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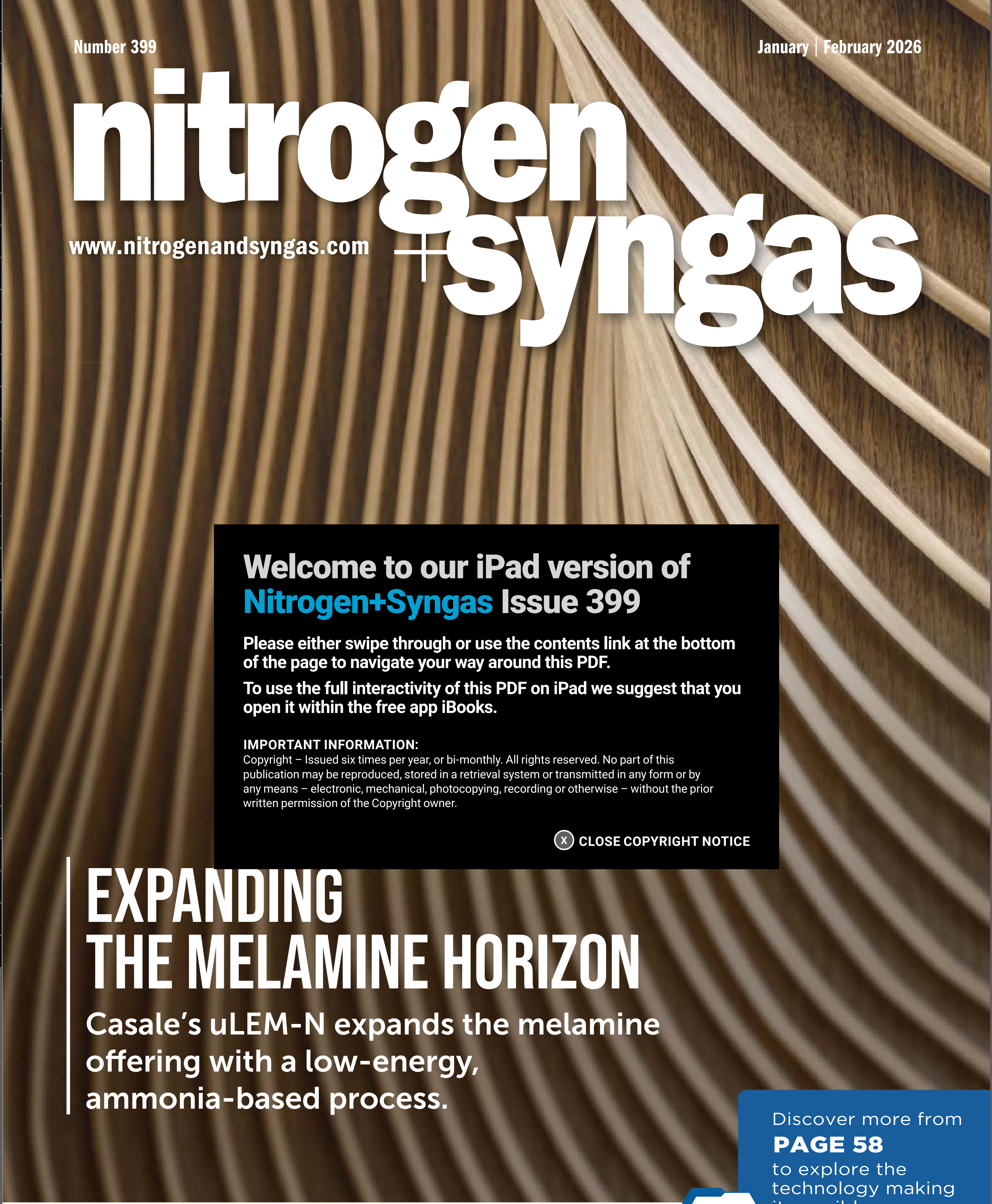

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EXPANDING THE MELAMINE HORIZON

Casale's uLEM-N expands the melamine offering with a low-energy, ammonia-based process.

Discover more from **PAGE 58** to explore the technology making it possible

MELAMINE

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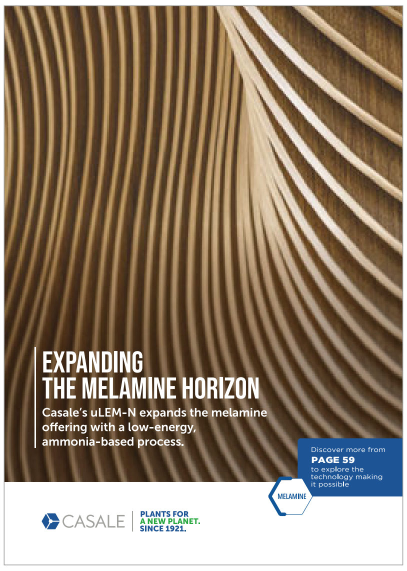

Cover: Casale

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Ample supply from LNG capping global prices

Modularised plant design

Redefining small-scale methanol production

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Published by:

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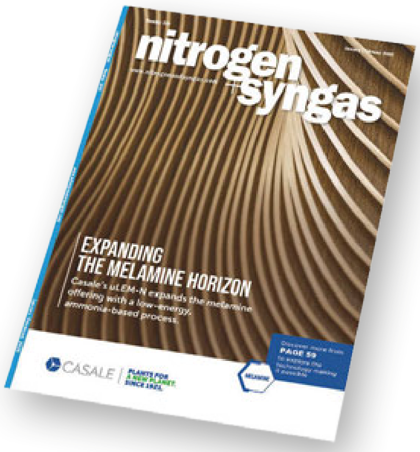
Predicting the unpredictable



> "EU nitrogen producers will act in 2026 to secure strategic, long-term sources of low emissions ammonia..."

The start of the new year has shown that 2026 is already proving to be a very eventful one, beginning with the US abduction of Venezuela's president Nicolas Maduro, which has prompted questions over production at the country's ailing nitrogen assets, as well as the potential for a future boost to gas supplies to Trinidad. Meanwhile the Iranian government faces its most sustained public challenge since the 1979 revolution, and possible US military intervention, threatening continued exports from the country. In Europe, the future of fertilizers' inclusion in the Carbon Border Adjustment Mechanism (CBAM) has been thrown into doubt barely a week after the new regulations came into force, as France and Italy pushed for an exemption for crop nutrient imports.

Such multiple uncertainties continue to weigh heavily on nitrogen and other markets, and make the job of forecasters all the more difficult. Nevertheless, at the end of December CRU published its list of things to watch for in the fertilizer market for in 2026, looking towards larger and longer-term trends that underlie the day to day market shifts of a rapidly changing world. On the nitrogen side, Indian urea imports are expected to remain high, as domestic supply faces limitations due to gas supplies. The baseline for Indian urea imports is expected to be 9.2 million t/a this year, just under the 9.4 million t/a of 2025.

In Europe, fertilizer affordability remains challenging, with crop price indices flat and fertilizer price indices up 25% relative to pre-2023 averages. Extra tariffs on imports of Russian nitrogen fertilizers and the EU's CBAM are imposing additional costs on the import of all nitrogen-containing fertilizers. To provide relief for farmers, the EU could consider targeted exemptions or softening of CBAM rules for fertilizers, or could consider the removal or lowering of tariffs to entice more supply from potential trade partners like Nigeria or the US. As we discuss in the article on pages 22-23, EU grey ammonia production and imports will come under increasing pressure from 2026 as the EU phases out ETS free allowances and phases in CBAM. To avoid the significant cost escalation expected from 2030 onwards, EU nitrogen producers will probably act in 2026 to secure strategic, long-term sources of low emissions ammonia, either through investment in capacity or offtake agreements. The US benefits from low-priced natural gas, a strong nitrogen industry, advanced carbon capture and storage (CCS) infrastructure and generous 45Q tax credits for CCS operations. These factors, along with relative proximity, make the US a natural partner for EU nitrogen producers seeking low carbon ammonia volumes to hedge against increasing carbon costs.

Elsewhere, China's urea production is expected to reach a record 72 million t/a in 2025, far exceeding domestic demand, as domestic capacity increases. The Chinese government seems to have been satisfied with urea export management in 2025: low domestic prices benefited local farmers, while producers and traders realised significant profits in the international market. If prices remain lower than in prior years, as seems likely, and with the rapid growth in domestic urea capacity, restrictions on export sales may well be eased. As a consequence CRU expects Chinese urea exports to increase to 5.9 million t/a in 2026, with the export window possibly opening as early as May. ■

Richard Hands, Editor

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Price Trends

Ammonia values in the Middle East, Far East and Southeast Asia edged higher at the start of January, while other major benchmarks were largely unchanged amid a subdued market. Conditions at the start of the year mirror late-2025, with prices supported by persistent supply tightness from the continued absence of Ma'aden's MPC facility, which removes an estimated 300–400,000 tonnes from the market. The unit is expected to return in mid-to-late January.

The key development remains the implementation of CBAM in northwest Europe, where activity has slowed. Default emissions values issued by the European Commission in late December have effectively priced US tonnes out of the market, forcing producers to verify carbon intensity to stay competitive.

Indian prices extended their upward trajectory, with delivered values reaching $550/t c.fr after confirmation of cargoes secured from Southeast Asia. Firm c.fr prices were supported by higher f.o.b. levels, though sentiment turned cautious on expectations of Ma'aden's restart and the potential for additional merchant supply should Indian producers bring forward shutdowns amid elevated feedstock costs. Supply in the Middle East remains constrained, with both Ma'aden's MPC plant and Sabic's Al Jubail facility still offline. In Algeria, one new pot sale for 10,000 tonnes at $600/t f.o.b. was reported.

In the US Gulf, GCA's January loadings continued to build, reaching approximately 97,400 tonnes. In Italy, Yara's Ferrera plant remains offline, prompting Ravenna to import ammonia; so far only one vessel carrying Algerian tonnes has arrived at Ravenna.

Global urea market action was largely confined to east of Suez, where India's National Fertilizers Limited (NFL) closed a fresh purchase enquiry on 2nd January. Having initially sought 1.5 million tonnes for shipment by 20 February, NFL received offers totalling just over 3.62 million tonnes. The lowest offers emerged from Koch, and counters to remaining participants - after several deadline extensions - saw acceptances eventually reach 976,750 tonnes.

Across the Indian Ocean in the Middle East, prices gained support following India's developments. Netbacks on the lowest offers were in the low-$410s/t f.o.b., though QatarEnergy concluded February business in the high-$410s f.o.b., and was reported to have sold prills via tender in the mid-$390s/t f.o.b. In Iran, with just one of seven producers running, prices inched up: the official weekly price was initially $390/t f.o.b., while the sole remaining producer, Pardis, subsequently sold granular material at $397/t f.o.b.; further business is likely above $400/t f.o.b. Seasonal gas curtailments are expected to last until at least February.

West of Suez, Mopco reported granular sales in the $450–455/t f.o.b. range in Egypt, though destinations for the cargoes were not disclosed. Any supply to Europe would in theory be subject to CBAM, which came into effect on 1 January. Signals from European officials that CBAM could potentially be halted have cast doubt on whether the mechanism will survive the year, despite assurances from other EU officials that it remains in place for now. ■

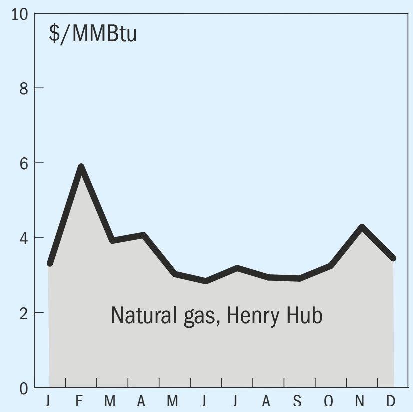
Table 1: **Price indications**

Cash equivalent	**mid-Dec**	**mid-Oct**	**mid-Aug**	**mid-Jun**
Ammonia ($/t)				
f.o.b. Black Sea	n.m.	n.m.	n.m.	n.m.
f.o.b. Caribbean	610	550	445-450	350-355
f.o.b. Arab Gulf	500-539	400-420	320-340	280-300
c.fr N.W. Europe	640-695	620-630	560-570	410-465
Urea ($/t)				
f.o.b. bulk Black Sea	345-355	380-385	460-470	355-365
f.o.b. bulk Arab Gulf*	355-395	330-410	386-515	300-390
f.o.b. NOLA barge (metric tonnes)	360-376	375-377	420-445	343-355
f.o.b. bagged China	390-400	389-390	445-490	353-360
DAP ($/t)				
f.o.b. bulk US Gulf	605-625	770	787-805	713-715
UAN (€/tonne)				
f.o.t. ex-tank Rouen, 30%N	365	310-315	327-330	310-320

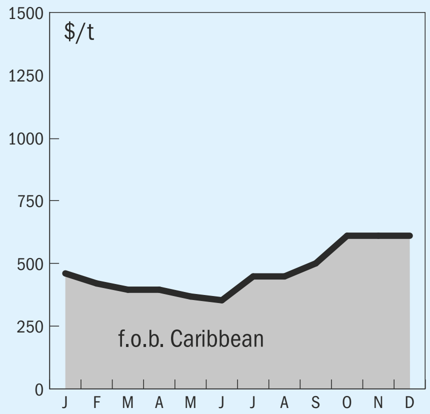
*Notes: n.a. price not available at time of going to press. n.m. no market. * high-end granular.*

END OF MONTH SPOT PRICES

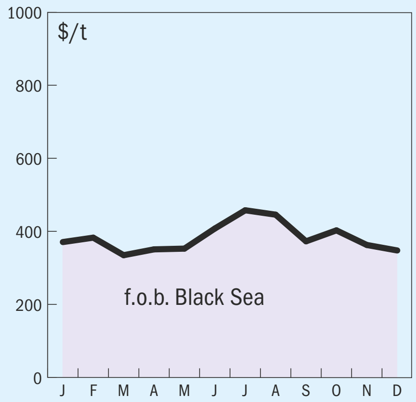
natural gas



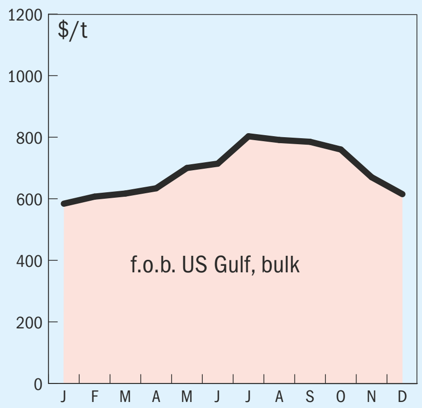
ammonia



urea



diammonium phosphate



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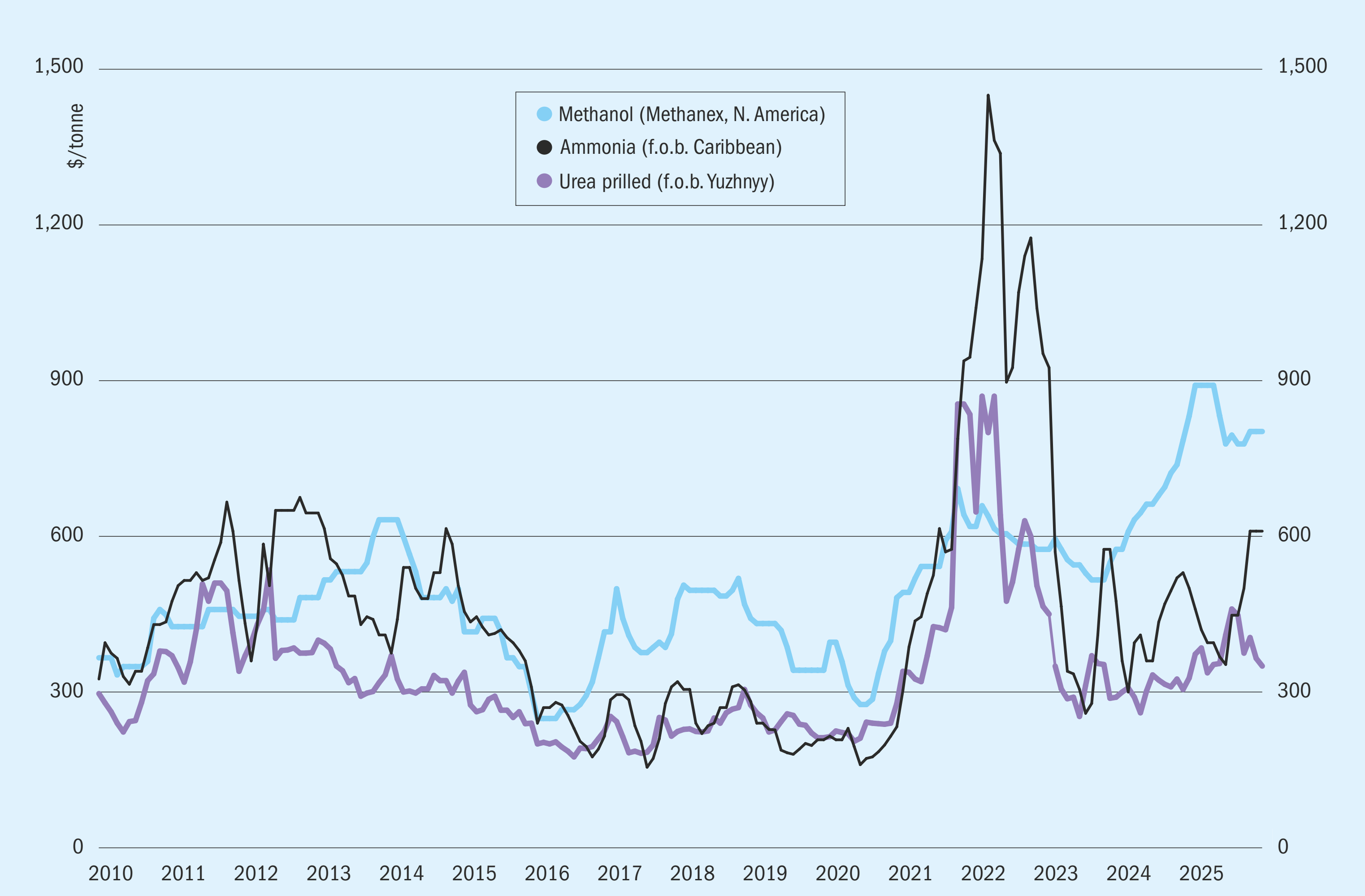
Market Outlook

Historical price trends $/tonne



Source: BCInsight

AMMONIA

- Ammonia prices are expected to ease through January as new supply comes online. Woodside's Beaumont facility produced its first ammonia at the end of December and is poised to start commercial production in early 2026, and there is also new supply from Gulf Coast Ammonia (GCA). In Saudi Arabia, the expectation is that both Ma'aden and Sabic will return to the market mid-to-late January.
- CBAM remains an issue in Europe. Importers are expected to prioritise Egyptian and Algerian material, which carry the lowest default values, though supply from both origins is tight. Market participants expect liquidity to remain thin through January as buyers and sellers adapt to the new regulatory framework.

UREA

- Prices should remain flat-to-firm in the near term, with low offers into India providing a positive boost for the market.
- Supply from China was constrained, with no further quota allocations for exports expected to be issued by Beijing in the near term, and remaining volumes under China's fourth quota allocation of 2025 said to be very minimal.
- Iranian supply is also offline for the time being; Khorasan Petrochemical Company (KHPC), Kermanshah Petrochemical Industries Company (KPIC), Lordegan Urea Fertilizer Company (LUFC), Razi Petrochemical Company (RPC), Masjed Soleyman Petrochemical Industries (MIS) and Shiraz Petrochemical Company (SPC) were all down due to domestic natural gas shortages, with Pardis said to be operating at 50%.
- The Carbon Border Adjustment Mechanism (CBAM) also affected urea shipments into Europe. Until further clarification is given, fresh import business is likely to be limited, although previously imported material in warehouses should be sufficient to cover local demand.

METHANOL

- Methanol markets were well supplied in December in spite of winter gas curtailments in Iran. China absorbed most seaborne flows, with import levels high, leading to high coastal inventories and episodic unloading delays that limited the upside for prices.
- US Gulf producers retained a structural cost advantage as Henry Hub gas prices remained low, while coal prices softened in China, improving coal-to-methanol margins. Demand was mixed: China restocking lifted near-term buying, but downstream margins stayed weak. Naphtha prices also eased, narrowing the cost advantages for MTO producers, while polymer market weakness also capped the upside for production volumes. Chinese c.fr prices rebounded to the low-mid $240s/tonne.
- Iranian and Trinidadian outages tightened marginal supply, while Venezuelan exports flowed amid sanction uncertainty. ■

Nitrogen Industry News

NIGERIA

Dangote planning two massive new ammonia-urea complexes

The Dangote fertilizer complex at Lekki.

Dangote Fertilizer, Africa's leading fertilizer producer, has awarded contracts to several major companies for the provision of licenses and technical expertise for the development of two new planned ammonia-urea complexes, one in Nigeria and the other in Ethiopia, as well as the provision of basic engineering and design services for the related plants.

The Nigerian operation envisages for new ammonia-urea trains. Saipem has been selected to provide its proprietary *Snamprogetti*™ urea technology, as well as process engineering services including all technical documentation required for the construction of the urea units, each with a record capacity of 4,235 t/d, for a total of 16,940 t/d (5.6 million t/a). thyssenkrupp Uhde Fertilizer Technology (UFT) will also license its *UFT*® fluid bed granulation technology for the urea plants. Topsoe will supply licenses for the four 2,500 t/d gas-based ammonia units which will feed the urea plants. The new trains will be built at Dangote's existing Lekki facility near Lagos, which already operates 3 million t/a of urea capacity.

Additionally, a complex in Ethiopia is planned to include two more 2,500 t/d Topsoe ammonia plants, with 3 million t/a of downstream urea capacity licensed by Saipem. Saipem and Dangote Fertilizer have signed a letter of intent for front end engineering design (FEED) services relating the new complex in Ethiopia, developed in partnership with Ethiopian Investment Holdings for the construction of a plant at Gode, in the Somali region of the country. ■

CHINA

NextChem awarded process design package

NextChem, via its nitrogen technology licensor Stamicarbon, has been awarded a licensing, process design package (PDP), and proprietary equipment supply contract based on its proprietary NX STAMI Urea™ technology, for a new urea plant in Eastern China by what NextChem describes as "a prominent fertilizer producer".

The plant, with a capacity of 2,700 metric tons per day, will adopt Stamicarbon's Ultra-Low Energy design. This enables a 35% reduction in steam consumption and a 16% decrease in cooling water usage compared to conventional methods, thanks to innovative high-pressure steam utilisation and advanced pool reactor design. The process also ensures very low biuret content in the final product and high-quality prills, thanks to Stamicarbon's prilling tower design. Key equipment, including the pool reactor and stripper, will feature E-type super duplex stainless steel, leveraging Stamicarbon's expertise in material science and industrial applications.

Fabio Fritelli, Managing Director of NextChem, commented: "This project marks the tenth global application of Ultra-Low Energy technology and the eighth in China, with seven operational plants demonstrating our benchmark role for energy efficiency in large-scale urea production. This contract further strengthens NextChem's presence in this geography and demonstrates our unwavering commitment to enhancing the sustainability of the fertilizer sector through cutting-edge technological advancements".

Contract awarded for nitric acid plant

NextChem has also announced that its nitrogen technology licensing division Stamicarbon, has been a licensing contract and the project development process for a new nitric acid plant in China. The project entails the application of Stamicarbon's state-of-the-art mono-pressure technology, part of NX STAMI™ Nitrates series, which uses oxygen instead of air as feed for the process, enabling high energy recovery and low operational costs. NextChem says that the award builds on the Group's longstanding expertise in nitrogen technologies and reflects its commitment to industrialising efficient, low-emission solutions for the agricultural supply chains.

Stamicarbon has also been awarded a licensing and PDP contract as well as technical assistance services for the revamping of a nitrogen fertilizer complex in northern China. The project is aimed at upgrading an existing urea plant based on proprietary NX STAMI™ Urea technology, allowing significant reductions in steam consumption and improving energy efficiency, while optimizing both capex and opex.

DENMARK

Dynamic green ammonia plant starts operations

A consortium including Danish companies Skovgaard Energy, Topsoe and Vestas says that it has reached an important milestone with the startup of operations in what they describe as the world's first-of-its-kind green ammonia plant. The plant, owned by Skovgaard Energy and located in Ramme Denmark, is a demonstrator for a dynamic approach to green ammonia production, which means that the plant will adapt to the inherent fluctuations in power output from the renew-

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PHOTO: SKOVGAARD

The Skovgaard dynamic ammonia plant, Denmark.

able power sources in integration with the plant's electrolysis and ammonia synthesis loop. This, say the developers, will ensure optimal production and improve the cost-effectiveness of green ammonia, ensuring less need for costly storage solutions of green hydrogen or renewable power. Production capacity is 5,000 t/a of green ammonia, with an associated CO_2 reduction of 9,600 t/a. The partnership has received euro 11 million in funding from the Danish Energy Technology Development and Demonstration Program (EUDP).

Kim Hedegaard, CEO Power-to-X at Topsoe, said: "This is a significant achievement. By working across the value chain, we're accelerating green ammonia as a pathway to diversify our energy supply and decarbonise energy-intensive industries and long-distance transportation like shipping and agriculture."

Niels Erik Madsen, CEO at Skovgaard Energy, said: "We are extremely proud of this groundbreaking project in Northwest Jutland driving innovation, growth and job creation locally. It demonstrates the energy systems of tomorrow – scalable worldwide to accelerate the green transition."

ITALY

NextChem acquires Ballestra Group

NextChem has signed a binding agreement to acquire the entire share capital of Ballestra Group, a global leader in the licensing, design and engineering of processing plants, as well as the supply of proprietary technologies and equipment for the chemical industry. Founded in 1960 and headquartered in Milan, Ballestra is the holding of a group of companies comprising BUSS ChemTech AG (Switzerland) and Ballestra Engineering and Projects Pvt. Ltd (India). It operates in over 120 countries with approximately 450 employees and offices in Europe and Asia. NextChem says that the acquisition will bring intellectual property, advanced proprietary technologies and distinctive engineering competences to its value proposition in specialty chemicals, including fluorine derivatives for lithium-ion batteries and for the metals and mining industries. This acquisition will also create cross-selling opportunities with Tecnimont, Maire Group's integrated engineering and construction services business unit, in relation to energy transition and material transformation projects. The enterprise value is €108.3 million, resulting in a purchase price of approximately €126.5 million, subject to adjustments at closing, which is expected in the first half of 2026.

Maire Group has also announced the full transfer of ownership of a stake equal to 7.9% of the share capital of NextChem SpA MI to Azzurra Next One SpA. Azzurra Next One is a corporate vehicle established for the transaction controlled by Azzurra Capital and indirectly participated by Azimut Libera Impresa SGR.

NORWAY

Proton Ventures joins Barents Clean Ammonia project

Barents Blue AS has announced Proton Ventures as a new partner in the Barents Clean Ammonia Project (project formerly known as the Barents Blue project). Barents Blue says that the Dutch engineering and project development company, a pioneer in the clean ammonia industry, "will bring significant resources and industry expertise to the project and the value chain for clean ammonia, important for the realisation of Europe's largest clean ammonia production plant located in Finnmark, Northern Norway".

Proton Ventures was established in 2001 and has been responsible for the development of several large-scale ammonia export hubs, including ammonia terminals and ammonia production facilities.

A new project development company, Barents Clean Ammonia AS, has been established, with Barents Blue holding 75% and Proton Ventures holding the remaining 25% of the shares. By joining forces, the partnership will advance the project towards a final investment decision in 2027, enabling production to commence in 2031. Barents Clean Ammonia is Europe's largest low carbon ammonia project. The first ammonia production train is planned to produce 1 million t/a of ammonia, and will be among the most energy efficient blue ammonia plants in the world, in compliance with the EU taxonomy and the Delegated Act for Low-carbon Hydrogen.

SOUTH KOREA

Alfa Laval signs MoU for ammonia fuel system collaboration

Alfa Laval Korea Ltd. has signed a Memorandum of Understanding (MOU) with Hanwha Ocean Ecotech, marking a significant step toward strengthening cooperation in developing safe and reliable ammonia fuel system solutions for dual-fuel vessels. The collaboration is founded on a shared ambition to advance ammonia fuel systems for dual-fuel vessels. Alfa Laval will contribute its proven capabilities in ammonia fuel and mitigation technologies through ammonia fuel supply system and FSS and ammonia release mitigation system (ARMS) and Hanwha will apply its extensive experience in system engineering and integration. This partnership will facilitate the exchange of expertise and improve productivity and safety on board.

"This MOU is more than just technical cooperation – it represents a strategic partnership to secure leadership in Korea and Asia's sustainable shipbuilding market. By combining our strengths, we aim to accelerate the decarbonization of global shipping with safe and reliable ammonia fuel solutions," said Young-Gu Choi, Managing Director of Alfa Laval Korea.

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Alfa Laval is actively engaged in several other key collaborations focused on ammonia as a marine fuel, such as a research and development partnership with WinGD, which has successfully tested the FCM Ammonia, ARMS and Fuel Valve Trains, laying a solid foundation for its commercial rollout. Another collaboration with South Korea's shipbuilder K Shipbuilding (KSB), WinGD, and the classification society American Bureau of Shipping (ABS), saw Alfa Laval contribute to the design of the entire fuel system, including the ammonia fuel supply system, fuel valves train, and ARMS with Alfa Laval also adding an Aalborg ammonia dual-fuel boiler system to the project scope.

UNITED KINGDOM

Tecnimont wins damages against EuroChem

Maire Group says that, in relation to its ongoing dispute with Russian EuroChem Group, its subsidiary Tecnimont has obtained immediately enforceable orders for conservatory measures to freeze assets of EuroChem Group for an amount of approximately €1.1 billion. These measures are based on the leave granted to Tecnimont by the ICC Arbitral Tribunal seated in London, to seize EuroChem's assets in every country, totalling €1.1 billion. Further seizure requests are underway in several jurisdictions. The Arbitral Tribunal has also found that Tecnimont is entitled to apply to judicial authorities to obtain asset freeze measures against EuroChem Group's assets worldwide, by way of security for the further potential damages caused by EuroChem Group's recent unlawful legal actions undertaken in Russia.

TRINIDAD & TOBAGO

Nutrien shuts down Point Lisas operations

Nutrien says that it underwent "a controlled shut down" of its Trinidad Nitrogen operations at the Point Lisas' facility from October 23rd, 2025. The company said that the shutdown was in response to port access restrictions imposed by Trinidad and Tobago's National Energy Corporation (NEC) and "a lack of reliable and economic natural gas supply that has reduced the free cash flow contribution of the Trinidad Nitrogen operations over an extended period of time". Nutrien says that it will continue to engage with stakeholders and assess options with respect to its operations in Trinidad. Ammonia and urea sales volumes from Nutrien's Trinidad operations were approximately 85,000 tonnes per month and 55,000 tonnes per month, respectively. Nutrien expects to be within its 2025 annual nitrogen sales volume guidance range of 10.7 to 11.2 million tonnes due to the continued strong performance of its North American Nitrogen operations.

Trinidad's Natural Gas Company (NGC) said that Nutrien's gas supply contract ran out on January 1st 2026 and would not be renewed unless "outstanding port user fees" were settled. NGC claims Nutrien owes $28 million in backdated port fees. Nutrien, however, rejects claims of unpaid fees, saying it had settled all port user invoices issued to it, despite the port contract having expired in 2019.

UNITED STATES

Woodside Beaumont produces first ammonia

Woodside Energy says that its Beaumont New Ammonia (BNA) facility in southeast Texas has begun production of ammonia following the completion of systems testing, representing the first phase of operations commissioning of the facility. Commercial production of ammonia from BNA is expected to begin following the handover to Woodside Energy from OCI Global in early 2026. Production of lower-carbon 'blue' ammonia is targeted to start in the second half of 2026. Woodside says it has also finalised agreements with leading global customers to supply significant volumes of conventional ammonia from the BNA facility. Deliveries will commence in 2026 and continue through year-end, under contracts that reflect prevailing market prices. Additional agreements are being advanced to align with expected BNA output, including for lower-carbon ammonia.

Woodside Beaumont New Ammonia vice president Kellyanne Lochan said: "We are pleased with the results of the commissioning and systems testing completed to date. These outcomes confirm the facility's production readiness and our ability to move toward commercial start-up following handover. This milestone also reflects the disciplined work of both the OCI and Woodside teams."

In the lead-up to handover, the project will continue with additional verification, performance testing, and operational preparedness activities. OCI and Woodside say that they remain focused on ensuring the facility safely and efficiently enters full operations, in line with regulatory and contractual requirements. BNA has a production capacity of 1.1 million t/a and is designed to support growing demand for ammonia, lower-carbon ammonia and hydrogen-adjacent products.

Yara and Air Products partnering on low carbon ammonia

Air Products and Yara International ASA say that they are working to combine Air Products' industrial gas capabilities and low-emission hydrogen production with Yara's ammonia production and distribution network, with several major projects under development.

At the Louisiana Clean Energy Complex, Air Products is developing the world's largest low-carbon energy complex, designed to produce >750 million scf/d day of low-carbon hydrogen, capturing 95% of the carbon dioxide generated during normal operation. Once the ammonia plant has achieved agreed upon performance levels, Yara would then acquire the ammonia production, storage and shipping facilities for approximately 25% of the total project cost (estimated between $8-9 billion). Yara would assume responsibility for related operations and integrate the entire ammonia output into its global distribution network. Air Products would own and operate the industrial gases production, where approximately 80% of the low-carbon hydrogen would be supplied to Yara under a 25-year long-term offtake agreement to produce 2.8 million tonnes of low-carbon ammonia per year. The remaining hydrogen would be supplied to Air Products' customers in the U.S. Gulf Coast via Air Products' 700-mile hydrogen pipeline system. About 5 million t/a of high purity CO_2 captured by the Air Products facility would be sequestered by a third party under a long-term agreement to be announced later. Final investment decisions by both companies are targeted by mid-2026, and project completion is expected by 2030.

Meanwhile, at the NEOM Green Hydrogen Project in Saudi Arabia, currently more than 90% complete and expected to start commercial production in 2027, Air Products is the sole offtaker of up to 1.2 million tonnes per year of renewable ammonia. Air Products and Yara anticipate entering into a marketing and distribution agreement

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where Yara would commercialise, on a commission basis, the ammonia not sold by Air Products as renewable hydrogen in Europe. The model maximises value for both companies and enables renewable ammonia to be delivered worldwide by Yara's shipping fleet. The marketing and distribution agreement is targeted to be completed during the first half of 2026. Yara is the world's largest trader and shipper of ammonia, currently transporting over 4 million t/a, supported by Yara's 12 ammonia vessels and 18 import terminals. In addition, Yara has a significant internal ammonia demand. Air Products is the world's largest supplier of hydrogen and brings leading low-emission hydrogen and ammonia production at scale.

"Air Products' two advanced projects are a strong strategic fit with Yara's flexible nitrogen system – enabling energy diversification and profitable decarbonisation while aligning with our disciplined capital allocation policy. The Louisiana project builds on a proven, capital-efficient model; producing ammonia from externally sourced hydrogen and delivering strong returns," said Yara's CEO Svein Tore Holsether.

NAMIBIA

Development funding for green ammonia plant

The African Development Bank has approved a $10 million loan to Hyphen Hydrogen Energy, a Namibian green hydrogen development company, to support a green ammonia project valued at more than $10 billion, and with the potential to position Namibia as a pioneer in the global green hydrogen economy. The loan, sourced from the Sustainable Energy Fund for Africa (SEFA), will support front-end engineering design (FEED) studies for solar and wind generation, battery energy storage systems, and electrolyser capacity and desalination infrastructure, aiming to de-risk the project and attract the financing required for its realisation.

The project aims to leverage the country's world-class solar and wind energy resources, The first phase includes 3.75 GW of renewable energy generation, battery storage, 1.5 GW of electrolyser capacity, and supporting infrastructure such as desalination facilities, pipelines, transmission lines, and enhanced port facilities. Once completed, the project is projected to produce 2 million t/a of green ammonia for export to key markets, while contributing to local economic development under a comprehensive socio-economic development plan embedded in the project's 40-year concession agreement. It will avert annual emissions of 5 million tons of CO_2, as well as supplying 3 million litres of clean water through desalination daily to the water-scarce region of Lüderitz in southern Namibia.

Moono Mupotola, African Development Bank Country Manager for Namibia and Deputy Director General for Southern Africa, said: "This is about far more than energy infrastructure," said. "This is about demonstrating Africa's capacity to lead the global energy transition, create quality jobs for our youth, and build prosperity while protecting our planet. Namibia is showing the world that Africa is not just participating in the green economy - we are defining it."

SPAIN

KBR awarded green ammonia project

KBR has been awarded a technology and engineering contract by IGNIS for a new green ammonia facility in A Coruña, Spain. Under the terms of the contract, KBR will provide proprietary engineering design and pre-FEED engineering services for a 200,000 t/a green ammonia plant. The facility will use renewable energy to produce green hydrogen, which will be converted to green ammonia.

Jay Ibrahim, President, KBR Sustainable Technology Solutions, said: "We are proud to support IGNIS in harnessing Spain's exceptional renewable energy resources to produce green ammonia for domestic and European markets. KBR's green ammonia solutions, along with complementary technologies such as H2ACT® ammonia cracking, make us a global leader in delivering reliable and energy-efficient ammonia technology at a lower capital cost."

NETHERLANDS

BASF to supply hydrogen-based ammonia to OCI's Geleen fertiliser plant

BASF and OCI Global have agreed for the first deliveries of renewable ammonia produced at BASF's site in Ludwigshafen in order to produce low-carbon fertilizers at OCI's site in Geleen. This initiative expands OCI's low-carbon portfolio and introduces the "Pure" product line, delivering the same fertilizer quality at a substantially reduced carbon footprint without compromising on performance. BASF says that its renewable ammonia is certified according to ISCC PLUS and is produced using a mass balance approach, through which renewable energy-derived hydrogen is attributed to the renewable ammonia grades.


PHOTO: DUTCH SAFETY BOARD

The Chemelot industrial complex, Geleen

VENEZUELA

Clariant announces divestment of its business in Venezuela

Clariant says that it closed the divestment of its legal entity (Clariant Venezuela S.A.) in Venezuela for $1.8 million to CMV Química CA, Venezuela as part of its ongoing footprint optimisation. In 2024, Clariant's operations in Venezuela generated sales of around $3.8 million and employed around 60 people.

INDIA

Foundation stone laid for new urea plant

Prime Minister Narendra Modi laid a foundation stone for a new ammonia-urea plant at Namrup in Assam on December 21st. The plant, to be constructed by the Assam Valley Fertiliser and Chemical Company Ltd (AVFCCL), will have a urea production capacity of 1.27 million t/a, and the project is scheduled for commissioning in 2030.

Start-up for new nitric acid plant

Deepak Nitrite Ltd says that its wholly-owned subsidiary, Deepak Chem Tech Ltd, has begun production at its new nitric acid plant in Nandesari, Vadodara district, Gujarat. The 70,000 t/a plant has been completed at a reported investment cost of $57 million. According to the company's filing, the new plant will allow Deepak to "reestablish supply security for key intermediates, support greater resilience across the group's chemical value chain and enable deeper penetration into high-value applications".

Toyo to build AN plant

Gujarat Narmada Valley Fertilizers & Chemicals (GNFC) has announced a contract award worth approximately $40 million to Toyo Engineering India Pvt Ltd for the supply of a second ammonium nitrate on an LEPC (Lump Sum Engineering, Procurement and Construction) basis. The plant will have a capacity of 480 t/d (160,000 t/a), and is projected to be built over a 20 month project timescale. The project received board approval during GNFC's most recent board meeting. Toyo Engineering India has established a strategic tie-up with Spain's INCRO SA for the technology license and supply of process know-how. The new ammonium nitrate plant represents a substantial expansion for GNFC, with the company stating that this installation will enhance their capacity by 94%. GNFC says that it will better position the company to serve India's growing demand for AN, while leveraging advanced international technology through the Toyo-INCRO partnership.

RUSSIA

MoU on new urea plant

Uralchem JSC and three Indian fertiliser companies; Rashtriya Chemicals and Fertilizers Ltd (RCF), National Fertilizers Ltd (NFL), and Indian Potash Ltd (IPL) have signed a memorandum of understanding to set up a joint venture to construct a urea plant in Russia. The signing ceremony was held in New Delhi in December during a state visit by Russian president Vladimir Putin to India.

The capacity of the urea plant is expected to be in the range of 1.8-2.0 million t/a, with the agreed basis for the joint venture being a supply of ammonia from Togliattiazot JSC and the financing of the project by the Indian companies until the commencement of the plant's commercial operation. The technical parameters and financial viability of the project are currently under detailed examination. The parties are also negotiating the corporate structure and governance approach in respect of the joint venture.

Dmitry Konyaev, Uralchem CEO said: "India is a leading agricultural player globally and also one of the world's biggest consumers of mineral fertilisers. For Uralchem Group, India has historically been a strategic market, and we are committed to expanding and deepening our cooperation with Indian partners. We welcome this memorandum, which is another step in the continuous development of our long-term and mutually beneficial relations."

Drone attack on Acron

Acron's fertilizer complex at Veliky Novgorod was reported to be on fire following a Ukrainian drone strike on December 10th. At least five explosions were reported at the facility, according to Ukrainian media. Novgorod Governor Alexander Dronov confirmed the attack and said the air defence system intercepted 19 drones over the region. Earlier, on December 4, Ukrainian drones struck the Nevinnomyssk Azot plant in Russia's Stavropol region, a major facility that produces over 1 million t/a of ammonia and 1.4 million t/a of ammonium nitrate annually.

CANADA

Green ammonia project "economically unfeasible"

World Energy GH2 has shelved its 1.2 GW green hydrogen and ammonia project in Stephenville, Newfoundland, after failing to secure offtake agreements. Project Nujio'qonik was conceived as a major green hydrogen/ammonia scheme backed by 2 GW of new wind capacity, intended to export green ammonia to Europe. However, despite a $50 million investment from South Korea's SK Ecoplant and high-profile endorsement by then German chancellor Olaf Scholz, the developer has confirmed that the project is being replaced by a new initiative, called Clean Grid Atlantic, which will use the wind resource to power domestic markets instead.

In an interview with CBC, John Risley, chairman of World Energy GH2 acknowledged that with no viable export market and a lack of domestic industrial demand, clean hydrogen in Canada remains "economically unfeasible" in current market conditions.

JORDAN

Agreement on gas-based ammonia plant

The Jordan Free and Development Zones Group (JFDZ) says that it has signed a memorandum of understanding (MoU) with Nitrogen Jordan for Fertilisers to develop a gas-based ammonia plant within the Kingdom. Under the MoU, an area of around 200 hectares within the Al Karameh Free Zone on the Jordanian-Iraqi border will be allocated for the establishment of an ammonia production plant. The announcement follows positive developments at the Jordanian Risha Gas Project, located near the Iraqi border and major Jordanian crossings, approximately 30 kilometres from Al Karameh Free Zone, according to a JFDZ statement.

Syngas News

CHINA

World's largest integrated green hydrogen-ammonia-methanol project

The first 320 MW phase of what China Energy Engineering Corporation Ltd says will ultimately become the world's largest integrated green hydrogen-ammonia-methanol project HyFlow has officially begun operation in Songyuan City in Jilin Province. With a total investment of nearly \$4.30 billion, the Songyuan project uses a "wind-solar-hydrogen-ammonia-methanol" integration model, creating an industrial chain that includes hydrogen production and storage, as well as hydrogen-derived chemicals such as ammonia and methanol, hydrogen energy equipment, and scientific research. The project eventually plans to develop 3 GW of renewable energy capacity from wind and solar power, alongside a target production capacity of 800,000 t/a of green ammonia and methanol. The annual production of green hydrogen in the project's first phase is expected to be equivalent to approximately one-fifth of China's current total annual green hydrogen production.

CIMC Enric commissions biomethanol project

CIMC Enric Holdings Ltd says that it has commissioned China's first large-scale biomethanol facility in Zhanjiang, Guangdong Province, marking a major step forward in the decarbonisation of global shipping and clean fuel supply chains. The project, developed by CIMC Enric and its subsidiaries, is designed as a fully integrated closed-loop system converting forestry residues into green methanol for use as marine fuel. With an initial annual capacity of 50,000 t/a, it is the country's first commercial scale green methanol plant, and is backed by the port of Zhanjiang and abundant local forestry wastes.

According to CIMC Enric, the Zhanjiang facility achieves more than an 83% reduction in lifecycle greenhouse gas emissions, measured across feedstock sourcing, production, storage and delivery. The entire value chain has been certified under the ISCC EU sustainability standard, while independent C-14 testing by Beta Analytic (USA) confirms full carbon traceability from biomass feedstock to final product. The project is aligned with international climate and regulatory frameworks, including the IMO's net-zero roadmap, the EU Renewable Energy Directive (RED) and the Carbon Border Adjustment Mechanism (CBAM), reinforcing its relevance for global shipping operators facing tightening emissions regulations.

"CIMC Enric's methanol plant in Zhanjiang precisely targets the IMO's 2050 net-zero emissions goal. It deeply aligns with the core demand for decarbonisation and emission reduction in the global shipping industry," said the company.

DENMARK

Topsoe and Maersk to set new safety standards for Power-to-X

Topsoe is partnering with Maersk Training to establish safety standards that support the emerging Power-to-X industry. Topse says that Power-to-X and the production of e-fuels are critical enablers of the transition to low-emission fuels. However, no comprehensive safety standards currently exist that address the full range of risks at these sites. Together, the two companies will develop realistic simulations, competency-based training and a strong operational culture designed to strengthen safety practices across the entire value chain. As Power-to-X technologies scale to meet global climate ambitions, both companies emphasise the need for robust, realistic and forward-looking training frameworks. The collaboration builds on Maersk Training's nearly 50 years of experience in high-risk environments.

Sundus Cordelia Ramli, Chief Commercial Officer Power-to-X at Topsoe, said: "The Power-to-X industry is scaling faster than regulation can keep up, and that makes proactive safety leadership critical. By combining Topsoe's deep technological expertise with Maersk Training's proven track record in realistic, competency-based training, we aim to ensure that this nascent industry is built on a foundation of competence, preparedness and care."

Per Larsen, Head of Innovation and Product Management at Maersk Training, said: "We bring nearly 50 years of experience in training. But we also recognize the value of strong partnerships – where additional expertise makes us stronger. This is not just about ticking boxes; it's about making sure the people on the front line are equipped with the right skills and mindset."

UNITED STATES

Greene Tweed achieves hydrogen compression breakthrough

Greene Tweed, a leader in advanced materials and high-performance solutions, says it has achieved a significant advancement in hydrogen compression technology. The company's newly engineered composite closed impeller set a record-breaking tip speed of 688 m/s in testing – nearly double that of traditional metallic impellers. The innovation highlights the potential of advanced composite materials to enhance performance, reduce costs, and improve efficiency in critical hydrogen pipeline infrastructure, specifically the transportation, storage and utilisation market segments.

Transporting hydrogen through pipelines requires large centrifugal compressors to maintain pressure. Conventional metallic impellers typically operate at speeds of up to 360 m/s for closed designs and 500 m/s for open designs before burst, limiting the achievable compression ratio for lighter gases and thus requiring more compressor stages, increasing the system size, cost, and maintenance requirements. With Europe planning tens of thousands of kilometres of hydrogen pipelines by 2040, the demand for faster, more durable, and cost-effective compressor technology is surging.

"We aim to revolutionize hydrogen infrastructure by breaking past the limitations of metals," said Magen Buterbaugh, Greene Tweed President and CEO. "By delivering solutions that cut costs, simplify operations, and drive scalability, Greene Tweed is setting a new standard for the industry. We are now collaborating with centrifugal compressor OEMs to bring this technology to real-world applications."

Synthetic natural gas project for Nebraska

A consortium consisting of TotalEnergies, Osaka Gas, Toho Gas, and ITOCHU have signed a joint development and operating agreement, granting the Japanese companies a combined 33.3% stake in the Live Oak project – a large-scale facility to produce renewable synthetic natural gas, also referred to as e-NG or e-methane, initiated by TES and TotalEnergies and currently under development in Nebraska. Following the agreement, TES and TotalEnergies will each maintain a 33.35 % stake in the project.

The partners are now preparing the front-end engineering design (FEED) phase, targeting a capacity of approximately 250 MW of electrolysis and 75,000 t/a of methanation. The project, subject to a final investment decision in 2027, is scheduled to begin commercial operations by 2030, with plans to export e-NG to Japan. Osaka Gas and Toho Gas will be the primary offtakers. This project helps the Japanese gas majors in achieving their goal of injecting 1% carbon neutral gas (such as e-NG) into the gas grid by 2030.

ASU contract for blue methanol plant

Air Water Gas Solutions, a subsidiary of Air Water America, will build an air separation unit to support the production of 1.1 million t/a of blue methanol at Sandpiper Chemicals' blue methanol facility in the US. The low carbon methanol producer has contracted Air Water to design, build, and operate the ASU to provide oxygen, nitrogen, and instrument air for blue methanol production. The project is still at the pre-final investment decision (FID) stage, with production targeted for 2030.

Sandpiper Chemicals' plant will also feature SynCOR autothermal reforming technology, developed by technology and solutions company Topsoe. The plant is expected to reform natural gas into hydrogen-rich syngas, capture much of the CO_2, and use the hydrogen in that syngas to produce blue methanol.

SWEDEN

Johnson Matthey opens first hydrogen internal combustion engine facility in Gothenburg

Johnson Matthey (JM) has officially opened its first hydrogen internal combustion engine facility, where emission control systems will be tested. Hydrogen internal combustion engines use zero carbon hydrogen fuel in tried-and-tested engine technology, presenting a viable path for decarbonising medium and heavy-duty transport, such as trucks and buses.

Announced back in July, the new testing area forms part of JM's existing site in Gothenburg, Sweden. The facility has


Opening ceremony for the new engine facility.

PHOTO: JOHNSON MATTHEY

been completed on time and on budget, representing a £2.5m investment over three years. The opening was performed by Damien Sotty, JM R&D Director, Daniel Sandqvist, Gothenburg Test Centre Manager and Jonas Edvardsson, Managing Director JM Gothenburg.

Tauseef Salma, JM Chief Technology Officer in Clean Air, said: "This investment shows JM is backing H_2ICE as a ready-to-go technology that will enable mobility partners to meet their decarbonisation and climate goals. Our state-of-the-art Gothenburg facility positions JM as a world leader in sustainable technology solutions, transforming energy and reducing carbon emissions."

The new Gothenburg installation supports engines up to 600kW (800hp). It will test the performance of catalysts within the wider engine after-treatment and control systems, providing key insights into the development of hydrogen mobility solutions. Gothenburg is already home to medium and heavy-duty diesel engine test cells. Johnson Matthey is a founding member of the Global Hydrogen Mobility Alliance, a coalition of more than 30 major companies across the automotive, energy and technology sectors, aiming to accelerate the deployment of hydrogen solutions in Europe's transport sector. The alliance – which includes companies such as BMW, Toyota, Hyundai, Air Liquide, and Linde – is urging EU policymakers to prioritise hydrogen mobility as a key component of their decarbonisation and industrial strategies.

SPAIN

Clariant catalysts selected for waste-to-methanol plant

Clariant says it is collaborating in Repsol's pioneering methanol plant in El Morell near Tarragona, Spain. The Ecoplanta project will be the first of its kind in Europe to convert municipal waste into renewable methanol, using Enerkem's advanced waste gasification process, supported by a range of Clariant's syngas purification catalysts and its highly active MegaMax methanol synthesis catalysts. Scheduled for completion in 2029, the plant will use 400,000 t/a of non-recyclable solid municipal waste to produce 240,000 t/a of methanol.

Georg Anfang, Vice President Syngas and Fuels at Clariant Catalysts, commented, "We are proud to collaborate with Repsol and Enerkem in the prestigious Ecoplanta project to support Europe's energy transition. Leveraging our decades of innovations in methanol synthesis catalysts, Clariant is uniquely positioned to drive the large-scale deployment of low-carbon methanol technologies that will play a decisive role in decarbonising hard-to-abate industries."

Michel Chornet, CEO of Enerkem, added, "We are excited to contribute to the Ecoplanta project and set an inspiring example for others on the path to decarbonisation. Our technology not only enables large-scale production of low-carbon methanol and the reduction of waste in landfills but also avoids substantial greenhouse gas emissions. According to estimates, abatement will be equivalent to 3.4 million tons of CO_2 in the first 10 years of operation."

After gasification of municipal waste, the trap and guard catalysts will be used to efficiently remove all types of impurities, such as metals, halogens, and sulphur species. The purified syngas will then be converted to methanol using the MegaMax series catalysts. Due to its high activity, the catalyst can optimise methanol yield while significantly reducing operating costs. It also offers enhanced selectivity, which reduces the formation of by-products and thus improves the sustainability and economics of bio-methanol production.

NORWAY

Technology selected for green hydrogen projects

Nel ASA says that it has entered into an agreement with GreenH to be the technology provider for the Enova-supported

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projects in Kristiansund and Slagentangen. GreenH develops, builds, owns, and operates hydrogen production facilities based on renewable energy. The company aims to establish a network of distributed hydrogen production sites to enable decarbonisation in the maritime, transport, and industrial sectors. GreenH focuses on scalable solutions located close to end users, reducing logistics costs and supporting the development of efficient, regional hydrogen value chains. The facilities in Kristiansund and Slagentangen are intended to supply green hydrogen to industrial and maritime users and form part of GreenH's broader efforts to establish a network of distributed hydrogen production in Norway.

"We have worked together with Nel on finding the right electrolyser concept for Kristiansund and Slagentangen over a longer period. We are very pleased with the signing of this agreement and thereby bringing in Nel as a partner on these two projects that are very important for GreenH," says Morten Solberg Watle, CEO of Green H AS.

Nel has entered into an agreement regarding delivery of electrolyser equipment, including associated engineering and technical support. Final scope, size, and delivery schedules will be confirmed later, but will be minimum 10 MW per site, totalling more than 20 MW.

JAPAN

MHI successfully produces hydrogen at ammonia cracking pilot plant

Mitsubishi Heavy Industries says that it has succeeded in producing 99% pure hydrogen by cracking ammonia using steam as the heating source. The production of hydrogen at pilot scale using the steam heating was conducted at the company's pilot plant in the Nagasaki District Research & Innovation Centre, marking a world first. By contrast to technologies that use heat from burner combustion, MHI's steam heating system operates at lower reaction temperatures, reducing operating costs. In addition, because a combustion furnace is not required, the system offers excellent features such as the potential for miniaturisation.

MHI aims to build on this achievement to promote the development of medium-scale, decentralised ammonia cracking systems near hydrogen demand sites. Based on the results of this pilot test, MHI, in collaboration with project partners Nippon Shokubai Co., Ltd. and Hokkaido Electric Power Co., Inc., will accelerate the development of this technology, which was selected by Japan's New Energy and Industrial Technology Development Organization (NEDO) for its "Development of Technologies for Building a Competitive Hydrogen Supply Chain" project.

ClassNK approves ammonia/methanol powered bulk carrier

ClassNK has issued approval in principle for a concept design of the Multiple Alternative Fuels Ready (ammonia/methanol/LNG) bulk carrier developed by Oshima Shipbuilding Co., Ltd. The certification confirms the feasibility of the vessel from regulatory and safety perspectives. ClassNK has published Annex 1 Alternative Fuel Ready of the Guidelines for Ships Using Alternative Fuels, which summarises the requirements for adding class notations to ships that do not use alternative fuels at the time of construction but are designed and partially equipped to accommodate such fuels in the future.

Methanol Reformer to supply MGC with methanol reformer for Niigata plant

Spain's Methanol Reformer has signed a sales and purchase agreement with Mitsubishi Gas Chemical Company, Inc. (MGC) for the supply of an L18 methanol reformer compliant with Japanese industry requirements. The system will be delivered and installed at MGC's Niigata plant, with commissioning planned for the second half of 2026. Methanol Reformer says that this, their first industrial project in Japan, reinforces the company's presence in the Asian market, while for MGC, the collaboration supports the adoption of innovative hydrogen-generation solutions designed to enhance operational applicability and efficiency with reliability.

The L18 system integrates methanol reforming technology to generate hydrogen on demand in a compact, modular, and efficient configuration suited for industrial environments. This hydrogen will support selected hydrogen applications at MGC's Niigata plant, contributing to the company's broader energy strategy.

SAUDI ARABIA

KBR selected for biomethanol plant

KBR has been awarded a contract for its PureM green methanol technology by Fikrat Al-Tadweer for a biomethanol plant in Saudi Arabia which will convert landfill gas into clean fuels. KBR's technology is designed for commercial-scale deployment with a low cost of renewable methanol production, and can utilise a wide range of feedstocks, including biogas, gasification-derived syngas, hydrogen, and pure CO_2, enabling flexibility and efficiency. Under the terms of the contract, KBR will provide technology licensing, proprietary engineering design, catalyst, and proprietary equipment for the biomethanol facility.

"We are proud to support Fikrat Al-Tadweer in its groundbreaking biomethanol project, which aligns with Saudi Arabia's national policy on eliminating landfill gas emissions and creating sustainable fuels," said Jay Ibrahim, President, KBR Sustainable Technology Solutions. "This collaboration underscores KBR's commitment to enabling global energy security and supporting the Kingdom's vision for a cleaner, greener future."

OMAN

Consortium formed to look at low carbon methanol project

Oman's Ministry of Transport, Communications and Information Technology has signed a memorandum of understanding with a consortium comprising HIF EMEA GmbH, Acciona Nordex Green Hydrogen and Al Meera Investments to jointly explore the development of a low carbon methanol supply and bunkering hub at Dhofar in Oman. This strategic collaboration aligns with Oman's Vision 2040 strategy, supporting national decarbonisation targets and positioning Oman as a pre-eminent green maritime and bunkering hub in the Middle East.

Under the MoU, the parties will jointly assess the technical, regulatory, and commercial framework required to establish a large-scale green methanol facility leveraging Oman's abundant renewable energy resources and strategic coastal infrastructure. Studies will cover bunkering and the export of green methanol produced in Dhofar region, based on the integration of wind and solar energy for green hydrogen production, CO_2 capture and supply from industrial or biogenic sources, and downstream conversion to methanol. The Ministry will facilitate engagement with Omani authorities and stakeholders to enable regulatory frameworks, land allocation, and exploring incentives for the project. ■

People

BASF has announced a new management board for the spin-off of its new Agricultural Solutions division as a separate company ahead of its listing and initial public offering (IPO) on the Frankfurt stock exchange. BASF says this will "establish the standalone business as an independent, pure-play agricultural company with global reach, robust growth prospects and strong cash flow generation." BASF will remain the majority shareholder and will continue to benefit from the company's growth and success, while implementing market customary corporate governance.

The new management board will take office from May 1st 2026 and will lead Agricultural Solutions through its transition to an independent, publicly listed company. It will comprise four members: **Dr. Livio Tedeschi**, President, BASF Agricultural Solutions, will assume overall responsibility as the Head of the Management Board. He will also become member of the Board of Executive Directors of BASF SE with responsibility for the Agricultural Solutions segment effective May 1, 2026, as previously announced.

Sascha Bibert will join BASF Agricultural Solutions from Vallourec SA and, as member of the management board, be in charge of Finance. **Maximilian Becker**, Senior Vice President Vegetable Seeds, BASF Agricultural Solutions, will be in charge of Business. **Dr. Melanie Bausen-Wiens**, Senior Vice President Regulatory, Stewardship & Public Affairs, BASF Agricultural Solutions, will be in charge of Technology.

"For over a century, Agricultural Solutions has supported farmers and breeders with innovations that help them grow their crops to their full potential. As we move forward as a fully integrated company with proven strengths in crop protection, seeds and traits, digital farming, and sustainability, we are uniquely positioned to serve evolving customer needs, while continuing to advance agriculture and create sustainable, resilient food systems for generations to come," said Tedeschi, incoming member of the Board of Executive Directors of BASF SE and Head of the Management Board of Agricultural Solutions. "Together with the new Management Board and our teams worldwide, we will turn our strategy and vision into reality – opening a new chapter for our business to become publicly listed."

Agricultural Solutions is being separated from BASF into own legal entities and is introducing an industry-specific ERP system. This transition has already been successfully accomplished in North America; for the remaining regions it will be completed by early 2027.

Taiwan Fertilizer Co., Ltd. Has announced the appointment of **Chen Yu-Hsin** as President, effective January 1, 2026. The board of directors resolved the appointment on December 30, 2025. The previous President was Chang Chang-Lang, who served as TFC Chairman and President and holds an MSc from the National Taiwan University Graduate Institute of Building and Planning. The new President, Chen Yu-Hsin, was a Senior Specialist at the Ministry of Agriculture and holds an MA from the National Chung Cheng University Graduate Institute of Political Science.

CVR Energy, Inc.'s board has appointed **Mark A. Pytosh**, a long-time executive within the CVR group, as President and Chief Executive Officer effective January 1, 2026, succeeding **David L. Lamp**, who will step down from those roles as of December 31, 2025. Pytosh, 60, who has served as the Company's Executive Vice President Corporate Services since 2018 and as President and CEO of the general partner of CVR Partners, LP since 2014, will retain his leadership and board roles at CVR Partners while assuming the top executive position and a new directorship at CVR Energy, as the board expands from nine to ten members. He will not receive additional board compensation while employed, and the company disclosed that there are no related-party transactions, pre-arranged selection understandings, or family relationships influencing his appointment, underscoring a continuity-focused but formally independent leadership transition. ■

Calendar 2026

JANUARY

26-28
Fertilizer Latino Americano, MIAMI, Florida, USA
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

29
IMPCA Methanol Mini-Conference America, ORLANDO, Florida, USA
Contact: International Methanol Producers and Consumers Association
Email: meetings@impca.eu
Web: https://impca.eu/events/12th-impca-conference-amercia-orlando-florida/

FEBRUARY

10-12
Nitrogen+Syngas Expoconference 2026, BARCELONA, Spain
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

MARCH

10-11
Clean Ammonia Storage Conference, ROTTERDAM, Netherlands
Web: https://www.stocexpo.com/en/visit/conference/

25-26
Gasification 2026, BERLIN, Germany
Contact: Mohammad Ahsan – Marketing & Delegate Sales, ACI
Tel: +44 (0) 203 141 0606
Email: mahsan@acieu.net

APRIL

7-9
AFA International Annual Conference & Exhibition, CAIRO, Egypt
Contact: Arab Fertilizer Association
Tel: +202-23054464 – 67
Email: events@arabfertilizer.org

21-23
Nitrogen+Syngas Expoconference USA, DALLAS, Texas, USA
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

MAY

4-6
IFA Annual Conference, ABU DHABI, United Arab Emirates
Contact: IFA Conference Service, Paris, France.
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

JUNE

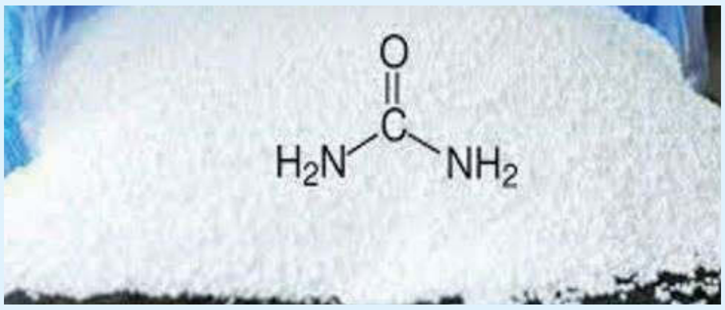
4-5
NH3 Event Europe, ROTTERDAM, Netherlands
Contact: Stichting NH3 Event Europe
Tel: +31 10 4267275
Email: info@nh3event.com

Plant Manager+

Problem No. 76 Additives to improve quality of prills

This round table discusses the benefits of different additives as an alternative to formaldehyde to improve the quality of prills. For example, the benefits of adding gypsum and/or AS to urea prills includes:

- **significant higher plant production capacity;**
- **nitrogen and sulphur (and calcium) as nutrients in one prill (higher nitrogen use efficiencies);**
- **significant higher crushing strength;**
- **large particle size;**
- **negligible additional heat load on prilling tower;**
- **smaller product size distribution with the Kreber Vibro prilling bucket;**
- **no formaldehyde but coating will be required;**
- **lower ammonia and dust emissions;**
- **biuret formation stops;**
- **payback times of only a few months.**



Urea + ammonium-sulphate fertilizers (UAS)

Sulphur deficiency occurs widely in many parts of the world, due to a combination of factors: reduced use of single super phosphate, which contains gypsum ($CaSO_4$), more sulphur being removed from fields due to increasing yields, and declining soil reserves due to erosion and leaching. In addition, emissions of sulphur dioxide from burning fossil fuels have historically provided a large sulphur input to soil, as both rain and deposition of dust. As these emissions reduce, so soil deficiencies are increasing. Fertilizers enriched with S are now increasingly used to correct sulphur deficiencies. A better source of sulphur may be ammonium sulphate (AS), which makes the sulphur available in a form that can be directly taken up by plants.

A nitrogen plus sulphur fertilizer can enhance the utilisation rate of nitrogen due to their well-known synergy; plants need sufficient levels of sulphur to be able to utilise nitrogen efficiently. Together, nitrogen and sulphur are vital building blocks for protein, and should be applied at the same time.

Urea + gypsum fertilizers (UCS)

Phosphoric acid is a major feedstock for phosphate fertiliser, but, for every tonne of acid produced, an average of 5.4 t of phosphogypsum (PG) is created. The outcome is that the annual PG output of International Fertiliser Association (IFA) members is in the range ~225-245 million tonnes. This amount and its contaminants pose a significant challenge for the industry to achieve better sustainability performance. Urea is the most widely used nitrogen fertiliser with some 200 million tonnes sold annually but suffers from significant nitrogen losses through ammonia volatilisation, CO_2 loss, as well as N_2O emissions and nitrate leaching. The emissions of CO_2 and N_2O contribute significantly to the carbon footprint of urea fertilisers. These two issues form possibly the two major environmental challenges in our industry. Urea with gypsum represents a potential next-generation fertiliser. It can deliver improved agronomic performance and higher nitrogen use efficiencies. And, because of the large volume of urea use, it can potentially contribute significantly to the reuse of PG. By recycling industrial gypsum wastes and reducing nitrogen losses, the use of urea-gypsum fertilisers aligns with global goals for climate-smart, resource-efficient agriculture.

Joao Amilton from Petrobras in Brazil initiates this round table discussion: What are the best additives to improve crushing strength and anti-caking resistance of prills? We operate with formaldehyde 37% and PVA solution (polyvinyl acetate). The medium crushing strength of our prills is about 0.654 kgf with formaldehyde (0.440 kgf without). The prill tower design is TEC induced-draft (original project was 800 t/d, but today operates at 1,350 t/d). Our operators don't like to work with formaldehyde because it's toxic to human health.

Mark Brouwer of UreaKnowHow.com, The Netherlands replies: I know, introduce another anti caking agent, URESOFT 150, that can be sprayed on the belt conveyor and which has no bad effect on human health.

Joao comes back with another question: Do you know URECOAT 2000 and Urefix?

Al-Mohaws of SABIC Agri-Nutrients in Saudi Arabia joins the round table discussion and shares his experience: We are using UF-85 (urea formaldehyde) to improve the crushing strength plus URESOFT 150 as an anti-caking agent. As regards URECOAT 2000, we have used it but we prefer URESOFT 150. We keep URECOAT 2000 as a stand-by in case of shortage of Uresoft 150.

Hana Stepic of Petrokymia, in Croatia joins the discussion: We use LENDAFORM 70 (urea formaldehyde) to improve crushing strength. We don't use anti-caking agent any more.

Les Farbotko, formerly of Incitec Pivot Limited in Australia, shares his valuable experiences: We have used formaldehyde, UF-75 and URESOFT 150 in the past when we made prills.

I believe UF-75 is far more user friendly than 37% formaldehyde, and poses much less risk to operators. As well as making prills harder, it also reduces caking tendency.

URESOFT 150 needs to be applied uniformly to the product if it is to be effective. This usually means multiple spray nozzles and some form of mixing drum. If you don't do this, you can make your caking problems worse than if you had not applied anything!

In my experience, UF75 was more effective than URESOFT 150, because it is easy to apply uniformly to every prill, and contains only a small amount of water, which is evaporated anyway.

Serpoush of Shiraz Petrochemical Complex in Iran asks for more information about PVA.

Janusz Mackowski of ZCh Police in Poland joins the discussion: I can imagine that PVA is added to prilled final product. What is your experience with polyvinyl acetate?

We tested a similar solution as anti-caking agent but we weren't very happy with it.

We also use urea formaldehyde condensate (highly concentrated) to improve the mechanical strength (introduced to melt of urea).

Joao replies: We use PVA solution too, but it's very uncomfortable to work with. Operators should dilute the concentrate PVA solution before injecting in urea prills. Pipes and pumps are frequently blocked and the humidity of urea increases.

Serpoush comes back: OK, so you are using UF-85 (urea formaldehyde) to improve crushing strength plus URESOFT 150 as anti-caking agent. Have you measured the improvement? How much improvement in urea crushing strength do you have in the prills? Do you have a fast method to test this improvement?

Janusz replies: You can achieve about 30% increase in crushing resistance of prills by adding concentrated UFC-85 to urea melt. The simplest way to measure this increase is to use laboratory scale and pencil. Of course you can also apply more advanced devices like those which are used to measure the resistance of small pastilles.

Mark rejoins the discussion: Adding solid additives like AS or gypsum proves to be a very effective way to improve your prill quality; larger prills, higher crushing strengths and multi-nutrient fertilizer plus very low pay back times.

Refer to: https://ureaknowhow.com/produce-also-higher-value-uas-and-ucs-fertilizers-and-upgrade-your-prill-quality/

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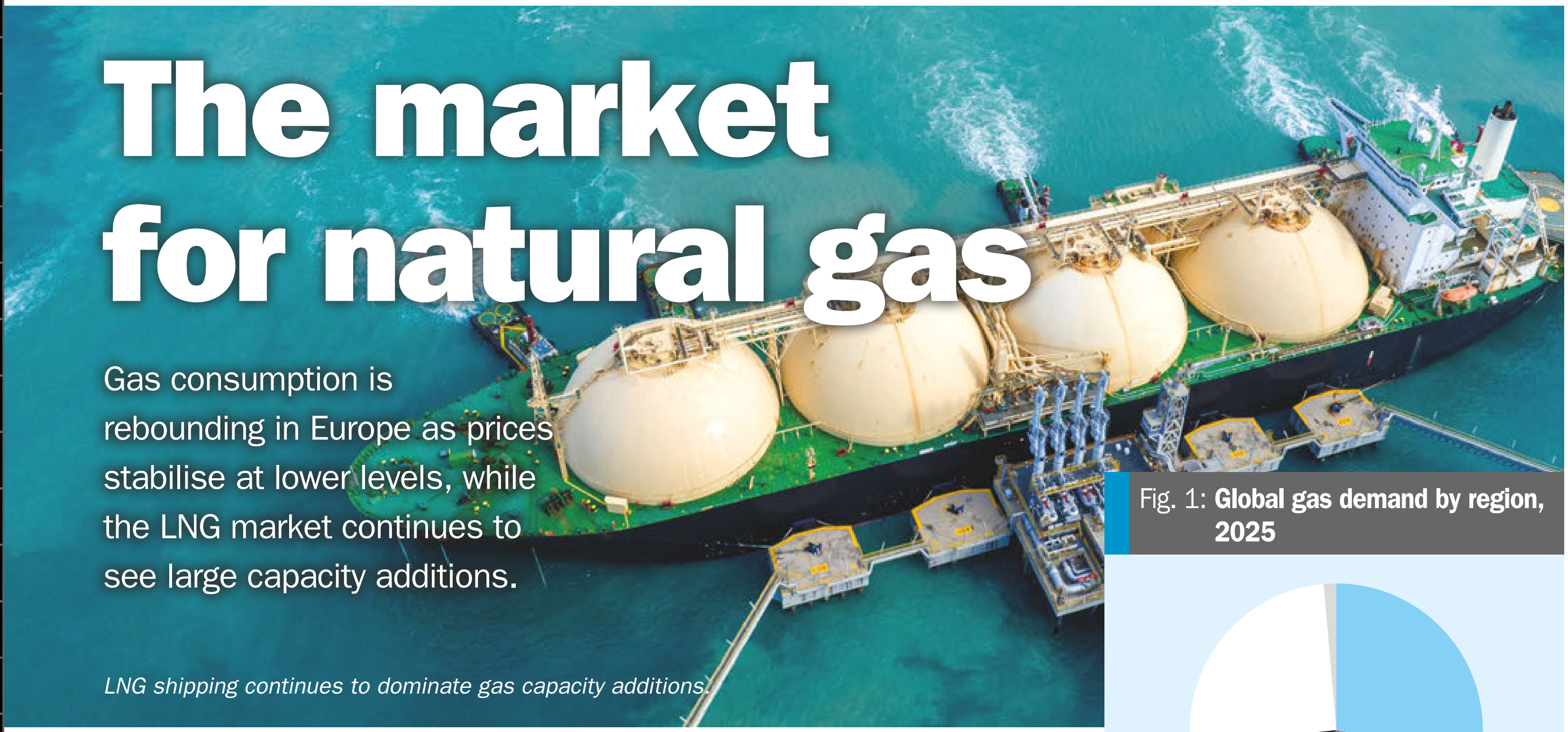


The market for natural gas

Gas consumption is rebounding in Europe as prices stabilise at lower levels, while the LNG market continues to see large capacity additions.

LNG shipping continues to dominate gas capacity additions.

PHOTO: IEA

Global gas consumption rose to roughly 4,120 bcm in 2024, an increase of about 78 bcm (1.9%) year-on-year. Growth was driven by power sector demand (notably linked to extreme summer heat), industrial rebound and regional heating/cooling needs. Rising electricity demand for AI/data centres is also playing a role. This growth continued into 2025, growth continued, but the pattern diverged regionally: Europe and North America showed stronger demand in the first half of the year, including a surge in European LNG imports, while China and some Asian buyers curtailed spot procurement amid high prices and abundant domestic supply. Overall, 2025 demand is likely to have risen by about another 1.9% over 2024. Natural gas continues to play a role in balancing fluctuating demand from renewable electricity.

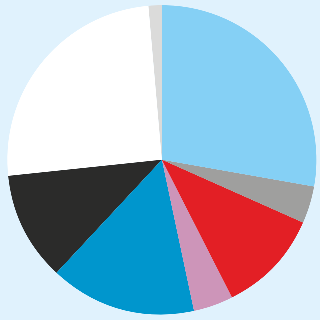
On the supply side, LNG trade expanded again, reaching roughly 555 bcm in 2024 – the eleventh consecutive year of growth. This reinforced LNG's role as the flexible backbone of cross-border gas supply. However, declining upstream deliverability in some producing basins, maintenance schedules, and sanctions-related disruptions have limited output in some regions. That dynamic, alongside new LNG supply, is already changing inter-regional flows: pipeline trade to Europe has fallen dramatically compared with the pre-2022 era, while LNG has provided an alternative source of supply and seasonal flexibility.

Regional highlights

Asia Pacific remains the primary demand driver to 2030. China and India together account for a large portion of incremental demand in the base case – around 40% – supported by industrial growth, some coal-to-gas switching, power-sector needs and expanding distribution networks. Price sensitivity in the emerging markets in Asia means that lower LNG prices could unlock additional demand, but only if import infrastructure is in place.

Europe's natural gas supply increased by an estimated 6.5% (19 bcm) Q1-Q3 2025. The strong increase in LNG imports, together with higher non-Norwegian gas production, offset the declines recorded in piped gas imports. LNG imports rose by 28% (or almost 28 bcm) and reached an all-time high of 127 bcm due to stronger domestic demand, together with lower piped gas imports and higher storage injections, meaning that the share of LNG in Europe's gas supply rose from 35% in Q1-Q3 2024 to 42% in Q1-Q3 2025. The US increased its LNG deliveries to Europe by 60% and alone accounted for almost all incremental LNG supply to Europe during this period. Russia's piped gas supplies to the European Union fell by 45% (or 10 bcm) in Q1-Q3 2025 amid the halt of gas transit via Ukraine, although Russian exports to Turkey rose by more than 20% (or almost 2.5 bcm). The share of Russian piped gas in Europe's gas demand is estimated at below 10%.

Fig. 1: **Global gas demand by region, 2025**



Source: International Gas Union

In North America, supply continues to grow, mainly from shale and associated gas, which is facilitating LNG export expansion. US production underpins global LNG liquidity and has been a central determinant of marginal global supply cost. US gas production is estimated to have grown by 3.3% in the first nine months of 2025, underpinned by rising LNG requirements and a stronger gas price environment. Despite a downward trajectory since the start of the year, Henry Hub prices averaged $3.11/MMBtu in 2Q and 3Q 2025, about 50% above the same period the previous year. This helped reverse a period of production decline in the higher-cost Haynesville Basin, while Appalachian output recovered to and surpassed pre-2024 levels. US domestic consumption is set to remain largely flat during 2026, with demand from new liquefaction projects set to drive production growth. Despite the scale of liquefaction capacity additions, the US market is expected to remain well supplied,

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 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76

with dry gas production growing by 3% in 2025 and about 2% in 2026, reaching new record highs in both years.

LNG

LNG supply growth is one of the major stories of global gas markets. There is around 300 bcm/year of nameplate supply capacity scheduled to come onstream between 2025 and 2030, with the US and Qatar accounting for the bulk of new capacity. In 2025 the US liquefaction sector saw a record run of final investment decisions, including Louisiana LNG, Corpus Christi expansions, CP2, Plaquemines and Port Arthur phase 2, reflecting policy support and developer confidence. Other projects in Canada, Mexico and selected African projects (e.g., Nigeria train additions, Congo FLNG) add further volumes, diversifying sources beyond the traditional Australia-Qatar-Malaysia suppliers. Some pre-FID projects in Mozambique and elsewhere remain uncertain.

Not all of this capacity will be available straight away; nameplate capacity does not equal delivered tonnage in the early years and typical liquefaction projects can take months or even years to reach steady output, and occasionally underperform due to commissioning or maintenance. The IEA and industry trackers assume progressive ramp rates and lower early-cycle utilisation. In addition, some older exporters, such as Australia, where gas fields are in natural decline, and facilities in Alaska as well as those dependant on pipeline gas are suffering feed-gas constraints, maintenance outages or geopolitical restrictions. Combined, these effects can reduce available supply by multiple tens of bcm versus static nameplate additions. New LNG will displace some pipeline trade flows, most notably to Europe, as much as it will add net global supply. However, even if 250 bcm/year is a more realistic figure for the actual supply increase, this supply will continue to reshape global gas markets.

The growth in LNG export optionality and the associated expansion of the global fleet will lower the marginal cost of serving distant buyers relative to the late-2010s era of tighter cross-basin flows. But the construction lead times of liquefaction plants and the sensitivity of investment decisions to price signals mean the industry faces a potential risk of underinvestment if prices fall and remain low.

Demand

Set against this, global gas demand is projected to increase by about 9% out to 2030, or around 380 bcm/year, most of this concentrated in the Asia Pacific region, including China, India, and ‘emerging Asia’. China and India together account for a large share of the base-case increase, and South/Southeast Asia offers significant upside in a price-responsive scenario. Industrial fuel switching, gas-to-power growth where renewables and nuclear cannot immediately cover rising electricity needs, and sectoral demand for shipping bunker fuel, heavy road transport, data-centre power via gas-backed generation etc all support robust demand growth.

Conversely, Europe is likely to see a modest structural decline in domestic demand due to increasing efficiency of use and progressive electrification of some sectors, as well as increased supply from renewable energy, but LNG will remain critical for security and seasonal balancing; North American demand is projected to grow more slowly, but sees continued industrial and data-centre power demand.

The International Energy Agency’s high-case scenario shows that if hub/spot prices converge toward the short-run marginal cost of competitive US LNG, price-sensitive Asian markets could unlock additional demand of ~65 bcm by 2030 versus the base case.

Prices and market structure

The gas industry continues to shift away from long term contracts towards gas-to-gas indexation and hub-based pricing, as well as some hybrid and shorter time contracts. LNG contracting in particular is evolving, with more destination-flexible cargoes, and new market entrants are increasing options for buyers. As noted above, there are some variable here; if incremental LNG supply outpaces base-case demand (due to slow infrastructure roll-out or a weaker macroeconomic situation), downward pressure on spot prices could persist, discouraging new FIDs toward the end of the decade and sowing the seeds of a post-2030 tightening. Conversely, a price convergence closer to US short-run marginal costs would encourage price-responsive demand in Asia and limit shut-ins.

Market liquidity will rise, due to a larger spot market and increased tradable volumes, but the transition creates transitional risks: stranded upstream or liquefaction investment if low prices persist, and short-term volatility tied to weather, storage cycles and geopolitical shocks.

Infrastructure

The LNG shipping order book and floating storage, regasification and use capacity will expand; shipping will be a binding constraint if fleet renewal and shipyard capacity lag cargo growth into the late 2020s. Investment in regasification terminals and distribution infrastructure in emerging markets is crucial to absorb incremental LNG supply.

Gas storage continues to be a systemic buffer. Europe’s storage targets and prudential policies influence seasonal spreads and flows; Asia’s limited storage capacity raises sensitivity to supply disruptions and seasonal shocks.

Decarbonisation

Carbon capture, usage and storage (CCUS) is moving from demonstration to deployment in selected value chains such as cement, chemicals, and hydrogen production. For new gas projects and LNG exporters, embedding low-emission options (e.g., CCUS at liquefaction plants) is becoming a competitive differentiator in some buyer markets. Elsewhere, low emission gaseous fuels such as biomethane, low-emission hydrogen, and even low carbon syngas-derived methane (‘e-methane’) are continuing to scale rapidly, albeit from a small base. The will remain a small portion of total gaseous energy through 2030, but could be important in niches and premium markets and provide strategic low-carbon options for particular buyers. However, the commercial roll-out of CCUS and low-emission gases depends on policy instruments, whether direct support, carbon pricing, mandates, low-carbon product markets, or offtake frameworks in order to close the price gap and unlock financing at scale.

Looking forward

The most probable outcome for 2030 is a larger, more liquid global LNG market with significant US and Qatari supply, diversified pricing, including broader hub indexation, and continued regional divergence in demand growth, with Asia driving the upside. The market should absorb much of the incremental supply in the base case, but not without periods of volatility and pockets of oversupply that pressure spot prices. CCUS and low-emission gases will be significantly larger than today but still limited relative to total gas volumes; they will, however, play increasingly visible roles in buyer differentiation and policy discussions. ■

European ammonia imports

Europe is likely to become an increasing ammonia importer over the coming years as low global ammonia prices and high European gas prices squeeze producer margins, but CBAM remains a wild card.

The Port of Rotterdam, staging point for most EU ammonia imports

PHOTO: GASUNIE

Europe's ammonia industry continues to struggle with high feedstock prices and increasing imports from outside the continent. CBAM will include carbon pricing into imported ammonia as it ramps up over the next few years, but increasing availability of relatively cheap low carbon ammonia may still allow for increased imports.

Feedstock prices

Since mid-2024 the European gas market has moved from crisis-era emergency buying and high price volatility toward a new equilibrium shaped by structural re-routing of supply, sustained LNG flexibility (especially from the United States), tighter policy on Russian energy, and a price regime that is much lower than the 2022–23 peaks but still sensitive to winter weather and geopolitical shocks. The European Union has extended its gas storage obligations and built more flexibility into the timing and compliance mechanics through to 2027, reducing some of the "rush-to-fill" distortions while preserving winter security. By 1 January 2026 aggregate storage was around ~62% full - lower than the pre-2025 peaks, but not critically low. Europe has also continued to add regasification capacity, including FSRUs in Germany.

Pipeline gas flows from Russia have continued to decline as a share of Europe's imports, while pipeline supply from Norway has become the largest single pipeline source. At the same time LNG, dominated by cargoes from the United States, became the marginal swing supply that European buyers used to balance winter shortfalls and replace lost pipeline volumes. The effective end of large-scale Russian gas transit via Ukraine around 1 January 2025 materially re-routed flows and added a persistent risk premium for central/eastern Europe until alternative routings and LNG volumes were fully operational, leading to a price spike with the Dutch TTF forward rate rising to roughly €50/MWh in early January 2025 and €58/MWh in February 2025. But by late 2025 the market had softened, and TTF rates traded down to the high-€20s/low-€30s/MWh range, driven by mild weather expectations, strong LNG arrivals and comfortable European supplies. Even so, this still represents a price of around $9.70/MMBtu, three times higher than US gas prices and a significant increase on major fertilizer supplying regions such as the Middle East, Trinidad and Russia.

In the medium term, US Henry Hub prices are expected to rise to $3.60/MMBtu by 2030, due to cost inflation and greater feedstock consumed for LNG export. Conversely, Dutch TTF prices are forecast to fall to an average of $8/MMBtu by 2030, lowering some of the price gap. But structurally higher European feedstock prices are expected to lead to reduced domestic ammonia production over the medium to longer term.

Russian imports

Set against the cost of producing ammonia within the EU has been the question of cheap imports from outside, especially Russia. 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. Most of this is ammonium nitrate and urea, however. On the ammonia side Europe only imported 540,000 tonnes from Russia in 2024, as shown in Figure 1, representing only 16% of the 3.3 million tonnes imported that year.

Tariffs

One way that the EU has attempted to deal with this is via the imposition of tariffs and other restrictions on Russian fertilizer imports. Fertilizers were not initially subject to sanctions, but as time has gone by, while the EU has not applied a blanket ban on all Russian fertilisers, it has layered measures that substantially restrict and tax such imports, including a new, phased tariff regime on certain fertilisers from Russia and Belarus (in force from 1 July 2025 and escalating over several years); and existing anti-dumping duties on ammonium nitrate and UAN - measures that have been subject to expiry reviews. These measures are intended to sharply reduce imports and revenues while preserving narrow food-security/transit exceptions.

US tariffs also complicate the picture. President Trump announced an amendment to the administration's reciprocal tariffs effective from November 13, 2025 which exempted critical fertilizers such as urea, ammonium nitrate, UAN, ammonium sulphate, DAP, and MAP from tariffs in order to provide relief to US farmers. However, ammonia was not one of the fertilizers named, and the eligibility of ammonia shipments for tariff relief will be determined on a case-by-case basis by the Secretary of Commerce and the US Trade Representative, depending on the status of trade talks with exporting nations. This could still place additional burdens on, e.g. Trinidadian exports to the US, potentially pushing them towards Europe instead.

CBAM

The other tariff-like restriction is carbon taxes, and the start of 2026 has seen the first costs imposed under the EU's new Carbon Border Adjustment Mechanism

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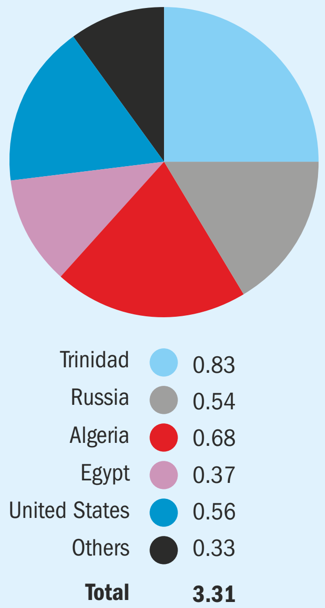
(CBAM). CBAM is a levy on carbon-intensive goods entering the EU, and the price of CBAM certificates will reflect the EU ETS prices corrected for any free allowances EU producers still receive, and carbon costs incurred during the production process in the producing country. The CBAM aims to mitigate 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.

The initial impact seems to have been to slow ammonia imports into northwest Europe, with no further spot sales into the region confirmed in the first week of January. Default CBAM values released by the European Commission in late December have effectively priced US material out of the European market. The free allocation for ammonia is identical under both the case of suppliers reporting a verified emissions intensity and the case of using the default method. This value is set at 1.52 tonnes CO_2/t ammonia, which represents the amount of embedded emission in the ammonia that importers are not liable to pay a CBAM charge on. Where the methods differ is in the emissions intensity level to be used in calculating the emission liable to CBAM. In the case of suppliers providing actual, verified data, this value is plant specific. In the default method, the emissions intensity is set based on country-level averages, with a 1% adjustment upwards to encourage suppliers and importers to move off the default method. The default emission intensities for ammonia for the EU's major trading partners is 2.10tCO_2/t for Algeria, 2,28 tCO_2/t for Russia, 2.44 tCO_2/t for Trinidad and 3.44 tCO_2/t for the US. It is unclear how the US was assigned its very punitive default value, given the dominance of natural-gas-based ammonia production in the country which typically sees emissions intensities around 2 tCO_2/t ammonia. The impact of this is substantial if US producers intend to rely on default values, with importers liable to significantly higher CBAM charges; US suppliers will have to report actual, verified emissions to avoid the prohibitive charge.

The effect has been to effectively price US ammonia out of the EU market. In the near term, European buyers are expected to favour Egyptian and Algerian tonnes, which carry the lowest default values, although availability from these origins remains tight. Trinidadian, Algerian and Egyptian ammonia also arrive duty free into Europe. US ammonia will attract a CBAM charge of around \$175/t under the default value and is also subject to a 5.5% import duty. Saudi and Russian ammonia also face a 5.5% import duty.

Fig. 1: **European ammonia imports 2024, million t/a**



Source: CRU

Longer term, however, a number of large capacity blue ammonia plants in the US Gulf Coast are likely to attract much lower rates under CBAM and could become a major source of supply to Europe.

Increased imports

Europe's ammonia market faces significant challenges as rising global capacity drives oversupply and pushes prices down, while structurally high site costs in Europe make operations less profitable. Stringent emissions regulations (EU's ETS), elevated energy prices, and growing global competition have already weighed on operating rates, with Western Europe's plants expected to run at just 81.3% in 2025 which is below historical levels. The forecast was revised upwards in line with the baseline from higher actual production figures and a softer TTF price outlook.

Overall, these challenges have led to plant closures and curtailments, including the mothballing of Yara's Hull plant in the United Kingdom and Achema in Lithuania intermittently halting production since 2022 as producers struggle to compete with lower cost suppliers. With domestic production becoming less viable, Europe will increasingly be reliant on imports from regions with cheaper energy and lower carbon intensity.

Over the next few years, CRU expects that European imports will grow steadily, increasing by 1.79 million t/a between 2026 to 2030 as declining ammonia prices narrow domestic margins and support higher import demand. Additionally, EU's CBAM will also encourage imports of low emissions ammonia by gradually phasing out free allowances, further supporting import growth.

Downstream production

While ammonia imports increase, European downstream fertilizer assets are expected to continue to operate. Margins for ammonium nitrate, a product which can consume imported ammonia, showed relatively similar figures for domestic European production via imported ammonia (\$113/t) versus domestically produced (\$141/t) ammonia in 2024. The introduction of CBAM is expected to improve things for EU nitrate producers. European producers are already subject to carbon costs under the EU ETS – by 2026, they are expected to pay around \$7 /t more for AN than in 2025, based on the weighted European average FGAN emission. This incremental increase improves the relative competitiveness of domestic producers, as imports were not previously subject to equivalent costs. Carbon costs are expected to rise steeply, driven by the phase-out of free allowances and increasing carbon prices. This creates an opportunity for low-emission AN, which could reduce carbon costs by around 89% by 2030.

EU urea remains roughly break even with imported. EU urea imports from Russia reached their highest monthly level in Jun 2025, in preparation for tariff implementation, but thereafter saw a major slowdown during 2025 Q3, with imports totalling well below 2022–2024 levels. Based on trend in the second half of 2025, an increase in imports to the average over 2022–2024 H1 during 2026 H1 will avoid the threshold of 2.7 million t/a to trigger higher tariffs. Imports are likely to switch towards North Africa where, although producers are to CBAM, they will continue to enter duty-free unlike other regions.

Voluntary carbon markets – trust and scalability

Carbon emissions from a power plant in northern Europe.

PHOTO: ADOBE STOCK

The voluntary carbon market (VCM) is maturing rapidly, and a succession of governance, standards and policy initiatives has been launched since 2020 to tackle weaknesses in integrity and scalability which have constrained uptake and undermined confidence.

For the chemical sector, which includes many hard-to-abate processes such as ammonia and methanol production, and embedded process emissions, the maturing VCM offers a pragmatic mechanism to meet residual emissions, channel finance to decarbonisation in supplier regions, and manage transition risk. But the market that emerges will be materially different from that of the early 2020s, with higher minimum standards, Article 6 alignment, closer public oversight and stronger traceability. This will drive up prices, favour standardised products and demand rigorous corporate governance of offset use.

Why integrity and scale matter

VCMs were created to provide flexible, finance-mobilising routes to greenhouse gas (GHG) reductions and removals that companies and investors could use to address residual emissions. But high-profile methodological failures, questionable baselines and weak monitoring have damaged confidence. Two interdependent market failures were most important:

- Weak integrity. If credits do not represent real, additional, permanent and verifiable emission reductions or removals, then any corporate claim underpinned by those credits is at best meaningless and at worst greenwashing.
- Lack of scalability. Fragmented standards, opaque registries and a diversity of bespoke project types limited liquidity. Buyers found it hard to aggregate, price and settle future commitments reliably.

Addressing both issues is essential. Integrity protects the climate outcome and corporate reputations; scale enables efficient pricing and the mobilisation of capital at the level needed for meaningful global emissions reductions.

Major initiatives

Formed in 2020 and hosted by the Institute of International Finance, the Taskforce on Scaling Voluntary Carbon Markets (TSVCM) published a blueprint for building a large, transparent global trading market. Its recommendations covered supply and standards, market intermediaries and demand-side governance, fundamentally reframing the VCM as a structured financial market rather than a piecemeal project registry ecosystem.

In response to the TSVCM, the Integrity Council for Voluntary Carbon Markets (IC-VCM) was established in 2021 to define threshold integrity standards and provide oversight across standard setting organisations. Its 2023 Core Carbon Principles (CCPs) define ten themes across governance, emissions impact and sustainable development. The IC-VCM's screening of methodologies - including the mid-2024 rejection of several renewable energy methodologies - signalled that many legacy credits would not meet future market standards. The organisation's CCP-Eligibility assessments are becoming a de-facto entry ticket for high-quality credits.

The Voluntary Carbon Market Integrity Initiative (VCMI), also established in 2021, developed a Claims Code of Practice that gives businesses practical guidance on how to use carbon credits credibly for near-term mitigation and long-term net-zero claims. The Code addresses both what can be claimed and how those claims should be communicated - an essential element in reducing reputational and regulatory risk for buyers.

Government initiatives

However, private governance alone cannot deliver a fully fungible, scalable international market. Governments are increasingly stepping into the space to provide legal frameworks, cross-border accounting rules and registries that prevent double counting and ensure transparency.

Notable developments include advanced economies publishing principles and charters for use of high-integrity credits (for example, initiatives announced by the UK and France in 2025) that leverage experience from capital markets regulation to add credibility.

There has also been integration of market and compliance mechanisms in some jurisdictions: Singapore's Carbon Pricing Act (from early 2024) allows covered entities to use a limited share of high-quality international credits to offset taxable emissions; the European Commission has proposed a constrained role for international credits in its 2040 pathway.

Finally, emerging market frameworks such as the Africa Carbon Markets Initiative and domestic VCM frameworks in Nigeria and Zimbabwe are designed both to attract finance and ensure Article 6 alignment. These policy moves are important for two reasons. First, they create demand signals by clarifying which credits are acceptable for compliance or quasi-compliance use. Second, by aligning with Article 6 accounting and registry rules they reduce sovereign risk and the risk of double counting - a recurrent criticism of earlier VCM practice.

Article 6

The political agreement reached at COP29 in 2024 on Article 6 was a watershed. It established clear methodologies for calculating reductions/removals, set rules to prevent double counting of internationally transferred mitigation outcomes (ITMOs), and mandated an international carbon credit registry. Three Article 6 mechanisms are particularly relevant:

Article 6.2 provides accounting and reporting guidance for countries to use ITMOs towards their nationally determined contributions (NDCs). It allows a host country to sell carbon credits to a buyer country in return for investment, capacity building and technologies otherwise not available. The buyer country can use the purchased carbon credits to meet its own climate targets.

Article 6.4 establishes a new Paris Agreement Credit Mechanism (PACM), which can be used to trade high-quality carbon credits. It allows a country or a private sector entity to generate certified emission reductions (carbon credits) from projects in another country. These credits can then be sold and used by the acquiring country towards its NDC. The goal is to achieve real, measurable, and long-term mitigation, and to promote sustainable development.

Article 6.8 sets out opportunities for non-market-based cooperation for enhancing climate action. This provides a framework that does not involve carbon units or trading. It is intended to facilitate non-market ways to implement NDCs, such as cooperation on finance, technology transfer, capacity-building, and common policy frameworks such as taxation and regulatory alignment.

For the VCM, Article 6 does three things; it brings a public, sovereign accounting backdrop to a previously private market; it establishes a route for standardising and certifying high-quality international credits; and it provides an international registry framework that enables credible traceability and prevents double counting. Over time, most high-quality voluntary credits will likely be aligned with Article 6, blurring the line between voluntary and compliance markets and enabling broader fungibility.

COP29

After nearly a decade of slow to non-existent progress, COP29 in 2024 delivered a number of breakthroughs, with governments agreeing, among other things, on: clear rules on how to calculate emission reductions or removals; how to avoid double counting involving Internationally Transferred Mitigation Outcomes (ITMOs); and establishing an international carbon credit registry. CRU expects that this formalisation will be a major driver of market developments in the future, with most, if not all, carbon credits eventually aligned with Article 6 requirements.

Since COP29, an increasing number of governments have made progress on Article 6 implementation, with some countries hosting emission reduction or removal projects finalising Article 6-aligned domestic carbon credit frameworks, while others have already started cooperating bilaterally with advanced countries. The United Nations (UN) keeps track of these developments in its Article 6 Pipeline. By mid-September 2025, there had been just over 100 bilateral cooperation agreements under Article 6.2, with most host countries based in Asia (43), followed by Africa (30) and the Americas (16). Japan and Singapore lead the list of buying countries, followed by Korea and Switzerland.

Policymakers will increasingly focus on the 'net' in net emission reductions As the VCM ecosystem matures, the market will grow, and demand for carbon credits should rise, as it will be increasingly recognised that meeting net targets by focusing mainly on reducing gross emissions will be difficult. This will require accepting that 'pure' solutions alone are unlikely to deliver the net reduction targets given the time available. We are seeing a similar change in attitude towards carbon capture and storage solutions, with the European Commission, for example, giving CCUS a much greater role in meeting net emission targets than in the past. Similarly, the Canadian government is increasingly exploring CCUS, including direct air capture solutions. These 'compromise' solutions were previously rejected by many climate advocates. It is likely that they will become increasingly accepted as governments reassess political and economic trade-offs, in particular for hard-to-abate sectors, where gross emission reduction solutions are either still prohibitively expensive or do not even exist yet.

Obstacles

Some obstacles remain, including the overhang in unretired, potentially 'low quality' credits. CRU expects the overhang of unretired credits to be addressed over coming years. Either project developers will deregister their projects altogether or, where possible, will relaunch them to higher specifications using the latest, more demanding standards. The latter might not be possible in all cases and could be costly for some. Demand for older vintage carbon credits, potentially seen as lower quality, should decline sharply as companies will no longer be able to use these credibly as part of their emission reduction efforts.

VCMs could also help channel financial resources to the "global south", supporting global climate finance efforts. As climate change is a global phenomenon it does not matter where a unit of greenhouse gas emissions is emitted, not emitted, or stored. Global cooperation should therefore be the most efficient and cheapest way to achieve any global net emission reduction targets. Internationally traded carbon credits could also help channel urgently needed financing, which could help address the remaining wide gap in global climate finance. In mid-August, the Zimbabwean government, for example, announced plans for a Loss and Damage fund financed out of Article 6-aligned carbon credit issuance, while the Nigerian government intends to use receipts from the sale of ITMOs to fund part of its climate commitments, as set out in its latest national determined contribution. More initiatives of this type from governments in developing and emerging countries are likely in the future.

All signs point to growth

Government involvement and the likely shift to focus more on net rather than gross emission reduction targets should be a further boost to market development. Overall signs therefore point to solid, potentially even rapid, long-term growth once the existing overhang of (lower quality) unretired carbon credits has been addressed. CRU expects most voluntary carbon credits to be Article 6-aligned in the future. Starting from a low base, the market could multiply its current size by 2030, with credits becoming increasingly standardised, helping price discovery.

CRU also expects the price for carbon credits to rise as newly launched credits will have to meet much more demanding standards. In many cases, this will add to a project's cost. Moreover, demand should grow, not least as governments in advanced countries will encourage closer international cooperation.

With more governments likely to follow Singapore's example of accepting international carbon credits towards compliance obligations, and the European Union potentially granting such credits a limited role in its future emissions targets, a convergence of pricing across the voluntary and compliance carbon markets is anticipated over time. This shift towards greater interchangeability would be significant, as high-quality voluntary credits become a viable option for meeting mandatory national targets, thereby integrating the two spheres.

The price of this combined market may also be influenced by the long-term cost of high-tech removal alternatives such as direct air capture (DAC). While DAC is currently a costly decarbonisation option that is unlikely to affect near-term prices, its increasing necessity in achieving net-zero goals – particularly as cheaper abatement options are exhausted – could eventually place an upward pressure on global carbon prices.

The era of low-priced carbon credit 'bargains' is ending. Regulatory changes mandate that only credits meeting rigorous minimum standards will be recognised, driving greater market efficiency and higher overall prices. Credits that incorporate co-benefits – for example, those aligned with UN Sustainable Development Goals (SDGs) – are anticipated to command an even greater price premium.

As voluntary carbon markets enter a new phase and become an increasingly viable option to reduce net emissions, businesses will need to stay up to date with the latest developments. This will be particularly true for businesses in hard-to-abate sectors, which might otherwise struggle to meet net emission reduction targets. CRU's Sustainability and Emissions Service can provide further information on VCMs and their implications. Contact us at: https://www.crugroup.com/en/data/sustainability-and-emissions/

Nitrogen+Syngas Index 2025

A complete list of all articles and news items appearing in *Nitrogen+Syngas* magazine during 2025.

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Nitrogen+Syngas 2026 Expoconference

The 2026 Nitrogen+Syngas Expoconference will take place in Barcelona, Spain, from 9-12 February. Join us at this industry leading event where leading market and technology experts and producers will gather to connect, share knowledge and learn about the latest developments in operations, technology, processes and equipment.

The 39th Nitrogen+Syngas Expoconference returns to Barcelona in 2026 and will be held at the Hyatt Regency Barcelona Tower from 9-12 February.

Conference programme

Covering the entire nitrogen and syngas value chain, the 2026 agenda features: 77 technical papers; a pre-conference day of workshops, including a certified Plant Safety Training Workshop; as well as a full-day commercial agenda focusing on global market outlooks, regulatory impacts, cutting-edge technologies, and collaborative project developments.

The industry-leading technical agenda provides 21 interactive sessions including 23 operator presentations, and insights from 65 expert speakers across three parallel tracks. Showcasing the latest technical advancements in operations, technology and product diversification – helping nitrogen and syngas producers working in both new projects and existing plants to optimise their processes.

New for 2026

New for 2026, AI translation will be available during the conference, providing live AI translation in audio and captions available in Spanish, Arabic, Russian, Bahasa, Turkish, Vietnamese, Mandarin and Japanese.

Setting the scene for this year's conference CRU's Charlie Stephen, Head of Nitrogen – Analysis & Forecasts, comments:

"2025 was a more supportive year for the European nitrogen industry, but the uncertainty in the outlook remains high with the commencement of the EU's Carbon Border Adjustment Mechanism (CBAM).

Nitrogen fertiliser producers benefitted from favourable market conditions in 2025, as strong demand coupled with supply interruptions buoyed nitrogen prices. On the urea front, Iranian winter curtailments gave global urea prices a bump coming into 2025. Egyptian gas shortages and country-wide shutdowns of nitrogen facilities in Egypt and Iran due to the Israel-Iran conflict helped to bolster prices through Q2, despite the return of China to the export market. A record year for Indian demand with some lacklustre tendering early in the year resulting in very strong buying in H2, keeping prices elevated into late Q4.

Ammonia prices saw five months of declines after entering 2025, with European import prices falling well below cost of production. However, supply interruptions across North Africa, the Middle East, the US and the Caribbean saw seven months of price climbs, with prices reaching levels not seen since the descent from the peaks of the 2022 Global Energy Crisis.

While a boon for nitrogen producers, 2025 was a challenge for farmers who were squeezed between high fertilizer prices and soft crop prices. The result is nitrogen fertilizer affordability hitting its worst level since March 2023. In Europe, the outlook continues to look challenging in 2026, with supply being constrained by the imposition of additional tariffs on imports of Russian fertilizers, and additional costs to be imposed with the commencement of CBAM.

The industry is still digesting the regulations specifying the details of how embedded carbon emissions in imported fertilizers is to be taxed, despite CBAM having officially commenced on 1st January 2026. Concern about the uncertainty saw heavy buying in November as importers sought to land product before the deadline. While CBAM will level the playing field for domestic producers incurring carbon costs under the EU ETS and importers sourcing from regions without a carbon pricing scheme, the bar will be progressively raised for both. Removal of free allocations will expose more of the embedded carbon in domestically produced and imported fertilizers, ratcheting up carbon costs to many hundreds of dollars per tonne of fertilizer by the early 2030s.

Given the scale of continuing competitive, cost 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, 9 February

08:00 REGISTRATION AND EXHIBITION OPENS

WORKSHOP
13:15 – 14:45

Urea plant upset scenarios workshop Operators only
Mr. Elbassyouni, D.Eng., *Process Engineer, Stamicarbon, Nextchem*

WORKSHOP
13:15 – 14:45

Plant revamping & decarbonisation opportunities
Ermanno Filippi, CTO, *CASALE*
Sergio Panza, Ammonia Technology Manager, *CASALE*
Francesco Baratto, Head of SynGas Department, *CASALE*

CERTIFIED OPERATOR TRAINING
15:00 – 1700

CRU N+S 2026 Safety Workshop
Moderated by Mark Brouwer, *Director, UreaKnowHow.com*

Speakers from: *Yara, Nutrien, Badotherm and UreaKnowHow*

Tuesday, 10 February

08:00 REGISTRATION AND EXHIBITION OPENS

COMMERCIAL AND MARKETS SESSION

09:00 **Welcome address**
Lisa Connock, Managing Editor Nitrogen+Syngas Magazine, *CRU Group*

09:10 **2026 nitrogen & syngas global markets outlook: Trends, pressures,cost, prices and policy impacts**
Charlie Stephen, Nitrogen & Hydrogen Analysis Lead, *CRU*

09:40 **Navigating global regulatory shifts for a resilient future: The impact of EPA, CBAM, tariff policies and sanctions on the global nitrogen and syngas industries** *CEFIC*

10:10 **NETWORKING COFFEE BREAK**

10:40 **Industry keynote panel**
Chairperson: Charlie Stephen, Nitrogen & Hydrogen Analysis Lead, *CRU*
Panellists:
Ignacio Fernandez Santiago, Chief Technical Officer, *FertigHy*
Torsten Brezina, Program Manager, *Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) GmbH*
Narayanan Valayaputtur, CEO, *EBIC- EFC*
Elias Frei, Director Division Hydrogen Technologies/Deputy Director Institute, *Fraunhofer Institute for Solar Energy Systems ISE*

11:30 **Low carbon ammonia and hydrogen: Navigating cross-border production economics and market integration**
Rebecca Ruan, Analyst Nitrates Market Services, *CRU*
Dr. Paul Butterworth, Research Manager, Economics & Sustainability, *CRU*

12:00 **In the spotlight: Regional updates – Guest country – Uzbekistan. Prospects for the implementation of green ammonia technology in Uzbekistan**
Bakhtiyor Sultankhodjaev, Deputy Head of Department, *State Unitary Enterprise - Center for Comprehensive Examination of Projects and Import Contracts*

12:30 **NETWORKING LUNCH**

(Correct at time of going to press)

Tuesday, 10 February CONTINUED

TRACK ONE

INDUSTRY INFRASTRUCTURE ASSETS: PROJECT SESSION
14:00 – 15:30

EET Hydrogen Production Plant 1
TBC, TBC, *Johnson Matthey*

The CERES Project (Australia) - Modularization of Ammonia Urea Complexes for Safe and Cost-effective Execution
Andrea Zambianco, Low Carbon Solutions Product Development Manager, *Saipem S.p.A.*

Nitric acid plant in Ostrava: A model for an effective and sustainable chemical plant delivery under turnkey conditions in Central Europe
Kadlec Zdenek, Head of Project Management Department, *CASALE*

TRACK THREE

TECHNICAL SHOWCASES
14:00 – 17:15

Celanese digitization journey - with NMM's AI software "Dynamic Risk Analyzer
Michael Sehr, Senior Technician Production, *Celanese/Near Miss Management*

Successful start-up of a next-generation ATR: A milestone for hydrogen and syngas industries
Giovanni Genova, H2 & Syngas Technology Leader, *CASALE*

Siemens autonomous process operations platform – A response to process industries' vision for AI in the control room
Mayank Patel, Industry Strategy Director, Chemicals, *Siemens Industry Software Limited*

Case study summary: Risk of tantalum sleeve with extended type diaphragm seals
Ricardas Razgaitis, Business Development Manager, *Badotherm*

Maximizing Hydrogen Recovery with UNICAT's PSA Technology and Adsorbents
Xavier Llorente, Regional Sales Manager, *UNICAT Catalyst Technologies, LLC*

A new high-pressure & high-temperature autoclave for corrosion testing under real process conditions
Manuel Prohaska, CEO, *MPC2 e.U.*

15:30 – 16:00 NETWORKING COFFEE BREAK

INDUSTRY INFRASTRUCTURE ASSETS: PROJECT SESSION
16:00 – 17:30

Villeta: Latin America's low carbon ammonia project
Terje Bakken, Director Green Ammonia and Fertilizers, *Atome PLC*

Gelsenkirchen-Scholven Uniper power plant – Industrial scale ammonia-to-hydrogen cracker project
Vaios Kitsos, Head of Technical Sales Ammonia Cracking, *Thyssenkrupp Uhde GmbH*

The Kassø E-methanol plant: From vision to reality. Technical support and operational performance of the first commercial-scale E-Methanol plant
Dennis Rasmussen, Chief specialist, *European Energy A/S*
Ivan Tiunov, Applied Catalyst Technology Engineer, *Clariant*

TECHNICAL SHOWCASES
16:00 – 17:15

An integrated approach to e-MeOH production
Klemens Wawrzinek, Project Manager BD & Sales, *Linde*

Optimising CO_2 Stripping in carbon capture with integrated heat pump systems, a focus on regenerator pressure selection
Andrea Orsetti, Senior Technology Process Engineer, *Nextchem*

Process e-heaters for fertilizer plants - Start-up service
Neerav Chaudhary, Process & Furnace Engineering Vice President, *ITT Engineering India Private Limited (ITTEIPL)*

Successful replacement of old MWK bayonet boiler with latest generation vertical floating head boiler
Uma Sankar Khan, Technical Professional Leader - Process
Amarnath Chandra Roy, Senior Technical Advisor, *KBR*

17:30 NETWORKING RECEPTION

(Correct at time of going to press)

Wednesday, 11 February

08:00 REGISTRATION AND EXHIBITION OPENS

TRACK ONE

AMMONIA PLANT OPERATIONS 09:00 – 10:30

Enhancing emergency response in an ammonia plant through DCS automation - four years of successful operation
Sannan Aleem, Manager Operations Ammonia Manufacturing, *Engro Fertilizers Limited*

Extending operational life of a double-walled ammonia storage tank through a novel rehabilitation approach: A case from a fertilizer manufacturing complex
Sadiq Usman Khattak, Section Manager (Inspection), *Engro Fertilizers Limited*

BLUE AMMONIA

Technology assessment for world scale BNH3 facility - A case study
Saudi Aramco

TRACK TWO

ADVANCEMENT IN HYDROGEN PRODUCTION 09:00 – 10:30

Field tests and published ASME code case for new alloy N0669
Raquel Rodriguez, Research Scientist, *Tubacex Innovacion, A.I.E.*
Benedikt Nowak, Project Manager, Research & Development, *VDM Metals International GmbH*

Methane pyrolysis for clean hydrogen production: A scalable pathway through the Hazer® process to clean hydrogen and graphite production
Liam Sheppard, Methane Pyrolysis Technology Manager, *KBR*

Enhanced H_2 production in fuel reforming and conversion processes using integrated multistage reactor
Silvano Cimini, Engineer, *Quality Engineering srl*

TRACK THREE

SUSTAINABLE FERTILIZER PLANT 09:00 – 10:30

Complete in-house technology: Integrated small-scale urea production with green ammonia
Luca Amicucci, Process Engineer, *Stamicarbon, Nextchem*
Govhar Mammadova, Process Engineer, *Stamicarbon, Nextchem*

From technology supply to strategic alliance: CASALE–Xin Lian Xin's cooperation for sustainable fertilizers
Francesco Baratto, Head of SynGas Department, *CASALE*

Toward carbon-neutral urea production: A comprehensive evaluation of g-Urea™ complex
Hiroo Kunii, Process Engineer, *Toyo Engineering Corporation*

10:30 – 11:00 NETWORKING COFFEE BREAK

TRACK ONE

AMMONIA PLANT: CO_2 REMOVAL SYSTEMS 11:00 – 12:30

Flawless construction & commissioning of OASE® system in KBR ammonia plant at Indorama
Ezekiel Nwafor Okereke, Process Engineer; Usman Suleiman Ubam, Process Engineer, *Indorama Eleme Fertilizer and Chemicals Limited*

Optimisation potential for CO_2 removal unit in ammonia plants through BASF OASE® white low-low pressure (LLP) flash innovative process
Mohammed Grerifa, Technical Marketing Manager, *BASF*

Successive failures of catacarb rich solution line at vintage ammonia plant
Mohsin Mukhtar, General Manager Production
Ali Haider, Senior Process Engineer, *Engro Fertilizers Limited*

TRACK TWO

LOW CARBON HYDROGEN SOLUTIONS 11:00 – 12:40

Hybrid green ammonia integration into an existing SMR-based ammonia plant in Indonesia
Iswahyudi Mertosono, Vice President of Business Development, *PT Pupuk Kujang*
Muhamad Reda Galih Pangestu, Business Development Staff, *PT Pupuk Kujang*

Commissioning, troubleshooting & stabilisation of 5 MW pressurized alkaline electrolyser for green hydrogen production in off-grid mode
Inderjeet Singh, Vice President - Technology, Green Hydrogen & its Derivatives
Archit Gupta, Manager - Technology Green Hydrogen & Derivatives, *Adani New Industries Limited*

Syngas and hydrogen production: SCT-CPO flexibility and industrial performance
Leonardo Falbo, Senior Technology Process Engineer, *Nextchem*

NX eBlue™: A competitive low-carbon alternative to conventional steam methane reforming
Matteo Mennella, H2 & Syngas Process Engineer, *KT Tech S.p.A.*

TRACK THREE

FERTILIZER PLANT: EMISSION REDUCTIONS 11:00 – 12:40

AI-powered predictive emission monitoring system (PEMS)
Hugo Rodrigues, Principal Consultant, *Siemens*

Innovative ammonia scrubbing system by utilizing CO_2 bubbling unit: An operation safety and economical solution for urea granulation plants
Tetsuo Yamamoto, Lead Process Engineer
Shinya Fukuzawa, Deputy Manager, *Mitsubishi Heavy Industries Engineering, Ltd*

Electrostatic innovation: How Yara transformed emissions control with AWS WESP
Alessandro Gullà, Sales Coordinator, *A.W.S. Corporation SRL*

Reducing moving bed heat exchanger footprints and materials requirements in fertilizer cooling: An experimental validation
Igor Makarenko, Chief Sales Officer
Pedro Isaza, Technology Development Director, *Solex Thermal Science*

12:40 – 14:00 NETWORKING LUNCH

(Correct at time of going to press)

Wednesday, 11 February CONTINUED

TRACK ONE

CARBON CAPTURE
14:00 – 15:30

High pressure regeneration amine system for CCUS in blue hydrogen applications
John Dowdle, Senior Research Scientist, *Dow, Inc.*

CO_2 specifications for CCS in ammonia plants: Impact of impurities and challenges in meeting off-taker's limits
Zubair Talha, Senior Process Engineer-Ammonia technology, *YARA Belgium SNNV*

The absorption advantage and cryogenic opportunity on carbon capture
Fabio Enrico Gianfranco, Head of Carbon and Emission Reduction, *NextChem S.p.A.*

TRACK TWO

ASSET SAFETY: MAINTENANCE AND EQUIPMENT
14:00 – 15:40

Remaining life assessment of high-pressure steam piping using API 579 creep level-II fitness for service assessment
Adil Pervaiz, Project Engineer – Deputy Manager (Project Engineering), *Fauji Fertilizer Company Ltd*

Assessments of micro additions in alloys for reformer tubes in SMR furnaces
Rafael Andrade, Engineering Manager, *ENGEMASA Engenharia e Materiais Ltda*

Managing integrity of reformer outlet components through a collaborative, proactive, and data driven approach
Daniel Blanks, Senior Structural Integrity Engineer and Team Lead, *Quest Integrity Group*
Syed Muhammad Hassan Murtaza Gardezi, Unit Manager - Equipment, *Fauji Fertilizer Company Limited*

Strategical spare parts for fertilizer industry using additive manufacturing of UNS S32906: A breakthrough in performance and delivery time
Aleksandra Gavrilovic-Wohlmuther, Head of Research & Development, *Christof Group SBN*

TRACK THREE

SYNGAS AND METHANOL PRODUCTION
14:00 - 15:40

SMR reformer solutions from Uni Abex – India
Uni Abex Alloy Products Limited, A Neterwala Group Company

Impact of shifting CO_2 injection point from synthesis loop to steam methane reformer inlet in a methanol process
Ahmed Al-Khalaf, Sr. Scientist, *SABIC*

Operations efficiency & process improvement experience: Revamp with parallel autothermal reforming and oncethrough methanol converter
Waqas Shehryar, Senior Process Engineer, *SIPCHEM*
Mark McKenna, Process Technology Manager, *Johnson Matthey*

Balancing performance and sustainability: The importance of pigtails and their material selection in steam reforming along with decarbonisation and LCA journey
Barinder Ghai, Director Technical Marketing and New business development, *Alleima*

15:40 – 16:10 NETWORKING COFFEE BREAK

BLUE AMMONIA
16:10 – 17:10

Ammonia plants - The transition to net-zero
Ilayaraja Karuppasamy, Senior Technology Proposal Manager - Ammonia Technology, *Topsoe NS*

Challenges in the conversion to clean ammonia
VK Arora, Director - Process Tech & Projects, *Kinetics Process Improvements (KPI)*

NITRIC ACID: TECHNOLOGY AND CATALYSTS
16:10 – 17:10

Xtranit - Increased NH_3 efficiency through advanced gauze geometries
Florian Knaus, Manager Applied Technology, *Umicore AG & Co. KG*

Amplifying your nitric acid production
Morteza Hadian, Process Engineer, *Stamicarbon/NEXTCHEM*

CHEMICAL INDUSTRY DECARBONISATION
16:10 – 17:40

Catalytic breakthroughs in syngas generation: Enabling efficiency and decarbonisation in modern chemical operations
Christian Schulz, New Business Development & Sustainability Manager, Global Chemical Catalysts & Adsorbents, *BASF SE*

Scaling renewable methanol: Unlocking clean energy for aviation and maritime
Kathryn Coxon, Business Development Manager, *Johnson Matthey*

Revolutionising e-methanol production process: TOYO's g-Methanol™ integrates SUPERHIDIC™ innovative energy saving distillation system
Govind Murali, Process Engineer, *Toyo Engineering Corporation*

(Correct at time of going to press)

Thursday, 12 February

08:00 REGISTRATION AND EXHIBITION OPENS

TRACK ONE

AMMONIA TO HYDROGEN
08:30-10:10

Ru-based catalysts for ammonia cracking - High-throughput testing to advanced materials for industrial Use
Dr. Christian Breuer, Global Technology and Application Manager, *Heraeus Precious Metals GmbH & Co. KG*

Advanced ammonia combustion technology for flexible low-carbon hydrogen production
Dr Hadi Nozari, Senior Process Engineer, *Johnson Matthey*
Nathan Becuwe, Process Engineer, *John Zink*

Hynext by T.EN™ - An update on Technip Energies ammonia cracking technology
Jan-Jaap Riegman, Product Development Manager, *Technip Energies*

Ammonia cracking nitridation - Influence of the chromium content in centrifugally cast austenitic Cr-Ni-Fe alloys solutions
Dominique Flahaut, Group Technical Director, *PARALLOY Group*

TRACK TWO

UREA: PROCESS CONTROL AND PRODUCTS
08:30-10:00

UFT®Add for automotive grade urea
Rolf Weiss, Senior Licensing Manager, *thyssenkrupp Fertilizer TechnologyGmbH*

Urea with gypsum: Agronomical and environmental benefits and innovative production technologies
Mark Brouwer, Director, *UreaKnowHow.com*

The impact of hydrogen and inert contaminated steam on the safety and process control of the urea solution process
Pieter Vidts, Global Process Engineer Urea, *Yara Sluiskil B.V.*
Jasper Stekelorum, Process Engineer, *Yara Sluiskil B.V.*

TRACK THREE

SYNGAS PRODUCTION
08:30-10:10

Refractory lining integrity under control: 24/7 monitoring with hot spot detection
Lukas Rothermich, *WIKA Alexander Wiegand SE & Co. KG*

Air Liquide GasPOx: Driving low carbon molecules from diverse feedstocks
Sayan Dasgupta, Head of Syngas, *Air Liquide Global E&C Solutions Germany*

Combining partial oxidation and innovative carbon capture for hydrogen generation
Sean Yan, Product Manager, Blue H_2, *Air Products LLC*
Dave Graham, Principal Research Engineer, *Air Products*

Improving SMR performance & reliability by correcting firebox temperature distribution: Design & retrofit solutions
BD Energy Systems, *LLC*

10:10 – 10:40 NETWORKING COFFEE BREAK

AMMONIA TO HYDROGEN
10:40 – 12:20

CASALE derisking strategy for MACH2™ technology
Aurelia Pipino, Fired Heaters Technology Manager, *CASALE*

Unlocking low-carbon hydrogen: Air Liquide's breakthrough in ammonia cracking
Laurent Prost, Head of HyCO Process Solution Development, *Air Liquide Global E&C Solutions Germany GmbH*
Dieter Ulber, Hydrogen Technology Director, *Air Liquide Global E&C Solutions Germany GmbH*

Driving the future of energy transport : BASF SYNSPIRE® ARC catalysts unlock green hydrogen via ammonia reforming
Marino Miccio, Sustainability Business Development Manager, *BASF*

UREA PLANT: OPERATIONS AND UPGRADE
10:40 – 12:20

Integrated revamp solutions for urea plants: Saipem's approach to energy and production efficiency
Luca Edoardo Vigano, Urea Technology Leader, *Saipem S.p.A.*

Enhancing urea plant energy index through SuperCups™ installation in urea reactor
Ali Haris, Manager Process Engineering, *EngroFertilizers Limited*

Enhancing urea plant efficiency and reliability by replacing heater recirculation section with new design perforated plate
Mohamed Mostafa Shams, Urea maintenance manager, *Misr Fertilizers Production Company "MOPCO"*

SYNGAS GENERATION AND CATALYSTS
10:40 – 12:20

Reformer optimisation with hybrid process models: Achieving operational excellence with AI-based digital tools
Lisa Krumpholz, Managing Director, *Navigance*

Optimising Ni use to support continued demand for steam reforming catalysts to manufacture syngas
Timothy O'Connell, Marketing Manager, *Johnson Matthey*

Applying the novel textured sphere technology to develop a new high-performance water gas shift catalyst
Wolfgang Kaltner, Regional Sales Manager, *UNICAT Catalyst Technologies, LLC*

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Thursday, 12 February CONTINUED

TRACK ONE	TRACK TWO	TRACK THREE
The value of flexible ammonia cracking plant operation Priyan Mistry, Business Development Manager, *Johnson Matthey*	**Cavitation damage in minimum flow valves of HP NH_3 pumps in Yara Belle Plaine urea plant** Lino Porro, Technology Manager Urea, *Yara Belgium*	**Advanced bench-scale testing of commercial catalysts for CO_2 conversion: Bridging lab-scale evaluation and industrial relevance in rWGS and dry reforming** Benjamin Mutz, Segment Lead Carbon Management & Renewables, *hte GmbH*

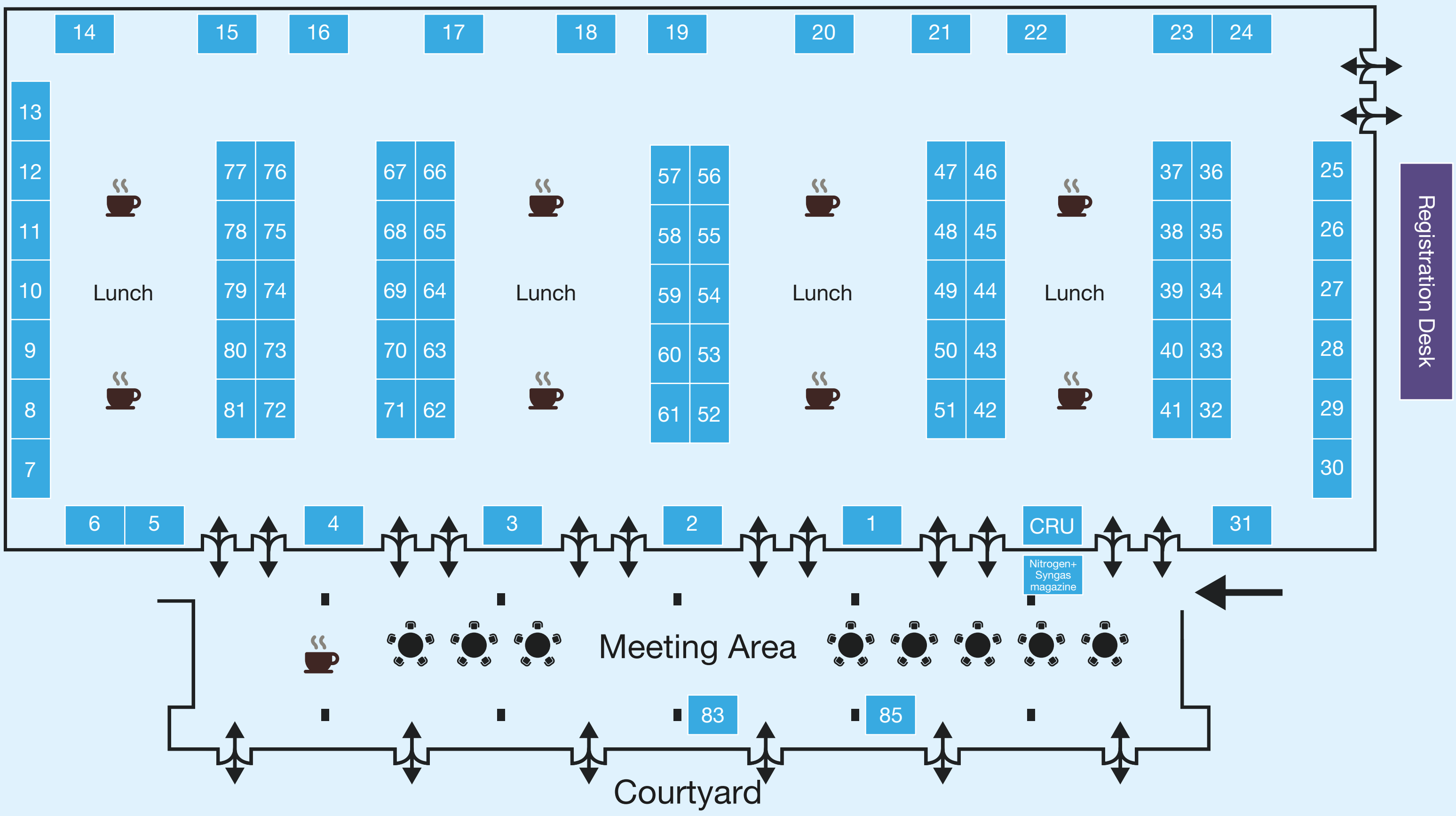
12:20 – 14:00 NETWORKING LUNCH

AMMONIA SYNTHESIS: CATALYSTS 14:00 – 15:30	DIGITAL AND AI POWERED SOLUTIONS 14:00 – 15:40	GREEN AMMONIA 14:00 – 15:40
Decoding industrial ammonia synthesis catalysts: From fundamental insights to AmoMax 10 Plus Rene Eckert, Lead Scientist, *Clariant*	**From data to decisions - Unlocking Industry 4.0: AI-ready historian and digital twin driving efficiency & reliability at Engro Fertilizers** Ahmad Hussain Iqtidar, Lead Process & Analytics, *Engro Fertilizers*	**Capitalising on new economic opportunities through flexible operation using advanced process control (APC)** Jorge Aguerrevere Clements, *Siemens*
New methods for faster and safer ammonia catalyst loading and activation Emir Zahirovic, Chief Technology Officer, *Catmasters, LLC* Rishika Chatterjee, Senior Solution Specialist, *Topsoe*	**Advanced optimisation and control for emerging ammonia plants: Addressing volatility and complexity with AI powered plant automation** Michael Kiesel, Senior Implementation Manager Advanced Automation, *Linde GmbH, Linde Engineering*	**Economic viability of small-scale green ammonia plant paired with renewable energy trading** Raimon Perea Marin, Technology Manager, *KBR*
Synloop savings based on Copernic's Neptune ammonia synthesis catalyst: Updated sensitivity analysis and scale-up/pilot plants Aruna Ramkrishnan, Chief Technology Officer, *Copernic Catalysts*	**Case study - Optimum and advanced process automation solutions based on AI and IIOT for erecting leak detection systems (LDS) on new HPCC in fertilizer plant** Dr. Mohamed Harb, General Manager, *Abu Qir fertilizers and Chemicals Industries Co.*	**Mastering design challenges in green ammonia plants** Marlen Weiß, *thyssenkrupp Uhde GmbH*
	UHPT smart valves Bernhard Druffel, *thyssenkrupp Uhde GmbH*	**Flexible low-load operation of Brownfield NH_3 plants – Simulations and industrial validations** Robert Kender, Senior Process Design Engineer, *Linde GmbH, Linde Engineering CASALE*

15:40 END OF CONFERENCE

(Correct at time of going to press)

Exhibition plan



EXHIBITOR LIST

1 Linde
2 Clariant
3 Institut Dr. Foerster
4 WIKA Alexander Wiegand SE & Co. KG
5 REMBE® GmbH Safety+Control
6 Aumund Fördertechnik/Schade Lagertechnik
7 Ratnamani Metals & Tubes Ltd.
8 Rotex
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11 Yantai Deyuan Heat Resistant Alloys Co., Ltd.
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14 NH3Process
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22 Paralloy Limited
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81 Solex Thermal Science Inc.
85 JGC Corporation

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65 Yantai Refra Heat Resistant Alloys Co.,Ltd

Exhibitor profiles

Arab Fertilizer Association — Stand 79

The Arab Fertilizer Association (AFA) is a non-governmental international Arab organization, established in 1975. It operates under the umbrella of the council for Arab Economic Unity. The Association brings together Arab and international institutions and companies engaged in the fertilizer industry and related fields with the aim to promote the development and advancement of the fertilizer industry and its applications, while adhering to environmental standard and requirements.

Contact: Mohamed Nagy
Email: m.nagy@arabfertilizer.org
Tel: +2 01142000013
Web: www.arabfertilizer.org

Air Products — Stand 39

Air Products is a world leader in the supply and service of gas separation systems. 230+ Air Products PRISM Membrane Systems are found in ammonia synthesis plants around the world operating efficiently and economically. PRISM Membrane Systems increase the efficiency of ammonia plants by recovering hydrogen from purge gas streams.

Contact: Kristin Brattstad
Email: brattsk@airproducts.com
Web: https://membranesolutions.com/

BORSIG Process Heat Exchanger GmbH — Stand 40

BORSIG Process Heat Exchanger GmbH offers pressure vessels and heat exchangers for cooling gases at very high temperatures (up to 1,500 °C) and high pressure (up to 35,000 kPa) such as waste heat recovery systems, waste heat boilers for ammonia, methanol and hydrogen plants, synloop waste heat boilers etc.

Contact: Antje Stoya
Email: info.bphe@borsig.de
Web: https://www.borsig.de/borsig-process-heat-exchanger-gmbh

Brembana&Rolle — Stand 33

Brembana&Rolle leads the market in the design and manufacturing of high-pressure heat exchangers, reactors, waste heat boilers, vessels/columns, fired heaters and process packages for fertilizers, petrochemicals, oil & gas, chemical and power plants, including nuclear. With five different production and assembling facilities located in Italy, Brembana&Rolle is supported by a wide agency network and an ever-growing product portfolio.

Contact: Alessandro Rolle
Email: arolle@brembanarolle.com / quotations@brembanarolle.com
Web: https://www.brembanarolle.com/ENG/home.asp

CASALE — Stand 52

CASALE is a Swiss-based company with over a century of expertise in the chemical industry, delivering integrated technologies, engineering, and construction solutions across the full value chain of nitrogenous and phosphate fertilizers as well as melamine, methanol, hydrogen, and syngas. CASALE also develops advanced low-carbon technologies such as blue and green hydrogen. Its offering spans technology licensing, engineering services, EPC project execution, and digital plant solutions.

Contact: Maria San Antonio
Email: m.sanantonio@casale.ch
Tel: +41 916419330
Web: http://casale.ch/

Christof Group SBN — Stand 36

Christof Group 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 mono-wall 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 deliver.

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

Dow — Stand 10

Dow is a global leader in materials science and strives to be the most innovative and sustainable materials science company world-wide. With operations in 30 countries, Dow provides advanced solutions for key markets such as packaging, infrastructure, consumer goods, and energy. In the energy sector, Dow brings decades of expertise in gas treating through its UCARSOL™ Formulated Solvents, helping customers efficiently remove acid gases and ensure reliable processing.

Contact: Diana Vásquez
Email: DVasquezGutierrez@dow.com
Tel: +1 979 2857952
Web: https://www.dow.com/en-us/brand/ucarsol.html

Eurotecnica Contractors and Engineers SpA — Stand 56

Eurotecnica, part of Proman Group, is known for its leading position as technology provider, designer and implementer of melamine production plants. Premier features of its proprietary Euromel® melamine process include: easy urea-melamine integration, total-zero-pollution, low energy consumption and superior reliability. 32 melamine plants, accounting for more than 1,400,000 t/a in licensed nameplate capacity, are based on Euromel® melamine process.

Contact: Stefano Sassi
Email: s.sassi@eurotecnica.it
Web: https://eurotecnica.it/

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: Jens Hesse
Email: Jens.hesse@heraeus.com Tel: +49 (0) 6181 35-4150
Web: https://www.heraeus-precious-metals.com/

KEY-TECH ENGINEERING — Stand 62

KEY-TECH has been serving the fertilizer industry for 30 years. Approved by leading process licensors, the company's product range utilises a wide range of materials and includes: HP urea grade valves, urea reactor trays, stripper ferrules, pipes, pipe fittings, metallic gaskets, static mixers, UG fasteners, HP thermowells, primary reformer inlet and outlet headers and pigtails, as well as a Leak Detection System (LDS) in technical collaboration with UreaKnowHow.com, approved by Saipem.

Contact: Gaurav Mehta
Tel : +91-9930447199
Email: gauravmehta@keytech.in
Web: http://www.keytech.in/key-tech/index.aspx

Navigance — Stand 64

Navigance supports chemical producers to maximise plant availability and optimise the efficiency of processes. Based on a unique combination of know-how, we build tailored, plant-specific process models and combine process data with machine learning and advanced data analysis technologies. Our services are available through a cloud-based platform, with secure, web-based access.

Contact: Lisa Krumpholz
Email: lisa.krumpholz@navigance.com / info@navigance.com
Web: https://www.navigance.com/

QUNGDAO NPA — Stand 20

NPA specialises in the production of heat resistant alloys products (centrifugally cast tubes and static cast fittings) for reformers and high temperature process gas heaters. NPA's strengths include: excellent product quality along with reliable after sales services, short lead time, and competitiveness. NPA focuses on the technological innovation and industrial upgrading of heat-resistant alloys and transforms its scientific research and technology advantages into production and market advantages.

Contact: Zhao Li
Tel: +86 151 0532 0257
Email: zhao.li@npa-china.com
Web: https://www.npa-china.com/Home.html

Siemens AG — Stand 16

Siemens delivers end-to-end automation, digitalisation and electrification solutions for fertilizer production. From automation, drives, and energy management to AI-powered emissions monitoring, digital twins, process simulation and modelling. This enables fertilizer producers to optimise productivity and safety, maintain regulatory compliance, and respond to volatile energy markets while advancing plant digitalisation.

Contact: Mayank Patel
Email: m.patel@siemens.com
Web: https://xcelerator.siemens.com/global/en/industries/chemical-industry/applications/fertilizer-production.html

Stamicarbon/Nextchem — Stand 51

NEXTCHEM Sustainable Technology Solutions

Stamicarbon, the nitrogen technology licensor of NEXTCHEM (MAIRE Group), designs and licenses fertilizer plant technologies, specialising in urea, green ammonia, and nitric acid. Stamicarbon has licensed more than 260 urea plants and realized more than 100 revamping and optimisation projects. Stamicarbon offers customers tailored solutions and services to maintain, improve and optimize plants in every stage of their life cycle, with a focus on sustainable fertilizer production.

Contact: Nikolay Ketov
Email: n.ketov@nextchem.com
Web: https://www.stamicarbon.com/

Yantai Deyuan Heat Resistant Alloy Co., Ltd — Stand 11

Yantai Deyuan Heat Resistant Alloy Co., Ltd. is a specialised manufacturer of heat-resistant alloy components, primarily centrifugally cast tubes and static castings for ethylene crackers and reformer furnaces. Building on a 30-year legacy from its predecessor, the company combines deep metallurgical expertise with a "Digital Workshop", aiming to create a world-leading, high-efficiency production facility, advanced alloy solutions and AI-powered inspection services.

Contact: Deyuan HRA – International Sales
Email: intl@deyuanhra.com / isd@deyuaninv.com
Tel: +86 137 9356 8286

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Urea technology showcase

Toyo Engineering Corporation, Stamicarbon and **Saipem** showcase their state-of-the-art urea technologies.

TOYO ENGINEERING CORPORATION

Advancement of ACES21-LP™: Low-Energy Concept

Author: Masaki Higaki

Since its establishment in 1961, Toyo Engineering Corporation (TOYO) has been a leading provider of urea process technology, consistently delivering reliable, efficient, and cost-effective solutions to the global fertilizer industry. In the late 1990s, TOYO introduced the ACES21™ process, which has since been implemented in 19 projects worldwide, including three of the largest single-train urea plants, each with a capacity of 4,000 t/d. In the early 2020s, TOYO further advanced its technology with the development of ACES21-LP™, currently recognised as the most energy-efficient and economically advantageous urea process.

Introduction to integrated technologies

This section provides a detailed description of the technologies integrated into the Low- Energy Concept ACES21-LP™ process.

ACES21-LP™

ACES21-LP™ is TOYO's latest urea synthesis technology, featuring the lowest synthesis pressure of 136 barg and the highest CO_2 conversion among modern commercial processes. TOYO was awarded the first project to apply ACES21-LP™ in 2023. The project involves building a 2,750 t/d urea plant for PT Pupuk Sriwidjaja Palembang (PUSRI-IIIB), designed for compatibility with both ACES21™ and ACES21-LP™. This project is currently in the construction stage and is progressing smoothly.

The key to realising ACES21-LP™ is the sophisticated use of DP28W™, conventional duplex stainless steel, and 316L stainless steel in the synthesis section, combined with reduced passivation air.

ACES21™ urea plant.

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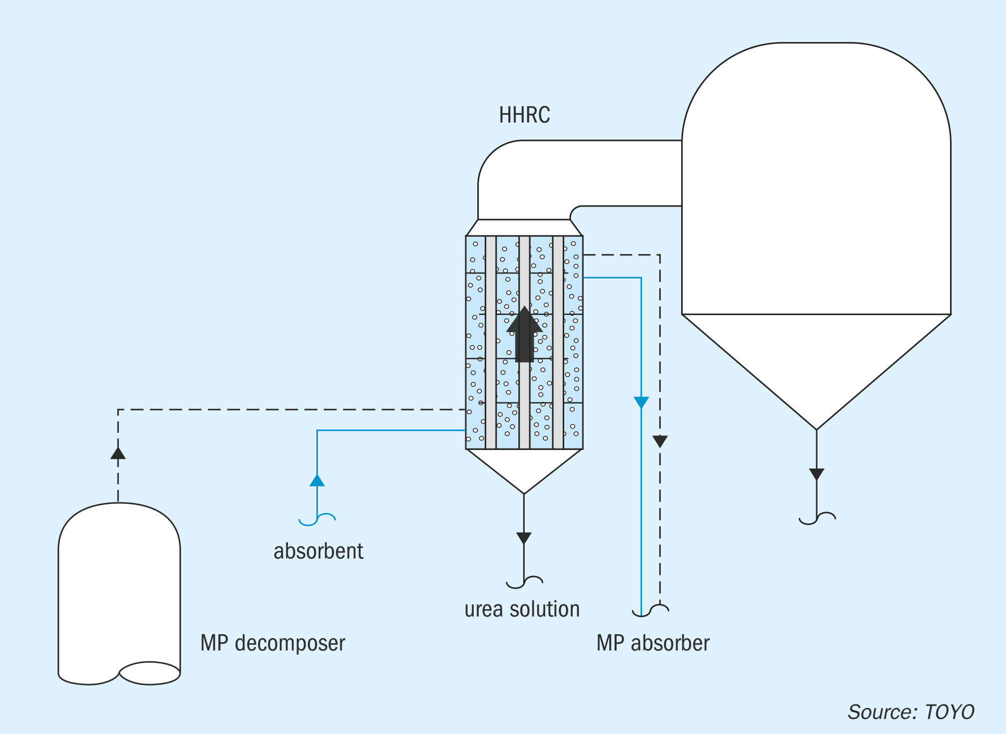
The concept of ACES21-LP™ enhances features of the current ACES21™ process as follows:

- lowest synthesis pressure among commercial urea processes owing to the uniquely optimised synthesis conditions and reduced passivation air requirement;
- highest CO_2 conversion among advanced modern urea processes;
- further energy savings (less opex) owing to less power requirements of the CO_2 compressor, ammonia and carbamate pumps;
- lighter weight of HP equipment in synthesis section by 5-10% owing to the milder mechanical design conditions of the synthesis equipment.

Since the basic process scheme of the current ACES21™ process is retained in ACES21-LP™, the ACES21-LP™ concept can be easily applied to currently operating ACES21™ plants with minor modifications.

Fig. 1: **The high heat recovery concentrator (HHRC)**



Source: TOYO

Development of the high heat recovery concentrator (HHRC)

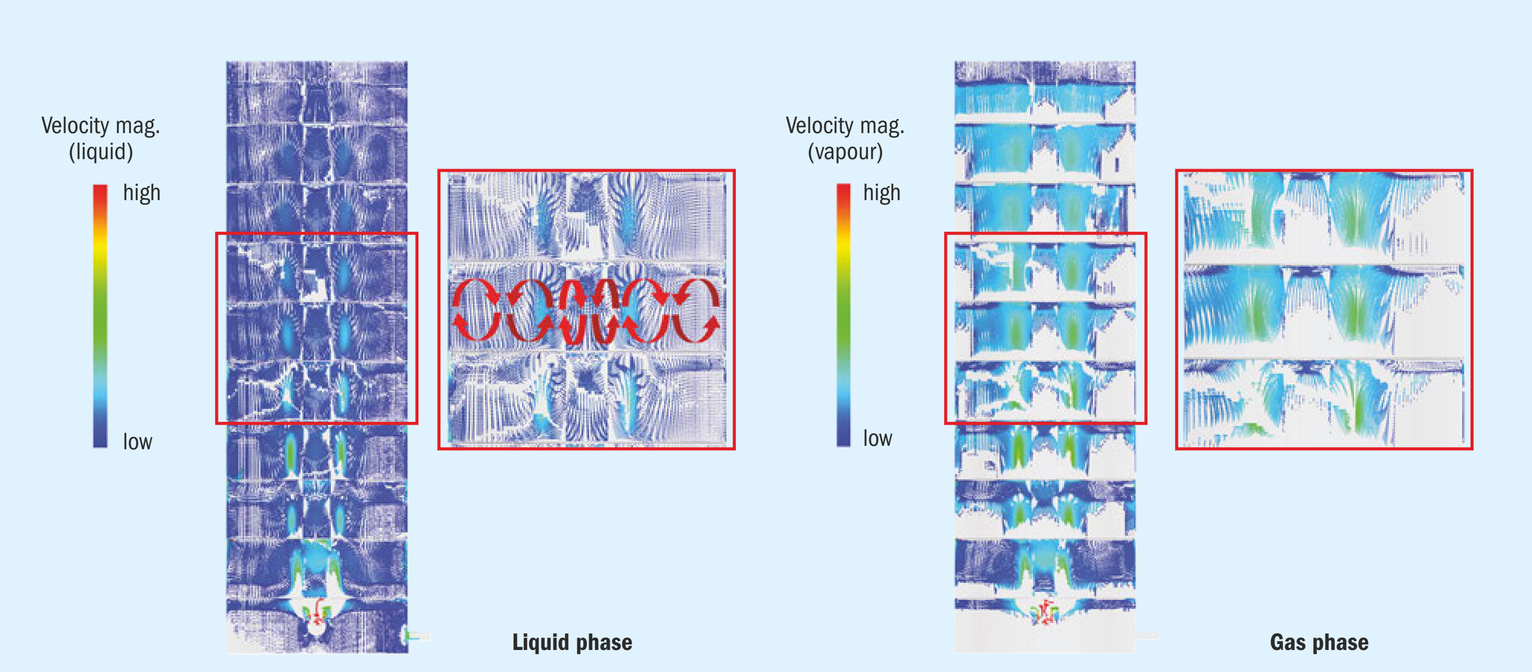
TOYO has recently developed a high heat recovery concentrator (HHRC). The HHRC is a high efficiency concentrator and has been incorporated into TOYO's latest standard process. The HHRC operates with the shell side fully filled with liquid, functioning as a bubble column. The absorbent liquid is supplied through nozzles located at the lower part of the shell, while the top gas from the MP decomposer (MPD) is introduced via spargers also positioned at the bottom. Inside the shell, the gas and liquid are mixed, and most of the gas is absorbed into the liquid. The resulting mixed-phase flow, containing the remaining unabsorbed gas, is discharged from the top and sent to the MP absorber.

This process configuration is illustrated in Fig. 1. In the HHRC, the outer surface of the tubes is constantly in contact with liquid, which significantly enhances the heat transfer performance.

To further improve the performance of the HHRC, it is essential to ensure sufficient gas dispersion within the shell to promote effective gas-liquid interaction. Additionally, increasing the cross-flow velocity of the liquid across the heat exchanger tubes is crucial for achieving a high heat transfer rate.

To optimise the design, CFD analysis was conducted to evaluate the internal flow conditions of the HHRC. CFD analysis confirmed that gas was uniformly dispersed across all baffle surfaces within the shell, indicating excellent gas distribution. It also

Fig. 2: **CFD analysis for the HHRC (liquid and gas velocity)**



Source: TOYO

showed that high gas velocity was realised near the boundary of tube bundle. This flow induces liquid circulation, forming two to three distinct circulation flows – one toward the centre and others toward the periphery, as shown in the image on the left of Fig. 2. These circulation flows lead to a high crossflow velocity. This enhanced crossflow velocity contributes to improved heat transfer rate, allowing for a reduction of required heat transfer area by approximately 40%.

It is also possible to replace the conventional evaporator in existing plants with the HHRC, for energy saving and/or upgrading of the plants.

Compared to the conventional evaporator, the HHRC offers the following advantages:

- significant improvement in tube surface wetting and enhanced gas-liquid interaction;
- improved heat transfer performance, enabling a reduction in required heat transfer area and more compact equipment design;
- suppression of biuret formation by reducing the heat transfer area;
- simplified equipment configuration and reduced operating costs.

A project adopting the HHRC is already underway, and commissioning of the plant is expected in 2027.

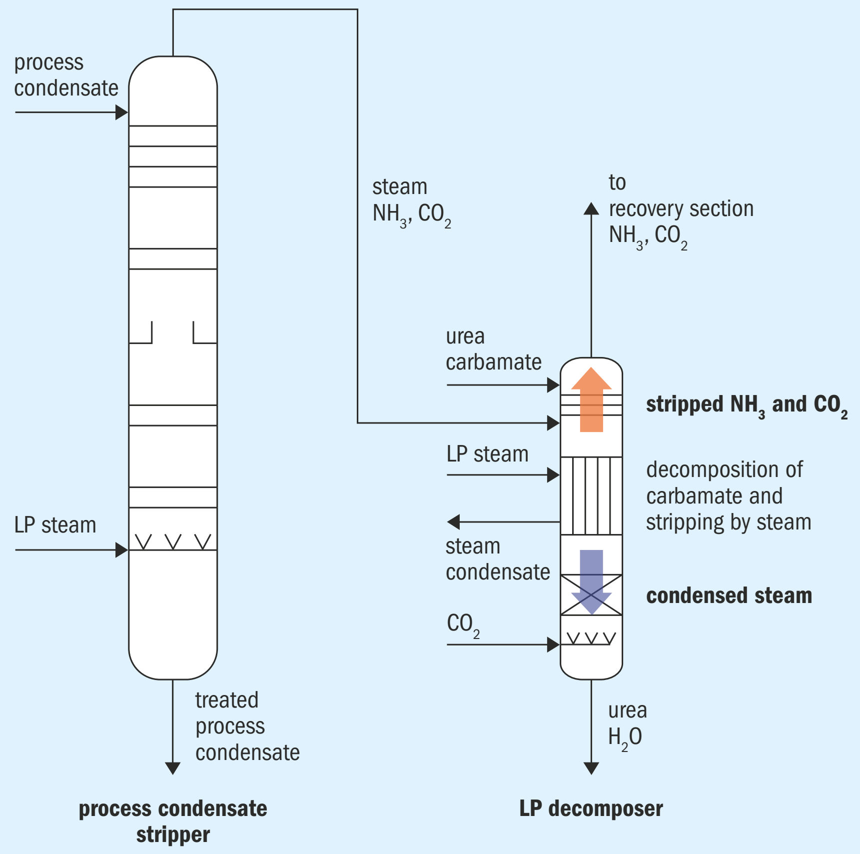
Direct integration of LP decomposition and process condensate treatment

The process condensate stripper (PCS) is employed to remove NH_3 and CO_2 from the process condensate via steam stripping, thereby reducing the NH_3 concentration in the condensate to a level suitable for discharge outside for urea plants. The stripping gas discharged from the top of the PCS contains not only steam but also the NH_3 and CO_2 removed during this step. This gas must be recovered and returned to the synthesis section to minimise raw material losses.

In certain processes, the gas is condensed using cooling water in a dedicated overhead condenser prior to recovery. However, this approach is inefficient because it requires cooling a large quantity of steam – the major component of the top gas – with cooling water. Moreover, installing additional equipment such as heat exchangers introduces pressure losses, necessitating operation of the stripper at elevated pressure to return the gas to the recovery section without auxiliary power. In general, lower operating pressure enhances stripping efficiency by facilitating the removal of residual components from the liquid phase; thus, additional equipment is undesirable from this perspective.

In TOYO's process, the top gas from the PCS is directly introduced into the LP decomposer (LPD) as shown in Fig. 3. This configuration eliminates the need for heat exchangers and avoids associated pressure losses. The top gas is effectively utilised as a heat source and provides approximately 50% of the heat duty required in the LPD, allowing the steam input to the LPD to be reduced by about half.

Fig. 3: **Flow diagram of direct integration between the LPD and the PCS**



Source: TOYO

Table 1: **Results of performance evaluation**

	Conventional	Low-Energy Concept
Steam consumption	Base	Approx. 10% decrease
Power consumption	Base	Approx. 5% decrease
GHG emission	Base	Approx. 10% decrease

Source: TOYO

Total integrated process based on "Low-Energy Concept"

Process description

The Low-Energy Concept ACES21-LP™ process is realised through the combination of the following four key elements:

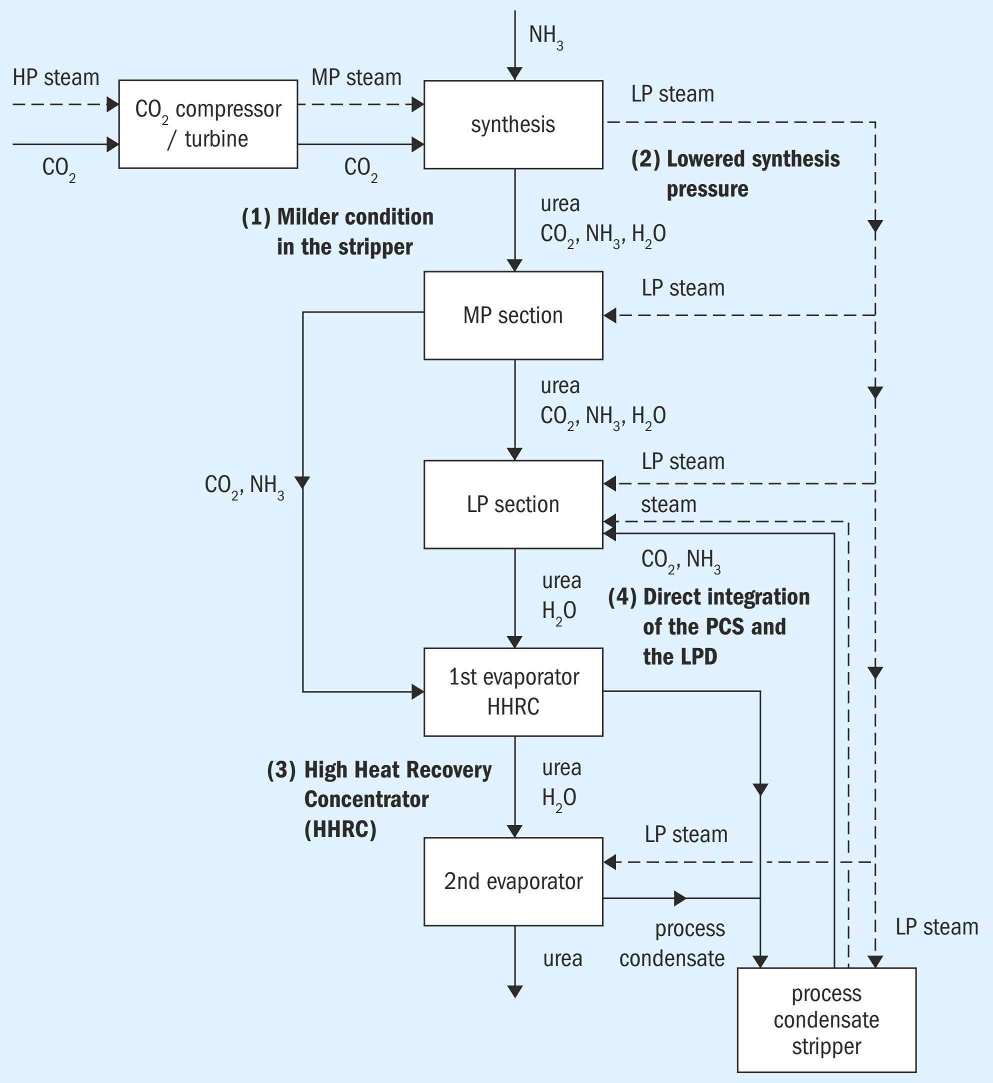
- milder condition in the stripper;
- lowered synthesis pressure;
- adoption of a newly developed HHRC;
- direct heat integration between the process condensate treatment and the LP decomposition.

A block flow diagram illustrating the integration effects is presented in Fig. 4. The specific impact of each element is discussed in detail below.

Milder condition in the stripper

In the Low-Energy Concept ACES21-LP™

Fig. 4: **Block flow diagram of Low-Energy Concept**



Source: TOYO

process, stripping in the stripper is carried out under milder conditions. This enables the extraction steam from the CO_2 compressor turbine to be supplied at a lower pressure. Consequently, the recoverable enthalpy within the turbine increases and the enthalpy of this steam is effectively recovered by the latest high-efficiency CO_2 compressor and turbine, thereby decreasing the demand for high-pressure steam in the steam turbine.

Lowered synthesis pressure

Lowering the synthesis loop pressure enhances stripping efficiency in the stripper. By combining lowered synthesis pressure with milder condition stripping, HP steam consumption can be further minimised, while the carbamate concentration at the stripper outlet is controlled to an optimal balance for effective energy integration with the downstream sections.

As discussed, lowering the synthesis pressure also contributes to reducing the power consumption of HP rotating machines such as the CO_2 compressor, and the ammonia and carbamate feed pumps. Moreover, it decreases equipment costs by lighter weight of HP equipment in the synthesis section by 5-10% owing to the milder mechanical design conditions of the synthesis equipment.

Adoption of newly developed HHRC

The residual carbamate in the stripper bottom liquid, which is optimised through milder stripping conditions and lowering the synthesis pressure, is decomposed in the MPD, and the resulting gas is directed to the HHRC. As described, this concentrator enables more efficient contact and absorption between the MPD top gas and the absorbent liquid compared with conventional evaporators, while effectively transferring the condensation heat to the tube side.

Consequently, the condensation heat (reaction heat to form ammonium carbamate) of the MPD top gas is efficiently recovered, allowing the urea solution to be concentrated to a higher level than in the conventional design. This improvement decreases the size of equipment and reduces steam consumption by approximately 40% in subsequent evaporator stages.

Direct integration of process condensate treatment and LP decomposition

Direct integration of process condensate treatment and the LPD reduces the LP steam consumption by approximately 50% in the LPD. LPD bottom effluent urea solution containing additional condensed water is sufficiently concentrated to a high level by the HHRC without need of any additional steam.

This process strategically integrates the aforementioned four innovative and proven technologies and optimises the operating conditions to overcome individual limitations, thereby achieving a substantial reduction in overall steam consumption.

Overall process performance

Operating variables are selected to maximise the integrated effect of the four key elements described.

Under the above conditions, steam consumption and power consumption can be reduced by approximately 10% and by 5% respectively, and resulting greenhouse gas (GHG) emissions can be reduced by approximately 10%.

Conclusion

TOYO's latest Low-Energy Concept ACES21-LP™ process is realised through the strategic integration of innovative and proven technologies. This process achieves significant reductions in energy consumption compared to the conventional design, resulting in substantial opex savings while contributing to a more sustainable urea industry.

Building on decades of expertise and continuous innovation, TOYO will continue to deliver solutions that address the environmental and economic demands of the urea industry.

STAMICARBON

From efficient urea melt production to large-scale granulation

Veronica Rivas, Murad Ismayilov, Nikolay Ketov, Stamicarbon (NEXTCHEM)

The urea industry is increasingly shaped by the need for higher efficiency under conditions of rising costs associated with feedstock, energy consumption, and emissions. For producers, maintaining competitiveness requires maximising conversion efficiency while reducing operating costs. The global fertilizer market continues to favour large-scale production units, where economies of scale enable lower capital investment and operational costs while also reducing emissions intensity.

While efficient urea melt production is a requirement for such plants, downstream processing plays an equally critical role. Granulation remains one of the most effective methods for producing mechanically robust urea granules that can withstand bulk handling, long-distance transport, and extended storage. When integrated with high-efficiency synthesis technology, granulation allows producers to fully realise the benefits of large single-train urea plants without compromising product quality or environmental performance.

This article follows the value chain from efficient urea melt production to large-scale granulation and examines how continuous improvement and digital support contribute to operational reliability at increasing plant capacities.

Ultra-Low Energy

As the world market leader in urea technology, Stamicarbon, the nitrogen technology licensor of NEXTCHEM (MAIRE Group), continually develops solutions to extend plant lifetime, reduce emissions, and lower energy consumption. Stamicarbon is recognised for pioneering urea technologies, including the invention of the CO_2 stripping process in the 1960s, which has since been continuously optimised for industrial application.

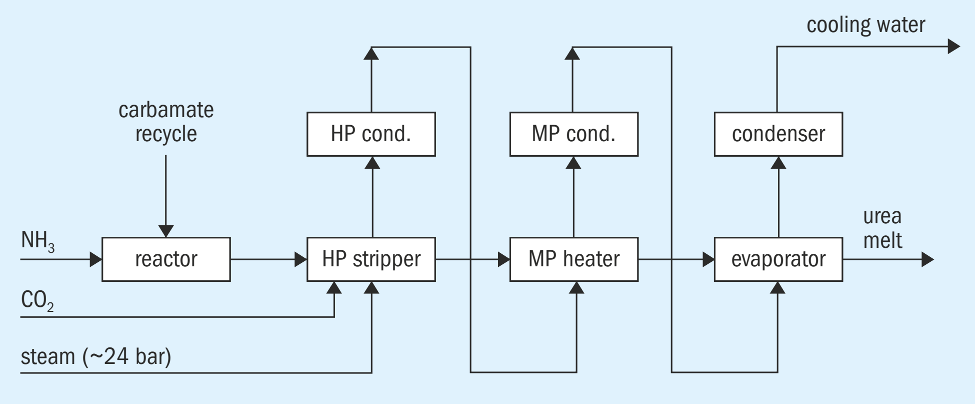
The most recent breakthrough in this development is the Ultra-Low Energy (ULE) design. This technology significantly improves the energy efficiency of urea production by allowing the heat supplied in the form of steam to be used three times instead of twice (Fig. 1).

The key technological feature enabling these savings is the medium-pressure recirculation section, which allows carbamate to be flashed at medium pressure and reheated using the heat of reaction and condensation. The reheated carbamate is then reused for heat recovery, particularly for evaporation duties.

As a result, steam consumption can be reduced by up to 40%, while cooling water consumption is reduced by approximately 16% compared with conventional CO_2 stripping processes. The design achieves the industry benchmark for steam consumption of less than 560 kg per metric ton of urea, compared with approximately 870 kg/tonne for traditional CO_2 stripping plants.

To date, the technology has been applied in ten projects worldwide. Seven operational plants with nameplate capacities ranging from 1600 t/d to 3850 t/d have demonstrated the designed energy performance under industrial operating conditions.

Fig. 1: **N=3 concept**



Source: Stamicarbon

A most recent project awarded in China involves a single-train urea melt plant with a capacity of 2,700 t/d based on the Ultra-Low Energy design. The plant is designed to combine high-capacity production with reduced energy consumption, reflecting the continued market demand for large-scale, energy-efficient urea melt plants.

Based on Stamicarbon's experience in new plant design, the Ultra-Low Energy design can also be applied to revamps of existing urea production, including non-Stamicarbon designed plants.

Granulation process

Large-scale urea melt production can be complemented by a downstream granulation process capable of handling large outputs while maintaining consistent product quality. Stamicarbon has extensive experience in designing urea granulation plants. This started with the first large-scale grass-roots granulation plant commissioned in Egypt in 2006. This plant was later successfully revamped to operate at a higher capacity.

The largest operating granulation plant based on the Stamicarbon granulation design is the Pardis III plant in Iran (Fig. 2), with a nameplate capacity of 3,250 t/d. Contracted in 2011 and started up in 2018, the plant is capable of operating at 110% of nameplate capacity with a turndown ratio of 60%. The granulation unit is integrated with a fertilizer-grade urea plant based on Stamicarbon's Pool Condenser design. Despite challenging climatic conditions, the plant has demonstrated reliable operation, achieving on-stream times exceeding two months during periods of extreme summer heat.

In the original Stamicarbon urea fluid-bed granulation process, urea melt with a concentration of approximately 98.5 wt-% is distributed by proprietary film-spraying nozzles (Fig. 3). Granule seeds are coated with thin layers of urea melt until the required product size is achieved. This process is characterised by low operating costs, reduced formaldehyde content in the final product, and limited dust formation. In practice, reference granulation plants have demonstrated long running times between the cleaning cycles, averaging over 90 days and reaching a record of 190 days.

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Fig. 2: Pardis III granulation plant.

Since the first implementation, nearly 20 Stamicarbon granulation plants of various capacities have been licensed, designed, and brought into operation.

Continuous improvement

In 2008, Stamicarbon introduced its optimised granulation design. This design features a simplified process layout (Fig. 4) with fewer equipment items, resulting in lower capital investment and reduced operating costs while maintaining product quality and high on-stream times.

In this configuration, urea melt is fed to the granulator in the same way as in the conventional design, while one of the main differences lies in the final compartment, where the granulated product is cooled to a lower temperature. After passing the lump screen, the product is conveyed via a bucket elevator to the classification system. From there, the solid product flows by gravity through the main screens. Coarse product is fed to the crusher after cooling to approximately 70°C, while crushed material and fines are recycled to the first compartment of the granulator as seed material.

An on-specification product is cooled to storage temperature in a solids-flow cooler using cooling water rather than cooling air. Dust-laden air from the granulator, coarse cooler, and all de-dusting points is collected and treated in a single granulator scrubber.

The elimination of two major fluidisation fans significantly reduces electrical power consumption. The fluid-bed granulator cooler has been omitted by extending the cooling zone within the granulator, while the fluid-bed product cooler has been replaced by a solids-flow cooler. Associated scrubbers, pumps, and fans have also been eliminated.

A water injection system installed downstream of the fluidisation air fan reduces the required flow of cooling air. Fine water droplets evaporate along the air path to the granulator, lowering the air temperature. This feature is particularly beneficial during hot ambient conditions when operating above nameplate capacity.

The reduction in equipment results in a smaller plant footprint and lower capital expenditure. Additional savings are realised in transportation, construction, insurance, and land use, while reduced equipment also leads to lower maintenance requirements.

Reducing emissions

During the crystallisation of urea melt in the granulator, ammonia present in the melt is released and may be emitted to the atmosphere. Stamicarbon's granulation process incorporates acidic scrubbing to capture this ammonia efficiently. Following dust removal, sulfuric or nitric acid is injected into a circulating aqueous solution that contacts the ammonia-laden air, forming an ammonium salt and reducing ammonia emissions in the exhaust gas.

The resulting ammonium salt solution can be sent outside battery limits or, when sulphuric acid is used, incorporated into the final product. In this way, no disposal streams are released to the atmosphere.

A technical challenge arises from the high water content of the scrubbing solution, which contains approximately 55 wt-% water, compared with the low water content of urea melt fed to the granulator. To manage this, a dedicated evaporation step is used to concentrate the recycled urea ammonium sulphate (UAS) solution before it is reintroduced into the granulator. The sulphur content in the final product remains low, typically around 0.05 to 0.1 wt-% S, allowing the granules to be marketed as standard urea.

In response to increasing agronomic demand for sulphur, Stamicarbon has developed a modular process for producing granulated urea enriched with higher levels of ammonium sulphate. Existing granulation plants can be retrofitted for this application with limited modifications and the installation of additional equipment.

Scaling up

In recent decades, urea granulation projects with capacities exceeding 3,000 t/d have become increasingly common. Such plants have demonstrated their ability to meet growing production and availability requirements.

Stamicarbon evaluated further scale-up while maintaining proven design principles and product quality. This assessment showed that a single-line configuration offers advantages over a dual-line configuration of equivalent total capacity, including an estimated reduction of approximately 30% in total capital investment.

In 2019, Stamicarbon licensed its first single-line 4,000 t/d urea granulation plant, equipped with a MicroMist Venturi™ (MMV) scrubber to meet environmental requirements. In 2022 and 2023, two other 4,000 t/d plants were licensed for a customer in Africa.

Based on experience gained from scaling conventional designs and operational and manufacturing expertise, the optimised granulation design can be extended to a single-line capacity of 5,000 t/d.

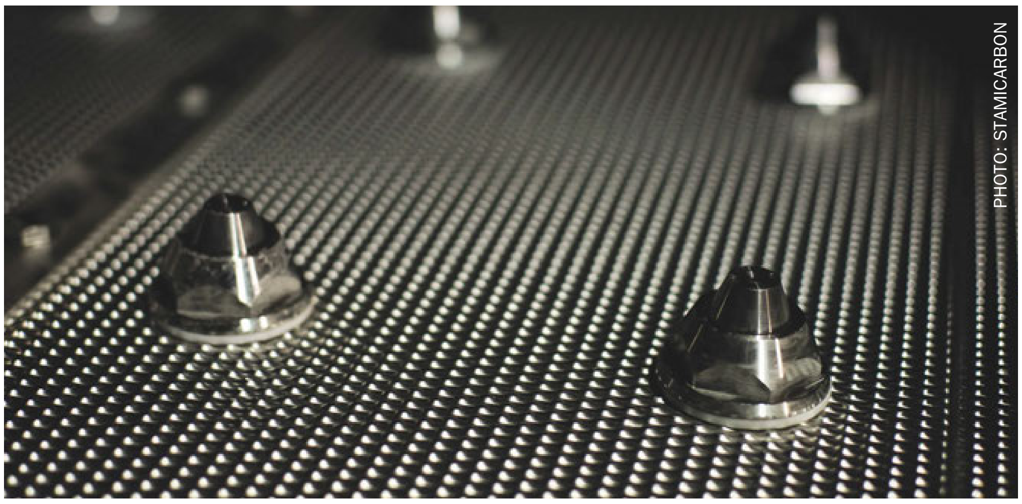
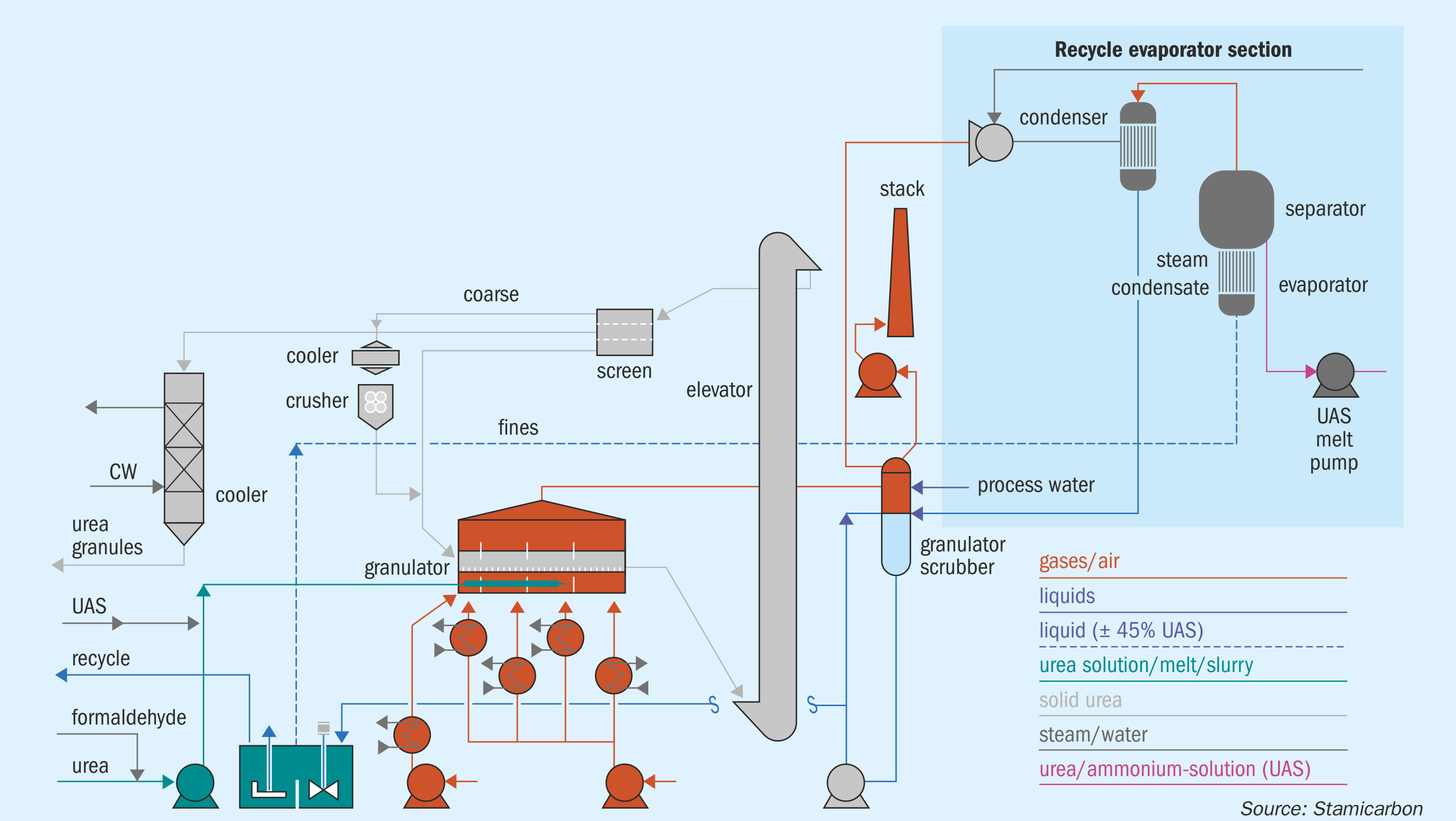


Fig. 3: Granulator film spraying nozzles.

Fig. 4: **Stamicarbon's optimised granulation design with optional recycle evaporator section**



Source: Stamicarbon

Digital support

As plant capacities increase and process integration becomes more complex, digital tools play an increasingly important role in supporting safe and efficient operation. One operational advantage of the Ultra-Low Energy design is the presence of the medium-pressure recirculation section, which reduces process disturbances typically encountered in conventional CO_2 stripping plants. However, to further enhance operational reliability, operator training remains essential.

As an example, the urea plant at Jinjiang Xinlianxin, with a capacity of 2,334 t/d, was the first facility to apply Ultra-Low Energy technology. Prior to start-up in February 2021, operating personnel were trained using Stamicarbon's Technology Training Simulator (TTS), part of the NX STAMI™ Digital portfolio, ensuring a complete understanding of plant behaviour under various scenarios. The startup was completed smoothly on the first attempt. The plant initially operated at reduced load and was subsequently ramped up to above 100% capacity within the first week after feedstock availability was secured. The start-up took place during COVID-19 lockdowns in China, with remote training via TTS enabling commissioning without on-site support.

PHOTO: STAMICARBON

Operator training simulator visual display.

Conclusion

Stamicarbon provides a complete range of technologies, products, and services that cover the entire urea value chain. Technologies for urea synthesis, including the Pool Condenser, Pool Reactor, and Ultra-Low Energy designs, enable improved plant efficiency, reduced operating and maintenance costs, and lower emissions. This is complemented by a range of finishing solutions, including proven state-of-the-art fluid-bed granulation technology, as well as technologies for producing urea prills, pastilles, and liquid fertilizers. Stamicarbon also offers digital solutions that support stable operation, high availability, and optimised energy performance in urea plants.

By leveraging extensive experience in nitrogen technology and collaborating with sister companies within NEXTCHEM (MAIRE Group), Stamicarbon can deliver a complete value chain of technological solutions for sustainable fertilizer and fuel production. ■

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SAIPEM

Saipem's Snamprogetti™ Urea Technology improving execution strategy and overall efficiency

Saipem's Snamprogetti™ Urea Technology has been licensed for more than 140 units, of which 115 are currently in operation. With a long history of innovations to reduce both capex and opex, such as the introduction of the carbamate ejector and the horizontal layout, Saipem now offers a well-proven design that provides operational flexibility, especially for high-capacity plants.

Below are the most recent improvements, which address major project challenges in execution strategy and overall efficiency. These developments leverage Saipem's experience both as a licensor of urea technology and as an EPC contractor.

Modularisation

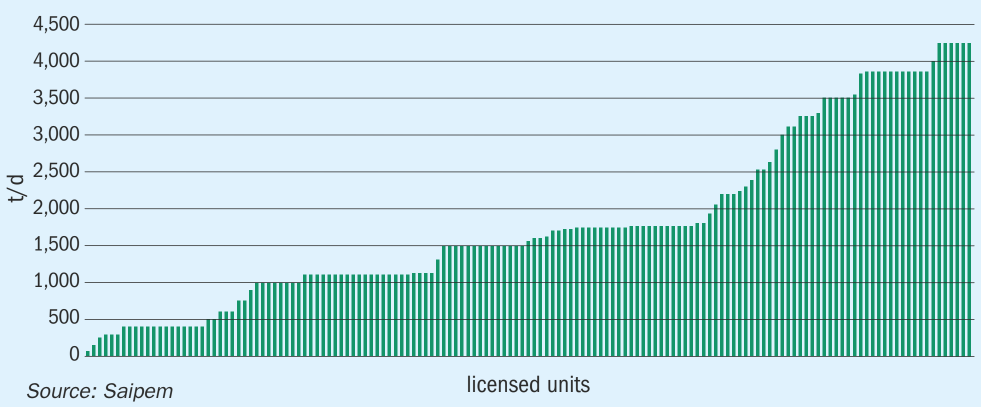
Saipem has further optimised engineering solutions to enable full modularisation of each unit within the ammonia–urea complex. The approach uses compact layout modules that cluster equipment to minimize plot occupancy and shorten pipe routes, bringing process advantages while maintaining operability and reliability.

A representative example is the CERES project, currently under execution. It represents a significant milestone in the ammonia and urea industry as it is the first Topsoe Ammonia SynCOR™ plant in an advanced stage of construction and the first to feature a very high degree of modularisation for both ammonia and urea plants. The facility will produce 2.3 million tonnes per annum (t/a) of high-quality urea. Saipem's proprietary Snamprogetti™ Urea Technology was selected for the synthesis and purification of the urea solution fed to the granulation section.

The process scheme applied to the project is robust and efficient and retains the technology's standard configuration without modifications, ensuring state-of-the-art energy recoveries and consumption. The horizontal layout and plot plan – developed by Saipem in its dual role as licensor and contractor to facilitate construction and maintenance – are proven in several reference plants.

As demonstrated by the CERES project, modularisation is effective even for high-capacity urea plants. Recent installations using Snamprogetti™ Urea Technology reflect the market's trend toward ever larger capacities. The graph in Fig.1 shows the progressive increase in nominal capacity for Snamprogetti™ Urea Technology and it is representative of a general trend for all urea technologies

Fig. 1: **Market shift toward larger urea plants relevant to Snamprogetti™ Urea Technology**



Source: Saipem

Higher efficiencies in ammonia-urea integrated plants

Saipem has continuously improved the energy efficiency of its licensed plants through several measures, including additional energy-recovery systems, the introduction of the double carbamate condenser scheme, and, more recently, the SuperCups™, which enhance mixing within the reactor to increase conversion and reduce energy demand for decomposition in the downstream sections.

A key contribution from Saipem is its ability to integrate the urea unit with the ammonia unit and utilities – this integration has the largest effect on overall natural gas consumption.

Notable features from recent EPC projects include:

- electrification of most drivers;
- use of high-efficiency integral-gear compressor technology (for example, in CO_2 service);
- combined-cycle power generation integrated with excess steam from the ammonia plant;
- integration of renewable power, where available, to minimise energy input and associated CO_2 emissions across the complex.

SATURN31™ – The new superduplex material for HP urea sections

SATURN31™ is a new superduplex material developed jointly by Tubacex and Saipem for use in the high-pressure section of urea plants. The development objective was to balance superior corrosion resistance with manufacturability and constructability.

Reference corrosion performance in urea high-pressure environments is well established from experience with 25/22/2 Cr/Ni/Mo and AISI 316L UG. The goal for SATURN31™ was to outperform these reference materials, achieving lower corrosion rates even in oxygen-free conditions, thereby allowing the elimination of a dedicated passivation air compressor at the bottom of the urea stripper.

Being a superduplex material it was important to ensure smooth manufacturability, excellent weldability, and good machinability. The material's improved mechanical properties also enable weight reductions and lower opex.

Several numerical simulations were carried out at the outset of the development to define possible chemical compositions, which were also tested in laboratory-scale heats; the composition finally selected was then tested in industrial-scale heats.

The new highly alloyed superduplex, SATURN31™, has high chromium and nitrogen contents and moderate additions of molybdenum, tungsten, and cobalt. The well balanced chemical composition and an optimised solution-annealing treatment produces a homogeneous distribution of austenite and ferrite bands, free from intermetallic phases and precipitates. This combination of alloying elements delivers excellent resistance to urea solutions with or without oxygen, and high resistance to localised corrosion (pitting and crevice corrosion).

Urea stripper ferrules were the first industrial application of SATURN31™. The material will next be used as a liner and for other internals in high-pressure equipment such as SuperCups™. Following ASME codification, SATURN31™ will also be used to manufacture pressure-resistant components for equipment and piping, opening the way to design and manufacture the entire high-pressure equipment in SATURN31™.

A particularly innovative development under way is producing the new generation of SuperCups™ using SATURN31™ via additive-manufacturing techniques.

Small-scale urea plants

Leveraging its extensive licensing, engineering, and construction experience, Saipem now offers a skid-mounted urea plant concept targeting capacities up to 100 t/d. The concept preserves the classic five-section process scheme to retain advantages such as operational flexibility and low environmental impact.

To optimise capex versus efficiency, particularly where energy is supplied from renewable sources, the design reduces some energy-recovery items compared with a traditional scheme. Additional optimisations include using single pumps (with spare units kept in storage) to minimise footprint. These layout optimisations are applicable to both skid-mounted and stick-built constructions.

Although these small-scale plants can be provided with conventional finishing such as prilling or granulation, pastillation is often more effective, based on capacity and layout (skid mounting/modularisation considerations. Such plants are suitable for technical production (for example, standalone DEF units) and for valorising waste streams (e.g., CO_2), and extra production (e.g, NH_3), or exploiting renewable energy.

Tuttle by Saipem urea prilling buckets.

Tuttle by Saipem urea prilling buckets

In 2018, Saipem acquired Tuttle's prilling-bucket technology and began marketing the product under the name Tuttle by Saipem. Between the early 1970s and 2018, Tuttle delivered over 500 prilling buckets worldwide.

After the acquisition, Saipem enhanced the technology to improve product quality (granulometry) and reduce dust. Improvements focused on both design and manufacturing. Extensive computer simulations – validated against historical data – were used to define design parameters for the desired product quality. On the manufacturing side, production moved from largely manual drilling to computer numerical control (CNC) machining.

Since the acquisition, Saipem has manufactured and delivered more than 50 buckets worldwide for new plants and replacements.

A recent development is a design and manufacturing procedure for the production of buckets for microprills. Microprills differ substantially from standard prills: typical diameters range from 0.42 mm to 2 mm, with an average of about 1 mm. Historically, the smallest prilling bucket was designed for an average diameter of 1.6 mm, so producing microprills required new design, manufacturing, and quality-control solutions.

Key challenges and solutions for the microprill bucket included:

- operating at rotational speeds more than 1.5 times higher than standard prill buckets;
- drilling hole diameters less than half those used for standard prills;
- implementing stepwise drilling and redrilling with intermediate cleaning to preserve drill-bit integrity;
- introducing enhanced inspection techniques, using concentrated light in a darkroom, to address the small hole size and challenging inspection angles.

These measures ensure reliable production of microprills while maintaining manufacturing quality and product consistency.

BREMBANA&ROLLE

THE FUTURE OF THE CHEMICAL INDUSTRY:

Paths to decarbonisation

A report on a conference, promoted and organised by the Brembana & Rolle Group, held at the Italian Association of Industrial Operators in Bergamo in October 2025. The event provided a clear, up-to-date overview of key developments in the chemical process industry. Users, process licensing companies, engineering and procurement companies and research institutions convened to discuss and debate front-end process and technology innovations in the light of current climate regulations, evolving market demands, and regional and geopolitical challenges. Keynote speeches, round tables and dedicated networking areas for face-to-face meetings were held throughout the full-day program. Contributions from the EU Commission, which focused on the new regulatory and subsidy framework for the chemical industry, and from a major investment bank outlining near-term dynamics in large industrial investment, drew significant attention.

Technical sessions

In the afternoon sessions, major public and private research organisations, including ENEA, Fondazione Kessler and the Polytechnic of Milan presented emerging technological perspectives and medium-term trends. They emphasised novel hydrogen routes as enablers of green chemical synthesis and new approaches to seasonal and long-term heat storage. Presentations highlighted how process technology can contribute to practical, credible decarbonisation roadmaps in critical chemical segments. From ammonia to methanol, urea and melamine, the conference showcased innovations that major players are pursuing in sustainable chemical synthesis, green energy generation and emissions reduction in heavy transport sectors.

Casale

Casale presented one of the most comprehensive portfolios of low-energy, environmentally advanced technologies for nitrogen-based chemicals and melamine. Its proprietary solutions are installed in over 300 ammonia converters worldwide, with proven industrial performance even at ultra-low turndown rates (10% load). Additionally, nearly 20 advanced syngas units using autothermal reforming and partial oxidation technologies are also in operation, enabling efficient, future-ready hydrogen production and supporting decarbonisation across multiple industrial sectors, including gasification. "Innovation is not just a goal – it's how we deliver impact," said Sergio Panza, Technology Manager at Casale. "With over 15 clean energy projects currently in progress or operation, Casale is enabling real decarbonisation across the fertilizer, hydrogen, methanol and melamine value chains."

Eurotecnica/Proman

Although melamine has a lower per-unit impact than some other chemicals, its widespread use makes reducing its environmental footprint important. Eurotecnica/Proman's Euromel® melamine and ET Sun Energy™ technologies offer a promising decarbonisation route. As Alberto Serrafero, Chief Technical Officer, explained: "Euromel® melamine technology is well known and appreciated by investors worldwide, being applied at 32 melamine plants and is the only technology with proven total-zero pollution. ET Sun Energy™ is a technology pioneered by Eurotecnica that enables thermal energy storage, successfully applied at the Andasol complex in Spain, currently Europe's largest electricity producer from concentrated solar power. In a green fertilizer complex where electricity is available from renewable sources, a Euromel® melamine plant can produce green melamine, supported by ET Sun Energy™ which ensures continuity of the required reaction heat."

NextChem

NextChem, the technology arm of Maire Group, offers end-to-end technology solutions, from syngas production via autothermal and steam reforming, catalytic partial oxidation and gasification to methanol synthesis designed for project-specific needs, and acts as a single point of accountability for project development and realisation, leveraging not only its technological portfolio but also the valuable support of the Maire Group's engineering and construction capabilities (Tecnimont and KT) and project development expertise (MET Dev). "Our mission," said Stefano Lillia, Strategic Marketing Manager, "is clear: to enable the industry to tap into a wide range of feedstocks and deliver scalable, sustainable methanol for the hardest-to-abate sectors, such as marine and aviation."

Stamicarbon

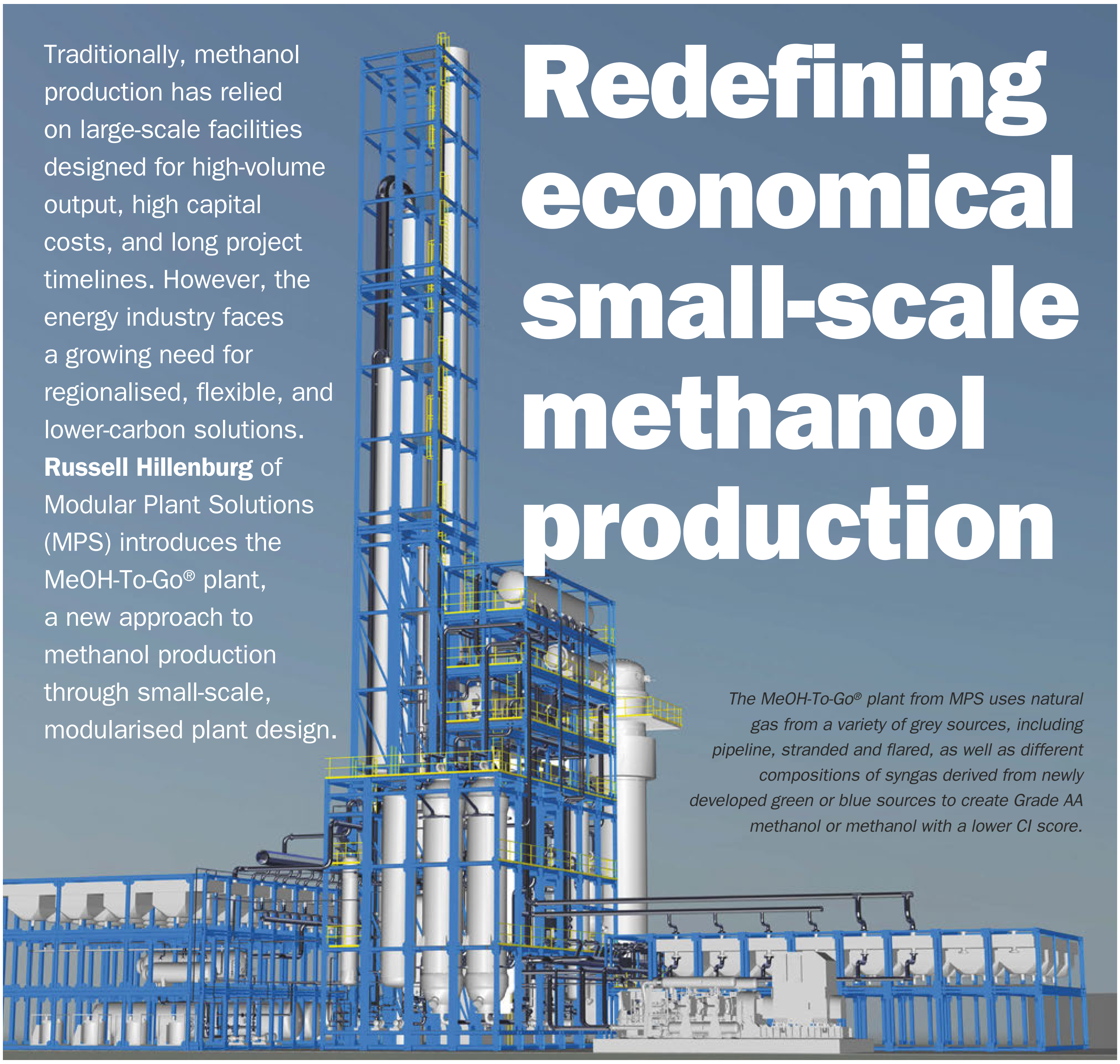
Through its nitrogen licensor Stamicarbon, NextChem is also pioneering future-proof solutions for ammonia production, with a particular emphasis on minimising the industry's carbon footprint and enabling the energy transition. The NX STAMI™ Ammonia technology portfolio, described by Deepak Shetty and Ankur Gupta, "includes designs tailored for small to large-scale production from renewable electricity or fossil sources with CCUS integration. Proprietary ammonia converters are engineered for enhanced flexibility – from 10% to 110% plant capacity – ensuring extended catalyst life and improved conversion efficiency, resulting in reduced energy consumption and lower operational costs."

Brembana&Rolle

Reactors, heat exchangers and vessels are the workhorses of the industry; reliable, well-established technologies and advanced designs are essential to meeting ambitious end-user targets. Drawing on extensive expertise in designing efficient, reliable equipment in collaboration with customers' process and mechanical teams, Brembana & Rolle concluded by presenting its G.R.E.E.N. (Gas, Renewables, E Fuels, Energy Efficiency, Nuclear) commitment to zero pollution. The company cited several applications where innovative solutions, grounded in established know-how, produced measurable emission reductions, raw material savings and effective substitution of fossil fuels. **brembanarolle.com**

Redefining economical small-scale methanol production

Traditionally, methanol production has relied on large-scale facilities designed for high-volume output, high capital costs, and long project timelines. However, the energy industry faces a growing need for regionalised, flexible, and lower-carbon solutions. **Russell Hillenburg** of Modular Plant Solutions (MPS) introduces the MeOH-To-Go® plant, a new approach to methanol production through small-scale, modularised plant design.



The MeOH-To-Go® plant from MPS uses natural gas from a variety of grey sources, including pipeline, stranded and flared, as well as different compositions of syngas derived from newly developed green or blue sources to create Grade AA methanol or methanol with a lower CI score.

PHOTO: MODULAR PLANT SOLUTIONS

In the global drive toward sustainable and decentralised energy production, methanol continues to prove its versatility as both a platform chemical and an increasingly important low-carbon fuel. Modular Plant Solutions' flagship plant, the MeOH-To-Go® plant, brings a new approach to methanol production through small-scale, modularised plant design. Built on a patented system, with modular frames that conform to the ISO-1496/CSC container standard, MeOH-To-Go® enables economical methanol production with a variety of feedstock possibilities, from remote stranded gas fields to renewable natural gas and syngas sources.

Rethinking scale: From world-class to modular-class

The MeOH-To-Go® plant is roughly one-twentieth the size of a conventional world-scale facility, yet it delivers commercial-grade AA methanol production through a highly engineered, modular system. Each module is prefabricated within frames the size of standardised ISO shipping containers, allowing plant module transport by truck, rail, or cargo ship and on-site assembly.

This approach offers multiple advantages:

- Predictable capital expenditure: Modular fabrication ensures repeatable designs and controlled costs.
- Accelerated deployment: Parallel manufacturing and plug-and-play assembly reduce project timelines.
- Reduced site risk: Minimal on-site construction lowers exposure to weather delays and labor shortages.
- Consistent quality: Factory-built modules ensure repeatable performance and easier maintenance.

By contrast, traditional methanol plants require extensive site development, field fabrication, and long commissioning phases. MeOH-To-Go® shifts much of that work off-site, an advantage that improves economics for smaller-scale projects.

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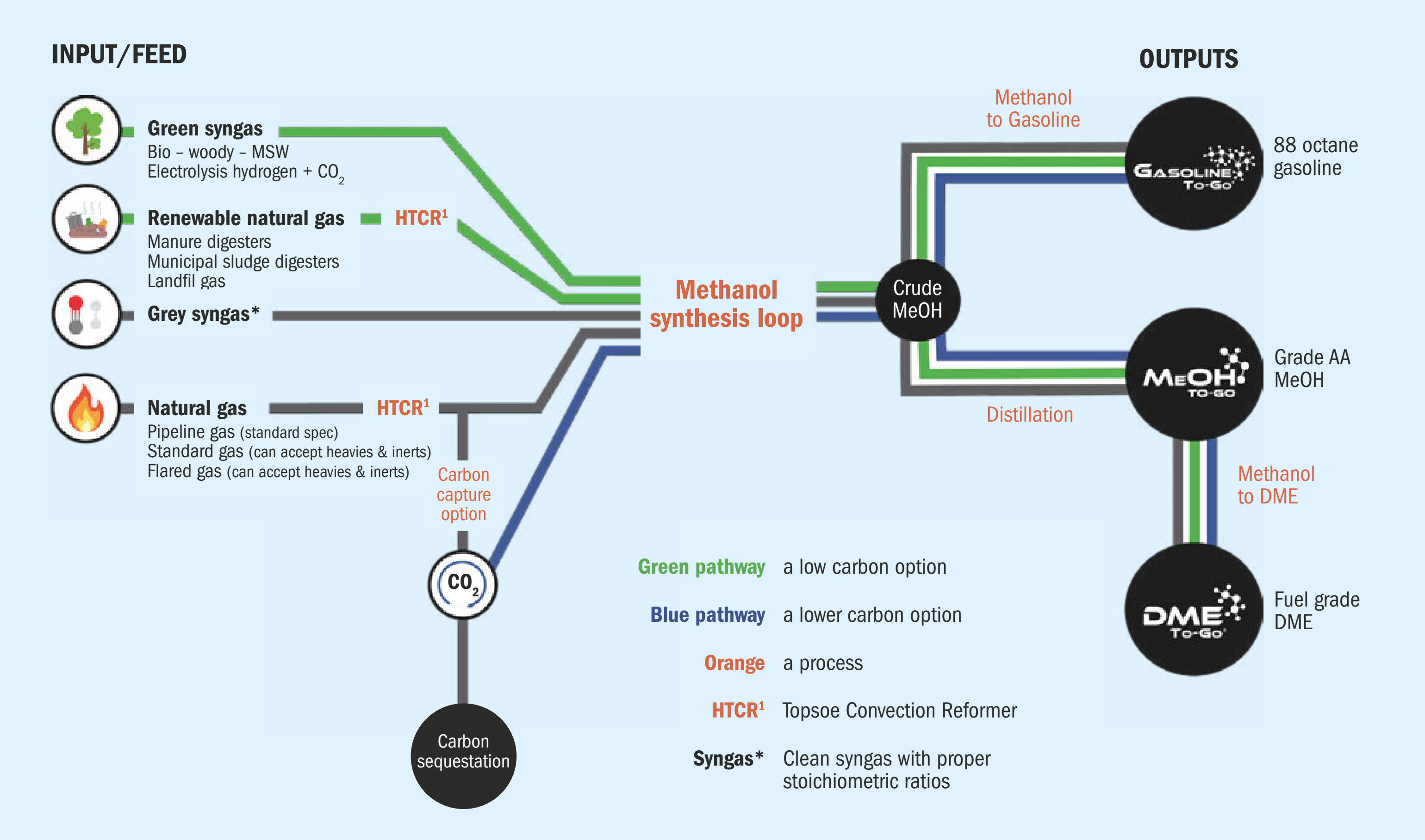
Fig. 1: **MPS offers small-scale modularised plants and add-on products that can meet a variety of customer needs and desired outputs – including lower carbon methanol, gasoline and DME.**



Source: Modular Plant Solutions

From flaring to fuel: Unlocking value in stranded gas

A key design driver for MeOH-To-Go® was the global challenge of stranded and flared natural gas. According to World Bank data, roughly 148 billion cubic metres of associated gas is flared annually – a waste of valuable resources and a significant contributor to greenhouse gas emissions.

Because MeOH-To-Go® plants can be transported and assembled in remote areas, they provide an economically viable way to capture, convert and monetise stranded gas. By turning this wasted feedstock into methanol, operators can reduce flaring, generate marketable products, and support local economic activity – all within a smaller carbon footprint.

The plant's feedstock flexibility also opens opportunities beyond stranded gas. MeOH-To-Go® can utilise grey natural gas, renewable natural gas (RNG), or syngas from green or blue sources to produce Grade AA methanol, either grey or low-carbon. This adaptability allows operators to align production with their feedstock availability, carbon reduction targets and market strategy.

Technology inside the box: The MeOH-To-Go® design

At the core of the MeOH-To-Go® concept is its patented modular structure (U.S. Patent 11952769, 2024), which integrates process and structural engineering within ISO-1496 compatible frames. Beyond simply "fitting equipment into boxes," this patented design allows for vertical orientation of modules and stacking of tall process components such as distillation columns – a first for a process plant based on ISO-1496 compatible frames.

This vertical module integration maximises space efficiency while maintaining full process capability. The ISO-1496 compatible modules also simplify shipping and on-site installation.

The MeOH-To-Go® plant includes all key process elements for methanol synthesis – reforming, compression, synthesis loop, distillation, and utilities – compactly arranged for transport and field assembly. The plant utilises Topsoe's high-efficiency convection reformer HTCR technology, and each module arrives pre-piped, pre-wired, and factory-tested to minimise commissioning time.

Modularisation as a strategy, not a scale-down

While "modularisation" has become a common buzzword in plant design, the approach with MeOH-To-Go® represents true modular engineering, not simply a scaled-down replica of larger systems. By standardising design and fabrication around ISO dimensions, MeOH-To-Go® achieves repeatability and scalability across multiple plant configurations.

This strategy extends to more than methanol alone. MPS's modular approach can integrate additional back-end processing units, including:

- Gasoline-To-Go®, for producing 88-octane gasoline and LPG directly from syngas or natural gas.
- DME-To-Go®, for producing dimethyl ether (DME), a clean-burning diesel alternative.

These pre-engineered add-ons allow customers to tailor production to market needs, for example, a methanol plant near a port that later expands to produce gasoline or low-carbon DME.

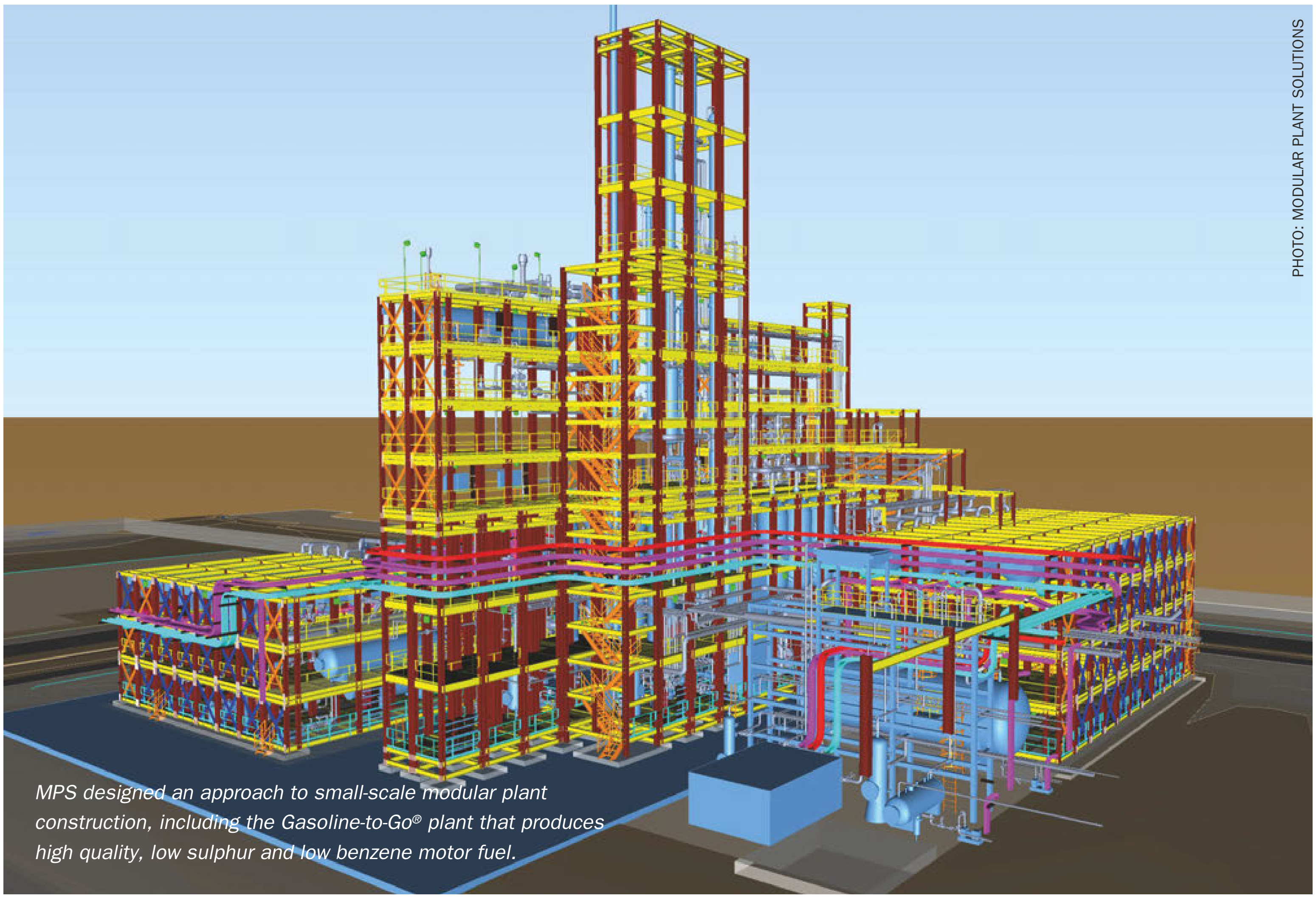


PHOTO: MODULAR PLANT SOLUTIONS

MPS designed an approach to small-scale modular plant construction, including the Gasoline-to-Go® plant that produces high quality, low sulphur and low benzene motor fuel.

Driving economical and sustainable methanol production

One of the primary challenges in small-scale methanol production has always been the balance between capital cost and operating efficiency. Historically, small plants could not compete on per-ton economics with mega-scale facilities. MeOH-To-Go® closes that gap.

Through modular construction, reduced labour requirements, and standardised equipment, the plant lowers total installed cost. The system's self-sufficient utilities minimise dependence on external infrastructure, enabling stand-alone operation – ideal for remote or distributed applications.

Furthermore, MeOH-To-Go® can integrate carbon capture or sequestration modules, supporting a range of low-carbon pathways. This makes it a compelling technology for companies seeking to align with decarbonisation mandates while expanding into new markets for renewable fuels and sustainable chemicals.

Licensing and industry collaboration

Beyond building and delivering turnkey MeOH-To-Go® plants, MPS has expanded its strategy through technology licensing and modularisation services. This enables energy companies and developers to apply MPS's patented modular structural system to their own small-scale projects – whether for methanol, hydrogen, ammonia, other syngas derivatives or products.

Licensing partners benefit from MPS's engineering expertise, patented modular approach and process integration experience, reducing design risk and accelerating deployment. As demand grows for localised production of fuels and chemicals, these partnerships make small-scale modularisation a practical reality across the energy sector.

A path forward for decentralised syngas applications

Methanol's versatility – as a hydrogen carrier, fuel component, and key building block chemical – makes it an important part of the shift toward a cleaner, more sustainable energy future. Yet the industry's ability to harness that potential depends on more flexible production strategies.

By making methanol production economical at small-scale, MeOH-To-Go® unlocks new routes for regional energy independence and chemical manufacturing. The plant's modular architecture supports rapid deployment in diverse environments, from oilfields and ports to biogas sites and industrial parks.

Conclusion

The MeOH-To-Go® plant represents more than a new way to build methanol plants – it represents a new way to think about process engineering itself. By combining modularisation, flexibility, and sustainability, MPS has redefined the economics of small-scale methanol production.

As the syngas and nitrogen industries evolve toward cleaner and more adaptable solutions, technologies like MeOH-To-Go® can help bridge the gap between intent and practical deployment.

MPS shows that smaller can indeed be smarter and more sustainable. MPS is working to bring some new applications online in the near future, leveraging various green feedstocks to produce methanol to fuel. ■

Membrane uses in methanol production

Global demand for methanol is set to increase fivefold by 2050, driven by decarbonisation in shipping and other hard-to-abate sectors. **Geir Arne Johansen** and **Hallgeir Angel** of Air Products Membrane Solutions discuss how membrane technology offers a proven, scalable solution to improve efficiency, reduce emissions, and enable compliance across both traditional and low-carbon methanol pathways.

Low-carbon methanol market

Global methanol demand is projected to grow from ~100 million tons today to over 500 million tons by 2050, with e-methanol expected to account for up to 250 million tons. Shipping is the primary driver of e-methanol adoption. E-methanol is methanol produced by combining green hydrogen, generated from renewable electricity via electrolysis, with captured CO_2 from sustainable sources. China, the Nordics, the US, Spain and Germany are emerging as global leaders in both the production and adoption of e-methanol, with commercial-scale flagship projects active and a growing pipeline of industrial offtake agreements signalling strong regional demand.

As of 2025, the EU's Fuel EU Maritime regulation is in force, requiring ships over 5,000 gross tonnage (GT) to reduce fuel greenhouse gas intensity by 2% compared to 2020 levels. Non-compliance triggers a fixed penalty of €2,400/t of fossil fuel equivalent, which translates to roughly €39/t in 2025 and will rise to ~€353/t by 2035. Shipping companies are already adjusting operations, with carriers like Maersk adding surcharges of €60–75 per container to cover compliance costs. The first commercial-scale penalties will be settled in mid-2026, based on 2025 fuel usage and verified emissions.

E-methanol currently costs two to four times more than conventional methanol, but carbon pricing and incentives are narrowing the gap. Economies of scale and policy support are expected to make e-methanol cost-competitive, positioning it as a cornerstone fuel for transport and industry

Bio-methanol currently costs more than fossil methanol, but incentives for carbon removal and circular feedstock are improving its competitiveness. Bio-methanol is methanol made from biomass feedstocks, offering a renewable and potentially carbon neutral alternative to fossil methanol. As biomass supply chains scale and carbon credit markets mature, bio-methanol is expected to become a cost-effective solution, positioning it as a critical component of the low-carbon fuel mix for shipping and industry.

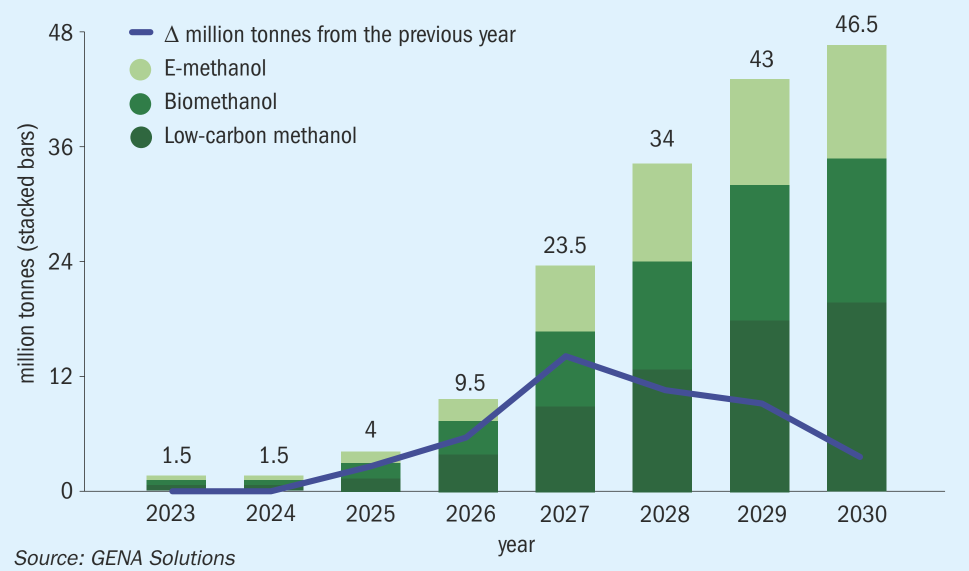
Future trends and applications

In 2025, e-methanol reached a significant milestone with the launch of the first commercial-scale plants in Denmark and China, marking its transition from pilot projects to industrial production. Demand has surged across hard-to-abate sectors like shipping and chemicals, driven by regulatory pressure and corporate climate commitments.

Future trends point to rapid global expansion, with over 20 large-scale projects underway and a projected renewable methanol capacity of up to 14 million tons by 2030. The portion of projects expected to be operational by 2028 could reach 34.2 million tons, up from just 3.8 million tons in 2025 (Fig. 1), reflecting a compound annual growth rate (CAGR) of over 100% between 2025 and 2028.

Policy incentives such as the US Inflation Reduction Act and EU's Fit for 55 package are accelerating adoption by subsidising green hydrogen inputs and penalising fossil fuel.

Fig. 1: **Renewable and low-carbon prospects to 2030**



Source: GENA Solutions

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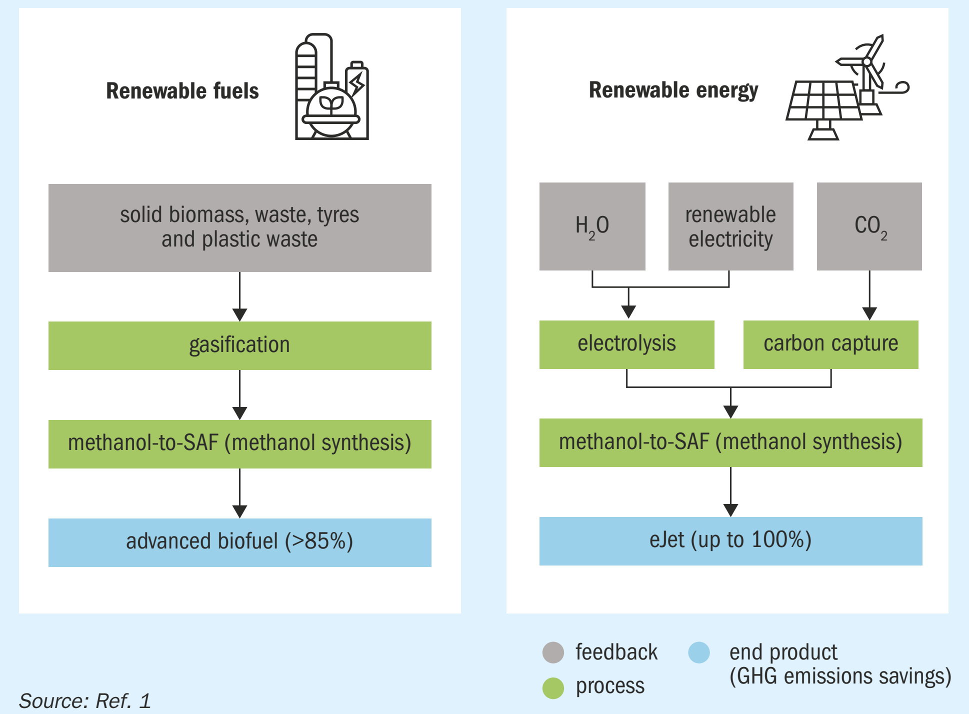
47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76

Fig. 2: Methanol-to-jet pathways



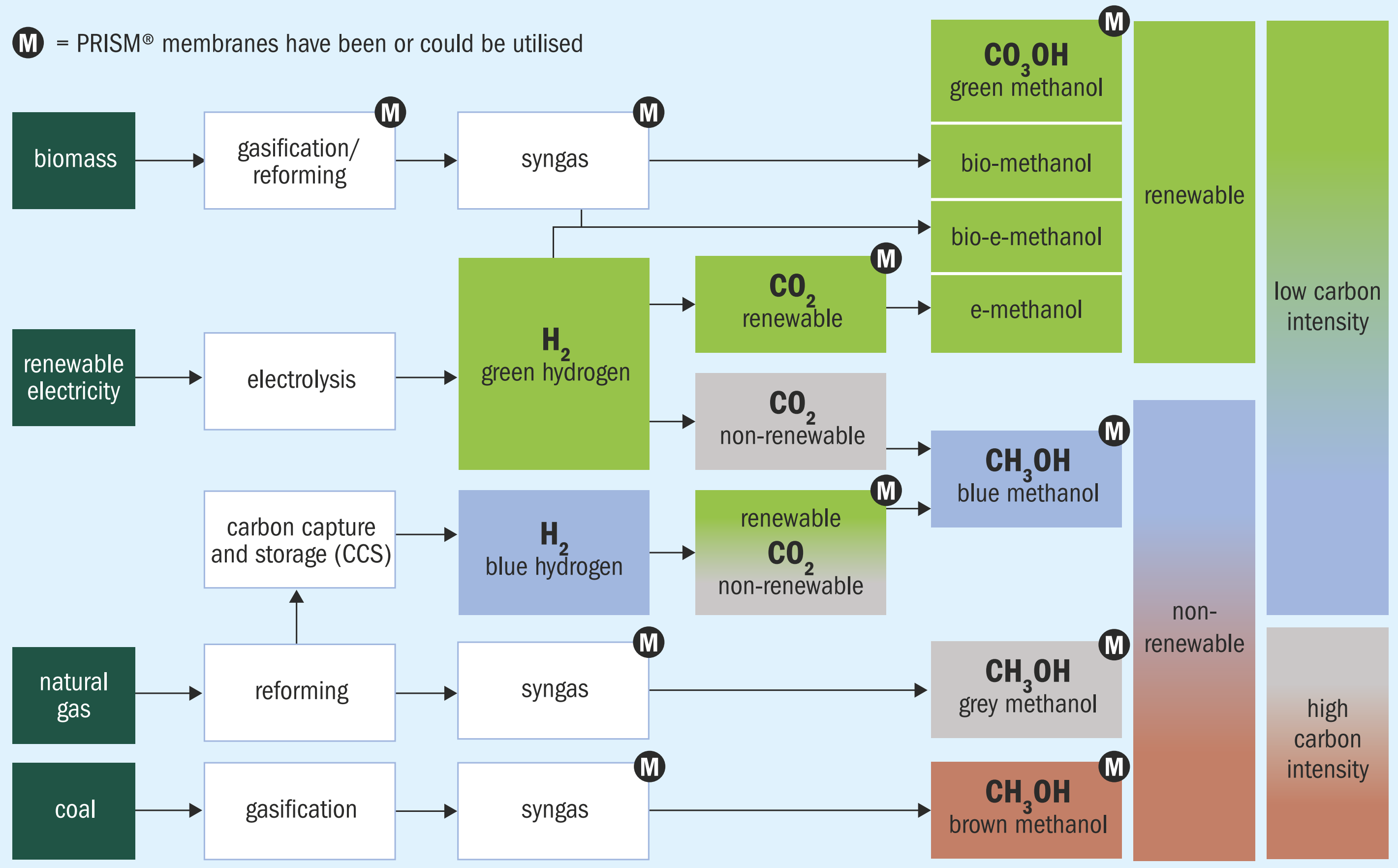
Source: Ref. 1

E-methanol also shows promise in aviation as a precursor for sustainable aviation fuels (SAF), particularly through methanol-to-jet (MtJ), a specific alcohol-to-jet (AtJ) pathway, and power-to-liquid (PtL) routes (Fig. 2) that can deliver near-zero lifecycle emissions. Compared to other bio-based SAF options such as hydroprocessed esters and fatty acids (HEFA) and AtJ pathways using ethanol or other alcohols, e-methanol derived jet fuel offers superior carbon reduction potential, up to 99% lower CO_2 emissions, while also avoiding land use and feedstock constraints. Although current production costs remain higher than fossil jet fuel, policy incentives such as the US Inflation Reduction Act and EU ReFuelEU mandates are actively narrowing the gap and guaranteeing market demand.

As renewable electricity and carbon capture technologies scale, e-methanol is increasingly viewed as a cornerstone molecule for aviation decarbonisation, with long-term potential to dominate SAF supply. Its versatility, scalability, and alignment with global net-zero targets position it as a strategic enabler of the low-carbon energy transition

Further e-methanol is emerging as a compliance-ready marine fuel under stringent climate regulations such as FuelEU Maritime and IMO net-zero targets. It enables shipping operators to meet GHG intensity reduction mandates while avoiding escalating penalties and reputational risk. With growing offtake agreements,

Fig. 3: Principal methanol production routes



Source: Ref. 2

fleet conversions, and policy support, e-methanol is positioned as a cornerstone solution for maritime decarbonisation.

Low-carbon methanol pathways

Methanol can be produced through various routes (Fig. 3), ranging from traditional coal and natural gas feedstock-based methanol (brown and grey) to biomass and renewable-based methanol (blue and green). Each pathway offers different benefits in terms of carbon footprint, feedstock flexibility, and regulatory compliance. Fig. 3 shows where PRISM® membranes have been or could be utilised to improve the efficiency of each process step.

The global shift toward low-carbon methanol is evolving into full-scale industrial production, driven by regulatory pressure, commercial demand, and technological maturity. Four distinct pathways define this transformation:

Carbon capture-integrated reforming

Blue methanol facilities integrate carbon capture into fossil-fuel reforming and/or the methanol synthesis loop, intercepting CO_2 emissions pre- or post-combustion. Captured CO_2 is stored in geological formations or used for enhanced oil recovery, reducing lifecycle emissions by more than half compared to conventional methanol. This pathway is attractive for regions with abundant gas and infrastructure but is reliant on permanent CO_2 storage integrity.

Biomass gasification with CCS

Biomass can be converted to syngas by gasification, or alternatively by reforming of biomethane produced by anaerobic digestion of biomass. These pathways can capture biogenic CO_2, achieving net-negative emissions. It actively removes carbon from the atmosphere, making it compelling for shipping and aviation. Scalability depends on feedstock availability, logistics, and land-use considerations.

Electrochemical CO_2 conversion

Electrochemical conversion uses electricity to directly reduce CO_2 into methanol within an electrochemical cell, bypassing separate hydrogen production and high-temperature synthesis. Modular and low temperature, it enables distributed methanol production at industrial sites and capture and conversion of flue gas on-site. When powered by renewable electricity, this pathway offers near-zero carbon methanol with minimal infrastructure.

Hybrid cycles

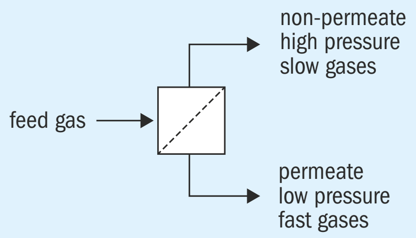
Hybrid cycles combine renewable hydrogen with captured CO_2 from flue gas, biomass combustion, or direct air capture. Designed for retrofits and new builds, these systems adapt to local carbon and energy conditions. Recognised under EU RED III and the US Inflation Reduction Act, these cycles deliver 70–90% lower emissions than fossil routes.

Membrane roles in methanol production

Fundamentals of membrane separation

PRISM® membrane separators use the principle of selective permeation of gases through semi-permeable barriers. Molecules of a gas will move through or "permeate" a membrane barrier if the partial pressure of the particular gas is lower on the other side (Fig. 4).

Fig. 4: Membrane separation



Source: Air Products

Different gases permeate at different rates, independent of their partial pressures in the process stream. It is the differences in these permeation rates by which membranes affect gas separation.

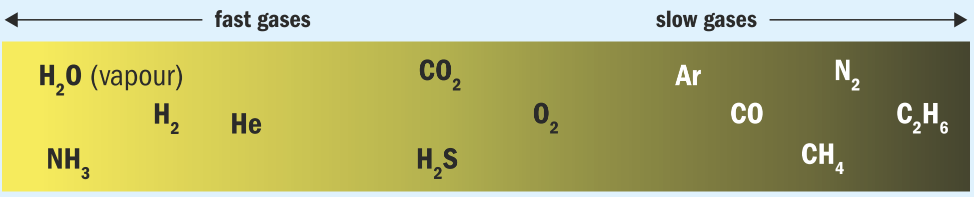
Hydrogen is a fast-permeating gas (Fig. 5) and can efficiently be separated from other slow-permeating gases.

Applications

H_2 recovery of synthesis loop purge gas for brown and grey methanol

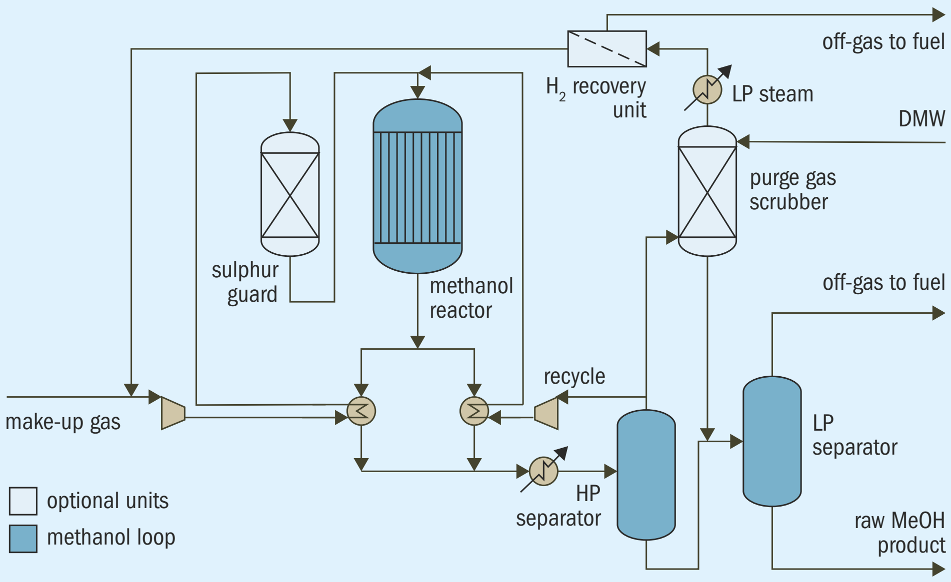
Air Products PRISM® membranes were successfully developed and implemented

Fig. 5: Relative permeability of various gases



Source: Air Products

Fig. 6: Natural gas methanol process with membrane-based hydrogen recovery unit



Source Ref. 3

for hydrogen separation of process gases in the late 1970s, for which the technology received the 1981 Kirkpatrick Chemical Engineering Achievement Award. Since the first commercialised, large-scale PRISM® membrane unit for methanol purge was built in 1982, Air Products has delivered more than 80 systems for methanol purge gas applications. Installed at both coal gasification and natural gas-based methanol plants (Fig. 3), creating great value and reduced CO_2 emissions for customers.

A PRISM® membrane purge gas recovery unit improves methanol plant efficiency by integrating into the synthesis loop (Fig. 6). In the process, a portion of the synthesis gas is purged to prevent the accumulation of inert components such as argon, methane, and nitrogen. This purge gas also contains valuable hydrogen and carbon monoxide. The gas is heated and fed into membrane modules at high pressure, where hydrogen permeates through the membrane and is returned to the synthesis compressor suction at a lower pressure. The remaining gases, including argon, methane, nitrogen, and carbon monoxide, stay on the non-permeate side and can be used as fuel in the reforming section. These systems recover typically 85-95% of the hydrogen from the purge gas, significantly increasing methanol production without increasing natural gas feed to the reformer.

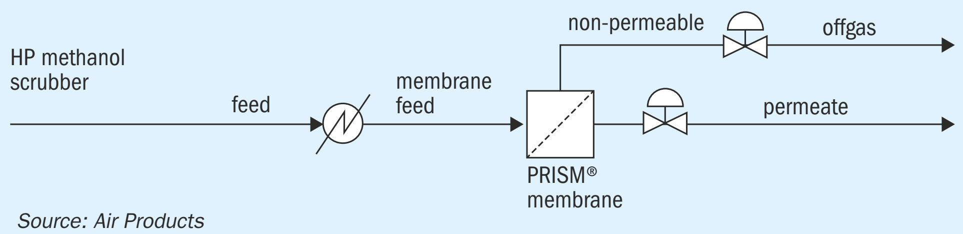
Syngas ratio adjustment with the PRISM® membrane

The syngas feed to the methanol reactor must maintain an H_2/CO ratio between 2.0 and 2.5 for optimal synthesis. Syngas for methanol production can be produced from a variety of feedstocks and processes, including reforming fossil fuels or biomethane and gasification of biomass. Depending on the feedstock and reforming process, adjustment of the H_2/CO ratio may be necessary.

PRISM® membranes are ideally suited for this adjustment because hydrogen, being a fast-permeating molecule, passes through the hollow fibre membrane more readily than carbon monoxide. This enables precise control of the syngas composition without complex cryogenic or chemical processes.

With over 40 years of experience and 70+ references in H_2/CO ratio and CO purification applications, membrane technology is proven and reliable across a wide range of capacities from 40 Nm³/ hr to over 400,000 Nm³/hr. Hollow fibre membranes provide a compact, modular solution that can be scaled easily, offering low pressure drop, high surface area, and robust performance under varying operating conditions. These systems are designed with no moving parts, thus offering unrivalled reliability and very low maintenance requirements compared to other technological options.

Fig. 7: **Hydrogen recovery**



Source: Air Products

Fig. 8: **CO_2 rejection from gasified biomass**

Source: Air Products

Table 1: **Purge gas treatment with and without membrane hydrogen recycle**

	Alternative A Utilise purge as energy source, no H_2 recycle	**Alternative B** PRISM® membranes integration, recycle H_2
Description	Burn purge gas as fuel; run additional electrolysis to replace lost H_2. (see note)	Install PRISM® membrane system to recover H_2 and recycle back into synthesis
Hydrogen handling	Lost hydrogen replaced by electrolysis	Hydrogen recovered from purge stream
Energy demand	~190.5 GWh/year for electrolysis	Avoids ~190.5 GWh/year
Electricity cost	$10 to 21 million/year (at €50 to €100/MWh)	Savings of $10 to 21 million/year
Methanol impact	No additional methanol	+9,000 to 12,000 t/year (3 to 4% increase)
Methanol/opex revenue	None	$13 to $17 million/year (at $1,400/t)
Capex	Additional high-capex electrolyses capacity to compensate for lack of H_2 recycle from membranes.	Low-capex membrane system
Environmental impact	High renewable power demand	Frees renewable capacity for other uses

Source: Air Products

Note: While membrane integration reduces renewable power demand for electrolysis, eliminating purge gas as a fuel source may require alternative energy (e.g., electricity or other fuels) to replace its previous role. This trade-off should be considered when evaluating net energy savings

H_2 recovery of synthesis loop purge gas for blue and green methanol

In low-carbon methanol plants, whether based on biomass or other renewable feedstocks the synthesis loop often requires a purge to prevent inert gas buildup. These purge streams contain valuable hydrogen that can be recovered using PRISM® membranes.

The same proven technology applied in traditional methanol plants can be adapted for blue and green methanol facilities, thanks to the flexibility of membrane systems in handling different gas compositions and flow rates. This recovery step improves overall plant efficiency and reduces the need for additional hydrogen production, supporting both economic and environmental goals.

CO_2 rejection from biomethane

With hundreds of references in the biogas market, PRISM® membranes are field proven and ideally suited for this application. Biomethane produced by anaerobic digestion, wastewater treatment, or landfills can be used as a feedstock for methanol synthesis. CO_2 that is co-produced by these methods can be fed to the methanol synthesis plant at a predetermined ratio or recovered for carbon capture. PRISM® membranes can selectively reject CO_2 while enriching methane in the non-permeate stream. PRISM® membranes simplify downstream processing by reducing CO_2 load before methanol synthesis, minimising compression requirements and improving catalyst performance.

By integrating membrane-based CO_2 removal with methane recovery, producers can achieve a cleaner syngas composition, enable higher methanol yields and support net-negative emission pathways when combined with carbon capture and storage.

Economic impact of hydrogen recovery: Two value pathways

In low-carbon methanol plants, the synthesis loop purge contains valuable hydrogen. How this hydrogen is managed determines both the energy footprint and the economics of the plant. There are two fundamentally different approaches as identified by Alternative A and B in Table 1.

Conclusion

Membrane systems offer a low-capex, high-impact upgrade that enhances sustainability and profitability, making them a strategic enabler for next-generation methanol plants.

For a 300,000 tonne/annum green methanol plant, membranes can cut renewable power demand by ~190.5 GWh/year, free up capacity for other uses, and deliver strong economic returns, potentially \$10 to 21 million/year in reduced electricity costs.

At the same time hydrogen recycled by the PRISM® membrane system adds up to \$9 to \$12 million/year in increased methanol production. ■

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Expanding the melamine horizon with uLEM-N technology

CASALE has expanded its melamine technololgy portfolio with uLEM-N, a market-driven technology development, which retains the industrial proven high-pressure synthesis section and urea-based offgas scrubbing of the LEM® and uLEM® technologies, and uses an innovative purification section which enhances the process reliability while minimising the energy consumption.

Simone Gamba, Gabriele Di Carlo, Roberto Mascioni, and Francesco Burattini (CASALE)

The high-pressure melamine technologies LEM® (Low Energy Melamine) and uLEM® (ultra-Low Energy Melamine) have been on the market since 2013, when CASALE acquired the former Borealis HP melamine technology[1,2]. Their key features include urea-based offgas scrubbing[3], which generates high-temperature and high-pressure anhydrous offgas, and the use of sodium hydroxide to create the alkaline conditions required for melamine purification. These technologies ensure the consistent production of high-quality melamine with minimal energy consumption, but they require a NaOH solution as a consumable chemical. In some regions (for example, Northern China) sourcing these chemicals can be difficult or costly.

Although methods exist to minimise sodium hydroxide consumption[4], in some regions the complete elimination of NaOH (even for initial plant filling or small makeup streams) may be required for the technology to be economically viable. Using ammonia in place of sodium hydroxide is well known in melamine production, and applying ammonia in an innovative way has produced a new process scheme. This new process, the latest addition to the CASALE HP melamine technology family, is called uLEM-N (ultra-Low Energy Melamine – Ammonia).

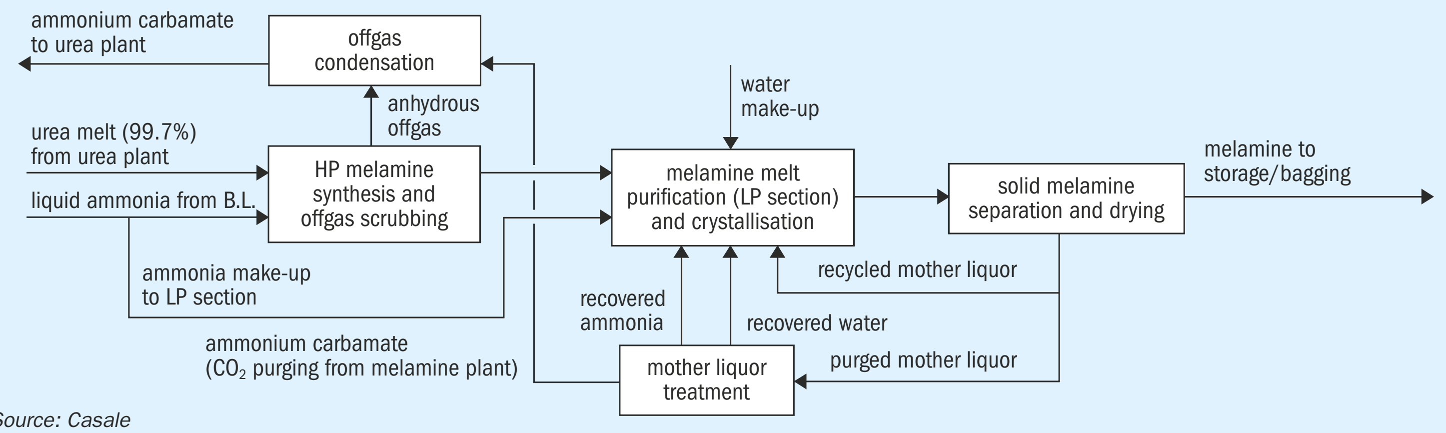
Even though using sodium hydroxide instead of ammonia provides lower energy consumption and a simpler process, an optimised ammonia-based purification technology is a good compromise whenever the use of NaOH is uneconomical. The uLEM-N technology completes the CASALE melamine portfolio, enabling CASALE to recommend the most suitable solution on a case-by-case basis.

Although new, uLEM-N has already been selected for its first industrial application by Anhui Haoyuan Chemical Group, which will build a new 60,000 t/a melamine plant in Xinjiang Province (P.R. China)[5].

uLEM-N technology overview

uLEM-N is a high-pressure (HP) technology in which melamine is produced in the liquid phase from urea. Alongside melamine, the

Fig. 1: **uLEM-N technology overview**



Source: Casale

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 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76

process generates an offgas composed of ammonia and carbon dioxide. In this technology, melamine synthesis and offgas separation occur in the high-pressure section of the plant. The offgas is condensed to ammonium carbamate within the plant battery limits, producing low-pressure steam that is used in the same melamine plant. The melamine product is purified in the low-pressure (aqueous) section of the plant (Fig. 1). The basic environment required for the purification is ensured by an ammonia-water solution.

HP melamine synthesis

uLEM-N technology retains the same synthesis section used in the LEM® and uLEM® technologies[1,2].

The HP section of a uLEM-N plant comprises a combined reactor[6,7] and an offgas scrubber[3], as shown in Fig. 2. The operating pressure is uniform throughout this section.

The combined HP melamine reactor consolidates the duties of the first and second reactors conventionally used in melamine plants into one piece of equipment. It consists of two coaxial reaction zones: a central reaction zone and an annular reaction (stripping) zone that surrounds the central zone (Fig. 3).

In the central reactor zone, the bulk conversion of urea to melamine is achieved, and the heat of reaction is supplied by circulating molten salts. In designing the combined reactor, the central reaction zone was not modified compared with the traditional first reactor.

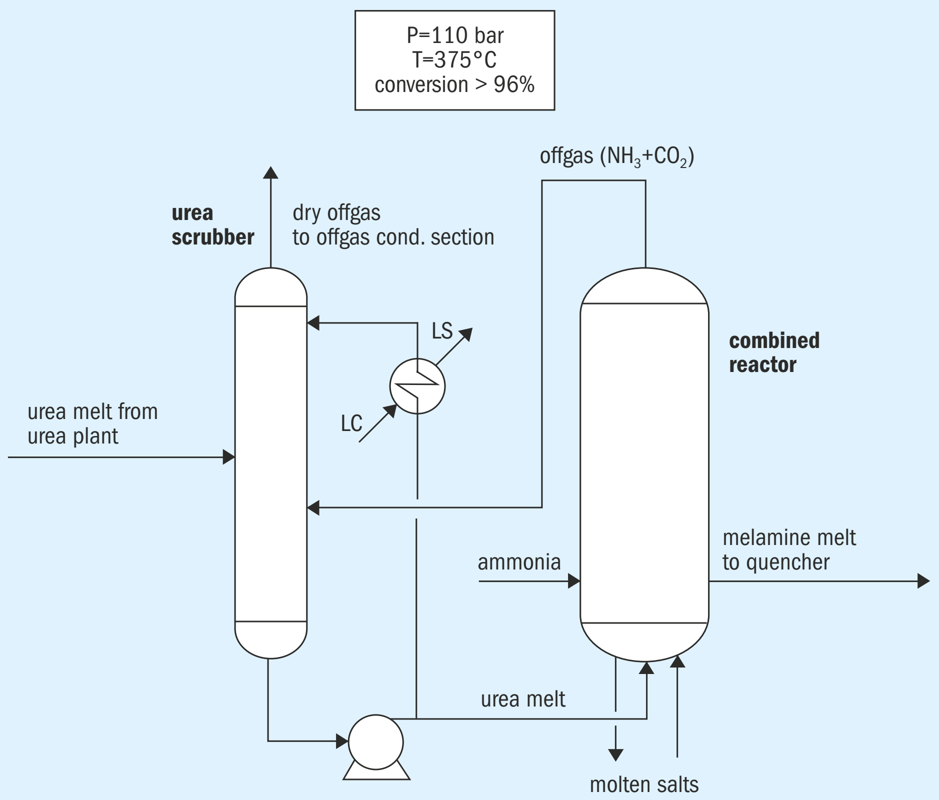
The annular section of the combined reactor performs the function of the second reactor in the traditional dual-reactor configuration.

The offgas from the central reaction zone and the stripping gas from the annular zone are discharged from the top of the combined reactor and routed to the urea scrubber.

Reactor internals have been carefully designed to enhance the stripping process in the annular zone; consequently, the two reaction zones retain their distinct identities and functions even though they are combined in a single vessel. The combined reactor performs better than a sequence of two reactors because it uses the stripping volume more effectively than a standard second reactor.

The melamine HP combined reactor is the standard reactor in the LEM®/uLEM®/uLEM-N process schemes. On request, LEM®/uLEM®/uLEM-N can still be supplied with the traditional dual-reactor configuration.

Fig. 2: **HP section of LEM®, uLEM®, and uLEM-N plants**



Source: CASALE

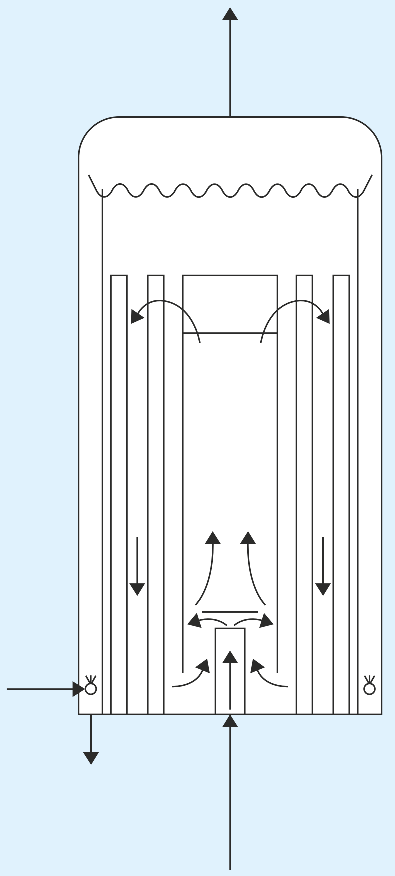
In the urea scrubber, the offgas is washed by counter-current contact with molten urea. The primary objective of this washing is to remove melamine from the offgas before it is recycled to the urea plant.

Offgas scrubbing with molten urea is a distinctive feature of melamine technologies. CASALE has long-standing know-how in designing and operating this type of scrubber in HP melamine plants, supported by industrial experience from operating plants.

Proper design of the scrubber and the heat exchanger[3], and the correct selection of the urea circulating pump, require deep practical knowledge of plant operation and maintenance. Accurate simulation models for design and material selection are not commercially available[8]; therefore, operational data and experience are the foundation of the company's expertise and enable the design of reliable urea-based offgas scrubbing units.

The first application of the scrubber dates back to the mid-1990s at the Castellanza plant in Italy (currently not in operation).

Fig. 3: **CASALE HP melamine combined reactor**



Source: CASALE

Following the Castellanza experience, upgraded scrubbers were installed first in Linz (2000) and then in Piesteritz (2004); both units remain in successful operation. Operation of the scrubbers at these plants enabled fine-tuning of operating parameters and optimization of the equipment design. Three additional scrubbers have been designed and built for LEM® plants, two of which have been in service since 2019 and 2023, respectively.

Using urea for scrubbing permits heat recovery from the offgas within the melamine plant and yields a high-pressure, water-free stream of ammonia and carbon dioxide. This makes a CASALE LEM®/uLEM®/uLEM-N plant straightforward to integrate with a urea plant.

Furthermore, avoiding offgas separation from the melamine solution in the low-pressure section of the plant reduces overall steam consumption.

Melamine purification and separation

In the low-pressure section of a uLEM-N plant, the melamine melt is quenched, purified, and crystallised in an ammonia–water solution. Final steps include solid–liquid separation and drying.

Leveraging extensive knowledge of the purification chemistry when sodium hydroxide is used, together with a deep understanding of the performance of the established synthesis and off-gas scrubbing configuration, the uLEM-N melamine purification and mother-liquor treatment strategies were developed to minimise energy consumption and ensure process reliability. Although uLEM-N inherently consumes more energy than its NaOH-based counterpart (i.e., uLEM®), it is well suited to regions where supplying caustic-soda solution is difficult or expensive.

The primary difference between sodium hydroxide and ammonia is their basic strength. With this in mind, the uLEM-N purification scheme incorporates innovative features that minimise CO_2 concentration in the melamine aqueous solution throughout the process, from quenching to crystallisation, thereby improving process reliability.

Industrial melamine production requires consistent manufacture of high-quality product, which is achieved through robust purification schemes. CO_2 – generated during melamine purification and mother-liquor thermal treatment from unreacted urea, oxyaminotriazines (OATs), and melamine hydrolysis – exerts an acidic effect that impacts systems using ammonia more severely than those using sodium hydroxide. For this reason, the uLEM-N process ensures that water recycled from the mother-liquor treatment back to melamine purification is free of dissolved CO_2. This is accomplished without undue energy penalty through a purpose-built, proprietary design of the mother-liquor treatment.

Mother-liquor treatment comprises a series of distillation and thermal steps intended to recover ammonia for reuse, remove CO_2 produced in the melamine plant (both LP purification and mother-liquor treatment sections), and destroy OATs. All water recovered by the mother-liquor treatment is recycled to the melamine process; consequently, uLEM-N operates as a zero liquid discharge (ZLD) process.

Although undesirable, OAT formation is unavoidable and is a primary reason for the mother-liquor treatment. OATs are produced in both the synthesis and purification sections and are kept in solution during crystallisation to prevent contamination of the final product. Their solubility in ammonia solutions is much lower than in sodium hydroxide solutions. Therefore, to avoid treating excessive mother-liquor flowrates (which depend on the maximum allowable OAT concentration and generation rate), uLEM-N purification operating parameters are selected to minimise OAT formation.

Commercial applications

CASALE LEM®/uLEM® technologies are currently used in five plants worldwide, with a total installed capacity of 250,000 t/a of melamine. Four of these plants are already in operation. The uLEM-N technology has been applied for a new 60,000 t/a plant; its basic engineering package was completed in 2025.

The commercial deployment of both NaOH-based and ammonia-based melamine processes demonstrates CASALE's expertise in managing both technologies. This capability allows the company to recommend the most suitable solution for each client, taking into account the plant location and local utility and raw-material costs.

Conclusions

uLEM-N was developed specifically for regions where supplying NaOH is difficult or costly. Although it inherently consumes more energy than its sister technology, uLEM® – a consequence of using ammonia instead of NaOH – uLEM-N still ensures consistent production of high-quality melamine and offers the lowest energy consumption and the best reliability-to-energy-consumption ratio among ammonia-based purification technologies.

Furthermore, uLEM-N uses the proven HP section (melamine synthesis and urea-based off-gas scrubbing) from its sister technologies, LEM® and uLEM®, thereby retaining the demonstrated reliability and durability of the process core.

With a comprehensive melamine technology portfolio, CASALE can address diverse client requirements and, leveraging its urea expertise, propose an optimised, tailor-made integration of melamine production with a urea plant. ■

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47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76

Wire-based additive manufacturing for HP equipment

Christof Group SBN is actively integrating advanced manufacturing solutions such as wire arc additive manufacturing (WAAM) into its portfolio for the manufacture of high-pressure equipment in urea and ammonia plants. WAAM technology is especially suitable for niche materials customised for high corrosion resistance to carbamate solution and addresses the need for fast and tailored manufacturing of spare parts explain **Aleksandra Gavrilovic-Wohlmuther** and **Serhiy Budnyk** of Christof Group SBN.

For decades, Christof Group SBN has been at the forefront of manufacturing highly complex, safety-critical high-pressure equipment for the fertilizer, chemical and petrochemical industries. Renowned for its engineering excellence, the company delivers tailor-made high-pressure, high-temperature heat exchangers and reactors that play a vital role in urea and ammonia synthesis worldwide.

Today, this expertise is evolving in step with a new wave of technological innovation. As the industry intensifies its focus on resource efficiency, energy reduction and environmentally responsible production, Christof Group SBN is actively integrating advanced manufacturing solutions into its portfolio. One of the most promising developments is wire arc additive manufacturing (WAAM), which is rapidly establishing itself as a viable industrial production method for complex components made from niche, high-performance alloys. WAAM enables fast and efficient production of super duplex parts with exceptional corrosion resistance and mechanical performance, that are recognised as key requirements for harsh urea plant environments. Beyond design freedom, the WAAM technology offers a compelling sustainability advantage since it drastically reduces material waste, compared to traditional subtractive processes such as milling.

A particularly attractive application lies in the on-demand manufacturing of spare parts for long-lifecycle systems, where availability, lead time and waste reduction are critical factors. Rapid, WAAM-based production, as demonstrated by Christof Group SBN, has the potential to improve spare-parts availability while reducing inventory requirements and waste. Overall, the integration of additive manufacturing (AM) technologies supports more sustainable and resilient production concepts for high-pressure process equipment.

The status quo

Super duplex stainless steels (SDSS) combine high mechanical strength with outstanding corrosion resistance, a result of their carefully balanced austenite to ferrite microstructure. These characteristics make SDSS the material of choice for components exposed to both high mechanical loads and aggressive corrosive environments. Typical applications include valves, heat exchanger tubes, pumps, shafts, impellers and rotors, operating in demanding process conditions. As niche materials, SDSS may suffer from relatively long delivery times and are limited to a few standard forms such as tubes, pipes, bars and plates/sheets. As a result, aspects such as sustainability and resource efficiency are often not adequately addressed.

AM is increasingly gaining attention as an alternative to conventional casting, forging and machining for the production of metallic components, including those made from SDSS. The technology offers clear advantages in terms of design flexibility, material efficiency and lead-time reduction. However, translating the excellent intrinsic properties of SDSS into additively manufactured parts remains a technical challenge. While some studies confirm that AM-processed SDSS generally retain good corrosion resistance, variations in mechanical performance have been reported, particularly under tensile and fatigue loading. These effects are often linked to residual porosity, which can reduce resistance to cyclic stresses and lead to scatter in mechanical properties. At the same time, controlling the microstructure during deposition remains critical. The high thermal input inherent to many AM processes can alter the ferrite to austenite balance, promote inhomogeneous grain structures, or lead to the formation of undesirable secondary phases, each of which can negatively affect material performance. Process parameters and their control therefore play a decisive role. Moreover, the choice and composition of shielding gas significantly influence arc stability, material transfer and melt pool behaviour. By optimising shielding gas chemistry and process parameters, manufacturers gain an additional lever to refine the deposition process, enabling improved control of microstructure and, ultimately, more consistent mechanical and corrosion properties in additively manufactured SDSS components.

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
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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 61 16 62 17 63 18 64 19 65 20 66 21 67 22 68 23 69 24 70 25 71 26 72 27 73 28 74 29 75 30 76 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

AM technology at Christof Group SBN

Over the past few years, Christof Group SBN has invested in a series of focused R&D initiatives to optimise the mechanical performance and corrosion resistance of various materials, including SDSS, with the aim to better understand how the microstructure evolves during AM processing. In particular, WAAM technology was of interest, as it is the AM process that combines continuous metal feeding in the form of wire and arc-assisted deposition technique, to create large and near net shape, complex 3D structures. WAAM offers several advantages vs. alternative AM technologies like laser-assisted powder sintering routes, by offering comparatively lower welding equipment's cost, easily available feedstock in the form of standard commercial metal wires and a higher deposition-rates. Compared with established steel manufacturing practices, WAAM offers significantly higher productivity, with deposition rates of up to 5 to 10 kg/h. An additional advantage of WAAM is that the maximum printable size depends primarily on the range of the welding robot used. The maximum printable dimensions of up to several metres can be increased by using robot tracks and welding manipulators. The combination of WAAM and subsequent milling enables the production of relatively complex shapes. This also means that topological optimisation and the production of generatively designed parts become more accessible. Compared to other direct energy deposition (DED) systems, such as direct metal laser sintering or additive electron beam manufacturing, WAAM offers relatively lower costs, due to reduced material wastes. Another peculiarity of the WAAM is the possibility to design functionally graded components where multiple materials can be combined to design a single component. Used materials are only deposited in agreement of target shape. This is especially important for workpieces that are traditionally milled from solid blocks and/or workpieces that are made from expensive materials.

Fig. 1: Optical microscopy image of microstructure of UNS S32906 sample produced by WAAM, after heat treatment. A balanced dual-phase composition, with near-equal proportions of ferrite and austenite phases distributed consistently across the deposited bulk is presented. Magnification 1000x.

Fig. 2: A flange made with WAAM technology. UNS S32906 filament, with diameter of Ø1.2 mm

Table 1: **Results from testing of mechanical properties of three heat treated WAAM samples. The samples are compared with UNS S32906 reference.**

Sample UNS S32906	$Rp_{0.2}$ (MPa)	R_m (MPa)	A_g (%)	A_5 (%)	m_E (GPa)
WAAM sample 1	667	830	13.1	24.4	173
WAAM sample 2	663	828	12.5	25.3	187
WAAM sample 3	645	801	12.9	28.5	165
UNS S32906 reference sample	min. 550	min. 750		min. 25	200

Rm: ultimate tensile strength
$Rp_{0.2}$: yield strength (room temperature)
Ag: uniform plastic elongation
A_5: total plastic elongation after fracture
m_E: module of elasticity (room temperature)

Source: Christof Group SBN

Results on UNS S32906 super duplex stainless steel

UNS S32906 is one of the most significant materials for urea critical process equipment. This material is designed to reach high requirements of mechanical strength, outstanding corrosion resistance and good weldability. To address the need for fast and tailored manufacturing of spare parts made of UNS S32906, Christof Group SBN initiated intensive R&D collaboration with hardware manufacturers, with the aim to successfully establish WAAM process parameters that guarantee mechanical and corrosion properties comparable to those of conventionally manufactured components. The wire feedstock used for this study is commercially available UNS S32906 wire with a diameter of Ø1.2 mm.

Microstructural examinations of the fabricated specimens revealed a balanced dual-phase composition, with near-equal proportions of ferrite and austenite phases distributed consistently across the deposited bulk (Fig. 1).

Mechanical testing, including assessments of yield strength, elongation and ultimate tensile strength in both, the build and travel directions, confirmed that controlled WAAM delivers samples that match the performance of their wrought counterparts (see Table 1). This indicates that the WAAM process preserves the inherent mechanical advantages of UNS 32906.

To evaluate corrosion performance, the samples are subjected to testing according to ASTM A262, Practice B. The results of the Streicher test reveal an annual corrosion rate of the WAAM sample that is significantly lower than the threshold of

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Table 2: **Annual corrosion rates according to ASTM A262, Practice B (Streicher test) and compared to UNS S32906 reference.**

Sample	m_1 (g)	m_2 (g)	Δ m (g)	t (h)	Corrosion rate (g/m²h)	Corrosion rate (mm/year)
WAAM sample	39.528	39.498	39.498	120	0.113	0.128
UNS S32906 reference sample	25.555	25.507	25.507	120	0.141	0.161

Source: Christof Group SBN

0.6 g/m²h, according to the applicable customer specification. Interestingly, the annual corrosion rate of the WAAM sample is considerably lower in comparison to the annual corrosion rate of the commercially available UNS S32906 reference sample material (Table 2).

The first attempts of Christof Group SBN to produce simple shapes with SDSS showed that the welding parameters and shielding gas play a decisive role in achieving a high-quality microstructure, but the creative choice of build-up strategy also plays an important role. Elaborated sets of parameters allow construction parts of UNS 32906 to be produced with a thickness of over 45 m, reaching the quality equal to traditional metallurgical routes such as forging, casting and cold forming (Fig. 2).

Conclusions

To address the need for fast and tailored manufacturing of spare parts, Christof Group SBN has developed a reliable solution using WAAM. This technology is especially suitable for niche materials customised for high corrosion resistance to carbamate solution. Through an intensive R&D initiative WAAM process parameters are successfully established. The procedure guarantees mechanical and corrosion properties comparable to those of conventionally manufactured metal components. Most notably, corrosion testing in simulated process environments, conducted in accordance with recognised standards, has demonstrated exceptional corrosion resistance. This positions additive manufacturing of UNS S32906 components as a viable alternative to traditional spare parts production methods, such as forging, casting, hot/cold forming, or powder-based metallurgical routes followed by subtractive machining with an overall drastic improvement of the delivery time.

The WAAM process enables near-net-shape manufacturing of customised geometries, making it particularly suited for complex, or obsolete spare parts, while minimising material waste. The primary benefit to clients is a considerable reduction in lead times. This allows a significant competitive advantage by improving plant availability, reducing costs while enabling fast recovery from planned and unplanned outages without compromising the quality and property.

Life management of reformer convection section tubing

The convection section of a syngas reformer is vulnerable to creep, corrosion, erosion, fretting and fouling which can cause deformation, local metal loss and failures that risk plant shutdown. Inspection access is limited, but solutions are available. **Olivia Chung, Tim Haugen,** and **Charles Thomas** of Quest Integrity discuss life management of the reformer convection section to reduce unplanned outages.

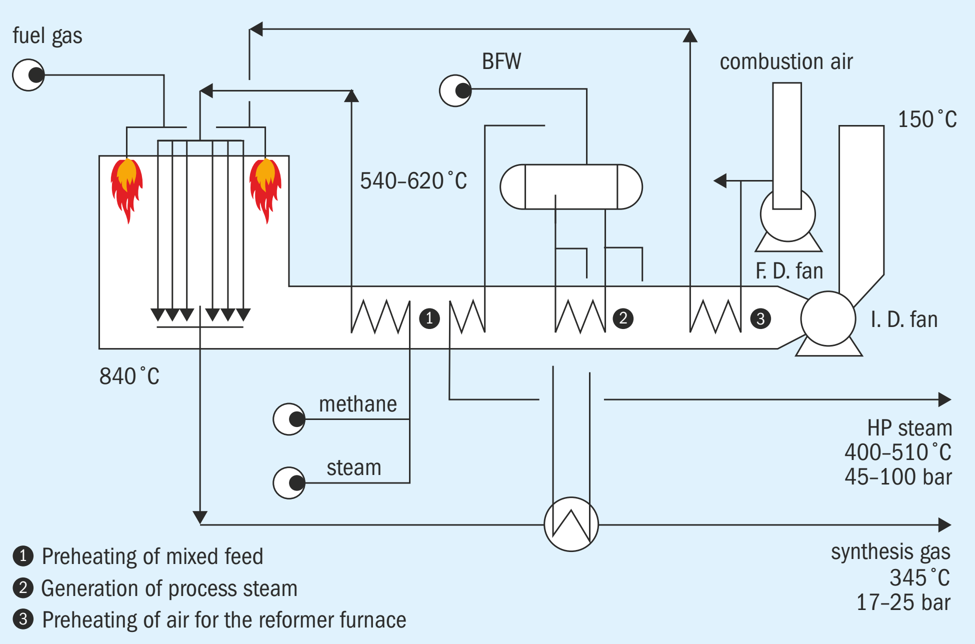
Overview of a reformer convection section

The reformer is frequently described as the heart of the syngas plant, consuming large amounts of energy to maintain the furnace temperature and drive the reforming process. To maximise efficiency, heat from the reforming reaction is captured and transferred to the convection section downstream of the reformer furnace. This section consists of several coils that recover heat from the flue gas via radiation and convection heat transfer. Fig. 1 shows an example arrangement of key processes that occur in a convection section.

The flue gas temperature in the convection section can range from 1,000°C immediately downstream of the reformer furnace to 250°C toward the stack. This wide temperature range in the convection section enables multiple process streams to recover heat and improve thermal efficiency of the plant. The key process streams include:

- Preheating the mixed feed (methane and steam) for the catalyst tubes in the reformer furnace.
- Generating steam for use in other plant processes.
- Preheating the combustion air for the reformer furnace.

Fig. 1: **Example arrangement of key processes that occur in the convection section of a reformer furnace[1].**



Source: Quest Integrity

Materials of construction and damage mechanisms

A variety of metallic materials and coil/header configurations are used to improve plant process and thermal efficiency, as well as optimise the mechanical integrity of the convection section tubes. From the range of services and operating temperatures encountered in the convection section of a reformer furnace, the materials of construction range from carbon and low alloy steel to creep strength enhanced ferritic (CSEF) steels and austenitic stainless steel tubes for superheater steam tubes and process mixed feed coils. The tubes and coils may be bare tubes or finned (to further optimise heat transfer), with various header-to-coil arrangements. The coils and tube bundles are often very tightly spaced within the convection section and header arrangements can similarly be complex.

There is also a range of life-limiting damage mechanisms for convection section coils that will vary depending on the process parameters. These include:

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PHOTO: QUEST INTEGRITY

Fig. 2: Example of a creep rupture in a superheated steam tube (material: 9Cr1MoV). Note the "fish mouth" rupture and deformation. The polished patch indicates a location of metallurgical replication.

- Creep: Time-dependent deformation of materials that can lead to macro-cracking. This damage mechanism is very dependent on the temperature, with coils and superheater steam tubes located nearest to the reformer furnace being the most susceptible given the higher flue gas temperatures. A diametral change is typically observed before a rupture/leak occurs, as shown in Fig. 2.
- Corrosion: General and/or localised metal loss resulting from interaction with the process on the internal surface and/or flue gas on the external surface. Fig. 3 shows an example of localised metal loss of a convection section.
- Erosion.
- Fretting damage due to mechanical vibration.
- Internal and external fouling: Reduces process throughput and thermal efficiency.

Damage to convection section coils and tubes can also affect tube supports and the adjacent refractory. The failure of any coil in the convection section is likely to pre-empt a shutdown of the reformer.

Inspection challenges and solutions

There are known challenges with respect to the inspection of convection section coils and tubes, with limited access being the primary barrier. Raised surfaces, such as fins, on the convection section coils and tubes also present a challenge for external inspection. Furthermore, the presence of external and/or internal fouling can mask damage underneath. Compared with the catalyst tubes in the reformer furnace, many convection sections have limited inspection and are instead maintained using conservative life-cycle predictions based on operating conditions, tube metallurgy and feedstock type. In recent years, the industry has developed the following solutions to address these inspection challenges:

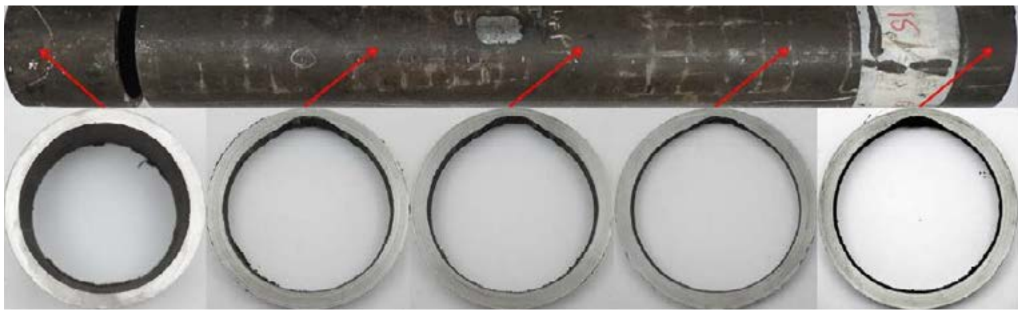

PHOTO: QUEST INTEGRITY

Fig. 3: Example of a localised metal loss observed in a convection section tube (material: carbon steel). The polished patch likely indicates a location of metallurgical replication.

- External damage detection: High-pressure, low-volume robotic water cleaning methods such as those offered by IGS (Tube Tech) are highly effective for removing external fouling, particularly for finned tubes, before an external visual inspection by use of remote videoscope and/or cameras, where accessible.
- Internal damage detection: Mechanical cleaning pigs remove internal fouling ahead of an ultrasonic inspection with an intelligent pig (e.g., FTIS® by Quest Integrity), which can detect radial deformation (e.g. bulging and out-of-roundness). The inspection data collected from FTIS® inspections can be used in a fitness-for-service (FFS) assessment.
- Header delivery system: Where possible, a header delivery system can be used to launch and receive the mechanical cleaning pig and intelligent pig. This patented solution, developed by Quest Integrity, is achieved by removing one flanged end of the manifold or header or by cutting one end cap, before inserting the delivery system (Fig. 4).

Application of engineering assessment approaches for integrity management

Engineering and condition assessment methodologies can be used to manage the integrity and service life of convection section coils. API 579-1/ASME FFS-1 "Fitness-for-Service" is a widely accepted standard that describes assessment approaches for determining the structural integrity of operating equipment containing identified flaws and/or damage[2]. The outcomes of an FFS assessment are that the equipment is safe to run as-is, remedial action is needed to remove the identified flaws and/or damage, or replacement of the operating equipment is required. Damage mechanisms covered in API 579-1/ASME FFS-1 include general metal loss, localised metal loss, dents, and creep.

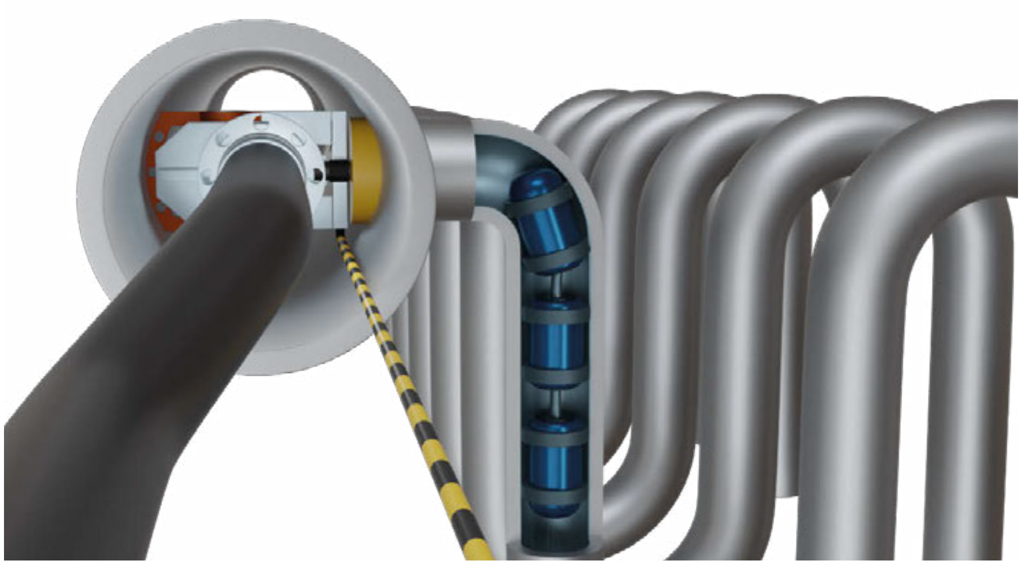

PHOTO: QUEST INTEGRITY

Fig. 4: Conceptual image of an FTIS® intelligent pig entering a coil connected to a manifold by way of the header delivery system (HDS) developed by Quest Integrity.

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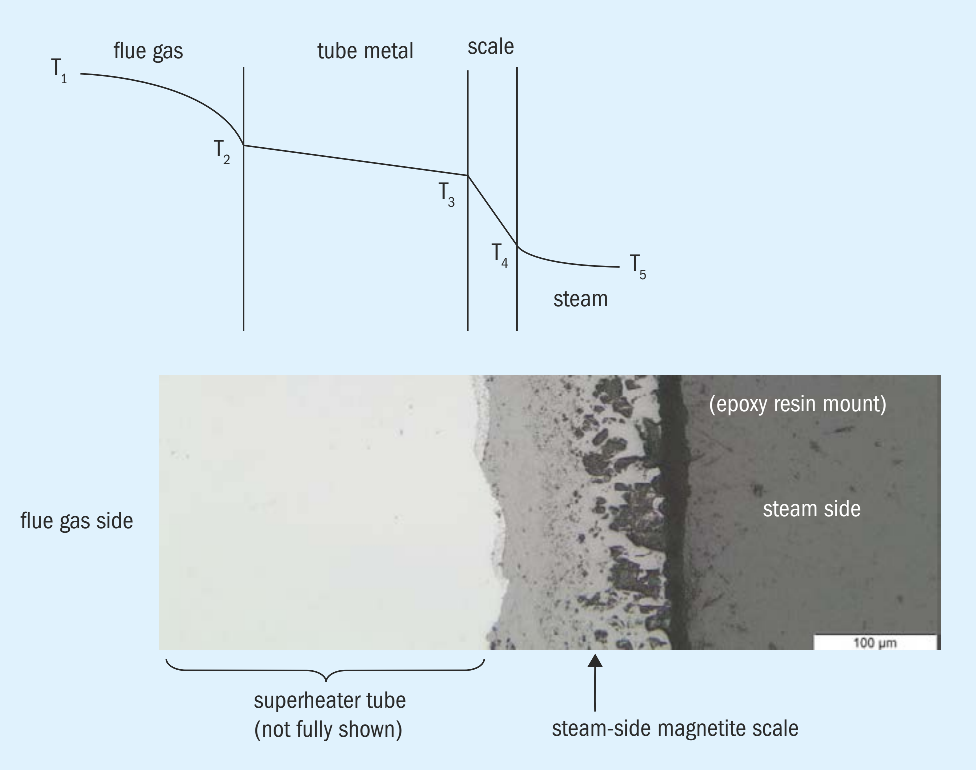
For each damage mechanism, three levels of FFS assessment can be undertaken, with Level 1 representing a basic assessment that generally incorporates inspection data, design conditions, and published material properties. However, Level 1 assessments are intended to be used as an initial screening check for comparison with a defined limiting criterion as the results can be conservative. As a result, a Level 2 or Level 3 assessment can be undertaken to improve the output from a Level 1 assessment, as inputs such as the determination of actual material properties from destructive testing or the use of computational analysis methods (e.g., finite element analysis and/or computational fluid dynamics) to improve the applied loads can be refined. Where sampling of convection section tubes and coils is possible, destructive laboratory examination and materials testing can be undertaken to ascertain the metallurgical condition of the material. Materials testing can incorporate tensile testing, Charpy V-Notch impact testing, fracture toughness testing, creep rupture testing and/or Omega creep testing, where appropriate and material permits. This information can be used as an input for a Level 2 or Level 3 FFS assessment, as previously noted.

For coils and tubes operating in steam service, the oxide thickness-based life assessment can be used as an alternative approach to API 579-1/ASME FFS-1. This methodology utilises correlations developed by the Central Electricity Generating Board (CEGB) in the UK and the Electric Power Research Institute (EPRI) in the US to describe the oxidation kinetics for low alloy ferritic steels and some CSEF steels (namely 9Cr1Mo and 9Cr1MoV steels)[3,4,5]. The thickness of the steam-side magnetite scale provides an estimate of the tube metal temperature (Fig. 5), which is then used as an input for a creep remaining life assessment. This methodology has been widely adopted by power generation operators for managing the integrity of boiler and heat recovery steam generator (HRSG) tubes in subcritical and supercritical fossil-fuelled power plant and planning for tube replacements. This approach could also be adopted for assessing the creep remaining life of convection section coils and tubes operating in steam service, assuming that any heat flux, steam-side oxide thickness, wall thickness and material properties are known. If access permits, the steam-side oxide thickness and metal wall thickness could be obtained using ultrasonic methods. Alternatively, this information could be obtained by destructive laboratory examination, with any materials testing undertaken to provide the actual material properties for the creep life assessment.

Fig. 5: **General schematic showing the temperature gradient from the external surface to the internal surface of a tube in steam service[6]. A detailed metallurgical section showing the typical appearance of the oxide scale is also shown.**



Source: Quest Integrity

Summary

Given the wide range of process services, materials of construction, and coil and tube arrangements that recover heat from the reformer furnace flue gas, the convection section of a reformer furnace remains a challenging asset for operators to manage. Although inspection access remains largely constrained, inspection solutions such as robotic water cleaning methods to remove external fouling for visual inspection and the use of adaptive header delivery systems to enable cleaning followed by intelligent pigging technologies to inspect the internal surfaces and monitor the wall thickness are available. Inspection data can be incorporated into an engineering assessment using standards such as API 579-1/ASME FFS-1 to understand the coil integrity. Furthermore, the oxide thickness-based life assessment for coils operating in steam service can also be adopted as an alternative methodology to determine the creep remaining life, where appropriate. This previously unobtainable information will improve understanding of the convection section condition and integrity, thereby helping operators plan periodic maintenance and bulk coil/tube replacements while mitigating unplanned outages from in-service failures. ■

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Future-proofing blue ammonia

VK Arora of Kinetics Process Improvements, Inc. (KPI) evaluates deep decarbonisation pathways for a new build ammonia plant of 3,500 tonnes/day on the United States Gulf Coast. Eight technology configurations are compared with results providing a framework for technology selection, balancing emissions reduction, process integration, and indicative economics.

Ammonia is increasingly viewed as an important contributor to low carbon energy systems, serving as a carrier of hydrogen, a carbon free fuel, and an essential chemical feedstock. Although global demand for low carbon ammonia is still developing, and while markets for green ammonia remain limited, deep decarbonised blue ammonia is emerging as the most practical near-term option - offering a practical pathway for early large-scale deployment due to established reforming technologies, expanding carbon capture projects, and favourable natural gas supply.

This study evaluates eight process configurations for a 3,500 tonnes/day ammonia plant on the United States Gulf Coast, including: steam methane reforming (SMR); secondary reforming (SR); pre-combustion CO_2 capture, compression and dehydration for sequestration (PCCS); post and pre-combustion CO_2 capture, compression and dehydration for sequestration (PoPCCS); autothermal reforming (ATR), partial oxidation (POx), convective reforming (CR), nitrogen wash unit (NWU), nitrogen wash unit with recycle (NWUR), two-stage pressure swing adsorption (PSA$^+$) for hydrogen purification, and hydrogen-rich firing (H2Fire). All schemes include feed purification, pre-reforming (where applicable), and integrated steam systems. The region provides low-cost natural gas, significant carbon dioxide storage capacity, and mature industrial infrastructure, which together enable deep decarbonisation at scale. Together, these factors enable deep decarbonisation at commercially viable scale, positioning Gulf Coast blue ammonia as a bridge technology toward longer-term hydrogen economy goals.

Technology configurations

The following blue ammonia production process schemes were broadly evaluated for high to deep decarbonisation options:

- Case 1: SMR + SR + PCCS
- Case 2: SMR + SR + PoPCCS
- Case 3: ATR + NWU + PCCS
- Case 4: ATR + NWUR + H2Fire + PCCS
- Case 5: ATR + PSA$^+$ + H2fire + PCCS
- Case 6: ATR + CR + PSA$^+$ + PCCS
- Case 7: POx + PSA$^+$ + PCCS
- Case 8: POx + NWU + PCCS

A brief review of catalytic methane pyrolysis (CMP) is also included as an emerging low carbon alternative.

All cases were evaluated under a common basis. Scope 1 and Scope 2 carbon intensities were estimated using standardised capture efficiency and regional grid assumptions. Results highlight differences in carbon capture performance and natural gas consumption.

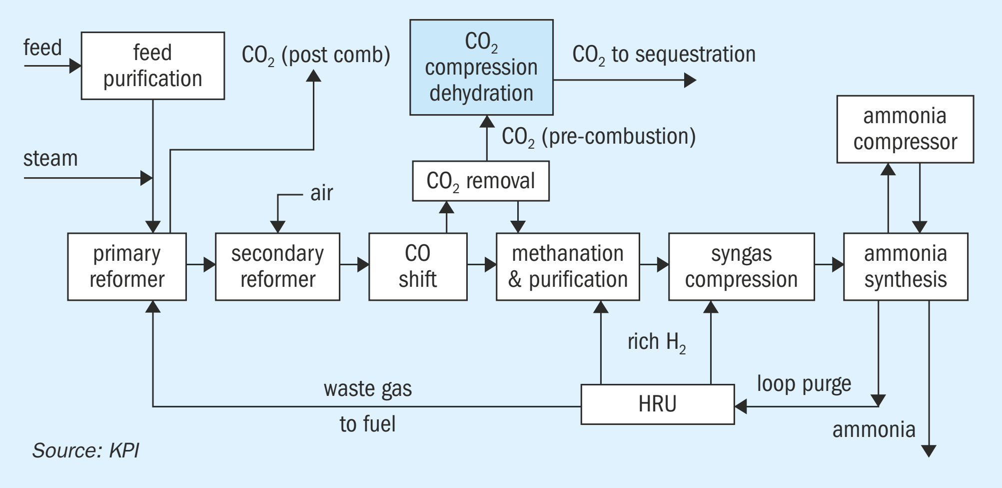
Each simulation estimated utilities, carbon capture performance, and Scope 1 and Scope 2 emissions for a 3,500 t/d ammonia plant with carbon dioxide compressed to 155 barg for sequestration. Post combustion capture was set at 95% (maximum), while pre-combustion capture exceeded 99.99%. Scope 1 emissions reflect direct plant releases, and Scope 2 emissions reflect grid power imports for the ASU and major OSBL units.

Hydrogen purification options were examined by comparing nitrogen wash and two-stage PSA (PSA$^+$), with and without recycle, to understand their impact on recovery, energy use, and integration.

Case description

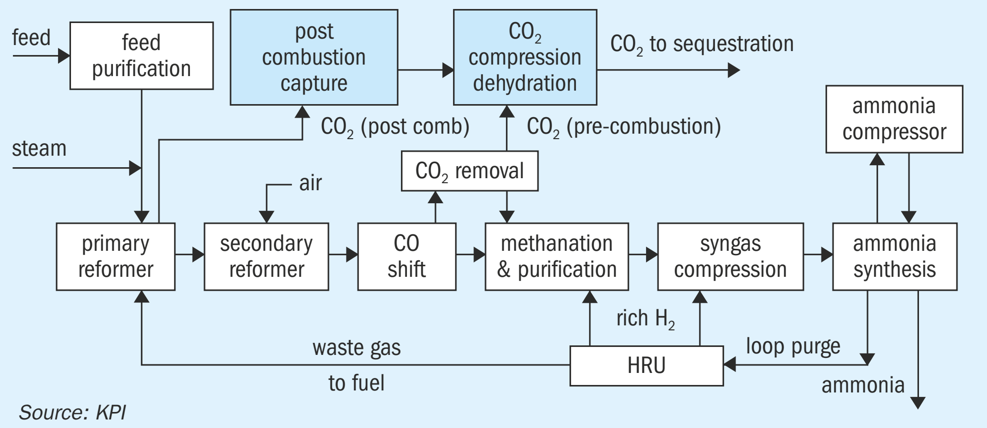
Each configuration (see process schematics in Figs 1-8) is briefly described to highlight the major process steps, integration features, and carbon management approach used in the evaluation.

Fig. 1: **Case 1: SMR + SR + PCCS (base case)**



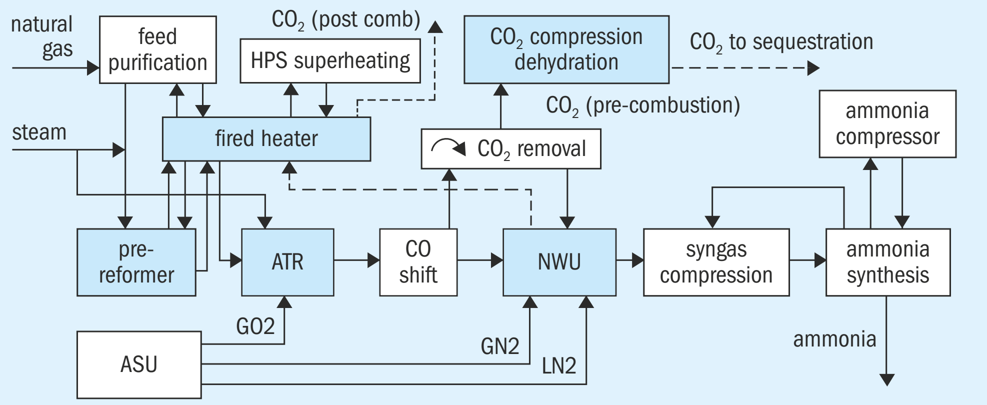
Source: KPI

Fig. 2: **Case 2: SMR + SR + PoPCCS**



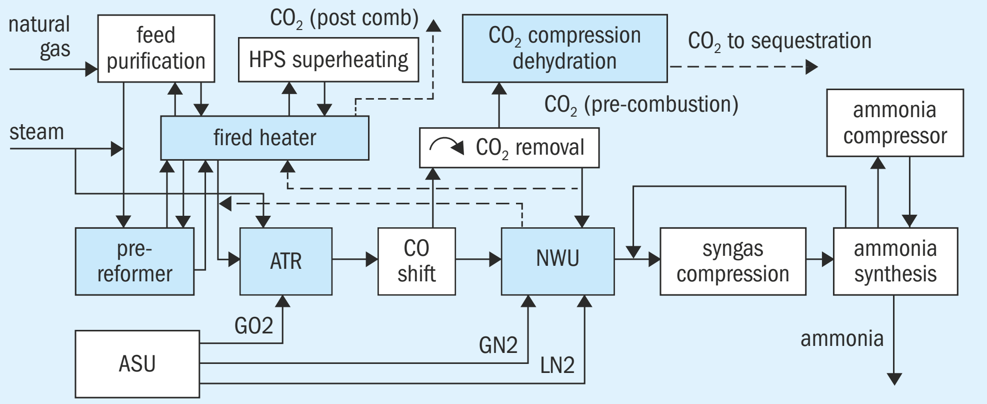
Source: KPI

Fig. 3: **Case 3: ATR + NWU + PCCS**



Source: KPI

Fig. 4: **Case 4: ATR + NWUR + H2Fire + PCCS capture**



Source: KPI

Case 1: SMR with SR and pre-combustion capture

This base case (see Fig. 1) represents a conventional but modern configuration widely deployed in commercial ammonia plants. It includes steam methane reforming followed by secondary reforming, along with compression and dehydration of captured pre combustion carbon dioxide for sequestration. This configuration provides moderate decarbonisation with well-established technology and operational reliability.

Case 2: SMR with SR and combined pre-combustion and post-combustion capture

This case (see Fig. 2) builds on Case 1 by capturing carbon dioxide from the reformer stack and combining it with the pre combustion carbon dioxide stream for compression and dehydration, enabling deeper decarbonisation. This approach enables deeper decarbonisation while maintaining the core SMR/SR process configuration.

Case 3: ATR with nitrogen wash and pre-combustion capture

This configuration (see Fig. 3) employs autothermal reforming operated at the lowest commercially viable steam-to-carbon ratio. Oxygen and process nitrogen are supplied by an integrated air separation unit (ASU). Hydrogen purification is performed in a nitrogen wash unit. Separate fired heaters provide process preheating and high-pressure steam superheating, using natural gas blended with plant off-gas as fuel.

Case 4: ATR with nitrogen wash recycle, hydrogen-rich firing and pre-combustion capture

This case (see Fig. 4) extends Case 3 by recycling carbon-containing streams to the ATR and using internally generated hydrogen-rich fuel for fired heaters. Recycling increases front-end equipment size and oxygen demand but significantly reduces carbon intensity – potentially improving project value under carbon pricing mechanisms or low-carbon certification requirements.

Case 5: ATR with two-stage PSA, hydrogen-rich firing and pre-combustion capture

This scheme (see Fig. 5) replaces the nitrogen wash unit with a two-stage pressure swing adsorption system to achieve hydrogen recovery comparable to nitrogen wash. Fired heaters utilise hydrogen-rich fuel for deep decarbonisation. As in Case 4, the front end enlarges due to higher hydrogen production requirements, but lower carbon intensity may offset increased capital costs depending on regional carbon policy and project financing terms.

Case 6: ATR with convective reforming, two-stage PSA and pre-combustion capture

This case (see Fig. 6) adds a convective reformer in series with the ATR and operates at a higher steam to carbon ratio. The convective reformer recovers high temperature heat to provide additional reforming duty, reducing natural gas and oxygen demand but lowering high pressure steam generation. The larger front end is balanced by improved carbon intensity under deep decarbonisation targets.

Fig. 5: **Case 5: ATR + PSA⁺ + H2fire + PCCS**

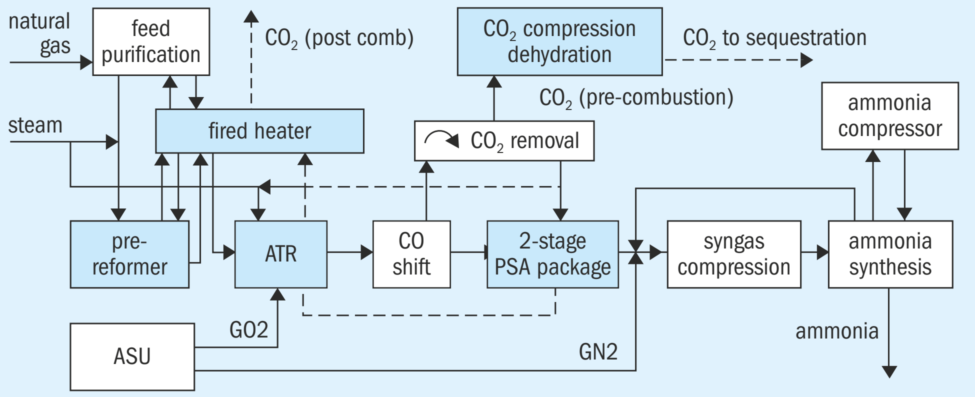


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Fig. 6: **Case 6: ATR + CR + PSA⁺ + H2fire + PCCS**

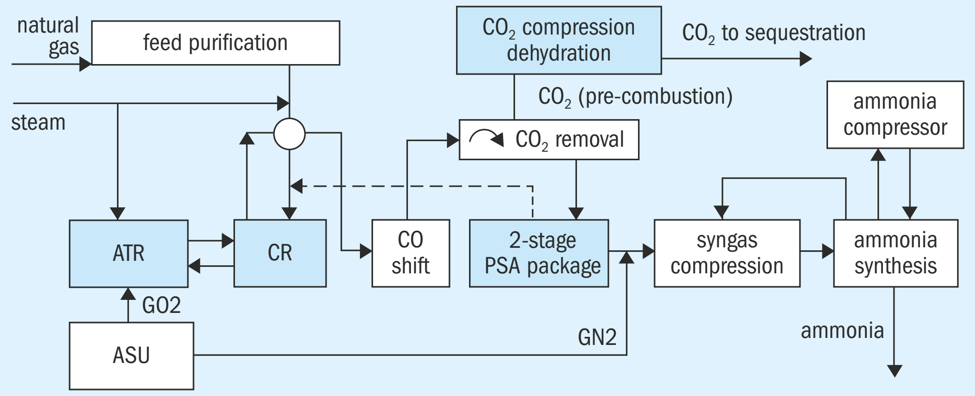

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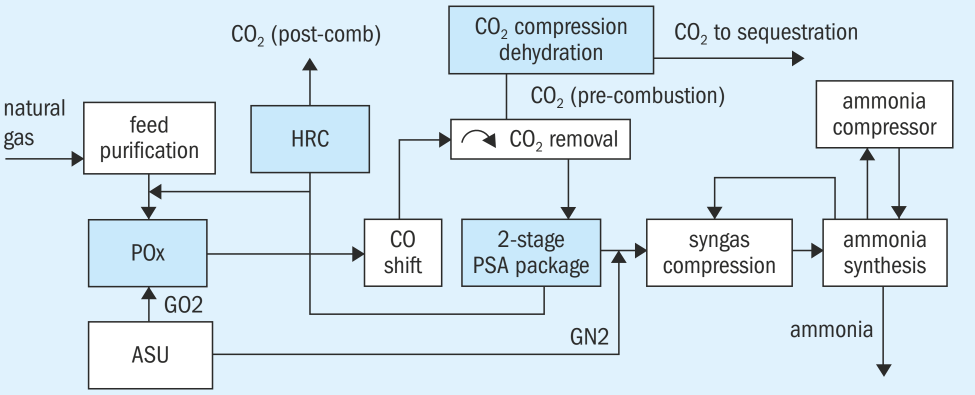
Fig. 7: **Case 7: POx + PSA⁺ + PCCS**



Source: KPI

Case 7: POx with two-stage PSA and pre-combustion capture

This scheme (see Fig. 7) uses partial oxidation and PSA⁺, which operates at much higher temperature than ATR and requires no catalyst. Oxygen demand is slightly higher, but methane slip is significantly lower. Integrated heat recovery for process preheating and high-pressure steam superheating eliminates the need for direct-fired heaters, further reducing emissions.

Case 8: POx with nitrogen wash and pre-combustion capture

This case (see Fig. 8) is similar to Case 7 but employs a nitrogen wash unit for hydrogen purification. No nitrogen wash recycle is applied. Despite the absence of recycle, the configuration still achieves approximately 97% carbon capture due to the inherently low methane slip characteristic of partial oxidation technology.

Steam system

The high-pressure steam level and degree of superheat were suitably selected for each configuration to minimise fired heater duty and reduce overall carbon intensity. Steam turbine drives were employed for major compression equipment (syngas and ammonia compressors) when sufficient HP or MP superheated steam was available; otherwise, motor drives were used to maintain energy efficiency. Surplus superheated high-pressure steam was expanded through back-pressure or condensing turbines for power generation, with net electricity credited as plant export. All other OSBL equipment, including the ASU, used motor drives, while the high-pressure boiler feedwater pump operated on steam or on motor as required. Process steam for the water-gas shift reactors was supplied from the process condensate stripper and the medium-pressure steam header. A minimum steam-to-gas ratio of 0.5 was maintained at the shift reactor inlet, with higher ratios applied as needed to control shift outlet temperature within catalyst and metallurgical limits.

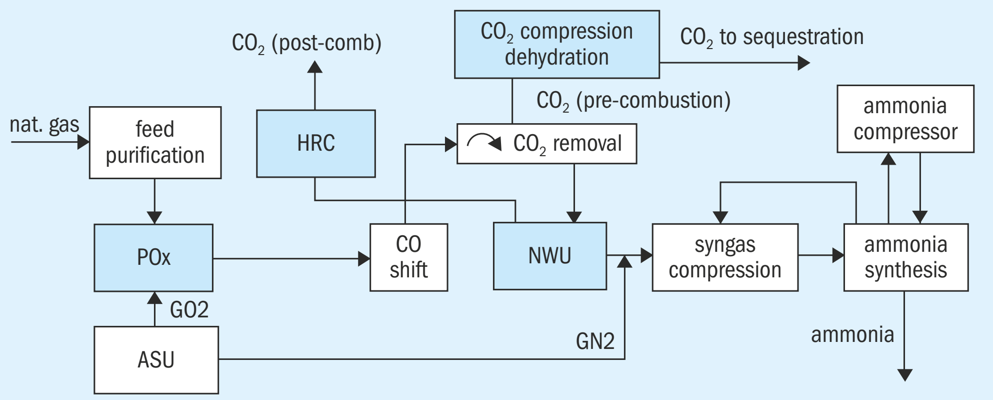
Emissions and carbon intensity evaluation

Carbon intensity calculations encompass Scope 1 direct emissions (combustion and process releases) and Scope 2 emissions from imported grid electricity (Louisiana regional grid factors). Pre-combustion capture efficiency was set at >99.99% (conventional acid gas removal), while post-combustion capture was limited to 95% (current amine technology). Upstream natural gas emissions are excluded, consistent with project-level carbon accounting boundaries.

Fig. 9 illustrates significant differences across configurations. Case 2 achieves modest improvement through combined capture but remains constrained by the 95% post-combustion ceiling, leaving residual flue gas emissions that prevent ultra-low carbon intensity thresholds required for future certification schemes.

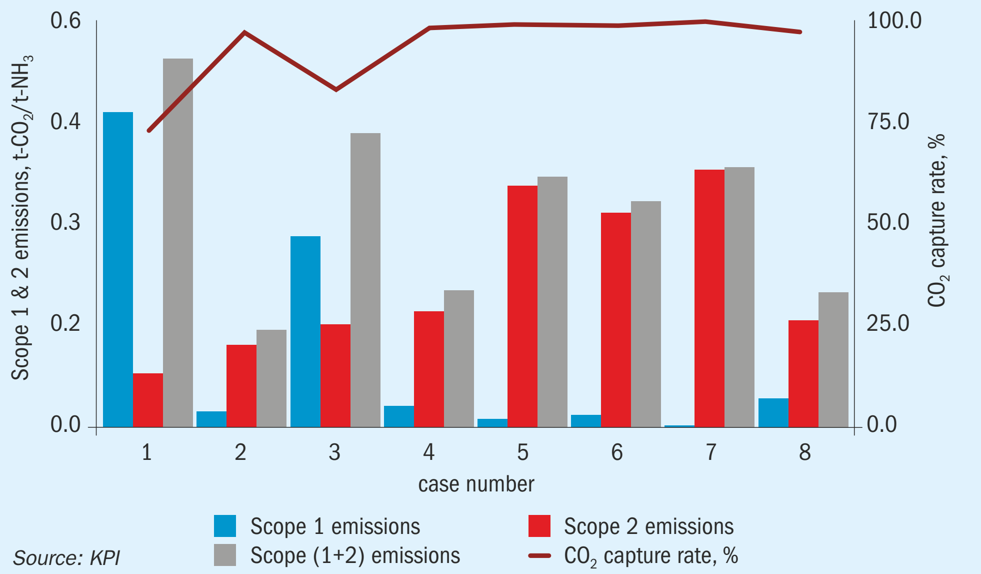
Cases 4 to 6 deliver the lowest carbon intensities by concentrating CO_2 in syngas for efficient pre-combustion capture, maximising hydrogen recovery, employing carbon recycle or convective reforming, and utilising hydrogen-rich fuel that eliminates fired heater stack emissions, enabling capture rates exceeding 98%.

Fig. 8: **Case 8: POx + NWU + PCCS**



Source: KPI

Fig. 9: **Scope 1 & 2 emissions**



Source: KPI

Partial oxidation Cases 7 to 8 achieve comparable performance due to inherently low methane slip, stable high-temperature conditions favouring complete conversion, and elimination of direct-fired heaters through integrated heat recovery. Multiple technology pathways achieve similar targets, offering developers flexibility based on site-specific conditions and risk preferences.

Process recycle reduction for lower carbon intensity

Lower carbon intensity can be achieved by minimising recycle, which requires reducing CH_4 and CO in the syngas/H_2 stream. Methane slip is primarily addressed under reforming operating conditions set for each configuration, leaving limited scope for further reduction. CO, however, can be lowered to single-digit ppm using either conventional methanation or selective catalytic oxidation.

Hydrogen purification: PSA vs nitrogen wash

ATR and POx with PSA differ from nitrogen wash in separation method. PSA uses cyclic adsorption to remove impurities, while nitrogen wash relies on cryogenic separation integrated into the synthesis loop. This difference influences energy use, integration, and flowsheet optimisation. Single-stage PSA provides lower hydrogen recovery, increasing feed demand, but its larger off-gas stream supports steam generation and reduces net power consumption. Two-stage PSA achieves recoveries comparable to nitrogen wash, though with additional compression duty.

Nitrogen wash offers high hydrogen recovery and direct loop integration suited for large plants, but requires refrigeration, has higher capital intensity, and provides less modular flexibility. The choice depends on site-specific economics, integration potential, and operating constraints.

Comparison of feedstock, fuel, and major utility needs provides insight into operating characteristics across the eight cases. Fig. 10 shows clear differences in feed, fuel, and oxygen use. Case 2 uses moderate natural gas without oxygen, but lowering carbon intensity through hydrogen-rich firing would increase natural gas demand and require major heater modifications.

ATR-based Cases 4 and 5 consume more natural gas and oxygen because recycle and higher syngas flow generate hydrogen-rich fuel. Case 6 behaves differently: the convective reformer recovers high-temperature heat for additional reforming, reducing feedstock and oxygen consumption but lowering high-pressure steam generation. Consequently, the steam system cannot support large syngas and ammonia compressors, requiring motor drives.

POx-based Cases 7 and 8 achieve deep decarbonisation through simplified heat integration: availability of additional process heat permits process preheating and steam superheating and eliminates fired heaters entirely while maintaining exceptionally low methane slip and stable carbon capture performance.

Residual CO removal

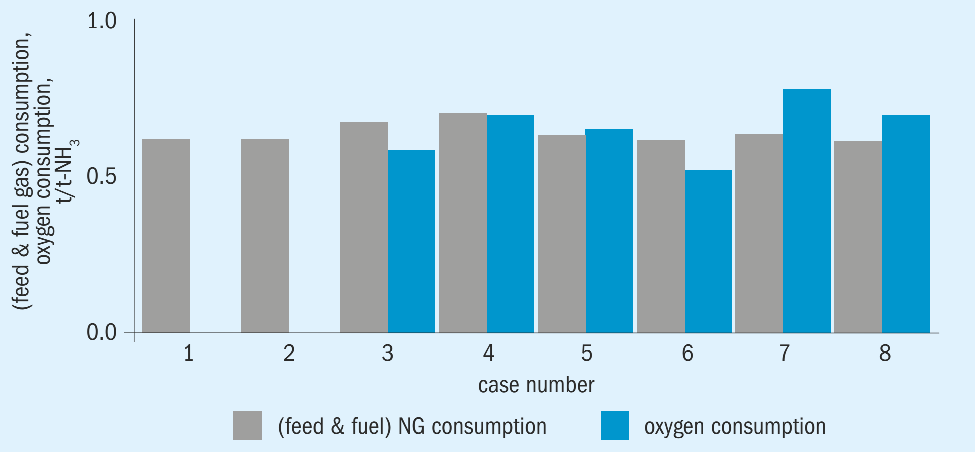
Selective CO oxidation represents a future improvement option for completely removing residual CO from shifted syngas (down to single-digit ppm levels) to minimise off-gas recycle to the front end (ATR or POx), reduce carbon intensity, and lower both capital and operating costs.

Selective CO oxidation removes CO without hydrogen penalty or inert buildup, improving loop efficiency and carbon dioxide capture. Challenges include sensitivity to gas impurities, limited commercial experience, and precious metal catalyst costs. It offers promising carbon intensity reduction for large-scale ammonia projects, but long-term reliability and economics require careful evaluation before widespread adoption.

Methanation is not a viable option for deep decarbonisation schemes as it consumes hydrogen and forms methane, which dilutes the synthesis loop, increases purge losses, and raises carbon intensity by converting captured carbon into an uncaptured form.

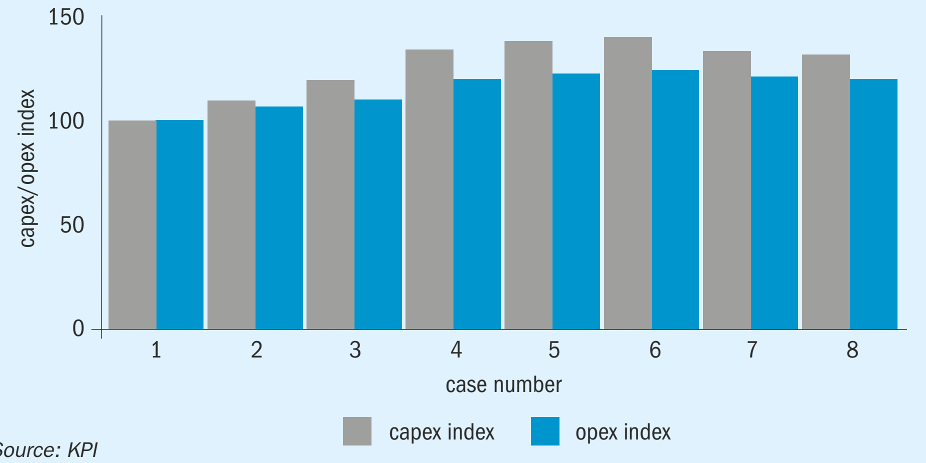
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46
47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76

Fig. 10: **Natural gas and oxygen consumption**



Source: KPI

Fig. 11: **Capex and opex indexes**



Source: KPI

Techno-economic viability

Economic performance review highlights important cost and long-term value differences across the eight cases. Fig. 11 shows Case 2 (SMR with SR and post-combustion capture) yields lowest capital and operating costs among deep decarbonisation pathways, but this advantage weakens when operational reliability is considered. At 3,500 tpd scale, the post-combustion system becomes extremely large, creating challenges with solvent handling, corrosion, foaming, aerosol formation, and parasitic power demand – reducing availability and increasing lifetime costs. Case 2 is also constrained by the 95% post-combustion capture ceiling (Fig. 9), preventing ultra-low carbon intensity required for future certification.

Hydrogen-rich firing has been considered to mitigate furnace emissions in Case 2, but application in large SMR heaters requires significant design modifications. In contrast, ATR and POx configurations (Cases 4 to 8) offer higher reliability, simpler carbon capture, better scalability, and stronger long-term economic value despite higher initial capital.

Emerging low-carbon pathways

Catalytic methane pyrolysis offers a promising route to very low-carbon ammonia by generating solid carbon rather than carbon dioxide, eliminating capture and storage requirements. Although at pilot scale, integration of pyrolytic hydrogen into ammonia synthesis could lower carbon intensity near-term.

Catalytic methane pyrolysis converts methane to solid carbon and hydrogen without process-related carbon dioxide emissions. Each ton of ammonia yields approximately 0.54 tons of solid carbon potentially saleable into carbon black markets if quality permits. However, with global carbon black capacity near 15 million tons annually and slow demand growth, pyrolysis can support only limited ammonia production before market saturation.

Economics depend strongly on carbon black revenue; wider adoption requires new solid carbon applications. Key technical challenges include catalyst life, reactor performance, and stable high-temperature operation. The absence of process carbon dioxide makes pyrolysis attractive where carbon capture faces geographic or policy barriers.

Other emerging options include electrified reforming, which may complement ATR and POx designs as power grids decarbonise.

Conclusions

This assessment demonstrates that deep decarbonisation of ammonia production requires integrated reforming, high efficiency carbon capture, and strategic process design – not simply minimising initial capital cost.

Case 2 delivers lowest capital and operating costs but cannot achieve future certification requirements. Post combustion capture limits removal to 95%, while large solvent systems face degradation, corrosion, foaming, and high parasitic loads that reduce reliability and increase lifetime costs. At 3,500 t/d, both the SMR and capture systems approach practical limits. Hydrogen-rich firing would require complete heater redesign, making Case 2 unsuitable for ultra-low carbon intensity targets.

ATR based Cases 4 to 6 and POx based Cases 7 and 8 provide the robust pathway forward. They achieve greater than 98% carbon capture by concentrating CO_2 in syngas, eliminate flue gas treatment complexity, and scale effectively to meet emerging certification standards. Overall carbon intensity will continue declining as power grids decarbonise, further reducing Scope 2 emissions.

Catalytic methane pyrolysis and electrified reforming offer long-term decarbonisation potential. Still, pyrolysis remains early in development, with no commercial references, and faces limited scalability unless new, higher-volume carbon applications emerge.

Overall, technology selection is site-specific and requires a balanced assessment of cost, reliability, carbon intensity, and long-term value.

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 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76

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Michelle Bingham
Email: michelle.bingham@crugroup.com
Tel: +44 (0)20 7903 2159

Editor:
RICHARD HANDS
richard.hands@@crugroup.com

Managing Editor & Publisher:
LISA CONNOCK
lisa.connock@crugroup.com

CEO Communities:
NICOLA COSLETT
nicola.coslett@crugroup.com

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Advertising enquiries:
MICHELLE BINGHAM
michelle.bingham@crugroup.com
Tel: +44 (0)20 7903 2159

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