workability. ■

References

1. Yanagawa T.: "Toyo's new urea process"ACES21-LP" provides great benefits to urea plant owners in cost and energy savings", Nitrogen+Syngas 2023, Barcelona (Mar 2023).
2. Ideguchi Y, Takahashi M.: "Superior mechanical reliability of urea plants through post-EPC assistance", Nitrogen+Syngas 2023, Barcelona (Mar 2023).

Digital solutions driving e-methanol market growth

Toyo Engineering Corporation has developed two new digital solutions, MethaMaster™ and MethaDynamics™, which enhance the operational efficiency of e-methanol production from variable renewable energy.

Toyo Engineering Corporation (TOYO), a global leading engineering contractor, has developed two digital solutions: MethaMaster™ and MethaDynamics™. Both tools assist TOYO's proprietary g-Methanol™ process in producing e-methanol at different phases: the design phase and the operational phase, respectively. Both are based on dynamic simulators that simulate the hourly results of e-methanol production using variable renewable energy (VRE).

The variability of energy source is a challenge for plant capacity design as well as for planning daily production. MethaMaster™ is used in the design phase to offer optimum capacity design. MethaDynamics™ is used in the operational phase for production planning to maximise e-methanol production and for automatic operation of the g-Methanol™ plant, even when utilising VRE.

By combining these two new digital solutions with the g-Methanol™ process to address the new challenges of VRE, TOYO provides seamless support from licensing to operational assistance (Fig.1).

The g-Methanol™ process

TOYO's unique MRF-Z™ reactor is the core of its g-Methanol™ process. The MRF-Z™ reactor was originally designed for natural gas-based conventional methanol. With decades of experience as an EPC and licensing business, TOYO is now applying its experience in conventional methanol for the transformation to e-methanol production technology, using its g-Methanol™ process. Fig. 2 summarises the main step developments of TOYO's methanol technology.

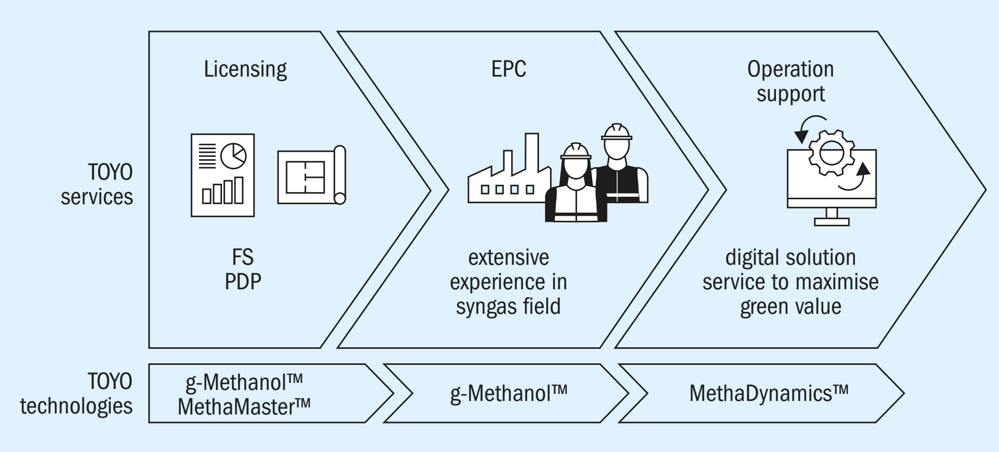
The MRF-Z™ reactor design has the following advantages[1]:

- reaction heat is recovered as medium pressure steam;
- a high heat transfer coefficient between the syngas and the cooling tube;
- maximises the methanol production per unit volume of catalyst;
- simple removal of catalyst saves time and manpower.

The MRF-Z™ reactor suits exothermic methanol synthesis due to its adaptable surface area and temperature control. Its features align well with e-methanol catalyst limitations: shorter lifetime due to by-product water and more frequent replacement.

As reference of the g-Methanol™ process, a 10 t/d e-methanol production plant is currently being prepared for operation in India.

Fig. 1: **TOYO's services and technologies for e-methanol**



Source: TOYO

MethaMaster™

Basic concept

MethaMaster™ offers the optimum configuration and design capacity of the g-Methanol™ plant including the electrolyser, battery and hydrogen storage as parameters of hourly dynamic simulation. Based on an hourly profile of VRE, hundreds of cases of configurations with different design capacities are simulated in a short time. The core of MethaMaster™ is its algorithm that maximises e-methanol production by utilising as much electricity as possible. Detailed examples of outputs include the operational load of the g-Methanol™ plant, the pressure of hydrogen storage, shutdown frequency, excess energy and more.

The basic model configuration of the g-Methanol™ plant in MethaMaster™ is

Fig. 2: **History of TOYO's step development in methanol technology**[1]

Source: TOYO

shown in Fig. 3. Based on customer's project constraints, the configuration, capacity range and other parameters are given.

Challenges in the design phase

Due to the fluctuating nature of VRE, batteries or hydrogen storage is required to store electricity or hydrogen when RE generation is insufficient for operation. To maintain the stable operations preferred in conventional plant management, drastic operational load change is undesirable, and situations that could lead to plant shutdown should be avoided. Therefore, setting the capacity of buffer facilities is extremely important. MethaMaster™ allows for the determination of appropriate buffer facilities size based on fluctuations.

The operational load of the g-Methanol™ plant is decided hourly depending on the remaining hydrogen storage to avoid shutdown. Too large storage is not appropriate due to the increase of capital cost, but too small storage cannot store enough hydrogen to avoid shutdown. The trade-off is analysed from the results simulated by many cases of dynamic simulation using MethaMaster™.

Output

MethaMaster™ outputs are listed below:

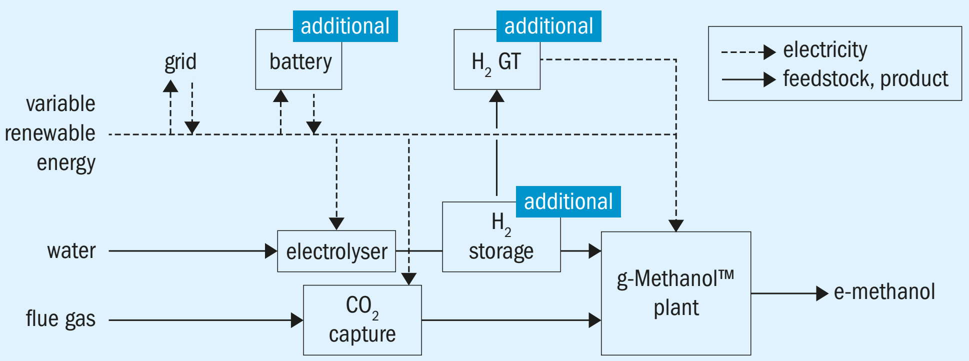
- hourly g-Methanol™ plant operational load (%);
- hourly pressure in hydrogen storage (barA);
- total shut down frequency and time for a year;
- electricity consumption (kW);
- excess energy: electricity which is not used (kW);
- capex (USD);
- opex (USD).

Those data are used in the calculation of the levelized cost of methanol (LCOM). The best configuration is selected mainly based on the result of production and the LCOM.

Levelised cost of methanol (LCOM)

MethaMaster™ is not only the tool for plant capacity design but also for economics. Based on the results of dynamic simulation, capex, opex and e-methanol production are calculated (equation 1). LCOM represents the production cost of e-Methanol, levelised by annual production adjusted for discount rate.

Fig. 3: **MethaMaster™ model configuration**



Source: TOYO

$$LCOM = \frac{capex + \sum_{t=1}^{n} \frac{opex_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{P_t}{(1+r)^t}}$$

(equation 1)

t = operational year *r = discount rate*
P_t = e-methanol production (t/d)

As MethaMaster™ can calculate capex and opex at any given capacity parameter, e-methanol plant lifetime cost can be estimated. A typical case of e-methanol plant lifetime cost break down is shown in Fig. 4. In this case, electricity cost is separated from the opex. Electricity cost and electrolyser capex account for the majority of the total cost. Hence, reducing both costs are key to reduce LCOM.

MethaDynamics™

Basic concept

MethaDynamics™ is a highly advanced digital solution meticulously designed to offer comprehensive operational support throughout the entire operational phase of e-methanol production. MethaDynamics™ assists users in achieving optimal operational efficiency by utilising its sophisticated operation support system. This system is specifically tailored to handle the intricate complexities associated with e-methanol production, especially under the VRE.

By taking into account predetermined facility capacities, the current status of the plant, forecasts for renewable energy availability, and e-methanol shipping schedules, MethaDynamics™ is capable of automatically generating the most efficient production plans. These plans are then seamlessly communicated to the control systems of each facility, ensuring that the execution is smooth and uninterrupted. This comprehensive approach ensures that all aspects of the production process are optimised, leading to enhanced efficiency and reliability in e-methanol production.

A sample operation plan created by MethaDynamics™ is shown in Fig. 5.

Complex operations under VRE

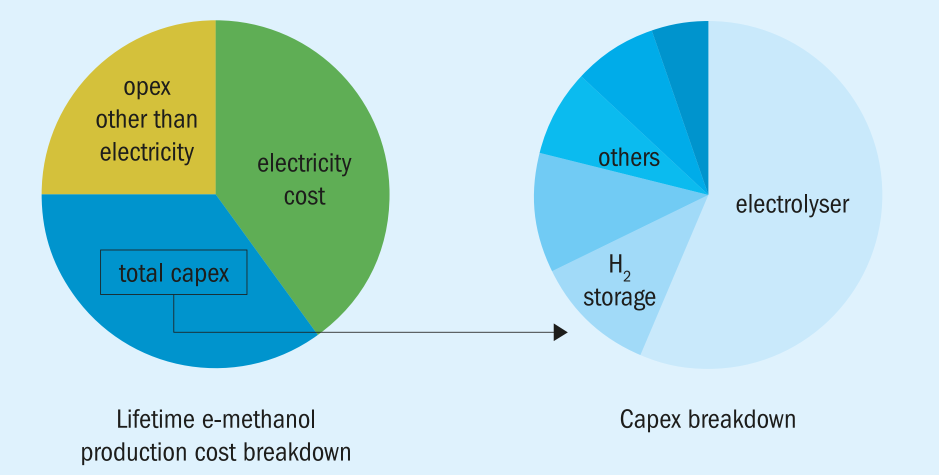
Efficient production under VRE conditions necessitates meticulous and strategic operation planning. This involves a comprehensive consideration of various critical factors such as predicted power generation, hydrogen storage levels, shipping schedules, and production efficiency at different operational loads.

For instance, if the hydrogen storage is depleted, the g-Methanol™ plant must shut down operations. To prevent such a scenario, it is essential to reduce the plant load in anticipation of decreased power generation, thereby conserving the available hydrogen. Conversely, when the hydrogen storage is full, halting hydrogen production can result in significant losses. Therefore, if an increase in power generation is expected, the plant load should be increased to actively consume the stored hydrogen, ensuring efficient utilisation of resources.

Similarly, if the e-methanol storage is insufficient, shipping operations cannot proceed as planned, necessitating adjustments in production to align with shipping schedules. The consumption rates of raw materials and utilities also vary with changes in the operational load, adding another layer of complexity to the planning process.

Given the inevitable deviations between forecasted and actual power generation, it is crucial to have a dynamic and adaptable operation plan that can respond to real-time conditions. This requires continuous revisions of the plan based on updated forecasts and the actual conditions of the plant. The complexity and the need for frequent updates make manual planning impractical, highlighting the necessity of an advanced system like MethaDynamics™. MethaDynamics™ provides the required flexibility and precision, ensuring that the production process remains efficient and responsive to changing conditions.

Fig. 4: **Typical cost breakdown**



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System architecture

MethaDynamics™ comprises two main components: the Cloud Planner and the On-premises Executor (Fig. 6).

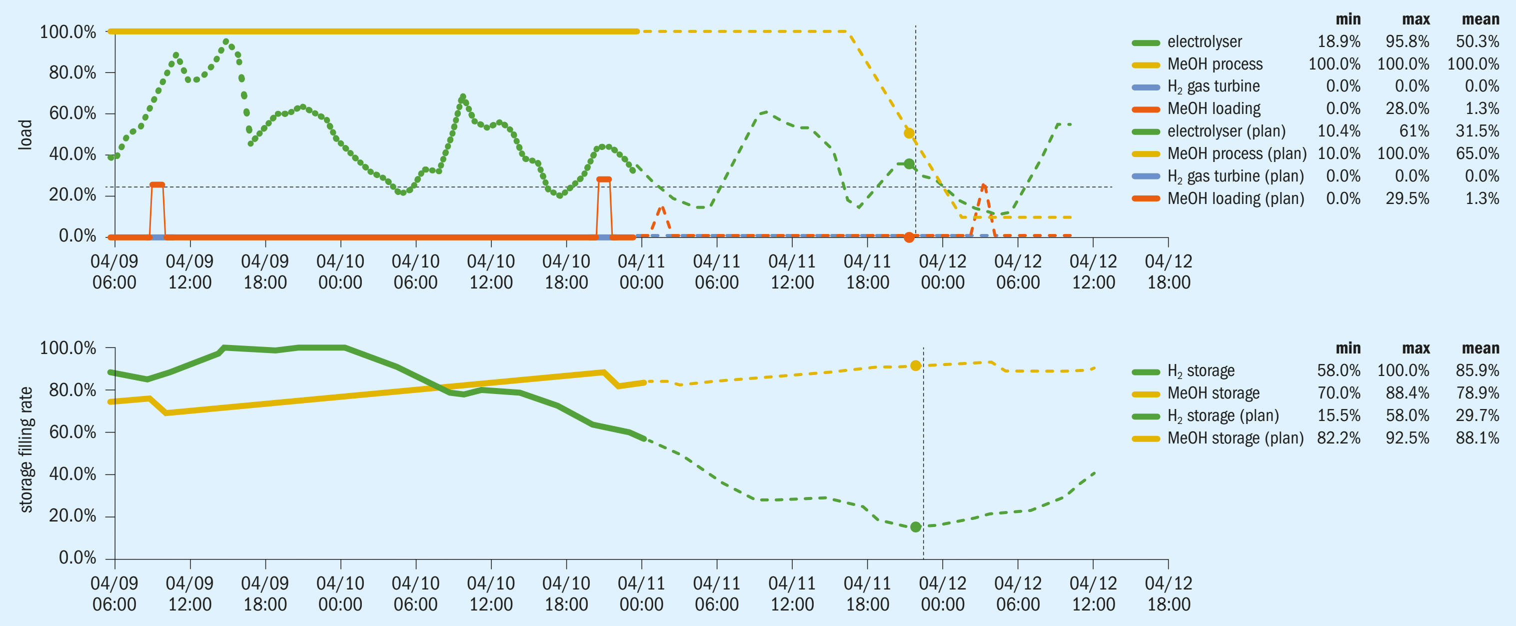
Cloud Planner

This component operates on the cloud, gathering data from a variety of external systems such as weather forecasts, power grid information, statuses of renewable energy facilities, and shipping plans. It periodically generates operational plans that take into account future conditions to a certain extent. Designed for long-term future planning, the cloud system executes cycles at hourly intervals, utilising dynamic and variable computing resources to handle fluctuating demands. It communicates with various external systems over the internet to gather the necessary data and ensure seamless integration. This allows the Cloud Planner to create comprehensive and adaptive plans that can respond to changing conditions and optimise the overall production process.

On-premises Executor

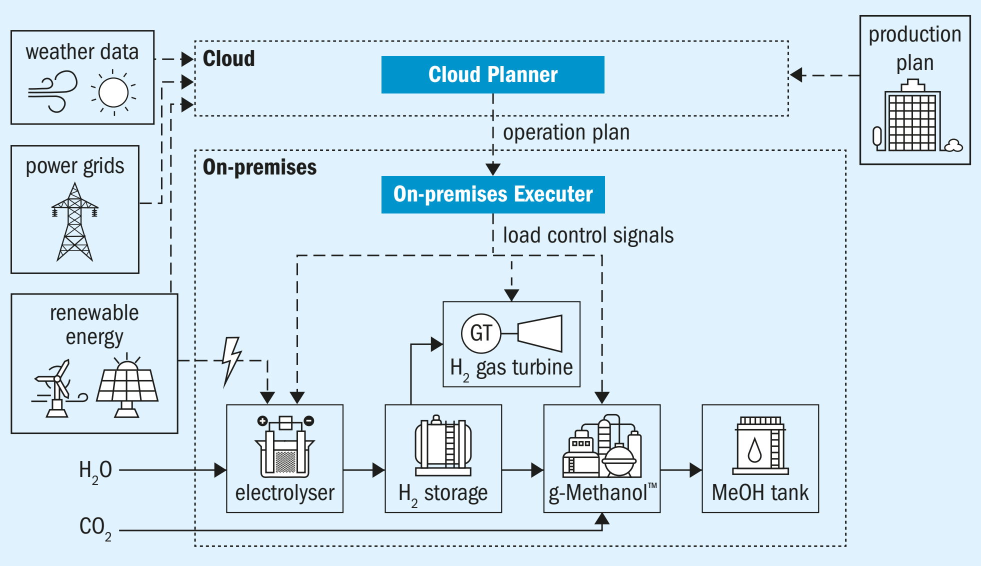
This component operates on-site, receiving plans from the Cloud Planner and issuing commands to adjust the load on each process unit accordingly. It considers detailed constraints to ensure safe and stable operations. Additionally,

Fig. 5: **Operation plan sample created by MethaDynamics™**



Source: TOYO

Fig. 6: **General system architecture of MethaDynamics™**



Source: TOYO

it collects operational data from the control systems of each process unit and shares this data with the Cloud Planner. This system focuses on precise plan adjustments to meet detailed constraints, operating with execution cycles at minute intervals to ensure timely responses to changing conditions. It relies on stable computing resources and maintains direct communication with the control systems of production facilities to implement operational plans effectively. By doing so, the On-premises Executor ensures that the production process remains efficient and responsive to real-time conditions, thereby enhancing the overall reliability and performance of the e-methanol production system.

Frequent updates based on new forecasts and plant status

Predicting power generation in the near future is significantly more reliable than forecasting power generation over a longer time horizon. This increased reliability necessitates frequent updates to the operation plan to ensure optimal performance. To achieve these frequent updates, automation in operation planning is essential. Automation aids in creating more efficient and responsive plans, effectively managing the complexities associated with operating under fluctuating renewable energy conditions.

MethaDynamics™ is designed to automatically and frequently update operation plans, ensuring that the system remains efficient and responsive. The MethaDynamics™ planning and execution cycle operates as follows (Fig. 7):

1. The amount of power generated by renewable energy sources is updated using the latest forecast information.
2. The operation plan is revised based on the most recent predictions of renewable energy generation and current plant status.
3. The plant operates according to the updated plan, even if there are deviations from the forecast.
4. Actual inventory levels and production amounts are measured and fed back into the system for the next planning cycle.
5. The planning period window advances, preparing for the next cycle of updates.

By automating these processes, MethaDynamics™ ensures that operation plans are continuously optimised, providing efficient and responsive solutions to the challenges posed by renewable energy fluctuations. This automation not only enhances the reliability of the operation plans but also significantly reduces the manual effort required, allowing for more precise and timely adjustments.

MethaDynamics™ brings a new level of efficiency and responsiveness to operation planning, making it an indispensable tool for managing the dynamic and complex environment of renewable energy production.

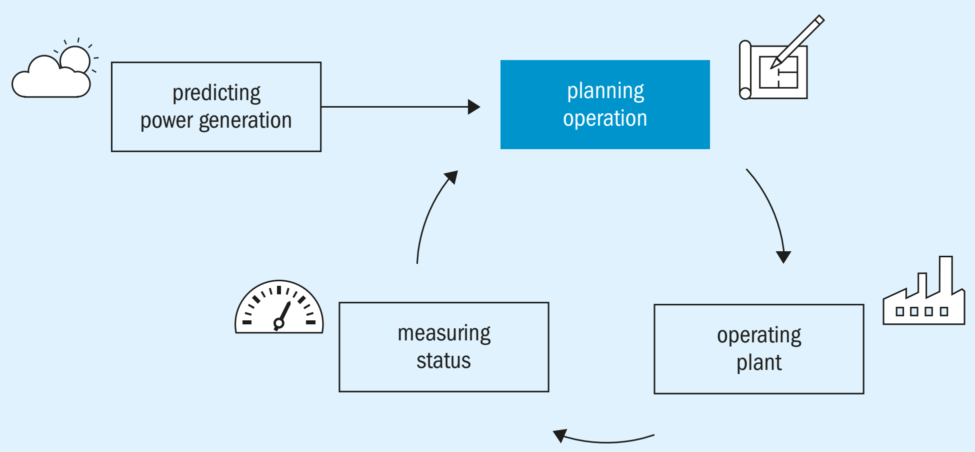
Conclusion

TOYO's new digital solutions for e-methanol production from VRE significantly enhance operational efficiency. MethaMaster™ optimises the design phase by buffering power fluctuations using batteries and hydrogen storage, ensuring continuous plant operation, and reducing production costs. MethaDynamics™ streamlines production planning and execution by automating responses to power variability, thus eliminating the complexity of manual adjustments, and improving productivity. Together, these solutions enable more stable and cost-effective e-methanol production. It is anticipated that these digital solutions will strongly support the development of the e-methanol market, contribute to the integration of renewable energy with industrial processes, and support the development of a value chain where e-methanol is increasingly utilised as fuel and chemical feedstock. ■

Reference

1. "Methanol synthesis using renewable energy", Nitrogen+Syngas No. 387, p. 3 (Jan-Feb 2024).

Fig. 7: **Planning and execution cycle of MethaDynamics™**



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Lower cost syngas via nitrogen quenching

Syngas generation units (SGU) represent a large portion of the capital and operational expenditure of ammonia plants and are critical from a mechanical reliability standpoint. Related capex/opex optimisation and mitigation of possible operational problems are key targets for ammonia plant owners. **Giovanni Manenti** introduces NITROQUENCH® technology which focuses on these key targets for ammonia SGU.

Syngas generation units (SGU) comprise one or more hydrocarbons, steam and/or oxidative reformers, a transfer line and a syngas cooling package. Oxidative reformers are based on air, enriched-air or oxygen, and operate according to adiabatic homogeneous syntheses, as partial oxidation reactors (POX) or gasifiers, or according to adiabatic heterogeneous syntheses, as auto-thermal reactors (ATR) or catalytic partial oxidation reactors (CPOX). A combination of steam and oxidative reformers is frequently adopted. The transfer line is a refractory-lined large-size conduit for bringing hot syngas from reforming to the cooling package. The syngas cooling package usually includes a high-pressure water boiler connected to a steam drum; other heat exchangers are often included in the syngas cooling package.

Hot syngas discharged from the reforming operation is at high temperature and pressure; after cooling, the syngas is at operating conditions useful for water-gas shift (WGS) operation. The hot syngas has a high H_2 and CO content; it is chemically aggressive towards mild-to-alloy steels at high metal temperatures.

SGU equipment has a complex design and manufacturing process, a long delivery time, and is often based on proprietary knowhow; such equipment is expensive and, in case of problems, is difficult to diagnose, repair or retrofit. Operational problems in syngas transfer lines and cooling packages are annoying and costly, and generally involve some safety concerns.

Possible operational problems in transfer lines and cooling packages

Aging of refractory lining or metal parts is normal under severe thermal-mechanical conditions and when exposed to aggressive gases; yet, when a part of the equipment undergoes faster aging than other parts, the aged part may jeopardise the overall SGU performance and opex, forcing a turndown, shutdown or repair. For instance, local degradation of refractory involves hot spots that, in the worst case, may rapidly evolve to damage pressure parts.

Corrosion or mechanical damage on internal bypass systems, frequently installed in syngas boilers and superheaters, usually leads to difficult outlet syngas temperature control or, in the worst case, to local overheating in the outlet channel or to excessive heat flux in exchanging tubes.

Excessive fines from upstream catalyst or refractory lining can result in excessive fouling on heat exchanging surfaces of the cooling package, eventually leading to poor performance. Such problems are usually difficult to solve; frequent mechanical cleaning may be necessary.

Failure of exchanging tubes in syngas boilers and heat exchangers is rare, typically only occurring after many years of operations. Yet, there are several case studies in the literature describing early failures on exchanging tubes. They may be the result of mis-operation, lack of inspection/maintenance, shifts from boiler water chemistry, operational overloads or poor equipment design/quality.

Finally, although infrequent, high temperature peaks from reforming may temporarily blow the transfer line and syngas boiler leading to local and/or latent damage to the refractory, ferrules, bypass systems and exchanging tubes.

Revamping/retrofitting projects

Revamping projects are aimed at improving ammonia plant production, environmental sustainability and economical balance. Heat and mass balances are tuned, energy consumption is optimised, catalysts are reselected, equipment is fully inspected and retrofitted where necessary. Yet, there are some items of equipment that can represent a critical bottleneck relative to the revamped load making the revamping project challenging from a technical, scheduling and commercial standpoint. The SGU cooling package, specifically the syngas boiler and heat exchangers, typically represents one of the most critical items of equipment in revamping and retrofitting projects.

Existing syngas boilers can usually accept limited revamping conditions from a thermal-hydraulics and thermal-mechanical standpoint. Major limits to running an existing syngas boiler at revamped conditions are peak heat flux at the tube inlets, maximum tube metal temperature, steam disengagement and stresses in the tubesheet and tube-to-tubesheet joints. Moreover, aged syngas boilers may seriously suffer from revamped conditions. Therefore, revamping projects often involve replacing the existing syngas boiler or exchangers.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

NITROQUENCH technology

NITROQUENCH is a new process method for ammonia syngas generation units. Specifically, it is conceived for ammonia SGUs based on adiabatic oxidative reforming by enriched air or oxygen, where an air separation unit (ASU) is installed. Availability of cold nitrogen (N_2) is essential, regardless of the source (ASU or imported nitrogen). NITROQUENCH can be adopted for new and revamping projects; it can also be implemented in existing ammonia SGUs as an add-on.

The new method comprises direct cooling of the hot syngas discharged from the reforming operation by mixing with cold N_2; the direct cooling is accompanied by the indirect cooling of the conventional syngas boiler/exchanger. The cold N_2 is liquid or gaseous or supercritical, preferably in cryogenic conditions, and is injected into the hot syngas by means of an injector mounted on the SGU equipment. N_2 is an inert species and takes part in the subsequent ammonia synthesis: its injection is therefore harmless. Fig. 1 depicts a typical ammonia SGU equipped with an ASU and implemented with NITROQUENCH. The SGU comprises an oxygen-based ATR, a transfer line, a syngas boiler and steam superheater (SSH) connected to a steam drum; a water gas shift (WGS) reactor is installed downstream of the SGU. The hot syngas from the ATR is first mixed with a cold stream of N_2 along the transfer line, then cooled down in the boiler and superheater.

Fig. 2 shows possible conceptual schemes of NITROQUENCH. The SGU includes the reforming, the transfer line and the cooling package. The reforming can be realised by any combination of reforming reactors (A = adiabatic pre-reforming, B = radiative steam reforming, C = convective steam reforming, D = adiabatic ATR/CPOX, E = adiabatic POX/gasifier); NITROQUENCH technology is chiefly conceived for ATR, POX and gasifiers working with O_2. The cooling package includes two heat exchangers installed in series. The cold N_2 is conveyed from cryo-storage to the SGU by an injection line and is injected into the hot syngas either upstream of the first heat exchanger (N-1) and/or in between the two heat exchangers (N-2) and/or downstream of the second exchanger (N-3). Operating temperatures shown in Fig.2 are indicative only: the hot syngas is cooled down after mixing with cryogenic N_2.

Fig. 1: **NITROQUENCH technology in a typical ammonia SGU**

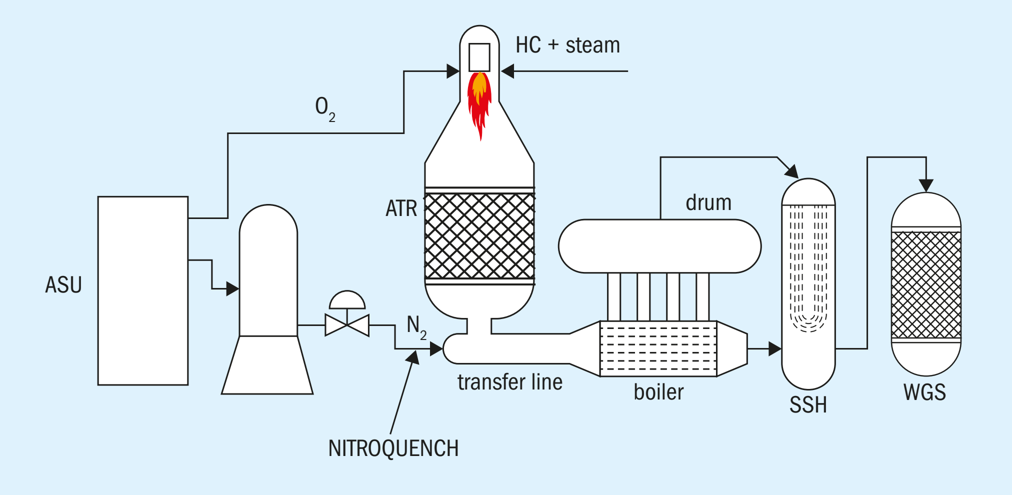
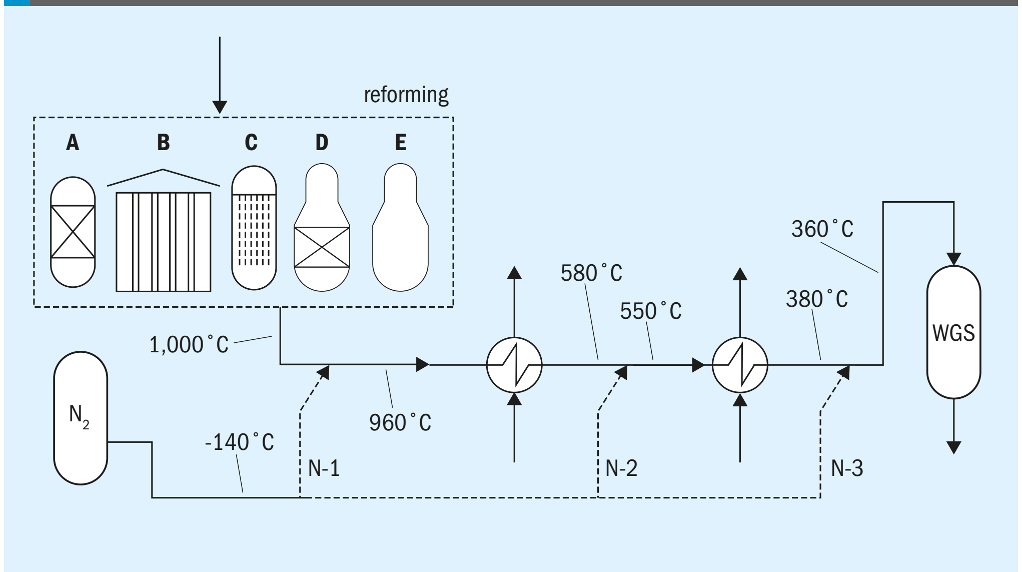


Fig. 2: **Conceptual schemes for NITROQUENCH**



NITROQUENCH is an intuitive and practical method. Use of cryogenic N_2, already available at site, to cool the hot syngas could also be regarded as smart use of low enthalpy. Depending on the N_2 physical state, temperature and flowrate, and depending on the process plant design and/or on the operational problems, the syngas temperature can be reasonably lowered by 10-100°C; the direct cooling is fast and with negligible syngas pressure drop. When applied upstream of the cooling package, major operational advantages of NITROQUENCH include:

- refractory hot face is at a lower temperature: possible hot spots or aging phenomena are mitigated;
- syngas temperature at the boiler/exchanger inlet is reduced: heat flux, thermal and mechanical stresses are lessened;
- heat load on boiler/exchanger is reduced: heat transfer performance and hydraulics are eased;
- possible temperature peaks from reforming are prevented and smoothed;
- additional process control of the SGU is possible by regulating temperature/flowrate of cold N_2.

When NITROQUENCH is applied downstream of the cooling package (and upstream of the WGS), the further cooling of syngas provides a major operational advantage when the boiler/exchanger has poor performance or is damaged: NITROQUENCH may restore the target syngas temperature at the WGS reactor inlet.

The abovementioned advantages lead to an extended lifespan of existing or aged equipment, mitigation of operational problems, restored performance, and equipment protection. For revamping or retrofitting projects, NITROQUENCH may enable the existing transfer line and syngas boiler/exchanger to be kept, despite the revamped load or operational problems. In case of new projects, NITROQUENCH may decrease

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

Fig. 3: **Major thermal parameters vs. N_2 injection flowrate**

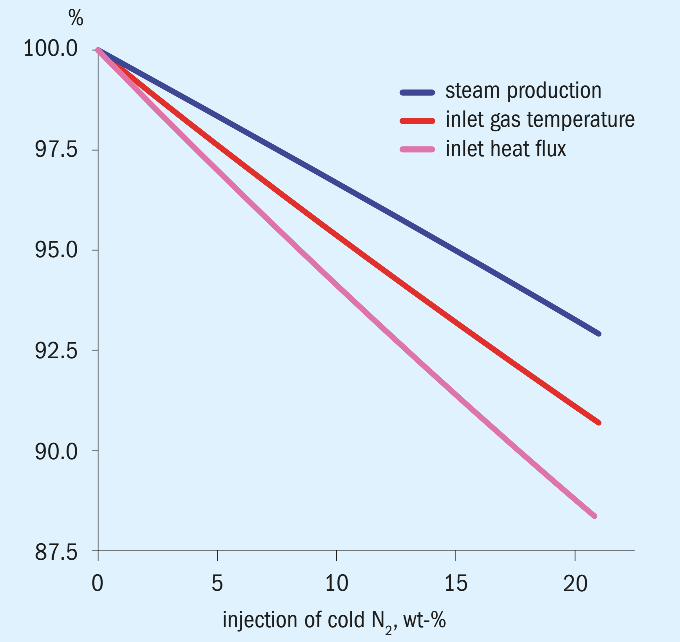


Table 1: **Conventional boiler design vs. new design**

Parameter	Conventional	New design 1	New design 2
NITROQ (% by wt.)	–	5.0	10.0
Gas flow rate (kg/h)	192,000	201,600	211,200
Gas MW (kg/kmol)	14.1	14.5	14.8
Gas temperature in, (°C)	1,000	977.2	955.3
Gas temperature out, (°C)	420	420	420
Maximum heat flux (kW/m²)	360	360	360
Exchanged heat (MW)	77.7	76.1	74.6
Steam production (t/h)	225.9	221.2	216.7
Exchanger surface (m²)	658	641	624
Gas velocity in (m/s)	19.2	20.0	21.1
Gas pressure drop (kPa)	7.9	8.6	9.5
Number of tubes	700	675	648
Tubes effective length (mm)	6,730	6,800	6,900
OTL (mm)	1,765	1,734	1,700

syngas boiler/exchanger dimensions and reduce mechanical design conditions.

If the technology is implemented as an add-on to existing plants, it presents a disadvantage: after the mixing with cold N_2, the syngas volume is increased and the partial pressure of the reactants is lowered. However, analysis shows that for a N_2 injection flowrate of up to 10-15% (relative to syngas mass flowrate), the impact on the pressure drop and WGS performance is not critical and can be absorbed. In other words, the disadvantage is more than compensated by the advantages.

Finally, it is important that the NITROQUENCH flowrate is preferably balanced with other possible N_2 injections (e.g., N_2 washing) to provide entry in the ammonia synthesis with a proper H_2:N_2 ratio. On the contrary, as when air is used for partial oxidation, excess N_2 must be removed (for instance by N_2 washing).

Illustrative example 1

An existing partial oxidation reactor operated with O_2 discharges a syngas for subsequent ammonia synthesis with a mass flowrate, temperature and pressure of 192,000 kg/h, 1,000°C and 3 MPa(a) respectively; the relevant molar composition is H_2 = 45.9%, H_2O = 29.4%, CO = 16.2%, CO_2 = 6.8%, CH_4 = 0.8%, N_2 = 0.8%, Ar = 0.1%. The syngas is cooled in a shell-and-tube boiler by means of high-pressure water boiling at 320°C circulating on the shell side; the design heat flux at the boiler inlet is 360 kW/m². Due to general signs of corrosion and local damage, there are concerns about the reliability and lifespan of the transfer line and boiler. Cryogenic gaseous N_2 is available at the plant at -140°C and 3 MPa(a), therefore NITROQUENCH can be implemented upstream of the boiler. Fig. 3 shows the trend of major thermal parameters against the N_2 injection flowrate. For instance, by injecting 7.5 wt-% (14,400 kg/h) of cold N_2 upstream of the boiler, the syngas temperature and heat flux at the boiler inlet are reduced by 3.4% (966°C) and 4.3% (345 kW/m²) respectively. Accordingly, the thermal-mechanical conditions in the transfer line and at the boiler inlet are significantly lessened; equipment reliability and lifespan are improved without reducing the plant production. The overall steam production in the boiler is reduced by 2.6% only.

Illustrative example 2

The syngas boiler of example 1 is planned to be replaced. Table 1 compares the boiler conventional design to the new design by implementing NITROQUENCH upstream of the boiler as in example 1. The comparison is based on identical exchanging tube, tube pitch, design heat flux, outlet syngas temperature and fouling coefficients. The new boiler based on NITROQUENCH can have a reduced tube number and diameter. For NITROQUENCH at 10 wt-%: (i) gas velocity at the tube inlet is increased by 10% (21.1 m/s) and this has a better cleaning effect, (ii) the inlet syngas temperature is lowered by 4.5% (955.3°C), which leads to lower thermal-mechanical stresses in the inlet parts (refractory, ferrules, tubesheet), (iii) the steam production is reduced by 4% (216,7 t/h), which may be considered an improvement for thermal-hydraulics, or an energy optimisation or part of heat balance tuning. In addition, if NITROQUENCH is implemented downstream of the boiler, a downstream injection of 5 wt-% of cold N_2 would lead to a tube length reduction of approximately 6%.

Conclusions

NITROQUENCH is a process technology aimed at optimising the design and mitigating typical operational problems of the ammonia SGU, chiefly based on oxygen partial oxidation. The availability of cryogenic N_2 is essential. Beyond its potential advantages, NITROQUENCH can be rapidy implemented and is cost-effective: generally, installation material comprises a 2" to 6" stainless steel line, a flow meter and regulating valve, and an injector. The technology could also be implemented in other process plants, such as H_2, HNO_3, HCN or CH_2O plants: the quenching nitrogen can be separated from the final product by any physical method, such as pressure swing adsorption, a selective membrane, or by condensation. NITROQUENCH is available on demand for process licensors, engineering companies and final users.

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