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

Number 396

July | August 2025

nitrogen+syngas

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Ahmed Abdelaziz Mohamed Arafat, Rotating Lead Engineer, **Brunei Fertilizers Company**

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Cover: *Casale*

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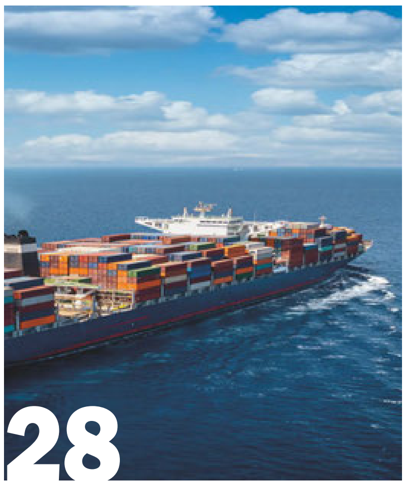
NUMBER 396
JULY | AUGUST 2025

CONTENTS

Ammonia markets

A surge of new merchant capacity



Sustainable methanol

A multi-pathway fuel for the energy transition

REGULARS

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Another month of market turmoil

> "Yara estimated that 20% of global urea capacity was offline..."

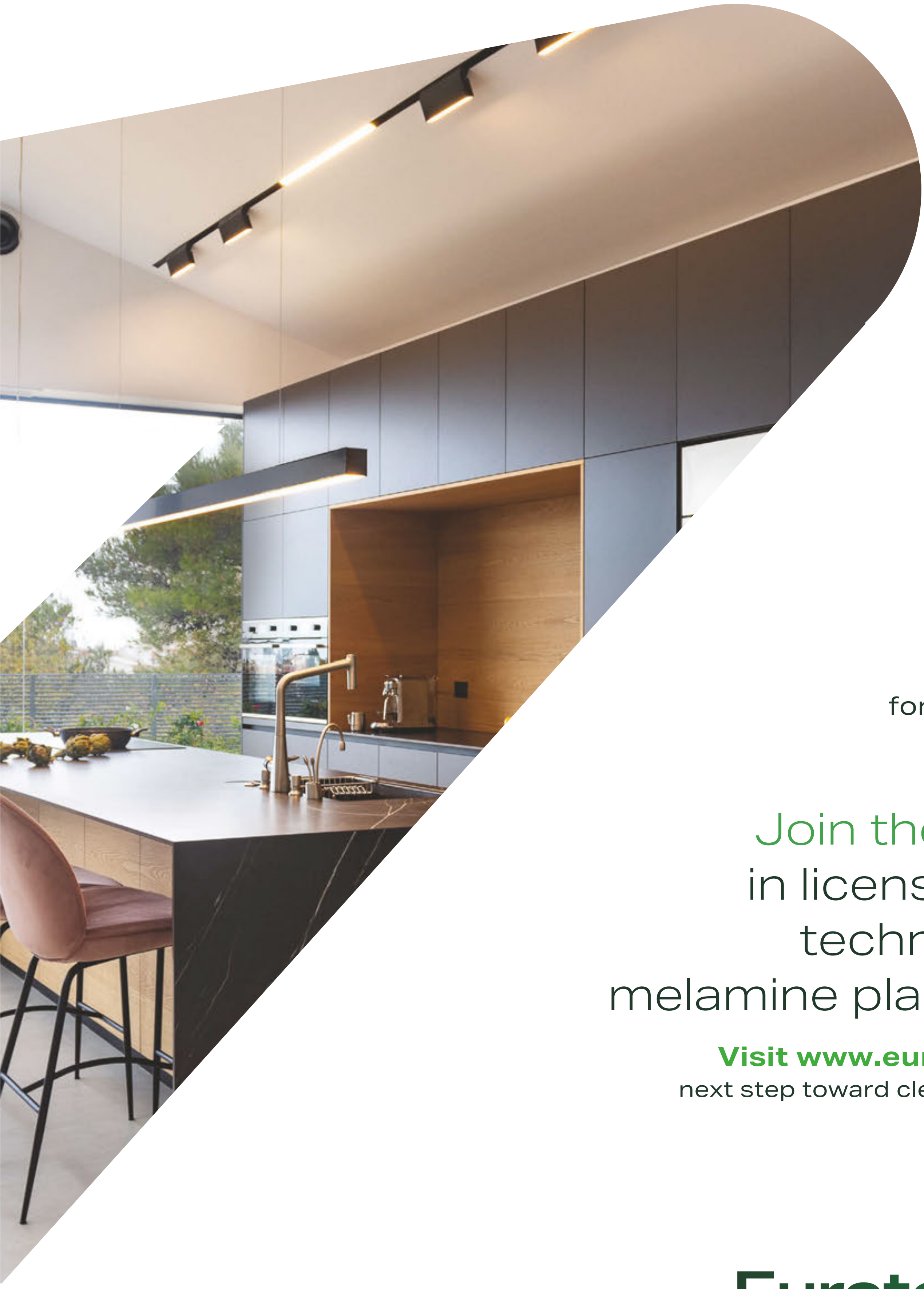
June saw fertilizer markets – urea markets in particular – thrown into chaos by the widening of hostilities in the Middle East. Israel's and then the United States' strikes on Iranian nuclear facilities and the retaliatory attacks on Israel and Qatar for a while held out the potential for the conflict to widen, perhaps even leading to attempts to close the straits of Hormuz at the entrance to the Gulf, something not seen since the 'tanker war' of the 1980s when Iraq tried to cripple Iran's oil exports during the eight year Iran-Iraq War.

Around 40% of global urea trade passes through the Straits, as well as 20% of LNG cargoes, potentially leading to feedstock shortages or price rises. But even without an attempt by one side or another to blockade the Straits, the fighting caused plenty of chaos, as Iran shut down its own domestic urea production, and disruptions in gas supply from Israel into Egypt from the Leviathan and Karish fields also led to temporary shutdowns in Egyptian urea production. Iranian missiles fired at US bases in Qatar increased nervousness about escalation, and at one stage during the month Yara estimated that 20% of global urea capacity was offline for one reason or another, leading to price spikes in most markets. Middle East f.o.b. prices jumped by around $150/t in a fortnight, something not seen since the Russian invasion of Ukraine in February 2022.

Fortunately the fighting has not worsened, and what is now beginning to be called the '12 Day War' ended with a US-backed ceasefire that – aside from another missile exchange between Israel and Iran the next day – seems to be holding. With Iranian urea production beginning to return to operation at the end of June, it looks as if the worst of the disruption may be past. CRU estimates that the shutdowns represented the loss of around 120-170,000 tonnes of Iranian urea, while Egyptian capacity has returned to around 80% operating rates overall by the start of July, with an estimated 300,000 tonnes of production lost. China has released more urea for overseas sale, which is also helping to bring markets back to an even keel in spite of India looking for 2 million additional tonnes by mid-August. Energy prices have also calmed, with oil back down to the low $70s/barrel for Brent crude at time of writing, after a jump of around $8/bbl, easing fears about a potential global economic slowdown.

However, set on top of other continuing market uncertainties, from US tariffs and ongoing trade disputes to the impact of the European Carbon Border Adjustment Mechanism (CBAM), not to mention additional sanctions on Russian fertilizer, and continuing high European energy prices, it feels like another reminder that the level of volatility we have seen in commodity markets since the outbreak of covid-19 may simply be "the new normal", and something that producers and consumers alike must find ways of adapting to. ■

Richard Hands, Editor



Price Trends

Ammonia benchmarks on both sides of the Suez were little changed in mid-June with a seemingly balanced supply-demand outlook, although those of a more bullish persuasion continue to support the notion that prices will soon – if they have not done so already – reach a floor. In Algeria, while activity was limited, producer Sorfert was believed to be seeking prices of $410-415/t f.o.b. for July delivery, up $10-15/t and equivalent to >$450/t c.fr NW Europe. Imminent tariffs on imports of Russian fertilizers into the EU may trigger an uptick in downstream capacity utilisation across the continent.

Across the Atlantic, Yara is shipping a Trinidadian cargo under contract to Mosaic at Tampa, the first delivery to the phosphate major since the pair agreed to a $392/t c.fr settlement for June consignments. Mosaic will soon also receive the spot cargo it purchased from Trammo at $370/t c.fr back in 2H May, with the tonnes originally sourced by the trader in Saudi Arabia and Bahrain. Across the US Gulf in Texas, there is still no word as to when next exports from the 1.3 million t/ar Gulf Coast Ammonia (GCA) facility will occur. Meanwhile, in the South Atlantic, Profertil was heard to have sold a spot cargo for 1H July loading from Argentina, with further details awaited.

East of Suez, business in the Middle East was limited following recent Eid holiday festivities, though cargoes continue to exit the region at a steady pace. As has been suggested in previous weeks, demand could soon pick up in India ahead of this year's Kharif season, although import appetite appears to be covered by contract deliveries for the time being. That said, Iranian material, which is heard to be on offer below $300/t c.fr, could soon find a home. Further east, South Korean contract prices remained largely stable amid the usual term cargo arrivals, while it was a similar story in Taiwan, China, where latest prices range from $300-340/t c.fr. In urea markets, NFL is seeking to secure 1.5 million tonnes of urea for west coast India, with some speculation that a low offer could have been submitted at below $380/t c.fr.

The Middle East was generally quiet but a granular sale was made to Australia at $390/t f.o.b. which is believed to have been sourced from Fertiglobe out of Ruwais. This would place the price in India well above $400/t c.fr. Russia has seen prilled sales of late at $360/t f.o.b. and above albeit for limited volumes. This again would put prices in India well over $400/t c.fr. Supply is tighter in the summer months because of the usual annual turnarounds and Russian availability has also been hit this week by the loss of Eurochem's Novomoskovsk plant which was hit by a drone on 7 June.

Nigeria has sold another cargo, with Indorama this time placing a cargo in the low $390s/t f.o.b. Dangote is looking to place another two cargoes for June with a tender taking place on 12 June. Asian availability is tight but demand is virtually non existent in the region although much needed rain that fell in Australia this week could help to absorb tonnages.

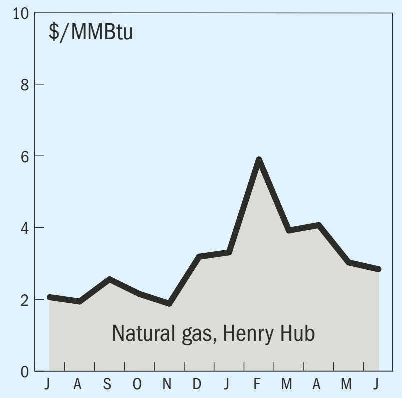
Table 1: **Price indications**

Cash equivalent	mid-Jun	mid-Apr	mid-Feb	mid-Dec
Ammonia ($/t)				
f.o.b. Black Sea	n.m.	n.m.	n.m.	n.m.
f.o.b. Caribbean	350-355	395	460	530
f.o.b. Arab Gulf	280-300	270-305	330-360	350-430
c.fr N.W. Europe	410-465	470-520	550-600	610-620
Urea ($/t)				
f.o.b. bulk Black Sea	355-365	350-355	385-395	305-320
f.o.b. bulk Arab Gulf*	300-390	345-389	402-445	319-358
f.o.b. NOLA barge (metric tonnes)	343-355	300-315	402-418	326-338
f.o.b. bagged China	353-360	n.m.	n.m.	n.m.
DAP ($/t)				
f.o.b. bulk US Gulf	713-715	628-640	588-595	n.m.
UAN (€/tonne)				
f.o.t. ex-tank Rouen, 30%N	310-320	340-345	330	278-280

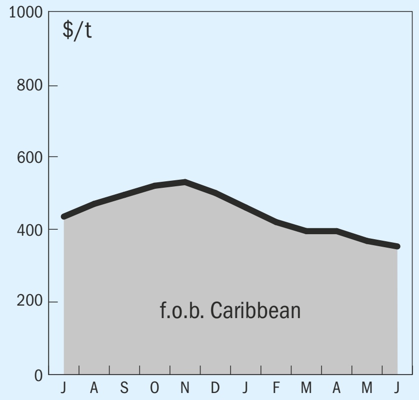
*Notes: n.a. price not available at time of going to press. n.m. no market. * high-end granular.*

END OF MONTH SPOT PRICES

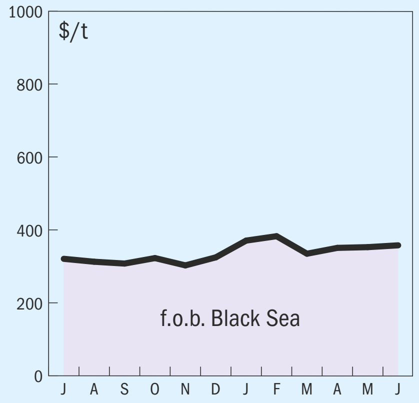
natural gas



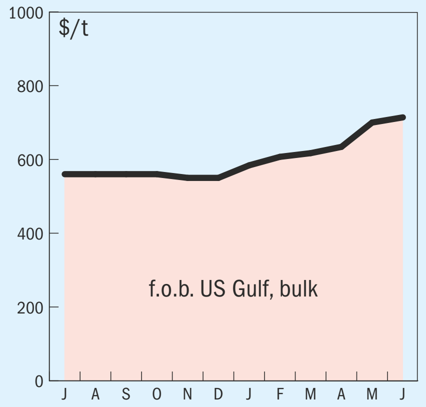
ammonia



urea

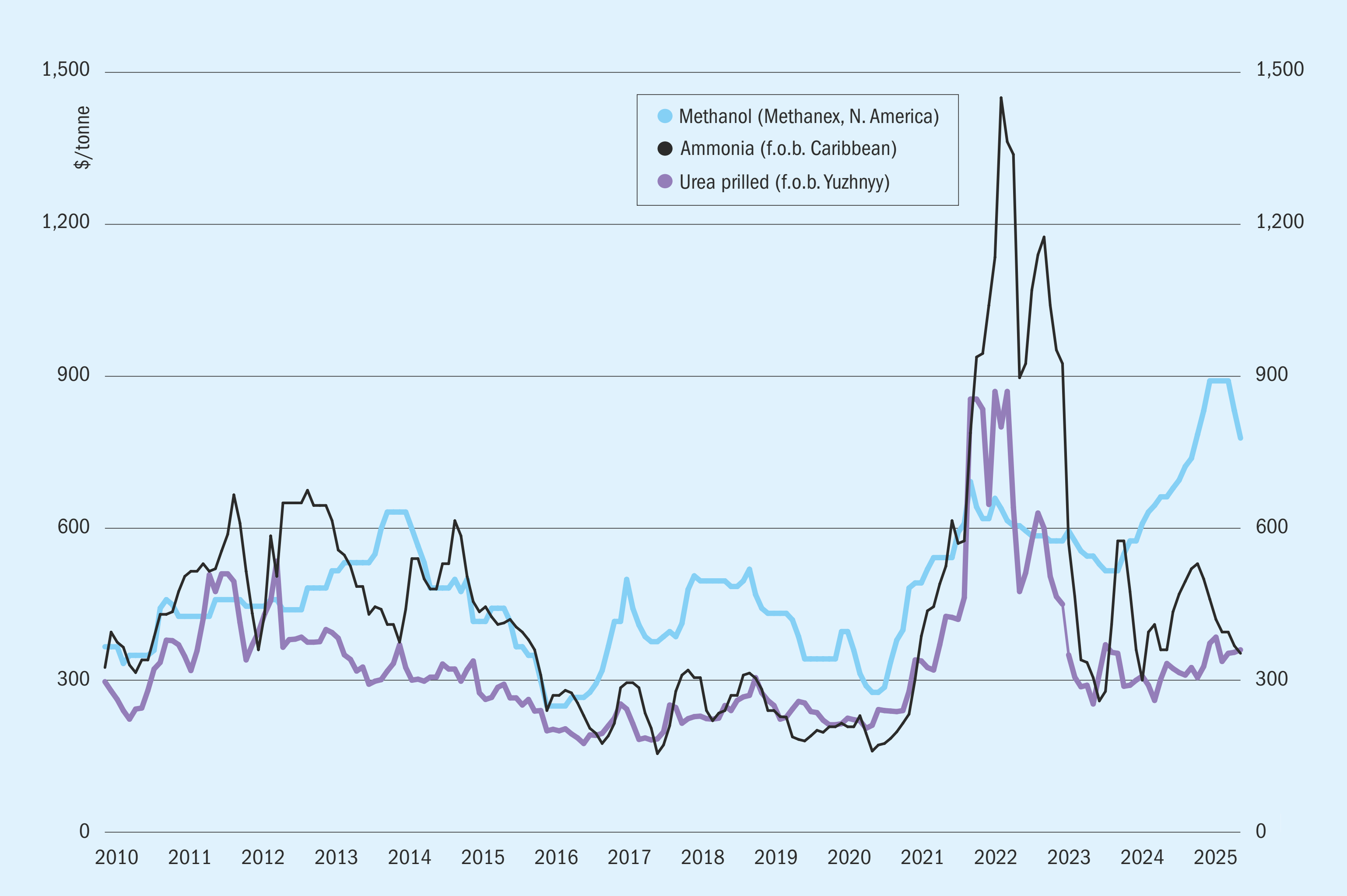


diammonium phosphate



Market Outlook

Historical price trends $/tonne



Source: BCInsight

AMMONIA

- The short term outlook appears balanced for the most part, although more bullish participants seem to be holding sway over market sentiment.
- Imminent tariffs on imports of Russian fertilizers into the EU may trigger an uptick in downstream capacity utilisation across the continent.
- US gas storage has been higher than expected from slightly warmer weather – this has led to a slight reduction in prices over the summer.
- European premiums for lower carbon ammonia are likely to emerge from the start of 2026 due to the creeping implementation of the Carbon Border Adjustment Mechanism.

UREA

- The short term outlook for urea is firm, though there is the potential for disruption from a low tender for India.
- North African prices may correct as European interest fades.
- The ongoing strikes by Israel on Iran may herald a broader and more serious conflict in the Middle East with the potential to severely disrupt vital energy and fertilizer trade.
- The US introducing tariffs and then flip flopping on its implementation raise market uncertainty and curbed fertilizer imports.
- Clarity on Chinese urea exports emerged in early May via a ‘quota allocation’ system for urea exports, with a total of 2 million tonnes of exports allowed between May-Sept 2025. While exports to India remain banned, they are likely to find home in South Korea, Sri Lanka, Philippines, and Mexico, and many in the industry expect the market to ‘find a way’ to access India, with prices likely to fall until restrictions are reimposed in October.
- f.o.b. values of $370-375/t are proving competitive in west coast Latin America.

METHANOL

- China continues to dictate the overall global methanol market. Chinese thermal coal prices have fallen by 10% since January and supply remains healthy for now, with a weaker demand outlook.
- Crude oil prices have risen on market uncertainty and low inventories but additional OPEC+ production will limit the upside to prices.
- Chinese MTO demand sets the methanol price cap, with overcapacity in Chinese olefin markets contributing to headwinds in that direction, although it remains to be seen whether the current conflict between Israel and Iran will affect Iranian methanol shipments to China; Iran represents more than half of Chinese methanol imports.
- Shortages of new supply projects outside of China will likely lead to higher prices to drive reinvestment in the longer term. ■

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

Nitrogen Industry News

AUSTRALIA

Fertiglobe to acquire Wengfu Australia's distribution assets

Abu Dhabi-based nitrogen producer and distributor Fertiglobe says that it is acquiring the distribution assets of Wengfu Australia Pty Ltd. through an asset sale and purchase agreement, expanding its downstream reach and enhancing access to supplying Australian customers. Fertiglobe currently supplies around 600,000 t/a of urea to Australia, with the potential to grow supply volumes through the Wengfu platform to meet demand. Wengfu operates in southeast Australia from five ports with eight warehouses, distributing 700-800,000 t/a of fertilizers to over 200 customers, with capacity to scale up to 1.1 million t/a.

Fertiglobe says that the acquisition aligns with its strategy to expand its presence in key strategic sectors, diversify its global footprint, and build resilience against seasonality. It provides access to a broader customer base, unlocks supply chain efficiencies, and supports the introduction of enhanced-efficiency and sustainable fertilizers. This acquisition also enables Fertiglobe to widen its distributed product portfolio to non-nitrogen fertilizers and allows it to expand fertilizer sourcing flexibility to supply the wider Asia-Pacific region. The transaction is subject to customary regulatory and legal approvals.

Ahmed El-Hoshy, Chief Executive Officer of Fertiglobe, commented: "Acquiring Wengfu's assets marks a strategic step in our value-driven growth strategy and accelerates our commercial footprint in Australia – one of the world's fastest-growing agricultural regions. It also provides us with a strong distribution platform across the Asia-Pacific region, strengthens access to our customers, and enhances our ability to competitively source and deliver our products and services. Having known Wengfu's team for several years, we have strong confidence in their ability to grow the business from here. The transaction is in line with our ambitions to expand our presence in key markets and reinforces our leadership position in the global nitrogen industry." ■

Low emission ammonia bunkering

NH3 Clean Energy, Pilbara Ports Authority, and Oceania Marine Energy have established a Joint Development Agreement (JDA) in order to establish hydrogen-derived, low-emission ammonia bunkering operations at the Port of Dampier in Australia by 2030. Under the terms of the JDA, the partners will collaborate to deliver the necessary infrastructure, regulatory approvals, and commercial frameworks to support the refuelling of ammonia-powered bulk carriers exporting iron ore to Asia. Specifically, NH3 Clean Energy will continue to develop its WAH2 ammonia production project in Western Australia; this initiative has already completed pre-FEED and is targeting FEED entry by mid-2025. Oceania will develop and operate ammonia bunkering vessels, working with NH3 and Pilbara Ports to align their design and operations with port and fuel supply needs, while Pilbara Ports Authority will oversee planning, upgrades, and licensing to ensure safe ammonia bunkering and regulatory compliance. The agreement envisages a final investment decision by late 2026, with the commencement of ammonia bunkering in 2030. Up to 29 dual-fuel, ammonia-capable bulk carriers are already on order for delivery before 2030, according to the Ammonia Energy Association, designed to meet new IMO emissions rules from 2027.

With around 300 bulk carriers currently transporting iron ore from the Pilbara to Asia, just 16 ammonia-fuelled ships refuelling exclusively at Dampier would require 600,000 t/a of clean ammonia, the equivalent of more than 90% of NH3's planned Phase 1 production from the WAH2 project.

INDIA

Construction begins on green ammonia plant

HHP Five Private Limited, a subsidiary of Hygenco Green Energies Pvt Ltd, has held a foundation-laying ceremony at the site of the company's new green ammonia plant in Gopalpur, Odisha. Hygenco is developing a green ammonia production facility with a total planned capacity of 1.1 million t/a. The project will be executed in three phases, beginning with Phase 1 in 2028, which will deliver an initial output of 220,000 t/a. This will be followed by Phase 2 in 2029, adding another 220,000 t/a to the production capacity. By 2030 and beyond, the facility will enter its third phase, which aims to significantly scale operations with an additional 730,000 t/a, bringing the total annual production to 1.1 million t/a. This phased approach reflects Hygenco's long-term commitment to advancing green hydrogen derivatives and supporting global decarbonisation goals. It follows Hygenco's earlier commissioning of India's first commercial-scale green hydrogen plant, which is supporting emission reductions in the steel industry.

Amit Bansal, co-founder and CEO of Hygenco, emphasised the company's broader mission: "Following our success in green hydrogen, this new venture into green ammonia will help drive industrial decarbonisation while creating export potential. It's a step toward building a self-reliant energy future for India."

PHOTO: INOX INDIA LTD

The INOXCVA ammonia tank

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

High purity ammonia ISO tank container

Cryogenic storage company INOX India Ltd has launched its first ultra-high-purity (UHP) ammonia T-50 ISO tank container. The container, designed, engineered and manufactured by INOX India is engineered to withstand high pressure levels, and complies with international standards including ASME Sec VIII, Div-1 with U-designated construction. Its core feature is a high-precision internal finish with a surface roughness below 0.3 RA, a standard extended to all piping elements with orbital-welded joints to guarantee the highest level of purity for ammonia. Insulation is via rock wool with polished stainless-steel cladding for superior thermal and acoustic protection. The tank also comes with a spring-actuated emergency shut-off mechanism, facilitating valve closing remotely.

Deepak Acharya, CEO of INOX India Limited said, "by developing India's first UHP ammonia ISO tank container we are enabling an entire ecosystem that will accelerate semiconductor and solar panel manufacturing capabilities across the world, and reduce our dependence on imports for critical industrial equipment."

GERMANY

BASF launches two renewable ammonia grades

BASF has expanded its sustainable product portfolio by launching two new renewable ammonia grades; renewable ammonia and renewable 24.5% ammonia solution. BASF produces the renewable ammonia grades at its Verbund site in Ludwigshafen by feeding renewable hydrogen into the ammonia plant, reducing the plant's natural gas consumption. The plant uses both gas-based hydrogen as well as renewable energy, and attributes the renewable component via a mass balance approach, allowing a proportion of production to be designated as renewable. The two product grades have been certified according to ISCC+ and can be used as 'drop-in' solution in the same way as the conventional products. The renewable ammonia grades are available in usual bulk mode.

"Our biggest goal is net zero of our products. With our renewable ammonia, we can significantly undercut the product carbon footprint of our other low-CO2 ammonia grades", said Dr. Jens Assmann, Vice President Business Management Ammonia Value Chain and Operations Amino Resins at BASF. "Demand for low-carbon or 'green' ammonia has constantly increased in the past years and is expected to still rise in the future. Our customers, as well as BASF's own downstream businesses, need low-carbon products already today to explore their market", Assmann emphasised. "We are proud to offer the first renewable ammonia produced in Central Europe with a very low carbon footprint."

KOREA

KBR awarded ammonia cracking contract

KBR says that they have been awarded a second ammonia cracking technology contract by Hanwha Impact Corporation for its clean power generation facility in Korea. Under the terms of the agreement, KBR will provide technology licensing, proprietary engineering design and equipment, and services for a 214 t/d hydrogen facility. The plant will use KBR's proprietary H2ACT® ammonia cracking technology to produce clean hydrogen and contribute to Korea's decarbonization goals.

"We are grateful for the trust Hanwa has placed in KBR to support their growth plans," said Jay Ibrahim, President, KBR Sustainable Technology Solutions. "KBR's innovative H2ACT technology was previously selected by Hanwha for large-scale, sustainable hydrogen production and this new award utilizes a design intended to further enhance the cost-efficiency of the project."

SAUDI ARABIA

NEOM hydrogen plant "80% complete"

NEOM Green Hydrogen Company (NGHC), a joint venture between ACWA Power, Air Products and NEOM, says that construction of its new green ammonia plant in Saudi Arabia has reached 80% completion across the hydrogen plant, wind and solar farm and transmission grid, with milestone equipment being received and installed, including wind turbines, hydrogen storage vessels, electrolysers, cold box and pipe racks. The 4 GW solar and wind power generation sites are scheduled for completion by mid-2026, with first ammonia product availability expected in 2027. The plant will produce up to 600 t/d of low carbon ammonia for transportation and industrial sectors globally, as well as using ammonia as a hydrogen carrier. Air Products is the primary EPC contractor and system integrator, and the exclusive off-taker of the green hydrogen produced in the form of green ammonia at the NGHC facility.

SOUTH AFRICA

Investment in large-scale green ammonia plant

The SA-H2 Fund – a partnership between climate finance investor Climate Fund Managers and Dutch development financing institution Invest International – has committed up to $20 million in development funding to complete the final stage of development of the Hive Hydrogen Coega Green Ammonia Project – South Africa's first large-scale green ammonia production facility.

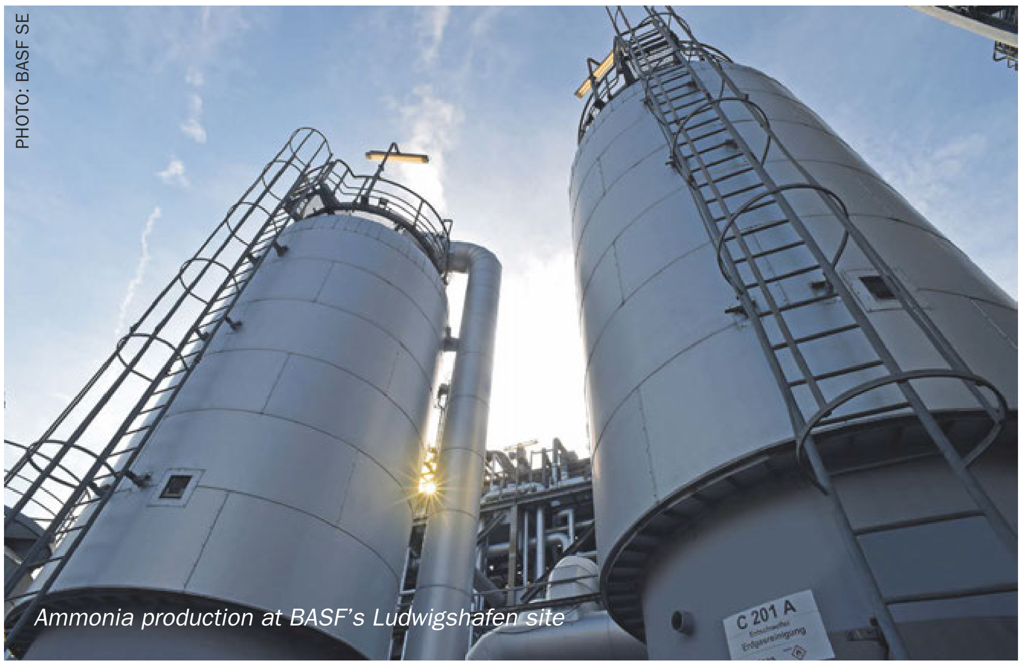


PHOTO: BASF SE

Ammonia production at BASF's Ludwigshafen site

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SA-H2 is dedicated to accelerating South Africa's energy transition and green hydrogen economy. The development funding will cover engineering, procurement and construction selection, front end engineering and design, and will also be put toward completion of the advanced stage permitting and environmental and social impact assessments, leading to offtake finalisation and financial close preparation. The agreement also secures the SA-H2 Fund's right to participate in construction funding for up to $200 million. Financial close is targeted for H2 2026, with commercial operations expected to begin in 2029.

The project is being developed by Hive Hydrogen South Africa, a joint venture between UK-based Hive Energy and South African renewable energy and investment company BuiltAfrica. Located in the Coega Special Economic Zone in Nelson Mandela Bay, Eastern Cape Province, the facility will integrate 3.6 GW of renewable energy generation (2.4 GW wind and 1.2 GW solar PV), a 1.2 GW electrolyser, desalination technology, air separation units, bulk ammonia storage and export infrastructure. Once operational, the plant is expected to produce 1 million t/a of green ammonia, making it the largest green ammonia production facility in South Africa. The project is expected to avoid 2.6 million tCO_2e emissions per year, and will also enable up to 20 GW of additional renewable energy plants to connect to the national grid, supporting broader clean energy integration across South Africa.

Sebastiaan Surie, head of New Ventures at CFM, said: "This is a landmark first investment for SA-H2 and a defining project for the country's green hydrogen economy. Hive's project brings together scale, technical ambition and global relevance – and has the potential to position South Africa as a competitive exporter of low-carbon energy. By deploying public capital to absorb early-stage risk, our blended finance model enables private capital to invest in the construction of this pioneering green ammonia plant on terms aligned with their mandates, accelerating the global energy transition."

The project targets growing export demand in Asia and the EU, and has signed a comprehensive memorandum of cooperation with Japanese conglomerate Itochu Corporation for potential involvement as a strategic equity investor and off taker in relation to the project.

CHINA

Marubeni signs a long-term offtake agreement for green ammonia

Marubeni has signed a long-term offtake agreement with green technology company Envision Energy Co., Ltd for ammonia produced from renewable energy in Inner Mongolia, China. Marubeni says that it will take a certain volume of green ammonia produced at a plant on a long-term basis and supply it to clients. This project marks Marubeni's first long-term offtake agreement for green ammonia, via which Marubeni aims to establish its position as a key supplier in the green ammonia market.

Envision plans to begin trial production of green ammonia with wind-generated electricity in Chifeng City, Inner Mongolia. The company's commercial green ammonia plants are scheduled to start operations from September 2025 onwards, with an initial production capacity of 300,000 t/a in the project's first phase. Envision is aiming to eventually produce 5 million t/a.

Construction on the Chifeng plant began in April 2023, and Envision started ammonia production in March 2024, as part of an initial exploratory phase to evaluate diverse electrolysis technologies, dynamic ammonia synthesis, and off-grid integration. The company says that it will be capable of supplying substantial volumes of renewable ammonia both domestically and internationally starting from Q4 2025. Following this initial stage, the second phase will double annual production by another 300,000 t/a, with the third phase set to add a further 900,000 t/a. Envision also aims to address electrolytic hydrogen production constraints by developing extensive hydrogen pipeline infrastructure, consisting of an 800 km main pipeline and multiple branches. This network will connect Ordos City in Inner Mongolia to Chifeng City in the East, streamlining hydrogen transport significantly. In addition to hydrogen pipelines, Envision is planning a dedicated 300 km liquid ammonia distribution pipeline from the production facility near Chifeng to Jinzhou Port, where it is developing an ammonia storage terminal and jetty for export purposes.

Casale to license ammonia-urea plant

Casale has signed two contracts with Xin Lian Xin Chemicals Group Co.,Ltd for the implementation of ammonia and urea technologies in the company's new urea complex in Henan province. Capacities for the two plants will be 2,700 t/d of ammonia and 3,500 t/d of urea. Casale says that the complex will be its first grassroots application of its HYPER-U urea technology; an improved self-stripping process incorporating a medium-high pressure (MHP) decomposition stage which significantly reduces steam and cooling water demand, enhances thermal efficiency, and lowers operational costs while drastically cutting the plant's carbon footprint. A new Strategic Cooperation Agreement signed between the two companies at the same time

PHOTO: CASALE

Xin Lian Xin's nitrogen complex, Henan.

highlights the ongoing collaboration between Casale and Xin Lian Xin, which has included eight ammonia synthesis units and three urea plants. Both parties also agreed to establish regular technical exchanges and form joint working teams to ensure the seamless implementation of current and future projects. This structured approach will allow for faster alignment, more agile development, and the ability to promptly respond to market challenges and opportunities.

EGYPT

Egypt tries to fill gas shortage with LNG

Egypt is looking towards hugely increased LNG imports to try and reduce domestic shortages. A second floating regasification and storage unit arrived in May and two more are expected to be in place soon. Reuters reports that the country has reached agreements with energy firms and trading houses to buy 150 to 160 cargoes of liquefied natural gas, as it ramps up purchases to meet power demands despite strained government finances, representing up to 8 million t/a of LNG. Egypt has already bought 2.25 million tons of LNG this year, almost as much as it imported for the whole of 2024.

JAPAN

INPEX begins commissioning of blue ammonia demonstrator project

INPEX Corp says that it has commenced commissioning work including the introduction of natural gas at its integrated blue hydrogen and ammonia production and utilisation demonstration test project in Kashiwazaki City, Niigata Prefecture. The project is the first of its kind in Japan to implement an integrated process from the production to the use of hydrogen and ammonia. The natural gas used as a feedstock for the process is domestically sourced from the INPEX-operated Minami-Nagaoka gas field in Niigata Prefecture. The CO_2 emitted during production is injected into previously depleted gas reservoirs in the Hirai District of the Higashi-Kashiwazaki gas field (using CCUS technology) to minimise atmospheric emissions. The hydrogen produced from this project will be used to generate electricity that will be supplied to local consumers in Niigata Prefecture.

Project demonstration operations are scheduled to commence in the fall of 2025, followed by the initiation of CO_2 injection into the reservoir. The production of hydrogen and ammonia as well as CO_2 recovery for commissioning are being conducted under a subsidy program adopted by the New Energy and Industrial Technology Development Organisation (NEDO), and the assessment and implementation of subsurface CO_2 storage are being conducted as part of a collaborative study with the Japan Organization for Metals and Energy Security (JOGMEC).

UNITED STATES

NOx release at Austin Powder

There has been a release of nitrogen oxides from Austin Powder's Red Diamond plant in Ohio. The company says that the decomposition of nitric acid caused the incident due to elevated temperatures inside a 5,000-gallon storage tank. This led to a visible release of nitrogen oxide gas, which was vented through the plant's built-in safety systems. Austin Powder says that its team activated emergency response protocols and notified the Ohio Environmental Protection Agency (EPA). Air quality modelling conducted at the property's fence line confirmed that NOx levels remained below health-hazard thresholds. The company is conducting an internal investigation to determine the root cause of the temperature rise that led to the gas release.

Linde to built ASU for blue ammonia project

Linda has signed a new long-term agreement with Blue Point Number One, a joint venture between CF Industries, JERA and Mitsui. Under the terms of the agreement, Linde will supply industrial gases to Blue Point's 1.4 million t/a low carbon ammonia plant in Ascension Parish, Louisiana. Linde will build, own and operate a world-scale air separation unit (ASU) to supply oxygen and nitrogen to the Blue Point project, expected to be one of the largest low-carbon ammonia projects in the world. Linde will invest more than $400 million in the new on-site plant, which is expected to start up in 2029.

"The Blue Point joint venture will help build a reliable and affordable low-carbon ammonia value chain to meet rising demand for ammonia as an energy source," said Christopher Bohn, Executive Vice President and Chief Operating Officer, CF Industries Holdings, Inc. "For industry-leading projects, trusted partners are crucial. Linde's experience in developing major clean energy projects, along with its technology and operational expertise, make them a strategic choice for the Blue Point project."

"We are proud to supply critical industrial gases to Blue Point, supporting their development of a robust supply chain for low-carbon ammonia," said Sean Durbin, Executive Vice President North America, Linde. "This will be Linde's third state-of-the-art ASU supplying a major autothermal reforming plant which builds from our experience in developing similar facilities in Texas and Canada. It is also the latest of a series of investments by Linde in our US Gulf Coast industrial gases corridor, increasing network density in a region where demand for industrial gases is continuously growing."

RUSSIA

Drone attack on Nevinnomyssk Azot

Russian and Ukrainian news outlets have reported that there has been a drone attack on the Nevinnomyssk Azot chemical plant in Russia's Stavropol district. The attack took place on the night of June 14th. Ukraine's Centre for Counteracting Disinformation said that the fertilizer plant "is a critical element of the Russian military-industrial complex. It produces up to a million tonnes of ammonia and more than a million tonnes of ammonium nitrate annually – a key component for explosives and artillery shells."

ROMANIA

Liquidators to sell Interagro plants

Two fertilizer plants, formerly part of the Interagro Group, are being offered for sale by the liquidator, Sierra Quadrant. The factories, Ga-Pro-Co in Săvinești and Donau Chem at Turnu Măgurele, are available for direct negotiation starting at €17.8 million plus VAT and euro 18 million plus VAT according to the liquidator, with a public auction to be held in September. Assets available include plants for the production of ammonia, urea, nitric acid, ammonium nitrate and liquid fertilisers, as well as transportation infrastructure for both road and rail. ■

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Syngas News

UNITED ARAB EMIRATES

Wood to work on UAE's first large-scale green methanol plant

UK engineering and consulting company Wood has received a contract from the UAE's chemicals and transition fuels hub TA'ZIZ to provide project management consultancy for the development of one of the largest methanol plants in the world. Wood will work with TA'ZIZ's engineering, procurement and construction (EPC) contractor, Samsung E&A, to deliver this project.

Gerry Traynor, President of Eastern Hemisphere Projects at Wood, said: "Wood is continuing to deliver complex projects at scale for our clients in the Middle East region, a key strategic growth region. This win with TA'ZIZ is testament to our world-class expertise in downstream chemical facilities and extensive project management capabilities. We are proud to support TA'ZIZ on this significant project for the UAE."

Located in Al Ruwais Industrial City in the western Al Dhafra region of Abu Dhabi, TA'ZIZ's plant is set to become the first methanol production facility in the UAE and one of the largest of its kind in the world. It will produce 1.8 million t/a of green methanol, powered by clean energy from the grid.

Construction of the plant is expected to be completed by 2028 under the EPC contract worth $1.7 billion. The facility is part of the chemicals and transition fuels hub, which will, in its initial phase, produce 4.7 million t/a of chemicals by 2028, including methanol, low-carbon ammonia, polyvinyl chloride (PVC), ethylene dichloride, vinyl chloride monomer, and caustic soda.

FINLAND

Koppö Energia to license thyssenkrupp Uhde methanol technology

Koppö Energia Oy has ordered a FEED (front end engineering design) contract from thyssenkrupp Uhde for its planned green methanol plant, as part of a power-to-x (P2X) project being developed by Koppö Energia in Kristinestad, Finland. The methanol plant will have a planned capacity of 450 t/d to support the maritime and e-gasoline fuel markets. Renewable hydrogen will come from a 200MW water electrolysis plant. CO_2 will be captured in the city of Vaasa in Finland from a waste incineration facility. It will then be liquified and transported via trucks to the P2X facilities.

Nadja Håkansson, CEO of thyssenkrupp Uhde said of the award: "We are proud that our technology and implementation know-how will contribute to this pioneering project by Koppö Energia Oy. This is an excellent proof point for cross-industrial cooperation in the establishment of green methanol as a fuel."

Thomas Zirngibl, Director at Koppö Energia said: "We are very pleased to cooperate with thyssenkrupp Uhde on this project as they bring the right technologies as well as the integration skills for ensuring a smooth tie-in and project delivery."

GERMANY

Uhde and Uniper to partner on ammonia cracking

thyssenkrupp Uhde and Uniper are entering into a strategic partnership to bring large-scale ammonia cracking technology to technological maturity. In the first phase, a demonstration plant with a capacity of 28 t/d of ammonia per day will be built at Uniper's Gelsenkirchen-Scholven site in Germany. The plant will serve as the basis for the planned hydrogen import terminal in Wilhelmshaven, northwestern Germany, where the technology is to be applied on a large industrial scale in a second phase. The aim of the partnership is to convert imported ammonia into hydrogen on an industrial scale and make it available for a wide range of industries such as energy, steel, and chemicals. The cooperation marks an important step towards strengthening energy security and the sustainable transformation of energy-intensive industries. The partners say that the use of ammonia as a transport and storage medium makes it possible to provide green or low-carbon hydrogen from global production sites in large quantities at low cost – a prerequisite for the successful ramp-up of the hydrogen economy.

Holger Kreetz, COO of Uniper said: "Uniper is actively committed to establishing hydrogen as an important component of the future energy mix that combines security and sustainability. Our aim is to strengthen the resilience of the economy. In order to meet Germany's future hydrogen needs, we are dependent on imports from abroad. The partnership between Uniper and thyssenkrupp Uhde is therefore an important milestone for the hydrogen ramp-up and the decarbonisation of industry. With the ammonia cracker in Scholven, we're laying the groundwork to trade hydrogen internationally and making it available across industries."

Nadja Håkansson, CEO of thyssenkrupp Uhde said: "Uniper's position as a leader in the energy markets and experienced asset operator, combined with our proven track record as a global leader in ammonia technology and large-scale plant delivery, forms a strong foundation for success. This joint capability ensures that the cracker plant is optimized not only for performance and efficiency but also for safety, long-term reliability, and total lifecycle cost. This integrated approach ensures a high level of confidence across the industry that the plant will consistently deliver top-tier operational performance throughout its entire lifecycle."

The project is supported by funding from the state of North Rhine-Westphalia to realise innovative components of the demonstration plant at the Scholven site. The plant serves to gain knowledge for the subsequent construction of a large-scale commercial plant. Both companies are also contributing significant funds of their own.

BASF to partner with Plug Power on hydrogen liquefaction plants

BASF says that it has signed a cooperation agreement with Plug Power to offer BASF's advanced DeOxo catalysts as part of Plug Power's hydrogen liquefaction plants globally to enhance their market offerings, improving reliability and cost efficiency. DeOxo catalysts, including the Purivate™ Pd15 product, offer exceptional performance at low temperatures, reducing the need for expensive precious metals. These materials have been fully qualified for use in Plug Power's hydrogen liquefaction plants, establishing BASF as a preferred and specified product provider. In addition to the DeOxo catalysts for the efficient removal of oxygen, Plug Power has also qualified adsorbents like Sorbead® Air for use in their hydrogen plants. Sorbead Air, a specialty aluminosilicate gel, offers energy-efficient dehydration of electrolysed hydrogen. The primary focus of this collaboration is on hydrogen liquefaction plants with capacities of 30, 60, and 90 t/d.

Hy2gen secures funding to accelerate Power-to-X projects

Renewable hydrogen producer Hy2gen AG has completed an additional funding round of €47 million from existing shareholders. The round was led by Hy24, via its Clean Hydrogen Infrastructure Fund, alongside engineering and technology company Technip Energies, and individual founding investor BenDa (the family fund of Hy2gen's Chair Dana Kallasch). The capital will be used to accelerate the deployment of Hy2gen's portfolio of projects producing renewable hydrogen and its derivatives in Europe, Canada and South America – to reach final investment decisions and prepare the construction phase. Hy2gen is designing, building, and operating green hydrogen, ammonia, SAF, e-methane and e-methanol plants using Power-to-X processes to support its clients in decarbonising energy-intensive and strategic 'hard-to-abate' sectors such as shipping and aviation, as well as chemicals and fertilizers. Hy2gen's most advanced projects would represent a total installed electrolysis capacity of approximately 2 GW and a funding requirement of more than €5 billion to start the construction phase by 2027. These include the 300 MW Courant project in Canada, a renewable ammonia and ammonium nitrate plant of approximately €2 billion of capex, currently finalising its design, with construction expected to begin by 2027, the 'Atlantis' plant extension in Germany, which started producing renewable hydrogen in 2023, and the Iverson project in Norway, aiming to produce 200,000 t/a of renewable ammonia annually using renewable hydropower. In addition, Hy2gen is collaborating with H2V in the Fos-Marseille industrial basin, on a 390 MW project with a capex of approximately €1.5 billion, contributing to the decarbonization of Europe's aviation sector with a production of 75,000 tons of sustainable aviation fuel.

Cyril Dufau-Sansot, CEO of Hy2gen, said: "Thanks to our financial and strategic investors we can take our projects to produce renewable hydrogen and hydrogen derivatives to the next level. Looking back at 2022, I am very pleased to receive another capital raise of €47 million thanks to our trusted investors. This enables us to establish ourselves as a top tier supplier of renewable fuels to cut industrial emissions. With this continued support, we maintain our trajectory to lead the development of the renewable hydrogen industry. The demand for renewable hydrogen and hydrogen derivatives is growing with the long-term economic need to decarbonize industries."

Pilot production plant for hydrogen electrolysers

thyssenkrupp nucera and Fraunhofer IKTS have opened the first pilot production plant for high-temperature electrolysis (SOEC) stacks at Arnstadt, Thuringia. It follows a strategic cooperatino agreement in March 2024 between the Fraunhofer research institute and nucera, a leading supplier of electrolysis technology for the production of green hydrogen. Building on the development work carried out by Fraunhofer IKTS, thyssenkrupp nucera will now work with Fraunhofer IKTS to advance SOEC technology for the manufacture of stacks for the production of green hydrogen on an industrial scale. The SOEC pilot plant initially produces stacks in small quantities and has a target production capacity of 8 MW per year.

SOEC stack technology is based on an oxygen-conducting ceramic electrolyte substrate with two electrodes, which are assembled together with coupling elements, the chromium-iron interconnectors, on several layers to form the stack. Chromium iron-based SOEC technology guarantees high corrosion resistance, optimized thermal cycle performance, and high long-term stability with regard to temperature cycling. In addition, stack technology requires only a small number of components and occupies a leading position compared to designs currently available on the global market. The SOEC cell design is also well suited for highly automated series production. SOEC electrolysis leads to higher efficiency because less electrical energy is required to split water vapor at high temperatures. When commercial high-temperature electrolysis is used in processes that generate large amounts of waste heat, such as in the steel industry, electricity consumption can be reduced by 20% to 30% compared to other technologies.

"The outstanding properties of SOEC technology have prompted us to work with our strategic partner Fraunhofer IKTS to develop high-temperature electrolysis to market maturity. We are convinced of the advantages of this electrolysis technology for the production of green hydrogen. It will play a central role in a new, climate-friendly energy mix," says Dr. Werner Ponikwar, CEO of thyssenkrupp nucera.

New installation for CO_2 to syngas catalyst

Clariant says that its ShiftMax 100 RE catalyst is now in operation at INERATEC's Era One e-fuels production plant in the Frankfurt Hoechst industrial park. The facility will transform around 8,000 t/a of CO_2 into up to 2,500 t/a of synthetic fuels and waxes. The e-fuels produced at the INERATEC facility can be used as drop-in replacements in existing engines and infrastructure without modification, making them an attractive near-term solution for hard-to-abate sectors like aviation, where electrification remains challenging.

Georg Anfang, Vice President at Clariant, said, "Our collaboration with INERATEC demonstrates how Clariant's catalyst technologies are helping to make sustainable fuels a commercial reality. As global demand for sustainable aviation fuels continues to grow, driven by both regulatory requirements and corporate sustainability commitments, our catalyst technologies are helping to bridge the gap between conventional and renewable energy systems."

Clariant says that its catalyst presents several critical advantages for industrial e-fuels production. Used in the reverse water gas shift process, the nickel-based reforming catalyst offers high efficiency in converting green H_2 and captured CO_2 into renewable syngas, the precursor for synthetic fuel. It also excels in selectivity, resistance to coking, and high-temperature stability while offering an extended lifetime. These combined properties enable greater productivity and durability, which are paramount for economic viability.

UNITED KINGDOM

Approval for hydrogen engine

JCB says that it has passed a significant milestone on its hydrogen technology development programme after securing the first full EU type-approval of its hydrogen engine for use in non-road mobile machinery. This means that JCB's hydrogen engine has been approved for sale and for use in machines and third-party OEM

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PHOTO: JCB

A hydrogen powered JCB excavator.

equipment in each of the 27 EU member states, and all other territories recognising EU type-approvals.

JCB Chairman Anthony Bamford, who has led the company's hydrogen engine project, said: "This is another very significant moment for JCB's hydrogen programme, It was not so long ago that some said that it was 'game over' for the internal combustion engine in Europe. For JCB to have secured full EU type-approval is proof positive that the combustion engine does indeed have a promising future in pursuit of a net zero world if hydrogen, a zero CO_2 fuel, is used instead of fossil fuels."

Lord Bamford added: "I could not be more delighted for the JCB team that put so much work into getting us to this stage. Now our focus will be on bringing our hydrogen technology to market. JCB's customers are patiently waiting for our hydrogen-powered equipment to make a difference on their job sites. They won't have much longer to wait."

SPAIN

Plans for biogenic methanol plant

Three European energy companies are planning to develop a green methanol plant in Spain that will capture around 380,000 t/a of biogenic carbon dioxide, which will be used to produce 200,000 t/a of methanol. Spanish renewable energy firm Magnon will oversee the carbon capture portion of the project, while partners Power2X and ErasmoPower2X will handle the hydrogen supply. Part of this will see ErasmoPower2X supplying green hydrogen from its facilities in nearby Saceruela. The project will be located at Magnon's industrial complex in Puertollano, Ciudad Real, where the carbon capture technology will be fitted into its existing biomass plant.

"This initiative … will decarbonise various Spanish industries [such as] steel, automotive, refineries, and aviation," said Niels van Buuren, EVP of Business Development at Power2X.

Spain has been scaling up its green hydrogen production capacity in recent years, positioning itself as a southern European hub for renewable hydrogen and its derivatives. The country has more than 20 low carbon methanol or power-to-liquid fuel projects at various stages of development, many of them clustered around industrial regions like Andalusia and Castilla-La Mancha. This momentum reflects broader European decarbonisation goals, including the latest Renewable Energy Directive (RED III), which sets binding targets for renewable fuels of non-biological origin in transport and industry. Additional frameworks such as the EU Hydrogen Strategy and the RePowerEU plan further incentivise member states to support synthetic fuel production as part of the bloc's push to phase out fossil fuels.

UNITED KINGDOM

JM to sell its Catalyst Technologies business

Johnson Matthey Plc (JM) says that it has reached an agreement to sell its Catalyst Technologies (CT) business to Honeywell International, Inc. for £1.8 billion ($2.45 billion) on a cash and debt-free basis. The transaction is expected to deliver net sale proceeds of around £1.6 billion ($2.18 billion) to the JM group, subject to customary closing adjustments. Following the sale of CT, JM says that it will be repositioned as a highly streamlined group focused on clean air and platinum group metal sales, supporting the delivery of at least mid-single digit CAGR over the next few years with a material increase in Group cash generation to at least £250 million of Group free cash flow by the 2027-28 financial year, underpinned by growth in underlying operating profit, capex reducing to close to maintenance levels and material working capital benefits.

Patrick Thomas, Chair of Johnson Matthey, said: "On behalf of the board, we are pleased to announce the sale of CT which, together with the refreshed strategy of the Group, represents a strategically and financially compelling proposition for shareholders. Today's transaction realises significant value for shareholders, creating a Group with the core strengths, focus and discipline to deliver strong returns for shareholders into the future."

Liam Condon, Chief Executive of Johnson Matthey, said: "Today's announcement represents a significant milestone in the history of Johnson Matthey. This allows JM to realise a very attractive valuation for this business that fully reflects its strong long-term growth prospects. We will now fundamentally reshape Johnson Matthey into a more focused and leaner business. This will better position us to leverage our strong capabilities and leading market positions in Clean Air and PGM Services to drive a step change in sustainable cash generation with higher returns to shareholders. JM is a great company and we are confident that the actions we have announced today will deliver substantial and sustainable value to our shareholders."

JM's Catalyst Technology division is a global leader in the licensing of process technology and supply of catalysts, with a pipeline of more than 150 projects in its sustainable technologies portfolio that is expected to deliver attractive long-term profitable growth as the world transitions to net zero. ■

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People

Nishant Kanodia, chairman of Matix Fertilisers and Chemicals Ltd, has been appointed to the board of directors of the International Fertilizer Association (IFA). The appointment was formalised at the IFA Annual Conference 2025 in Monaco, with the theme of 'Investing in the Future of Food'. With approximately 500 members across more than 80 countries, IFA champions policy, innovation, and sustainable fertilizer practices that contribute to global food security.

Alzbeta Klein, CEO & Director General of IFA, said: "We are delighted to welcome Nishant Kanodia to the IFA Board. India's pivotal role in global agriculture, together with Mr. Kanodia's visionary leadership, will be instrumental in advancing IFA's mission for sustainable, resilient food systems worldwide."

India's agricultural sector has transformed a mid-20th-century food scarcity to becoming a leading global producer of staples, cereals, pulses, fruits, and vegetables. Through technology adoption, nutrient management, and farmer empowerment, India now plays a central role in global food security and consciously contributing to climate-resilient farming.

Speaking on his induction to the IFA board, Nishant Kanodia said: "It is a privilege to join the IFA board at a time when India is increasingly central to global food security. The need for balanced nutrient management and innovation-driven growth has never been greater. I look forward to supporting IFA's efforts to empower farmers, protect ecosystems, and enhance productivity globally and in India."


Nishant Kanodia, Chairman, Matix Fertilisers and Chemicals.

Under Mr. Kanodia's leadership, Matix Fertilisers has established itself as a market leader in eastern India, with a 20% share of the region's urea market. It produced a record 1.47 million tonnes of fertilizer in the 2024-25 fertilizer year at its facility in Panagarh, West Bengal, operating at over 115% of annual rated capacity.

In a regulatory filing, Tata Chemicals has said that **N Chandrasekaran** will step down as chairman and director effective from May 29th 2025. S Padmanabhan has been appointed as the company's new chairman. Additionally, acting on the recommendations of the Nomination and Remuneration Committee, the board approved the appointment of **Modan Saha** as an additional director in a non-executive, non-independent capacity. Tata Chemicals noted that Saha is currently leading key strategic initiatives at Tata Sons.

Chandrasekaran, in a letter to the board, wrote: "I am writing to formally inform you of my decision to step down from my position as a director and Chairman of the Board of Directors of Tata Chemicals Limited with effect from 29th May, 2025. After careful evaluation of my current and future commitments, I have decided to step down from the Board. It has been a privilege to chair the Tata Chemicals board and I sincerely appreciate the support and collaboration during my tenure."

Methanol Chemicals (Chemanol) has appointed **Fares Al Abbad** as acting CEO, following the termination of **Sabri Abdullah Al Ghamdi's** contract for personal reasons, the company said in a disclosure to Tadawul. Al Abbad has over 27 years of experience in the petrochemical industry and project development, where he assumed senior roles at Sabic and its affiliate Petrokemya, and previously held the position of Vice President of Manufacturing at Chemanol. He will assume the duties of acting Chief Executive Officer until the new CEO officially assumes the position, which is expected to take place in July. He was also part of the team involved in oil-to-petrochemical conversion projects, and holds two patents in the same field. **Sabri Al-Ghamdi** will now become a non-executive director. ■

Calendar 2025/2026

SEPTEMBER

8-11

69th AIChE Ammonia Safety Symposium, ATLANTA, Georgia, USA
Contact: Ilia Kileen, AIChE
Tel: +1 800 242 4363
Web: www.aiche.org/ammonia

15-17

TFI World Fertilizer Conference, CHICAGO, Illinois, USA
Contact: The Fertilizer Institute
Tel: +1 202 962 0490
Email: info@tfi.org

OCTOBER

12-15

Global Syngas Technologies Conference, SAN DIEGO, California, USA
Contact: Global Syngas Technologies Council, PO Box 18456, Sugar Land, TX 77496 USA.
Tel: +1 713 703 8196
Email: info@globalsyngas.org

13-17

Ammonium Nitrate/Nitric Acid Conference, OMAHA, Nebraska, USA
Contact: Sam Correnti, DynoNobel, Karl Hohenwarter, Borealis.
Email: sam.correnti@am.dynonobel.com, karl.hohenwarter@lat-nitrogen.com, annaconferencehelp@gmail.com
Web: annawebsite.squarespace.com/

14-16

World Methanol Conference, LISBON, Portugal
Contact: OPIS CMAI
Email: Events@ChemicalMarketAnalytics.com

20-22

Ammonia Energy Association Annual Conference, HOUSTON, Texas, USA
Contact: Ammonia Energy Association
Email: meetings@ammoniaenergy.org
Web: https://ammoniaenergy.org/conferences-events/

JANUARY

26-28

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

FEBRUARY

10-12

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

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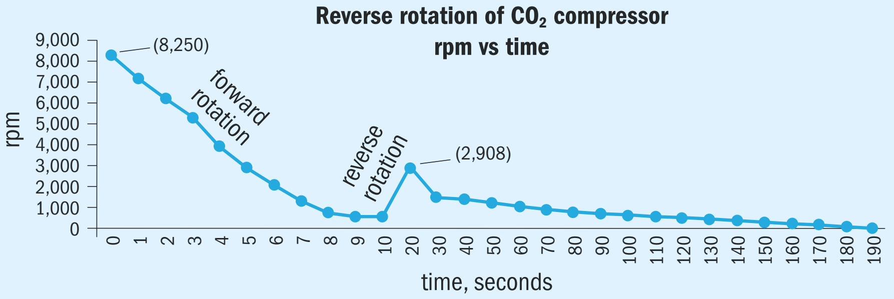
Plant Manager+

Problem No. 75 Reverse rotation of the CO_2 compressor

Reverse rotation of an inline four-stage centrifugal CO_2 compressor is an unwanted phenomenon which sometimes occurs in urea plants. Reverse rotation can lead to damage to the internals of the CO_2 compressor and an unexpected outage. This discussion shares experiences and provides suggestions on how to avoid reverse rotation of the CO_2 compressor. ■



Miss Bhawna of NFL in India kicks off this round table discussion: What harm can reverse rotation of the CO_2 compressor do and how it can be prevented?

Niranjan Murthyp of Mangalore Chemicals and Fertilizers in India asks for further clarification: First let us know which type of compressor and why it is rotating in reverse direction?

Bhawna replies: When the centrifugal compressor tripped the higher pressure at the discharge side of the centrifugal compressor can overcome the lower pressure that is always present at the suction side of the compressor. In this situation reverse flow is possible. Some plants have reported reverse rotation phenomena in the CO_2 centrifugal compressors.

Serpoush of Shiraz Petrochemical Complex in Iran contributes to the discussion with his valuable experience: In the CO_2 compressor outlet, three valves (check valve, shutdown valve and bleed valve) may stop the reverse flow by depressurising the compressor discharge pipe line, and in doing so preventing reverse rotation. The shutdown valve and bleed valve are automatic valves and are located in the discharge outlet pipe line and before the non-return valve that is actuated by trip signal(s).

Ajay from CCFL in India shares his opinion: Reverse rotation of the compressor may damage internals such as bearings, seals etc.

Mark Brouwer of UreaKnowHow.com in the Netherlands joins the discussion: CO_2 compressors typically have four reverse flow protections in its discharge line:

1. Trip shut-off valve
2. Vertical non-return valve (NRV)
3. Horizontal non-return valve
4. Pressure release valve

But reverse gas flow through the compressor is possible, caused either by passing of the level control valve of the 3rd separator or by passing of the non-return valve at the 3rd suction. A compressor is not designed for reverse rotation, this phenomenon may cause damage to the bearings and misalignment. To overcome this problem, the pressure release can be linked (open) with the trip logic of the compressor.

Pawan Verma of IFFCO in India also joins the discussion: Reverse gas flow through the CO_2 compressor is only possible when the NRV provided in compressor is passing and the size of the vent control valve provided in the final discharge line and at the 3rd discharge line is insufficient to discharge the volumes trapped.

The problem of reverse flow may be overcome by regular servicing of the non-return valves and by increasing the vent valve size provided in the compressor.

Prem Baboo, Expert of UreaKnowHow.com shares his valuable expertise and experience: We have also experienced reverse rotation in our urea line-II in 1997. When the centrifugal compressor tripped, the higher pressure at the discharge side of the centrifugal compressor was able to overcome the lower pressure that is always present at the suction side of the compressor. This is a situation that possibly creates reverse flow. Some plants have reported reverse rotation phenomena in the CO_2 centrifugal compressor. Reverse rotation is an unwanted phenomenon in a centrifugal machine as it is always associated with severe radial vibration and axial displacement which may lead to damage of the bearings and rubbing of seals with the stationary components. Bearing failure is a definite possibility. Seals are not rated for this rotational speed. Internal compressor components may become dislodged. There is a high possibility of vibration damage in the reverse position. Coupling is rated for the rotational speed as long as the train does not become energised. Rotor over speed can cause over stressing in the bearing (journal/thrust) causing fit to loosen or worsen.

To safeguard against reverse rotation in CO_2 compressors the following changes are proposed: During shutdown the anti surge valve (HV-62) provided from the 4th stage discharge to the 1st stage suction and the 2nd stage vent (HV-61) provided from the 2nd stage discharge to the atmosphere should be open. In addition, HV-63 provided from the 2nd stage discharge to the 1st stage suction logic should be changed so that it opens through the solenoid during tripping. The timing of opening of HV-61 should be decreased. In addition, the final discharge vent (PV-3) logic should be changed to open it during tripping of machine. The capacity of the CV should be on the higher side.

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Mark comes back: Reverse rotation can be avoided by installing kick back from casing to casing and installing the non-return valves at discharge of final stage.

Syed Salman of Agritech in Pakistan shares his valuable experience: In my view, reverse movement of the shaft is only possible in case of high poly-tropic/discharge head or in simple words "surging". Once the compressor is tripped due to actuation of the surge counter security, reverse movement is almost impossible because:

- Kick backs will automatically open and equalise the pressure between the suction and discharge ends of compressors.
- Generally auto valves at the compressor discharge open automatically to relieve the discharge line.
- Additional protection in terms of non-return valves is also available.

Gas within the compressor at its discharge ends does not have much force to first stop the compressor nor much capability to provide the force required for meeting the requirement of the starting torque. However in case of reverse rotation, an important point is the speed of the compressor i.e. at high speeds it will definitely causes vibrations and damage to seals.

Bhawa comes back: Please refer to the detailed paper by Mr Gautam and Mr Panda of IFFCO Phulpur about the case of reverse rotation of the rotor of a centrifugal CO_2 compressor. A centrifugal machine experiences reverse torque due to reverse flow of high pressure fluid from the discharge side to the suction side through the rotor as soon as the machine is tripped at full load. But reverse rotation is an unwanted phenomenon as it is always associated with severe radial vibration and axial displacement of the rotor which may lead to damage to the bearings and rubbing of seals with the stationary components.

This paper describes how the reverse rotation of the CO_2 compressor trains provided in phase-II urea plants at Phulpur was diagnosed by the analysis of post trip data picked up by Data Manager-2000 and the step-by-step in-house approach to find the solution. https://ureaknowhow.com/1997-gautam-iffco-phulpur-reverse-rotation-co2-compressor/

And a similar case is described by Prem Baboo: Reverse rotation phenomenon in the CO_2 compressors during stopping of turbine was observed in 1997. In our Vijaipur unit, CO_2 compressors were installed for four streams of the urea plant namely (11, 21, 31, and 41). CO_2 Compressors are of BHEL (India) design. In our case line-I urea plant (11, 21 streams) were commissioned in 1987 whereas line-II urea (31, 41 streams) were commissioned in 1997. Reverse rotation is an unwanted phenomenon as it is always associated with severe radial vibration and axial displacement of the rotor which may lead to damage to the bearings and rubbing of seals with the stationary components.

This paper describes how the reverse rotation of CO_2 compressor trains provided in line-II urea plants at Vijaipur was diagnosed by the analysis of post trip data picked up by Data Manager and the in-house approach to find the solution. https://ureaknowhow.com/forums/topic/reverse-rotation-of-co2-compressor/#post-120694

Syed replies: In my understanding, the case study you have shared is self-explanatory. Actually, it is a sort of investigation report based on PDCA cycle, revealing some design constraints regarding relieving the 3rd stage pressure through the 4th stage and uneven depressurisation of inter-stage piping and equipment. This uneven depressurisation generates enough torque to be capable of rotating the shaft in the reverse direction. Latterly, the problem was resolved by instantaneous opening of the "2-1" recycle valve with the application of a solenoid valve along with the 2nd stage vent and by incorporating some modifications in the interlock system. In my view, there should be no reverse rotation in the compressor if there is no design constraint. Anti-surge, vent and non-return valves are provided in order to prevent such problems in the worst conditions.

Let me share our experience with you regarding design constraint. We have a turbine driven centrifugal compressor comprising of LP and HP casing and each casing consists of 2 stages installed on CO_2 service. The original equipment manufacturer is MHI, Japan. The anti-surge system is provided by CCC, USA consisting of 1-1, 2-1 and 4-3 kick backs. The machine is designed to raise the pressure from 0.9 kg/cm²^2.g to 178 kg/cm^2.g under normal operating conditions. A few years before, we were shutting down the plant in an emergency due to some problems in our national gas headers. The compressor tripped due to actuation of low pressure security at the first suction. This was surprising because everything was going smoothly as per our standard operating procedures. Latterly it was found that 2-1 kick back opens rapidly letting down the pressure from 44 ~ 0.9 kg/cm^2.g in order to meet the flow requirements at the 1st suction. This sudden opening results in formation of dry ice, even after the injection of hot gas and restricts the flow passage downstream of the kick back. This design constraint was resolved by some counteractive measures.

Sandeer Kochar of GNFC in India shares his valuable experiences: We, at GNFC Bharuch, are facing the same problem of reverse rotation in the CO_2 compressor. Based on Prem Baboo's technical paper and after consultation with the OEM BHEL, opening of the 2nd stage recycle control valve (HC-1) has been incorporated into the machine trip logics. However, after this modification, we are still experiencing reverse rotation. Our control valve response timings are as follows:

Sr no.	Tag no.	Description	Start open/ fully open (seconds)
1.	HC-1.3	2nd discharge vent to atm	0.5/5.5
2.	HC-2	4th to 1st recycle	0/4.4
3.	HC-1.4	4th discharge vent to atm	5.5/12
4.	HC-1	2nd to 1st recycle	0/22 (newly added)

Recycle from the 2nd stage discharge to the 1st suction takes 22 seconds to fully open. Can reducing this time solve our problem? If yes, then how many seconds are needed to fully open? Our plant operates at 40,000 Nm^3/hr CO_2, whereas the control valve has a nominal capacity of 30,200 Nm^3/hr. Can closing of the CO_2 inlet valve on compressor tripping solve the reverse rotation problem? ■

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Recent developments in the ammonia market

Increased merchant ammonia capacity over the next few years may lead to longer term price declines.

Global production of ammonia increased by another 6 million t/a to 202 million t/a in 2024. Merchant supply, while only a small fraction of the total, nevertheless increased significantly by 1.1 million t/a to 17.7 million t/a, just under 9% of the total. It remains the case that most ammonia is consumed at the point of production, mainly in captive downstream urea, ammonium nitrate, nitric acid and ammonium phosphate production, as ammonia is more difficult and expensive to transport than most downstream products. Merchant ammonia demand therefore tends to be focused more on industrial uses such as caprolactam, acrylonitrile, adipic acid, and isocyanates, or for ammonium phosphate manufacture, which is centred on regions of phosphate mining like Florida, Morocco, Jordan etc. However, there are now an increasing number of low carbon merchant ammonia plants under development which may change this calculus.

India remains the largest importer of ammonia, at around 2.2 million t/a in 2024, with the US at 2.0 million t/a, Morocco at 1.7 million t/a and South Korea at 1.2 million t/a collectively representing 40% of all ammonia trade. India, the US and Morocco are all focused on domestic ammonium phosphate production, with South Korea mainly using imported ammonia for nitric acid for industrial uses.

Trinidad, Saudi Arabia and Indonesia were the largest exporters in 2024, at 3.5 million t/a, 2.4 million t/a and 1.8 million t/a respectively. Canada and the US exported 1.0 and 1.4 million t/a, and Algeria 1.3 million t/a. This means that the top six exporters represented two thirds of all ammonia exports. Russia dropped to seventh place due to sanctions at 978,000 t/a.

New capacity

New merchant ammonia capacity is being commissioned, beginning this year with the Gulf Coast Ammonia project in the US, which has been pushed back from a target completion date in 2023 to 1H 2025. The Woodside Beaumont plant is now scheduled to come onstream in the second half of 2025. These two plants will add 1.3 million t/a and 1.1 million t/a to US ammonia capacity and 2.4 million t/a to merchant ammonia supply, which is expected to weigh on prices going into 2026. Additional supply will follow from Qafco's Ammonia 7 Project and Fertiglobe's TA'ZIZ plant in 2026 and 2027, respectively, which will further add to availability and extend the period of depressed prices. Some relief may come in 2028 when the startup of the ammonium phosphate section of the Ma'aden III plant in Saudi Arabia will remove 1.1 million t/a of ammonia from the market, and by 2029 the market is expected to begin to rebalance and supply pressures ease, leading to a modest price recovery.

Table 1: **New merchant ammonia capacity 2025-2029, ex-China**

Plant	Country	Type	Capacity, million t/a	Date
Gulf Coast Ammonia	US	Grey	1.3	2025
Woodside Beaumont	US	Blue	1.1	2025
Qafco Ammonia 7	Qatar	Blue	1.2	2026
TAZ'IZ	Abu Dhabi	Blue	1.0	2027
Ma'aden III downstream	Saudi Arabia	Grey	-1.1	2028
Returning capacity	Russia	Grey	+2.0	2025-29
Total			**5.5**	

Source: CRU

Supply – Russia

Togliattiazot's transshipment terminal at Taman in the eastern Black Sea has been delayed and is now expected to start ammonia shipments this year. It will come at a similar time to the startup of the new ammonia transhipment terminal at Ust-Luga on the Baltic Sea. Ust-Luga has a planned capacity of 1 million t/a this year, with a potential expansion to 1.5 million t/a by 2026, offering a more efficient alternative to the current truck-based transport. It remains to be seen if Russian producers can deliver all of that ammonia to port. EuroChem's 1 million t/a Kingisepp plant supplies ammonia to Ust-Luga, but it only managed to export around 600,000 tonnes from Ust-Luga in 2024. The second train at Kingisepp, scheduled for 2026, could boost output, but much of the ammonia will be used for urea production. Other plants that previously exported via Ust-Luga have shifted focus to downstream products, further limiting ammonia exports. There is also the potential for war-related disruption; Ukrainian drones attacked the port of Ust-Luga in January 2025 and could do so again.

EU tariffs on Russian fertilizers but excluding ammonia could help boost ammonia exports, but despite combined


PHOTO: PORT OF UST LUGA

Russia's Baltic port of Ust-Luga, now expanding its ammonia throughput.

export capacity of 3 million t/a at Taman and Ust-Luga, Russian exports may rise to 1.0 million t/a in 2025 and as high as 2.6 million t/a by 2029, in line with increased ammonia production and improved utilisation rates, expected to reach 97%.

Trinidad

Trinidad, conversely, had been facing pressure on its ammonia exports as US demand contracts and US supply expands. Trinidad returned to its position as the largest exporter of ammonia in 2023 due to contractions in Russian exports, but domestic gas supply issues have hit production in recent years, reducing operating rates to below 75%. Trinidad's exports of ammonia increased from 3.1 to 3.5 million t/a in 2024, but this is still down from 5.3 million t/a a few years earlier.

Low carbon capacity

With a surge in merchant capacity expected in the medium term, CRU has incorporated low carbon ammonia projects that have reached a final investment decision into our base case scenario, reflecting the expectation that new end markets such as power generation, hydrogen carriers, and marine fuel will not generate significant demand in the near term, forcing new blue ammonia capacity to compete with traditional grey ammonia markets. Blue ammonia volumes will attract interest from EU importers as the Carbon Border Adjustment Mechanism comes into force from 2026, with importers able to reduce costs by substituting imports of grey ammonia with low emissions ammonia. This will enable suppliers to attract premiums for low emissions ammonia.

Woodside's Beaumont project and QAFCO's Ammonia 7 project are both based around carbon capture and sequestration to produce low emissions ammonia. Fertiglobe's Taziz project, scheduled later for 2027, will produce lower carbon ammonia via other means. New supply from renewable-energy based ammonia projects, like NEOM in Saudi Arabia, are not reflected in this analysis due to the greater potential for it to service any new end-use demand that does eventuate.

Demand – Europe

High feedstock costs continue to force the closure of European ammonia capacity. Stringent emissions regulations such as the EU's Emissions Trading Scheme, elevated energy prices, and growing global competition have weighed heavily on operating rates, with Western Europe's plants expected to run at just 55% in 2025, well below historical levels. Recent closures include Yara's closure of its Tertre ammonia plant in Belgium, which means that it will have to rely on imported supply to meet its downstream production needs. Yara also reportedly has plans to mothball its 300,000 t/a Hull plant in the UK, which exported around 214,000 t/a to its downstream operations in Europe in 2024. LAT Nitrogen is also halting ammonia production at its Grandpuits site in northern France due to rising production costs. The site has a capacity of around 440,000 t/a of ammonia and typically produces a surplus of approximately 130,000 t/a. As producing ammonia in Europe becomes less economical compared to importing, the region will increasingly rely on other sources where production costs are lower. This would result in a surge of import demand from less efficient plants or higher cost producers, leading to the upward revision of Europe's imports.

To curb carbon leakage from imports, the EU has introduced the Carbon Border Adjustment Mechanism (CBAM). This aims to align imported goods with EU-produced ones by factoring in embedded emissions, applying the EU ETS carbon price, and considering carbon costs paid outside the bloc. From 2026 to 2033, CBAM obligations will gradually expand as free EU ETS allowances are phased out, though potential policy adjustments remain a possibility. CRU's Emissions Analysis Tool estimates CBAM liabilities based on the weighted average emissions intensity of ammonia imports. The tax is projected at $67/t in 2026, rising to $130/t by 2029 due to increasing carbon prices and the gradual removal of free allowances.

Recovery in European ammonia production is restricted by sustained margin pressures and high feedstock costs, with TTF prices staying above historical norms. As such, ammonia production is expected to remain below historical levels, with margins staying negative for much of 2025. While CBAM's introduction in 2026 will level the playing field on carbon costs, structural cost challenges will persist.

Morocco

Morocco's ammonia imports are expected to increase as it continues to build new ammonium phosphate capacity. OCP had a record year for exports in 2024 and is expected to maintain this performance in 2025. However, the company has been prioritising TSP exports, particularly to India, which does not require ammonia input. Consequently, ammonia import growth is expected to be marginal in 2025 before gaining momentum as ammonia prices ease and phosphate demand recovers. CRU projects an increase in imports from 1.64 million t/a in 2025 to 1.84 million t/a in 2029 as DAP output rises rise from 2.33 million t/a in 2025 to 2.45 million t/a in 2029, and MAP production from 1.53 million t/a to 2.04 million t/a.

India

India's ammonia imports are projected to rise to 2.3 million t/a in 2025 due to depleted DAP stocks, with steady growth to 2.6 million t/a by 2029, in line with DAP production reaching 2.2 million t/a. Meanwhile, India's urea production is expected to decline to 30.3 million t/a in 2025 before a modest recovery to 31.5 million t/a by 2029. However, the gap between production and domestic consumption is projected to widen, reducing internal ammonia consumption.

China

In 2024, China produced a record 73.1 million t/a of ammonia, an 8.1% increase year-on-year. Over the next five years, 14.2 million t/a of new ammonia capacity is expected to be built, with 5.9 million t/a coming from 15 plants in 2025, 4.7 million t/a from ten plants in 2026, and 1.7 million t/a from three plants in 2027. Three additional plants with a combined 1.9 million t/a capacity are set to come online in 2028, with no new capacity expected in 2029. Most of the new capacity is based on bituminous coal and many closures involve anthracite or natural gas. During the same period, around 1.8 million t/a of ammonia capacity is expected to be closed, including 1.0 million t/a from anthracite-based plants and 0.8 million t/a from natural gas-based plants.

China's self-sufficiency in non-fertilizer industries continues to increase. Acrylonitrile demand is now 100% self-sufficient, dimethyl formate 90%, and ammonium nitrate about 80%, reducing demand for merchant ammonia. Additionally, about one quarter (3.4 million t/a) of the new capacity from 2025-2029 will be integrated for non-urea use, further limiting merchant ammonia demand. This rapid capacity growth and increased self-sufficiency are expected to reduce China's ammonia imports over the forecast period. Chinese ammonia imports may decline to 0.4 million t/a this year, and may be as low as 0.2 million t/a by 2029, driven by a worsening arbitrage between domestic prices and import cost. Chinese ammonia exports will also likely rise, reaching 165,000 t/a by 2029, making China in almost a net exporter. The growth in domestic supply, alongside tight export restrictions on urea, is expected to create an oversupply in the medium term. Additionally, China's port ammonia storage capacity is set to reach 600,000 m^3 by 2026, as new tanks under construction in Nanjing and Lianyungang will add 100,000 m^3.

Tariffs

US tariffs on Canadian ammonia, delayed from 4 February to 2 April 2025, could impose a 25% levy on exports, creating risks for both the Canadian nitrogen industry and US agriculture. Canada exports over 1 million t/a of ammonia to the US and relies heavily on this market, though it has experienced a 9.5% year on year decline in exports, indicating higher domestic consumption. This may mitigate the tariff's impact if implemented. As a low-cost producer, Canada could absorb the tariff and maintain margins, despite limited alternative offtake options. However, given ammonia's inelastic demand, any reduction in Canadian exports could push US fertilizer prices in the Northern Plains higher.

The European Union's proposed tariffs on Russian and Belausian fertilizers, aimed at boosting domestic production and reducing reliance on imports, are expected to increase fertilizer costs in Europe. While this measure may encourage more domestic fertilizer production, it will also drive higher ammonia demand. However, high natural gas prices will continue to make domestic ammonia production costly, leading to a rise in ammonia imports. The EU's reliance on imports is projected to grow from 31% of ammonia demand in 2024 to 44% as imported ammonia remains the more cost-effective option. It's also worth noting that while ammonia is excluded from these tariffs, the EU reinstated a 5.5% import duty on ammonia, including Russian imports, in June 2023 after a six-month suspension.

Trade

Overall, global ammonia imports are projected to grow steadily, reaching 21.4 million t/a by 2029, with European and Moroccan demand rising, while China's imports are expected to decrease due to expanded domestic production. Russian and US ammonia exports are expected to increase, though competition will intensify with new capacity. US tariffs on Canadian ammonia could raise fertilizer costs, impacting both the Canadian nitrogen industry and US agriculture.

European imports are expected to grow steadily, increasing by 800,000 t/a in 2026 as weak margins from declining ammonia prices support higher import demand. In contrast, China's ammonia imports are forecast to decline as domestic production capacity expands. Russian exports are set to grow, reaching 2.6 million t/a in 2029, but they are unlikely to completely return to pre-war levels. Meanwhile, US ammonia exports are expected to gain market share, driven by new capacity from the Gulf Coast Ammonia and Woodside Beaumont projects. This increase in supply will heighten market competition, particularly with improved availability from the Middle East. As a result, Trinidad's export growth is forecast to see some declines. Europe's demand for blue ammonia will grow with the implementation of CBAM, capturing some share from grey ammonia imports.

Pricing

Ammonia prices are expected to decline from 2025 due to the major capacity additions noted above, and the increase in exports from Russia. These will create a significant market surplus, keeping prices depressed through to 2028. European production continues to face challenges from high energy costs, which combined with falling ammonia prices will result in favourable importing conditions with the potential for further production curtailments and plant closures.

While strong supply from the US Gulf, North Africa, and the Middle East will limit sharp price increases, potential delays in capacity expansions, unplanned outages, and a more volatile energy market could provide upside pressure toward late 2026. Nonetheless, overall, prices are expected to remain on a downward trajectory. A recovery is not anticipated until 2029, when the market is expected to rebalance, and no significant new capacities are added. ■

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Ammonia safety update

As well as a recent US Chemical Safety Board report on an ammonia release incident, the past year has seen considerable focus on safety of ammonia at sea, in preparation for its possible use as a clean burning maritime fuel.

Ammonia is the second largest chemical produced worldwide by tonnage after sulphuric acid – approximately 200 million tonnes in 2024. While its toxic properties are well known and characterised, the sheer volume of ammonia being produced and used worldwide means that safety incidents regrettably continue to occur, and safe handling of ammonia remains an important topic for the industry. This article looks at some of the developments in ammonia safety in the past year.

CSB report on ammonia release

In November 2024 the US Chemical Safety and Hazard Investigation Board (CSB) issued its interim report on an ammonia release which occurred at Cuisine Solutions in Sterling, Virginia on July 31st 2024. At the time of the incident, 286 personnel, which included employees and contractors, were on site. The company, producing packaged foods, had an ammonia refrigeration system to control chilled water temperature in its processes and to operate freezers and food storage areas. Emergency pressure relief valves, set at 300 psi, protected the heat exchangers and associated equipment from excess pressure conditions, and discharged ammonia to the atmosphere.

At about 8:20pm personnel located in a cafeteria and break area inside the building and adjacent to the release point identified and reported an ammonia odour. An emergency pressure relief valve had discharged ammonia from a release valve horizontally near the roof of the building and formed a white cloud of ammonia vapour which was partially visible outside the emergency exit door for this area, on the west side of the building. Accordingly, the site manager directed all personnel to evacuate the building via the opposite (east) side of the building. However, some personnel unwittingly exited the building near or into the ammonia cloud and were exposed to ammonia vapour. Four workers were admitted to local hospitals, including one to intensive care. Fortunately there were no fatalities. Cuisine Solutions reported that approximately 170 pounds (77kg) of anhydrous ammonia were released. The three-way valve to isolate the emergency pressure relief valve was turned to stop the release by approximately 9:30 pm with the assistance of emergency services.

The CSB says that it is continuing to gather facts and analyse several key areas for its final report, including: potential causes of the ammonia emergency pressure relief valve opening; the total quantity of ammonia released; Cuisine Solutions' emergency action plan for an ammonia release, and its process safety management and risk management programs and policies; and general codes and standards for ammonia refrigeration systems.

Maritime ammonia safety

Recent updates in ammonia safety have focused on enhancing guidelines for using ammonia as a marine fuel, particularly for ships. The International Maritime Organisation (IMO) has recently (March 2025) released interim guidelines and says that it is working towards finalising comprehensive safety standards, including those for ships using low-flashpoint fuels like ammonia. The IMO's Maritime Safety Committee (MSC) approved the guidelines in December 2024, following their development and finalisation by the Sub-Committee on Carriage of Cargoes and Containers (CCC) in September 2024.

The interim guidelines provide a goal- and function-based safety framework covering ship design, equipment, operations, bunkering, toxicity mitigation, and crew protection. While the guidelines are non-mandatory, they align closely with the IGF Code and SOLAS (Safety Of Life At Sea) principles. The guidelines aim to ensure that ammonia-fuelled systems offer at least the same level of safety and reliability as conventional oil-fuelled machinery, recognising ammonia's specific hazards, including high toxicity, potential for explosive atmospheres, and material compatibility challenges. They encourage early uptake while noting that further refinements will be necessary as operational experience is gained, particularly in relation to toxicity controls and emergency systems.

EMSA

The European Maritime Safety Agency (EMSA) published its own comprehensive study on ammonia as a shipping fuel in July 2024. The two-part study first detailed an extensive analysis of ammonia properties and characteristics and how these are applicable as marine fuel. The second focused on potential areas of a vessel where hazards might arise.

The main hazard of ammonia in comparison to other conventional and alternatives fuels is of course its toxicity, but a secondary concern is its corrosive nature and the potential for stress corrosion cracking of metalwork. Toxicity of ammonia adds complexity to ship designs based on ship-specific gas dispersion analyses supported by relevant risk assessment covering several scenarios (e.g. loss of containment from storage tank or piping, during bunkering etc.).

An analysis for PPE requirements and standards was conducted. It should be ensured that suitable protective equipment is provided for persons on board, for both routine operations and emergency conditions. Experience from land-based industry shows that the choice of PPE in different areas is subject to the expected concentration and exposure time to ammonia therefore different chemical suits and

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accessories may be required. Toxic areas determination as described above is a critical step to decide what PPE will be used for each space onboard.

As regards ship specific hazards, the report considered internal combustion engines (ICEs) and the ammonia engine fuel system, and then how that related to the engine fuel oil system, common engine components, engine auxiliary systems, hydraulic and sealing oil systems, the fuel supply and recirculation system, bunkering and reliquefaction plants. A workshop with engine vendors' experts was conducted to validate components selected for the fault tree analysis (FTA) in a hierarchical structure. These potential points of failure are detailed in the report. Out of the eight subsystems mentioned above, the fuel supply system was determined to have the shortest mean time to failure (MTTF) at 9,406 hours, as it is a more complex system which has more failure modes, contributing to a higher failure rate, and the report recommends that effort should be taken to plan for control measures and improving design failures, such as valves leaking due to incorrect gasket material selection.

Ammonia spills at sea

The American Chemical Society (ACS) also published a paper in September last year covering risk assessments of ammonia fuelled ships and the consequences for human health of ammonia releases from damaged fuel storage tanks. This research focused on the effects of accidental ammonia releases during ship-to-ship collisions, affecting ammonia tank integrity, considering factors like tank types and locations, breach sizes and positions, weather conditions, and dispersion patterns, using PHAST software for modelling. The results indicated that semi-pressurised tanks pose greater health risks on human health than fully refrigerated ones. Underwater releases are less hazardous, as a significant amount of ammonia dissolves before surfacing. Mitigation efforts, such as water curtains and containment basins, were evaluated for their effectiveness in minimising the impact of ammonia releases. These measures significantly reduce risks to nearby populations but are less effective for crew safety onboard. This underscores the challenge of ensuring onboard safety in ammonia-fuelled vessels, highlighting the need for innovative and effective safety design.

The ammonia powered vessel Fortescue Green Pioneer at the port of Southampton, UK earlier this year.

PHOTO: UK MARITIME AND COASTGUARD AGENCY

The report formed part of the basis of a report by the International Tanker Owners Pollution Federation (ITOPF) highlighting the distinct nature of claims arising from ammonia spills compared to traditional oil spills, and on the unique impacts associated with ammonia's toxicity and reactivity. As noted above, when spilled into the marine environment above the waterline, part of the liquid ammonia rapidly boils, releasing ammonia vapours. The ammonia that comes into contact with water will dissolve, with part of it also evaporating. For large surface spills, approximately 60% of the spilled volume would dissolve, with the remaining ammonia evaporating. This evaporation/dissolution ratio remains consistent when spilled underwater at shallow depths. However, if the spill occurs at depths less than 2 meters, the quantity of vapours produced and lost to the atmosphere may decrease to between 5% and 15% of the spill volume. When spilled in large quantities, ammonia vapours will absorb moisture from the air, forming a dense white cloud of ammonium hydroxide (NH_4OH) that can travel laterally for several hundred meters, particularly in high wind conditions. As ammonia vapour temperatures increase to ambient conditions, they become less dense than air and will dissipate into the atmosphere.

Ammonia that dissolves in seawater will form a corrosive, caustic solution of NH_4OH, which is less dense than seawater and will form a layer on the water's surface. The violent reaction between ammonia and water is exothermic, leading to a localised temperature increase on the water surface. The concentrations and elevated temperatures will decrease with distance from the incident location. The rate at which the ammonium hydroxide plume disperses depends on the intensity of mixing in the aquatic environment, which is influenced by tidal currents and wind-induced wave action. A release in high-energy open water will disperse more rapidly than one in a sheltered port or inland waterway.

ITOPF's analysis highlights how storage conditions influence the nature of ammonia release, either as a boiling pool on water, producing a mix of vapor and liquid, or a flash release creating a toxic cloud.

Focus on shipping

The focus on ammonia safety at sea is increasing. Classification society DNV published guidelines in May 2025 in collaboration with industry partners such as Yara Clean Ammonia, to promulgate new recommended practices that offer a clear framework for the safe use of ammonia as fuel. Laurent Ruhlmann, HESQ Vice President, Yara Clean Ammonia, puts it like this: "While ammonia presents certain challenges, shipowners and operators can confidently integrate it into their operations by implementing structured safety protocols, clear regulatory guidance and comprehensive crew training. Seafarers must receive ammonia-specific instruction, covering safe handling, emergency response and maintenance procedures. Regular simulated emergency drills and credible scenario-based training should also become standard practice to ensure operational safety and preparedness." ■

CONFERENCE REPORT

IMTOF 2025

The conference included a Monday night dinner at Searcy's restaurant at the top of London's iconic skyscraper 30 St Mary Axe, aka 'The Gherkin'.

PHOTO: WORKPLACE

This year's International Methanol Technology Operators' Forum (IMTOF) was held at the Holiday Inn Regents Park hotel, London, from June 15 to 18.

Johnson Matthey, fresh from their announcement of a sale of their catalysts business to Honeywell (see Syngas news, this issue), ran their biannual IMTOF meeting in London in early June. JM's Alberto Giovanzana, giving the keynote address, noted that the participants in the room between them represented 24 million t/a of methanol production worldwide, just under one quarter of all methanol produced, and a majority of production outside of China. From JM's perspective, that was also 11,000 cubic metres of installed catalyst. Methanol production continues to see rapid expansion, with the recent start-up of Methanex's Geismar III plant in Louisiana, and its continued progress as a low carbon marine fuel. JM has sold seven licenses for renewable methanol plants in the past year.

Methanol markets

Mark Berggren, formerly of Methanol Market Services Asia, now under the Energy Aspects banner, as usual gave the main methanol market presentation. China continues to dictate the global methanol market, with Asia ex-China also seeing significant growth. There was a price run up in methanol markets in 4Q 2024 due to unplanned downtime for Atlantic Basin plants and some uncertainty over US tariffs, but spot methanol prices have dropped 35-40% this year as Chinese thermal coal prices fall and supply is relatively healthy while the demand outlook is slightly weaker. However, geopolitics continues to add 'noise' to markets, with the potential for disruption of Iranian exports to China in the wake of the recent conflict with Israel and the US, vessel restrictions at Chinese ports, and the complications of US export licenses to China. Crude oil prices are rising in Q3 2025 due to low inventories, but the upside is limited by growth in OPEC+ production as production restrictions are eased.

China and Asia in general will be responsible for 75% of demand growth over the next few years. Chinese growth is slowing but still dominates, while India and southeast Asia are seeing higher growth. Uses of methanol are diversifying and MTO is no longer the sole driving factor, with considerable growth in conventional chemical derivatives and biodiesel. Methanol fuel uses are still waiting on regulatory developments, but even so another 17 million t/a of methanol is expected to be required over the next 5 years. However, Chinese MTO demand continues to set the price cap (around $300/t). Chinese c.fr prices are expected to rise through 2025, limited by olefins economics, but prices sufficient to justify new investment are required. In the absence of gas-based projects, Chinese coal-based projects may fill any supply gap that emerges. Gas supplies are becoming an issue for several major producers and exporters, including Trinidad, Chile, Iran, Malaysia, Brunei, Egypt and Turkmenistan.

Simon Maddren of Energex Partners also looked at methanol market trends. On the supply side, cheap US gas has underpinned the competitiveness of US methanol exports, but elsewhere gas prices are rising due to increased LNG demand growth. Places such as Trinidad and Equatorial Guinea are seeing methanol have to compete with LNG exports for gas feedstock. Foreign investment in China is down to a fraction of what it was, and Chinese 'Belt and Road' outflows of investment are also well past their peak as China begins to invest more inwardly and decouples from major investment partners. China may add 30 million t/a of new domestic methanol production over the next 10 years, and Chinese coal prices are expected to stabilise the methanol floor price. Outside of China, many new projects may fall short of final investment decisions aside from the US Gulf, which remains an attractive location.

Policy targets and regulations are driving new low carbon methanol demand growth, but may need to adapt and evolve to mitigate the risk of slippage. China actually represents one third of new low carbon methanol projects, using biomass. Overall, Energex sees 16 million t/a of low carbon methanol production by 2035, destined for major shipping companies. The potential demand for methanol fuelled vessels could be even larger. Methanol based on hydrogen from electrolysis is further up the cost curve however, and may need biomass-based methanol to pave the way before it sees major investment money.

A panel discussion on the Tuesday drew together some of these strands. Methanol has considerable advantages as a low carbon shipping fuel compared to some of its competitors. Ammonia still faces regulatory hurdles, and some end users, such as shipping lines, remain extremely concerned about its toxicity. LNG meanwhile is not necessarily going to be available as a bunker fuel in some of the destinations that cruise ships visit, although around 2/3 of all bunkering takes place in the top five ports – Singapore, Rotterdam etc. Meanwhile battery powered vessels are also attracting interest for inshore or riverborne uses. But methanol still seems to have the advantage for now. Initial growth for low carbon methanol seems to be focusing on biomass – cooking oil, municipal waste, agricultural waste etc, but the panel acknowledged that this was a limited feedstock pool for large scale applications, and the industry will need to move to carbon capture and storage/use and green methanol in the longer term. While e-methanol can be costly, for end uses like car parts etc, the incremental cost of having green plastics as opposed to fossil fuel-based ones is trivial compared to the value of the product, and indeed may add more value to consumers than the extra cost.

Transforming methanol production

A number of papers by JM highlighted their approach to the changing methanol market. Charles Yiu of JM described how large-scale designs have paved the way for sustainable methanol production, reviewing JM's portfolio of rectors, including the radial steam raising converter, tube cooled converter, and axial steam raising converter, differing loop configurations, and catalyst combinations, including the most recent eMERALD simple synthesis loop for e-methanol production, first installed in a 10 t/d demonstrator plant for CRI in 2010, and with commercial scale units expected to be on-stream in the next few years.

John Swinney of JM presented the Enhanced Series Loop (ESL), designed to maximise the benefits of the company's new generation catalysts. The ESL is a low circulation ratio loop, which with previous generation catalysts would have resulted in lower syngas efficiency. However, the improved activity and stability of the new generation catalysts means that the ESL can achieve comparable syngas efficiency to the Series loop, with the additional benefits of a simpler loop design, lower catalyst volume and improved heat recovery resulting in increased steam export.

Mark Kent of JM showcased the company's range of promoted methanol synthesis catalysts, tailored to meet specific customer requirements, and offering significant improvements in long-term activity retention versus current generation unpromoted catalysts.

JM's Kathryn Coxon meanwhile examined using JM's eMERALD e-methanol technology for producing sustainable aviation fuels (SAF) via Honeywell UOP's eFining methanol to olefins technology.

Digitalisation

Traditionally, methanol process plants have been designed, operated and simulated for continuous steady-state operation. For methanol process plants that operate on renewable feedstock and energy, the inherent intermittency caused by the variation in wind and/or solar power due to weather conditions can cause issues with the plant operation. Alan Faulkner of JM looked at this issue via deterministic dynamic simulation and advanced stochastic approaches.

Julien Grosclaude of Rely Solutions, a developer of green hydrogen and power-to-X systems, showcased his company's digital tool Odyssey for optimising the configuration of renewable plants with reference to several case studies.

Operator experiences

Several operators also presented case histories of issues experienced. Methanex reported on an incident at its Damietta plant in Egypt in 2019 when a 110 barg (1,595 psig) superheated steam coil outlet header ruptured, producing an instantaneous release of high-pressure steam. The failure occurred after eight years in service, and without any prior indications. The failure mechanism was determined to be stress relaxation cracking adjacent to the longitudinal seam weld, which resulted in a large 'window' torn out of the side of the header. The initial investigation focused on the materials and fabrication of the header, but deeper analysis highlighted that code compliance does not always equate to fit for service.

Proman described a similar incident at a methanol plant in Trinidad within its main synthesis loop, which featured a pair of radial-flow steam raising converters. Subsequently, two issues within the synthesis loop were identified: internal gas bypassing, and uneven feed gas distribution. Internal inspections confirmed that circumferential cracks on the top of the outlet collector shroud was the cause of internal gas bypassing. To mitigate the effects of this, a specially designed protective sealing blanket was designed, manufactured, and installed.

Natgasoline experienced a seven-week outage in November 2023, and a plant trip in January 2024. A root cause analysis revealed a yellow dust-like deposit in some water cooled reactor tubes, while other tubes had outages of as much as three feet (0.9 m) from the top of the tube sheet to the catalyst. The direct cause of the differential pressure experienced was failure of the bottom mesh screen on the gas cooled reactor (GCR), which triggered migration of inert support media throughout the synthesis loop with eventual disintegration and deposition in the WCR, leading to outage variances and flow restriction.

Munira al-Amri of OQBI in Oman and Barinder Ghai of Alleima both concentrated on reactor exit pigtails and the importance of materials selection to reduce the incidence of creep related corrosion, as well as methodologies for estimating service life, while Kobus Harmse of OMC compared different methods of cleaning a steam reformer convection section.

There was also experience from green methanol plants. Marcelo Daller of HIF gave an overview of the Haru Oni plant which uses renewable hydrogen and recovered biogenic CO2, covering plant configuration, renewable energy integration, thermal design, and organisational structure, as well as ongoing development projects, including differences in feedstock management, heat integration and operational flexibility.

SUNGAS renewables is using gasified biomass to produce green methanol at its 500,000 t/a Beaver Lake facility in North America, currently in the front-end engineering design stage and expecting a final investment decision in 2026. ■

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Syngas project listing 2025

A round-up of current and proposed projects involving non-nitrogen synthesis gas derivatives, including methanol, synthetic/substitute natural gas (SNG) and gas- and coal to liquids (GTL/CTL) plants.

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
AUSTRALIA							
Worley	JM (DAVYTM)	Bell Bay Powerfuels	Tasmania	Methanol	900	DE	2029
BOTSWANA							
n.a.	n.a.	Botswana Oil	Ikaegeng	CTL	12,000 bbl/d	DE	On Hold
CANADA							
n.a.	Expander	Rocky Mtn Clean Fuels	Carseland, AB	BTL	15	DE	n.a.
n.a.	Topsoe	Air Products	Edmonton, AB	Hydrogen	1,500	UC	2025
n.a.	n.a.	Methanex	Medicine Hat, AB	Methanol	+150	RE	n.a.
n.a.	Linde	Dow	Edmonton, AB	Hydrogen	n.a.	DE	2028
CHINA							
n.a.	Honeywell UOP	Inner Mongolia Jiutai	Hohhot, Mongolia	Methanol to SAF	300	CA	n.a.
n.a.	JM (DAVYTM)	Shenhua Baotou	Baotou, Mongolia	Methanol	6,000	UC	2026
n.a.	Air Liquide	n.a.	n.a.	Methanol	380	UC	2025
DENMARK							
Technip	Topsoe/Sasol	Arcadia e-Fuels	Vordingborg	Green F-T	240	DE	On hold
n.a.	n.a.	European Energy	Kasso	Methanol	127	C	2025
EGYPT							
n.a.	n.a.	Scatec	Ain Sokhna	Methanol	120	DE	n.a.
n.a.	n.a.	C2X	Suez	Methanol	900	FS	n.a.
FINLAND							
n.a.	n.a.	Veolia	Äänekoski	Methanol	36	UC	2025
GERMANY							
n.a.	Linde	Shell	Rheinland	Hydrogen	44	UC	2027
HUNGARY							
n.a.	Plug Power	MOL	Százhalombatta	Hydrogen	1,500	C	2024
INDIA							
BHEL	n.a.	Coal India Ltd	Dankuni	Methanol	2,000	FS	n.a.
n.a.	n.a.	Coal India Ltd	Raniganj	SNG	1,370	DE	n.a.
n.a.	n.a.	ReNew E-Fuels	Malkangiri, Odisha	Methanol	1,300	DE	2029
n.a.	n.a.	ReNew E-Fuels	Rayagarda, Odisha	Methanol	900	DE	2029
INDONESIA							
n.a.	Topsoe	PT Bukit Asam	Muara Enim	Methanol/DME	6,000	UC	On hold
IRAN							
Namvaran	Topsoe	Badr-e-Shargh Pet Co	Chabahar	Methanol	5,000	UC	2026
PIDEC	Casale	Apadana Methanol	Assaluyeh	Methanol	5,000	C	2025
n.a.	Casale	Fateh Sanat Kimia	Dayyer	Methanol	5,000	UC	On hold
ITALY							
n.a.	Tecnimont	Alia Servizi Ambientali	Empoli	Methanol	375	BE	2028
n.a.	K-T	Eni	Livorno	Hydrogen	n.a.	DE	n.a.
n.a.	n.a.	Eni	Pavia	Methanol	330	DE	n.a.
LATVIA							
n.a.	n.a.	AE Risinajumi	n.a.	Methanol	60	FS	2028

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
LIBYA							
n.a.	n.a.	Sirte Oil Co	Marsa el Brega	Methanol	300	RE	2025
MALAYSIA							
Samsung	Air Liquide	Sarawak Petchem	Sanjung Kidurong	Methanol	5,000	C	2024
n.a.	KT Kinetics Tech	Petronas	Pengerang	Hydrogen	80	BE	2028
Samsung	n.a.	H2biscus	Sarawak	Methanol	1,400	FS	n.a.
MEXICO							
n.a.	KT Kinetics Tech	Pacifico Mexinol	Topolobampo	Methanol	5,400	FS	2029
NIGERIA							
n.a.	Air Liquide	Brass Fert & Petchem	Brass Island	Methanol	5,000	DE	2027
PORTUGAL							
n.a.	Casale	CAPWATT	Mangualde	Methanol	240	DE	2029
RUSSIA							
China Chengda	Topsoe	Nakhodka Fertilizer	Nakhodka	Methanol	5,400	UC	2027
SAUDI ARABIA							
n.a.	Uhde	ENOWA	NEOM	Methanol	12	UC	2025
McDermott	Air Products	Chemanol	Jubail	Methanol	3,000	RE	2027
SPAIN							
Tecnicas Reunidas	n.a.	Nascar	Almeria	Methanol	110	BE	2026
n.a.	Topsoe	Forestal del Atlantico	Galicia	Methanol	120	DE	2028
n.a.	n.a.	C2X	Huelva	Methanol	450	CA	2027
n.a.	JM (DAVYTM)	La Robla NE	Castilla y Leon	Methanol	424	DE	2027
SWEDEN							
n.a.	Topsoe	Liquid Wind	Ornskoldsvik	Methanol	160	DE	2027
Wood	JM (DAVYTM)	Perstorp (Project Air)	Stenungsund	Methanol	600	DE	2028
Worley	Topsoe	NorthStarH2	Ostersund	Methanol	300	DE	n.a.
UNITED ARAB EMIRATES							
Samsung	JM (DAVYTM)	TA'ZIZ	Ruwais	Methanol	5,400	DE	2028
UNITED KINGDOM							
Linde	JM (DAVYTM)	Equinor	Saltend	Hydrogen	380	DE	2028
n.a.	n.a.	Cromarty Clean Fuels	Nigg, Scotland	Hydrogen	6	FS	2026
n.a.	Topsoe	Standard Gas	n.a.	Methanol	n.a.	FS	n.a.
UNITED STATES							
n.a.	JM (DAVYTM)	HIF	Matagorda, TX	MTG	1,840	DE	n.a.
KBR	JM (DAVYTM)	Methanex	Geismar, LA	Methanol	5,000	C	2024
Technip	Topsoe	ExxonMobil	Baytown, TX	Hydrogen	2,700	DE	2028
n.a.	Topsoe	Nacero	Penwell, TX	Methanol/MTJ	5000	DE	n.a.
n.a.	JM (DAVYTM)	SunGas Renewables	Beaver Lake, LA	Methanol	1,300	BE	2029
n.a.	n.a.	Methanex	Beaumont, TX	Methanol	+600	RE	2025
n,a,	JM (DAVYTM)	n.a.	TX	Methanol	360	DE	2029
URUGUAY							
n.a.	JM (DAVYTM)	HIF	Constancia	Methanol	2120	DE	2028
UZBEKISTAN							
n.a.	Air Products	GCC MTO	Karakul	Methanol/MTO	3,360	DE	2028
VIETNAM							
n.a.	KT Kinetics Tech	Binh Son Refining	Dung Quat	Hydrogen	50	DE	2028

KEY
P – Planned/proposed
C – Completed/commissioning
CA – Contract awarded
BE – Basic engineering
DE – Design engineering
FS - Feasibility study
UC – Under construction
n.a. – Information not available

CONVERSION:
1 t/d of hydrogen = 464 Nm^3/h
1 t/d of natural gas = 1,400 Nm^3/d

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Sustainable methanol: A multi-pathway fuel

No longer viewed as only a chemical feedstock, methanol is increasingly being regarded as a low-carbon energy carrier. **Zinovia Skoufa** of Johnson Matthey discusses the role of sustainable methanol as a multi-pathway fuel for the energy transition.

Methanol is a clean-burning fuel making it an attractive alternative for maritime applications.

PHOTO: SHANSCHE/ISTOCKPHOTO

Methanol has long been a foundational chemical in global industry, used to manufacture paints, adhesives, synthetic fabrics and thousands of other products. Increasingly, however, it is being viewed not only as a chemical feedstock, but as a low-carbon energy carrier. Its ability to be produced from a variety of sustainable sources, and to serve both as a fuel and a platform for further chemical synthesis, positions it as a highly flexible and scalable option in the energy transition.

What distinguishes sustainable methanol is the potential of carbon intensity reduction due to the origin of its feedstocks, of which there are various possible combinations. Unlike conventional methanol, which is typically derived from natural gas or coal, sustainable methanol is produced using low-carbon or renewable inputs. These include biomass and organic waste, non-recyclable municipal solid waste, and captured CO_2 combined with green hydrogen. Each of these routes varies in technical complexity and regional suitability, but together they provide a compelling portfolio of solutions for reducing lifecycle emissions, improving resource efficiency and building energy resilience.

As governments, industries and financiers accelerate their decarbonisation strategies, sustainable methanol is gaining traction as a practical, deployable technology. It can be integrated into existing infrastructure, used in hard-to-electrify sectors, and scaled globally using well-understood processes. Its role is not limited to one use case or region. Instead, it offers a suite of pathways that can be applied across diverse geographies and supply chains.

Production pathways: Biomass, waste and CO_2

There are three primary routes to sustainable methanol production which are gaining traction today, each with its own feedstock base and process technologies (Fig. 1).

Biomass-to-methanol involves the conversion of lignocellulosic or organic residues into methanol through gasification. Feedstocks include agricultural by-products such as straw, husks and manure, forestry waste like bark and offcuts, and industrial residues such as black liquor from the pulp and paper sector. These materials absorb carbon during their growth and would otherwise decompose or be burned, releasing CO_2 or methane into the atmosphere. Gasification transforms this biomass into synthesis gas, which is then catalytically converted into methanol. The process is already being commercialised in several pilot and industrial-scale facilities, particularly in regions with high biomass availability.

Waste-to-methanol makes use of the non-recyclable organic fraction of municipal solid waste, including packaging residues, textiles and contaminated materials. These wastes are typically incinerated or landfilled, both of which carry emissions and air quality consequences. Instead, they can be gasified into syngas and used as a feedstock for methanol synthesis. This approach diverts significant volumes of waste from landfill, lowers methane emissions and creates a value stream from otherwise discarded material. Waste-to-methanol technologies are now being piloted in several urban and industrial regions, where reliable waste supply chains exist and landfill diversion is a policy priority.

CO_2-to-methanol, also referred to as e-methanol, involves synthesising methanol from captured carbon dioxide and green hydrogen produced via electrolysis using renewable electricity. The CO_2 can come from industrial point sources such as cement or steel plants, from biogenic sources, or through direct air capture, once again using renewable feedstock sources E-methanol is particularly promising for countries with abundant renewable energy resources and strong ambitions to become hydrogen exporters or low-carbon fuel hubs.

All three routes feed into the same core methanol synthesis step, which enables technology providers and project developers to draw on decades of process engineering experience. Existing fossil methanol plants can in many cases be adapted or replicated for sustainable feedstocks, reducing time-to-market and capital investment risk.

Environmental performance and emissions impact

Methanol's decarbonisation potential is significant, particularly when produced through sustainable pathways. According to the International Renewable Energy Agency, methanol production and usage account for approximately 0.3 gigatonnes of CO_2 emissions annually, around 10% of the chemical sector's total. Transitioning to renewable feedstocks could drastically cut this footprint.

The benefits extend beyond climate. Methanol is a clean-burning fuel that emits significantly lower levels of nitrogen oxides, sulphur oxides and particulate matter than heavy fuel oil or diesel.

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Fig. 1: **Biomass / waste route to sustainable methanol production**

Source: JM

This makes it an attractive alternative for maritime and off-grid applications, especially in urban coastal zones with strict air quality standards.

Methanol is also biodegradable and water-soluble, making it safer to transport than many hydrocarbon fuels. Its use as a marine fuel is already in effect by a growing number of ship operators and engine manufacturers, with several commercial vessels now running on dual-fuel methanol engines.

Technology maturity and deployment outlook

The production of sustainable methanol builds on a well-established industrial process. Methanol synthesis via catalytic conversion of syngas has been deployed globally for decades. The challenge now lies in adapting this process to non-fossil feedstocks, many of which contain higher levels of impurities or present variable composition.

Technology developers with expertise in catalyst formulation and process engineering, such as Johnson Matthey, have made notable advancements in this area. Their systems are designed to process variable syngas from biomass and waste sources and deliver high-purity methanol at scale. Improvements in gas clean-up, loop efficiency and catalyst robustness are helping to close the cost gap between sustainable and conventional methanol.

In the case of e-methanol being able to accommodate hydrogen intermittency is key. Here, technology convergence is central to unlocking efficiency gains. Scalable, flexible designs that can accommodate fluctuating electricity inputs and high amounts of water in the methanol synthesis loop are being developed to ensure reliable, robust production in dynamic energy markets.

Critically, much of the infrastructure needed to transport, store and distribute methanol is already in place. Global trade routes for methanol exist, with tankers, terminals and bunkering systems adaptable for methanol produced via any route. This infrastructure readiness sets methanol apart from other alternative fuels like ammonia or hydrogen, which still face logistical hurdles.

Policy frameworks and market signals

Many jurisdictions still lack specific frameworks to differentiate between fossil-based and renewable methanol, or to reward the full lifecycle emissions savings of sustainable methanol production. Closing this policy gap will be essential for investment certainty.

However, policy support is growing, with the monumental IMO decision to enact a carbon penalty for noncompliance. However, there are several elements which will be reviewed after implementation including the cost of noncompliance, and the cost gap between eFuels and traditional marine fuels will remain in the immediate term. To enable wider adoption of sustainable fuels, industry will need clarity on the GHG default values for and a compliance framework to certify marine fuels, such as those developed by ISCC, along with clarity on the reward mechanism for using zero and near-zero (ZNZ) fuels.

Private sector demand is also rising. Several shipping companies have announced e-methanol fuel contracts for future-ready vessels. Industrial buyers are exploring methanol as a low-carbon feedstock for olefins and aromatics. In parallel, carbon offset markets and voluntary climate initiatives are beginning to factor in alternative fuels like methanol as part of broader emissions reduction strategies.

To attract investment and scale production, clearer offtake signals and stronger alignment between energy, waste and industrial policy will be required. Project bankability will hinge on stable feedstock access, long-term purchasing agreements and incentives that support infrastructure buildout.

A strategic molecule for a fragmented transition

No single fuel will solve the climate challenge. The energy transition will unfold unevenly, shaped by geography, resource access and political will. In this context, methanol's flexibility is a major strength. It can be produced from agricultural surplus, urban waste, industrial carbon or renewable power. It can be shipped, blended, stored and used across multiple applications.

This adaptability makes methanol a strategic molecule, one that connects sectors and closes loops. It enables cross-sector synergies, such as turning pulp industry waste into marine fuel, or pairing excess renewable electricity with captured CO_2 to make circular feedstocks.

Sustainable methanol will not displace every fuel, but it does not need to. Its value lies in its ability to integrate into diverse supply chains and act as a bridge between today's infrastructure and tomorrow's low-carbon economy.

As technology improves, policies align and costs fall, sustainable methanol is increasingly likely to become a central feature of the global energy system. It is not a concept or a pilot. It is a commercially viable, environmentally credible solution ready to be deployed, at scale, across sectors and around the world. ■

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Waste to methanol to maritime fuel

The production of methanol from waste offers a groundbreaking solution for sustainable urban waste management as well as producing an alternative renewable fuel for maritime transport. **Giacomo Rispoli**, **Andrea Angeletti** and **Alessia Borgogna** of Nextchem provide an overview of the waste conversion process and its application.

Using fossil fuels to power the world economy has become unsustainable as the speed of human activity outpaces the natural processes needed to renew the Earth's resources. Moreover, fossil fuels create emissions and waste that harm the planet and impact economic growth. Adopting a circular economy is one way of reducing the production cycle by emphasising waste reduction, reuse, recycling, and energy recovery.

Circular economy processes also include the thermochemical conversion of waste into new chemical products, a sustainable solution that provides an alternative to conventional disposal methods. When applied to non-recyclable waste, the chemical conversion reintegrates these materials into the production cycle.

Unrecyclable plastic residue is the main example: about 40% of the total differentiated plastic becomes non-recyclable waste. Another example is unsorted municipal solid waste, that can be processed to be biologically stabilised and to reduce its volume. Through mechanical and biological treatments, the waste becomes drier and has a lower calorific value, ranging between 14 and 18 MJ/kg (approximately one third of gasoil LVH). Lastly, wood demolition waste, which despite its frequent contamination by halogenated compounds and heavy metals which makes it difficult to treat in traditional waste to energy plants, remains a valuable source of biogenic carbon for the production of fuels and chemicals.

Chemical recycle of waste can clearly play an important role in making the transportation sector more sustainable by creating clean fuels. This article discusses how waste-to-methanol can be used in the maritime industry, which is reducing its emissions to comply with new EU rules that took effect January 1, 2025 calling for an 80% reduction in maritime emissions by 2050.

Global waste production trends

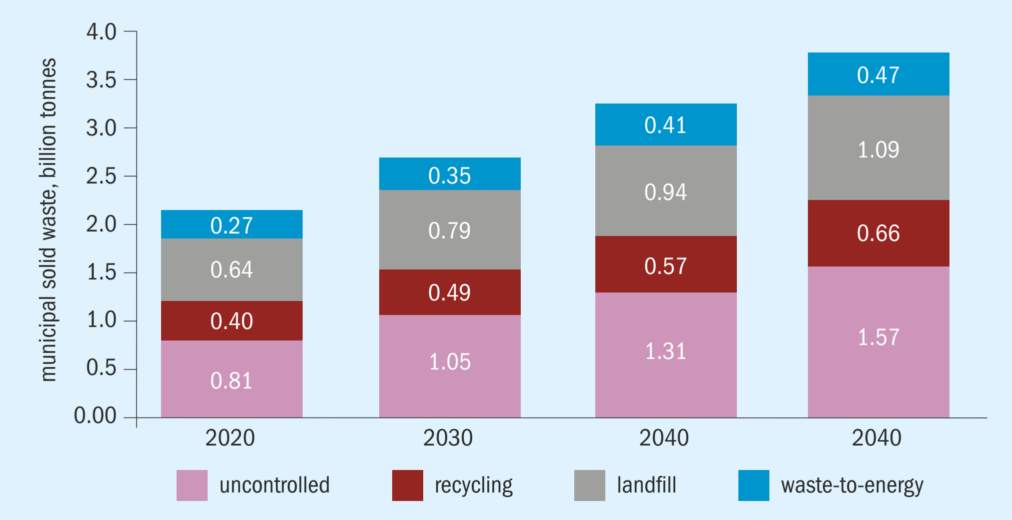
Although the focus on recycling is continuously increasing, waste production itself is also on the rise (Fig. 1). By 2050, the global population is expected to reach about 10 billion, accompanied by an increase in the GDP of many developing countries. Consequently, both global and per capita waste production is set to increase, as higher GDP in the past has been dramatically linked to the growth of a "take-make-dispose" economy.

Waste-to-energy is responsible for emissions of significant amounts of GHG gases (mainly CO_2 and NOx). European incinerators that produce energy generate a significant amount of direct CO_2 emissions (580g CO_2eq/kWh), which is twice the current average amount generated by the EU28 electricity grid (298g CO_2eq per kWh) and significantly greater than energy produced through conventional fossil fuel sources such as gas.

In Europe, the waste management sector is a significant contributor to methane emissions, ranking as the second largest emitter, with approximately 97 million tonnes of carbon dioxide equivalents (CO_2eq) emitted in 2022, according to the EEA.

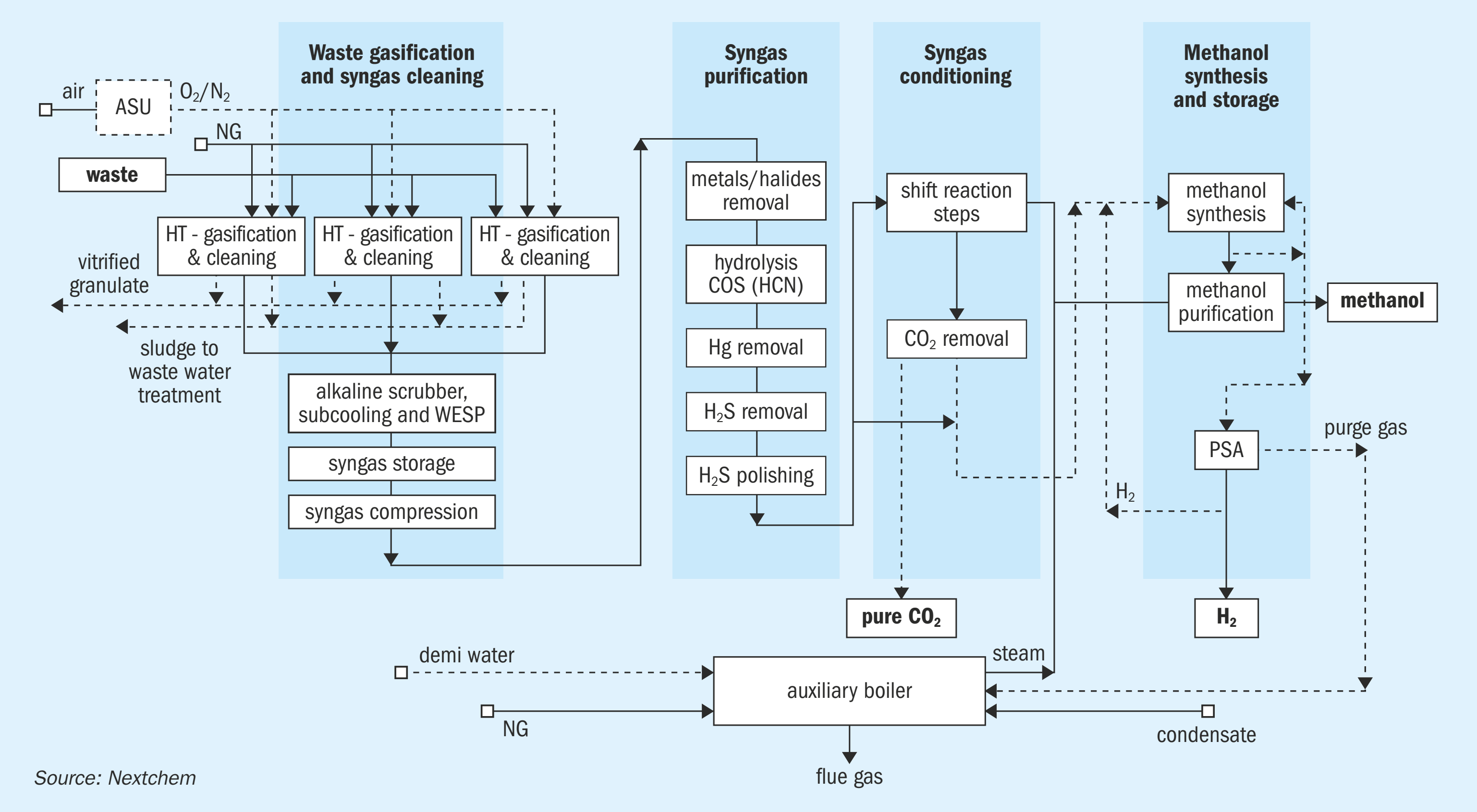
The NX Circular™ gasification technology commercialised by MyRechemical, Nextchem's subsidiary dedicated to waste-to-chemical solutions, sinks its roots in a very robust industrial track record with more than 20 years of industrial experience and more than 2 million hours of total operation. The pure oxygen gasification and inert melting process was specifically designed for difficult waste disposal at the end of the

Fig. 1: **Increasing global production of municipal solid waste**



Source: UNEP I Beyond an Age of Waste - Global Waste Management Outlook 2024

Fig. 2: **Block scheme of waste-to-methanol process**



Source: Nextchem

1990s and largely applied to produce high value syngas. MyRechemical, leveraging MAIRE group's experience in gas processing and Nextchem's technology portfolio, combined this process with syngas conversion to valuable fuels and chemicals (hydrogen, methanol, ethanol, sustainable aviation fuels, fertilizers, olefins).

This integrated approach from waste to fuels and chemicals is a game-changer for the energy transition path, seamlessly blending proven technologies with groundbreaking environmental innovations.

The primary innovation introduced by MyRechemical is the integration of waste management and chemical synthesis sections. Producing valuable molecules from waste offers a sustainable solution for urban waste management. The waste-to-chemical technology commercialised and licensed by MyRechemical is nearing final implementation following the agreement between Nextchem and Eni for the first industrial waste-to-methanol plant in an existing refinery assuring its transition to sustainable sources.

Using waste as a feedstock is beneficial not only for the environment and the community but also brings economic advantages. Instead of being a cost, the feedstock becomes a revenue source, with its value ranging from €50 to €250 per ton, depending on the kind of waste and geography.

Waste conversion to methanol process

The process of converting waste to methanol consists of four main sections:

- Waste gasification
- Syngas cleaning and purification
- Syngas conditioning
- Methanol synthesis from conditioned syngas

High-temperature conversion (gasification) and cleaning and purification

The core section of the waste-to-methanol process is the NX Circular™ gasification unit. The high-temperature gasifier is capable of simultaneously converting the combustible fraction of the waste into syngas and melting the inert fraction, producing an inert vitrified solid once the molten slag is cooled. This system uses pure oxygen as the gasifying agent. The temperatures reached at the melting section in the bottom of the reactor are very high, between 1,600 and 2,000°C, ensuring the melting of the slag and the total conversion of the waste. In the intermediate section, the gasification section, near the solid inlet, the temperature drops to around 700°C, then rises again in the upper section of the reactor, the stabilisation section, to at least 1,100°C, thanks to the introduction of additional oxygen. A minimum temperature of 1,100°C is necessary to ensure the breakdown of longer-chain compounds (tar) and complexes such as dioxins, which are particularly harmful. To prevent the reformation of dioxins, which become stable

IMAGE: NEXTCHEM

Rendering of waste - to-X plant.

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again at 800°C, the produced syngas is rapidly cooled through an evaporative quench to about 90°C. This abrupt cooling preserves the syngas composition at its optimal quality. The cooled syngas needs to be cleaned through two washing columns, one alkaline and one acidic. The main components of the cleaning section are two washing columns, a wet electrostatic filter, and an additional sub-cooled column for the removal of metals.

Downstream of these two sections, a clean syngas is obtained with a composition within the following ranges: H_2 = 37.5 to 41%; CO = 36 to 46%; CO_2 = 15.5 to 5%; H_2O = ~5%. The composition of the produced syngas is obviously dependent on the composition of the waste, which, by its nature, is variable. The criticality of the process lies precisely in the heterogeneity of the waste, which results in the production of a syngas that varies both in terms of composition and flow rate. The conditioning and synthesis sections, however, need to operate under stable flow conditions. Therefore, the washing and conditioning sections are connected by a gasometer, i.e., a syngas tank, which allows the damping of flow rate fluctuations.

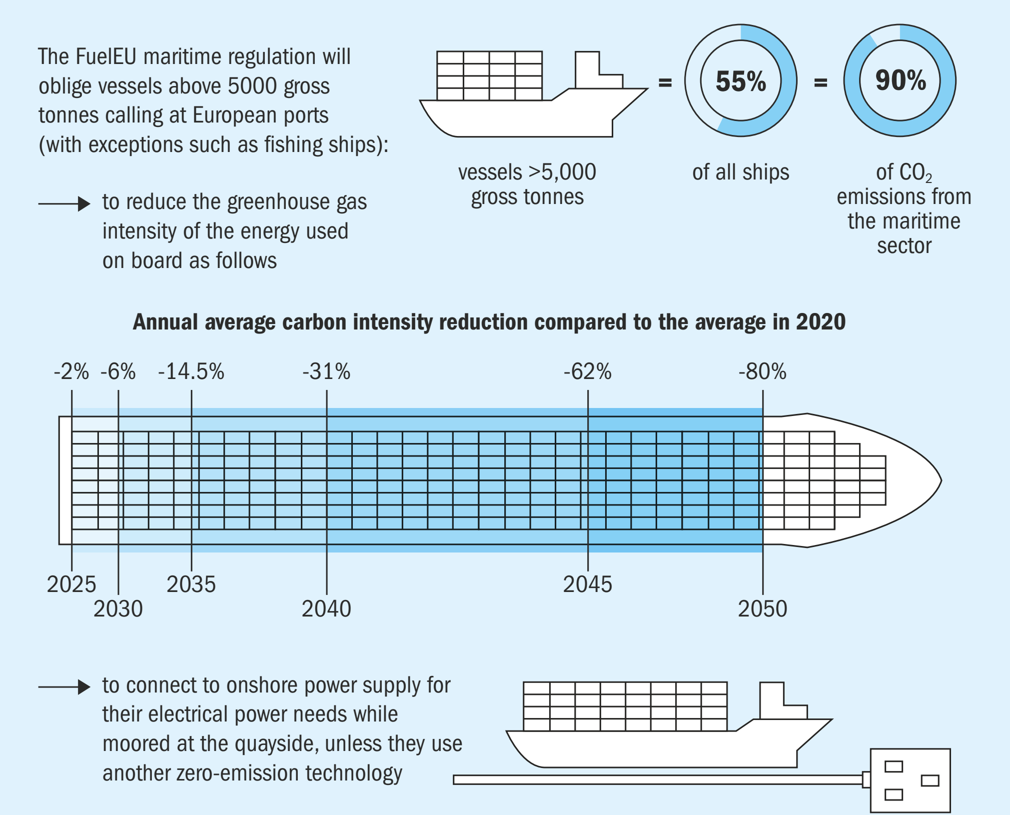
Once compressed, syngas is routed to the purification section involving the following steps: removal of residual dust and metals, removal of HCl, hydrolysis of the COS and HCN, H_2S removal through an oxy-reduction system and a final polishing step based on zinc oxide absorbents in order to reduce sulphur content down to ppb as required by catalyst adopted for downstream synthesis.

Conditioning section and methanol production

The conditioning section has the task of modifying the composition of the syngas produced by gasification, as within the range in which it varies, it is not suitable for methanol production. The requirements for methanol synthesis are: methanol module, MM = $(H_2 – CO)/(CO + CO_2)$ equal to 2.1; $CO_2/(CO + CO_2)$ greater than 0.2 but less than 0.5; CO_2 content less than 12%; H_2O content less than 0.05%.

The syngas stream is separated, and only the minimum amount necessary undergoes conditioning treatment. This separation involves the need for more severe operations for the line being conditioned but ensures a reduction in the volumes of the necessary equipment. To increase the hydrogen content in the syngas, the first step of the conditioning section is a reactor where the shift reaction occurs. The added steam, 1.5 times the volume of dry syngas, is transformed into hydrogen, while CO is converted into CO_2. CO_2 is subsequently separated in a removal system with amines. At this point, the two separated syngas streams are reunited. To these two streams, a stream is added of almost pure hydrogen derived from the separation, through pressure swing adsorption (PSA), operated on the purge fraction necessary for the recirculation of the unreacted fraction to the synthesis reactor (see Fig. 2). The syngas now has a methanol module of 2.1 and meets the other requirements, except for the water content, which can be easily reduced to the desired value through condensation. The conditioned syngas is compressed to 80 bar and introduced into the synthesis reactor where it is converted into methanol. The unconverted fraction of the reacting gas, once separated, is recirculated into the synthesis reactor to increase the overall conversion. Due to the inerts that can accumulate, a purge fraction, mentioned above, must still be considered. Methanol is then purified to required grade and stored.

Fig. 3: **FuelEU maritime regulation infographic (Decarbonising maritime transport – FuelEU Maritime - European Commission)**



Source: https://transport.ec.europa.eu/transport-modes/maritime/decarbonising-maritime-transport-fueleu-maritime_en

Application of methanol in the maritime sector

Methanol is increasingly being recognised as a viable alternative fuel for the maritime sector due to its environmental and economic benefits. As a clean-burning fuel, methanol significantly reduces emissions of sulfur oxides (SOx), nitrogen oxides (NOx), and particulate matter compared to conventional marine fuels. This makes it an attractive option for meeting the stringent emission regulations set by the International Maritime Organization (IMO). Additionally, methanol can be produced from renewable sources such as biomass, municipal waste, and carbon dioxide, further enhancing its sustainability profile. The use of methanol as a marine fuel also offers operational advantages, including ease of handling, storage, and transportation, as it is a liquid at ambient temperature and pressure. Several shipping companies have already begun to adopt methanol-powered vessels, demonstrating its feasibility and potential for widespread use in the industry. As the maritime sector continues to seek ways to reduce its environmental impact, methanol stands out as a promising solution for achieving cleaner and more sustainable shipping operations.

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Methanol is a versatile and clean fuel that can be used in existing marine engines with some modifications, replacing bunker oil and fossil origin diesel. Additionally, methanol can also be used with fuel cells, offering an efficient alternative for maritime transport. This significantly reduces emissions of atmospheric pollutants. Indeed, maritime transport is a significant source of greenhouse gas emissions, contributing to air pollution and climate change. To address this challenge, the European Union introduced the Refuel Maritime directive, which came into force on January 1, 2025, setting ambitious decarbonisation targets for the maritime sector. The directive aims to reduce emissions by 6% by 2030 and 80% by 2050 compared to 2020 levels. It also mandates the use of advanced technologies and alternative fuels to achieve these goals (see Fig. 3).

Methanol is also safer to handle and transport compared to other alternative fuels. Methanol is liquid at room temperature and can be stored and transported with minimal modifications to existing liquid fuel infrastructures. This makes methanol a practical and convenient choice for the maritime sector, which can adopt this technology without having to invest in new costly infrastructures (e.g., the use of LNG, ammonia, or hydrogen).

Conclusions

The production of methanol from waste offers a groundbreaking solution for sustainable urban waste management. This innovative process not only reduces the amount of waste sent to landfills but also minimises environmental impact and greenhouse gas emissions. The methanol produced can serve as an alternative fuel for maritime transport, aiding in the sector's decarbonisation efforts. Remarkably, converting urban waste into methanol can cut CO_2 emissions by over 70% compared to traditional fossil fuels. This process breathes new life into the carbon and hydrogen found in waste, preventing them from contributing to landfill pollution. Economically, the feedstock becomes a revenue source rather than a cost, ensuring a high margin between production costs and the price of methanol from renewable sources. This guarantees a swift return on investment. ■

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Revamping methanol plants for sustainable decarbonisation

Casale is specialised in revamping natural gas-based methanol plants. Decarbonisation of methanol plants is a goal for many producers achievable with a proper revamping strategy. **Pietro Moreo** of Casale discusses how Casale's innovative technologies and extensive experience ensure reliable efficient capacity and performance enhancements together with CO_2 emissions reduction tailored to meet revamping project targets.

Significant carbon emissions are attributed to the methanol Industry (about 200 million tonnes/annum). In many countries direct carbon pricing or compliance instruments like carbon taxes have been implemented or will be put in place in the near future. It is a matter of fact that this trend will have an important impact on methanol plants in view of the associated costs.

Most of the lifecycle emissions associated to methanol molecule resides in the end-of-life stage, for instance when the methanol is combusted in a ship or other transport vehicle. These emissions are stoichiometric and cannot be avoided. They are the same for any methanol. In methanol from natural gas (NG), the end of life is, on average, about 60% of the overall emissions. Without considering end of life, about half of the emissions are associated to production in the plant while the remaining are for NG production and transport and for methanol product transport.

Therefore, plant design can have direct impact only on this portion of the methanol carbon footprint and, indirectly, on other NG production and transport.

The price of carbon in the world has been increasing significantly, from \$20 up to values higher than \$80, and this trend is going to identify a further not negligible difference in the production cost as a consequence of the plant efficiency and carbon intensity.

Plants equipped with syngas generation via oxygen (SMR+ATR, pure ATR, Exchange Reformer + ATR, etc.) achieve very low carbon intensity and energy consumption (approx. 0.3 tonne CO_2/tonne CH3OH); modern pure steam reforming (SMR) based units have higher emissions (about 0.5-0.6 tonne CO_2/tonne CH_3OH) while vintage plants have emissions up to 1 tonne CO_2/tonne CH_3OH. In view of the trend of carbon prices, the gap in production cost is going to depend not only on NG cost and relevant consumption but also on CO_2 emissions and relevant price or compliance instruments.

CO_2 emissions reduction and energy saving for existing vintage SMR based units mean significant methanol production cost reduction; CCS (carbon capture and sequestration) is an option but with significant associated costs (30-120 \$/t CO_2). CCS needs several associated infrastructures (pipelines, ships, storage, etc) almost always not linked to methanol producers' core business; plant NG consumption is increased by CCS (generally carbon capture requires additional steam and/or power).

On the contrary plant revamping affects efficiency in NG conversion to methanol, intrinsically leading to decarbonisation; it is important to underline that typically the emissions reduction target does not exclude combination with capacity increase; revamping is the real sustainable route to improve margins reducing the cost associated to carbon compliance.

The target of the revamping is the key parameter to select the right philosophy of intervention: Casale is in the position to customise its own technologies to suit clients' specific needs.

Gained through 30 years of experience, Casale has acquired an unrivalled track record in revamping (retrofitting) existing plants of any type to improve their performance and, with it, a deep knowledge of the workings of fertilizer and methanol plants.

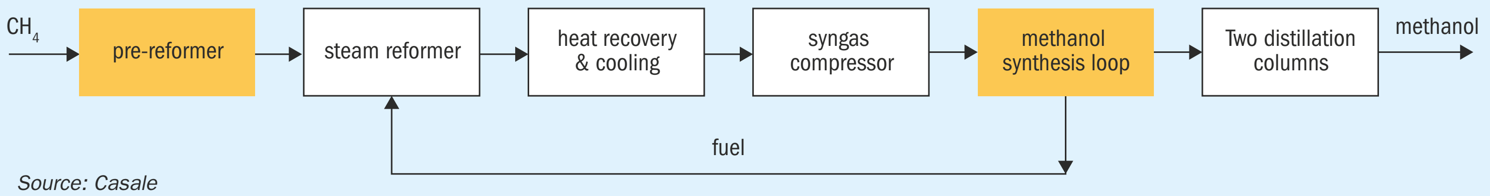
If a revamping option is already available from previous experience, it is included in the revamping experience concept that provides a detailed definition of the most appropriate solution for customer's unit.

The integration of process and engineering know-how and project implementation capabilities has enabled Casale to be a world leader in plants revamping. Casale's wide technology portfolio includes items suitable for revamping any plant type and section.

Revamping of the syngas generation section is usually only considered for plant capacity increase but it is also the most important section for energy saving and emissions reduction. Revamping of the reforming section for capacity increase, energy saving and CO_2 emission reduction can be carried out according to different strategies which can be alternative or complementary. The technologies suitable for this purpose are:

- pre-reforming;
- partial oxidation reactor (POx);
- autothermal reactor (ATR);
- heat exchange reformer.

Fig. 1: **Reforming section revamping with pre-reformer**



Source: Casale

To maximise methanol production and, at the same time, to minimise energy consumption, it is imperative to have the highest possible carbon efficiency in the synthesis section. To achieve this goal, Casale has the unique advantage to retrofit the old adiabatic converters with its plate-cooled IMC internals. When revamping of the main reactor is not convenient, a different way of processing a higher flow of make-up gas is to install an additional converter with its own methanol condensing section downstream. This reactor is isothermal due to the superior efficiency and flexibility.

Revamping options for the distillation section should be evaluated to comply with the increased methanol production from the reaction section and/or with the energy saving targets.

Casale advises installing a pre-reformer reactor when the aim of the revamp is to increase the plant capacity. It allows the primary reformer to process additional natural gas without any alteration. So, it is particularly useful when no modifications can be made to the primary reformer. Alternatively, if the plant loading is not increased, the pre-reformer reactor allows the heat duty to the primary reformer radiant box to be reduced. The pre-reformer unit is an adiabatic reactor containing an optimised steam reforming catalyst. The catalyst is more active because it has a much higher nickel content than primary reformer catalyst. As its name suggests, the pre-reformer reactor is installed upstream of the primary reformer (Fig. 1).

All higher hydrocarbons are completely converted to methane, and equilibrium is established for the methane reforming and shift reactions. The product gas from the pre-reformer contains only methane, carbon monoxide, carbon dioxide, hydrogen and steam – the ideal feed gas for the primary reformer. The Casale pre-reformer reactor design is based on axial-radial catalyst bed technology.

Because the gas from the pre-reformer is already partially reformed, it is possible to raise the throughput of the unmodified primary reformer by up to 10% without increasing the firing duty and thus without jeopardising the life of the catalyst tubes.

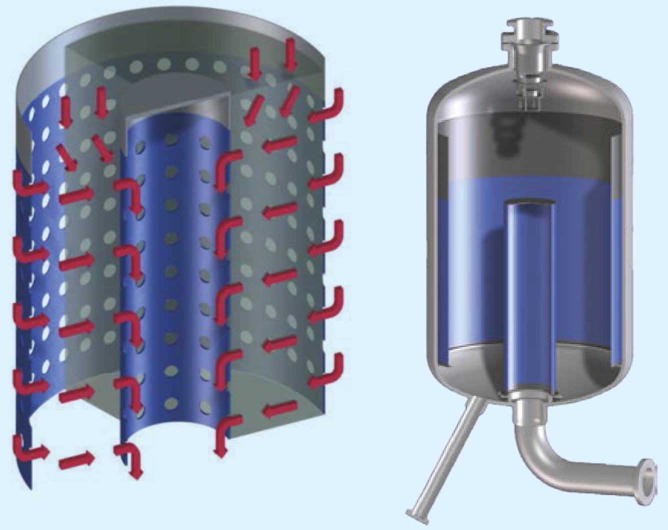
Several pre-reformers supplied by Casale are in operation in revamped ammonia and methanol plants (Fig. 2).

One of the most interesting ways to revamp the reforming section, if the target is to increase the plant capacity significantly and/or to reduce the energy consumption and CO_2 emissions, is the installation of a high-temperature heat-exchange reactor that uses the residual heat in the effluent from the primary reformer to produce syngas from methane (steam reforming). In conventional plants, this high-grade heat (usually at a temperature of about 900°C) is used in the waste heat boiler to produce HP steam. Casale relies on the supply of the high-temperature heat-exchange reactor developed by Technip Energies, named TPR® (Technip Parallel Reformer®).

In the process scheme of a reforming section revamped with the TPR, the preheated mixed feed consisting of natural gas and process steam flows in parallel to the primary reformer radiant box (about 70-85% of the gas) and to the TPR exchanger reformer (about 15-30% of the gas). The outlet of the primary reformer is fed to the TPR shell side as heating medium for the steam reforming reaction of the tube side.

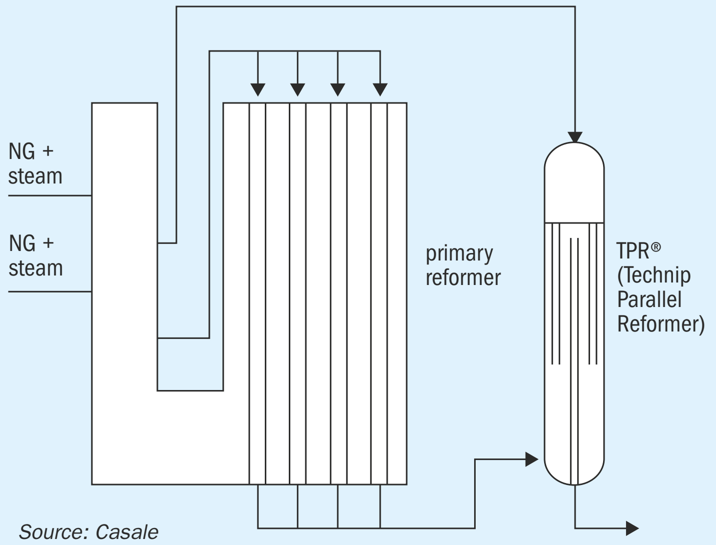
The TPR is a compact heat exchanger reactor for steam reforming. Other than in the fired reformer, the heat for the TPR is supplied by hot process gas rather than by hot flue gas. Up to 30% additional feed can be reformed using the TPR in parallel to the fired reformer.

Fig. 2: **Casale axial radial pre-reformer concept**



Source: Casale

Fig. 3: **Reforming section revamp with TPR**



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39
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41
42
43
44
45
46
Contents
ISSUE 396
NITROGEN+SYNGAS
JULY-AUGUST 2025

1 47
2 48
3 49
4 50
5 51
6 52
7 53
8 54
9 55
10 56
11
12
13
14
15
16
17
18
19
20
21
22
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Fig. 4: **Upgrade with ATR in parallel with SMR**

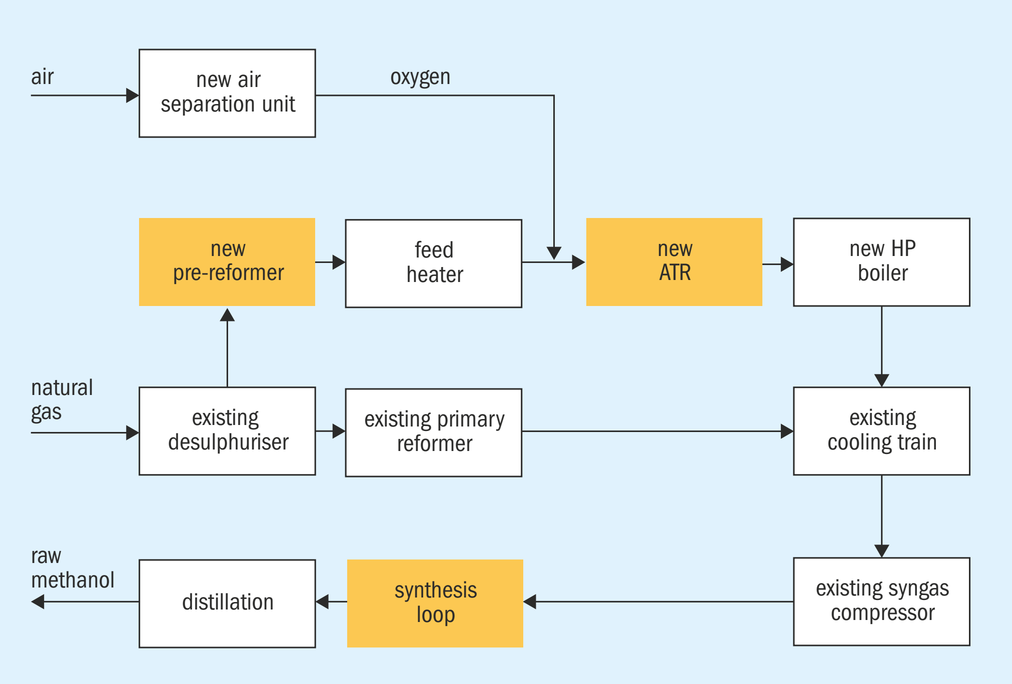

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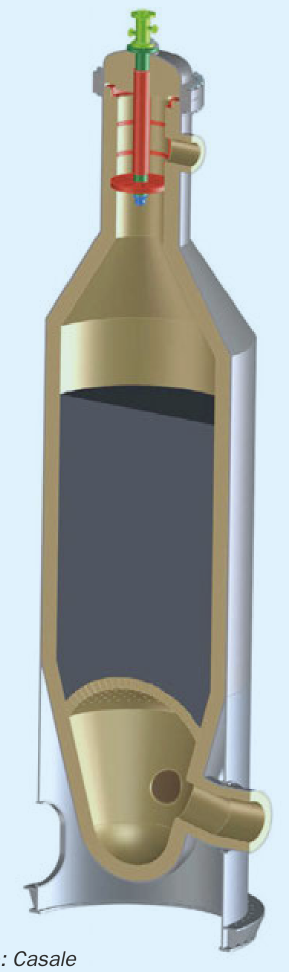
Fig. 5: **Auto-thermal reformer (ATR)**



Source: Casale

Since the steam reformer effluent is used to meet the heat duty of the TPR, the steam production in the downstream process gas boiler is reduced significantly. The design is optimised considering both syngas and steam requirements. TPR minimises export steam, especially when steam revenues are not favourable. The technology further allows zero export steam enabling stand-alone plants that do not need to be connected to an external steam network.

TPR has provided cost-effective solutions to customers for more than 50 years and has been successfully employed in several H_2 plants for capacity revamps (Fig. 3).

Autothermal reforming is an alternative technology to produce syngas for capacity increase purpose and/or energy saving and CO_2 emission reduction.

The auto-thermal reformer (ATR) can be installed downstream of the primary reformer or in parallel to the reformer itself. Installation downstream of the reformer involves the modification of the front-end train and the replacement of the reformer waste heat boiler. This kind of solution can decrease the syngas stoichiometric number (SN = $(H_2\text{-}CO_2)/(CO+CO_2)$) significantly and it is recommended when a large capacity increase is requested. The installation in parallel to the steam reformer requires a dedicated fired heater, waste heat boiler and it is generally combined with the installation of an upstream pre-reformer reactor (Fig. 4).

In autothermal reforming, the feed gas partially burns with oxygen from an air separation unit, providing the heat for the endothermic reformer reaction, that takes place on the catalyst bed. For this challenging service, the burner design is crucial for smooth operation and Casale provides a water-cooled design to improve reliability.

Casale has acquired sound experience in the design of ATR reactors for both ammonia and methanol production and for both two-step reforming and pure autothermal reforming (with natural gas or coke oven gas) configurations in revamping projects and in new plants. Casale has several referenced ATR reactors for methanol production in operation or scheduled for start-up, with capacities ranging from 350 to 7,000 t/d. At present there are more than ten units in operation equipped with a Casale ATR (Fig. 5), including two 5,000 and a 7,000 t/d methanol plant.

A different option for the plant revamping could be a new syngas generation section based on a pre-reformer followed by an ATR fed with pure oxygen combined with a process heated reformer (TPR) in series/parallel to the ATR. This section is sized to generate the necessary additional syngas flowrate and it is equipped with Casale proprietary autothermal reforming unit, patented axial-radial pre-reformer reactor and with the Technip proprietary Parallel Reformer (TPR).

Thanks to these distinctive technologies, comparing this design with a standard pure ATR section, the natural gas consumption for the new syngas generation unit, with the TPR addition (Fig. 6), is expected to be reduced by up to 5% and the oxygen demand is reduced by more than 15%. Furthermore, the size of the ATR fired heater and the size of the waste heat boiler are significantly reduced. Therefore, the proposed syngas generation process offers the following advantages:

- minimisation of the oxygen import and related electrical power consumption in the air separation unit;
- minimisation of fired duty for process purpose which leads to lower natural gas consumption and CO_2 emissions;
- minimisation of fatal steam production with a lower investment cost linked to the lower size of the related steam system, including the waste heat boiler, steam drum, steam superheater, deaerator, HP BFW pumps.

Partial oxidation (POx) is an advanced technology that allows the production of syngas to be enhanced, creating a tangible value for the client. The new section is based on a POx reactor where natural gas reacts in the presence of oxygen without catalyst. Pure oxygen is generally supplied by an air separation unit.

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Fig. 6: **ATR+TPR concept**

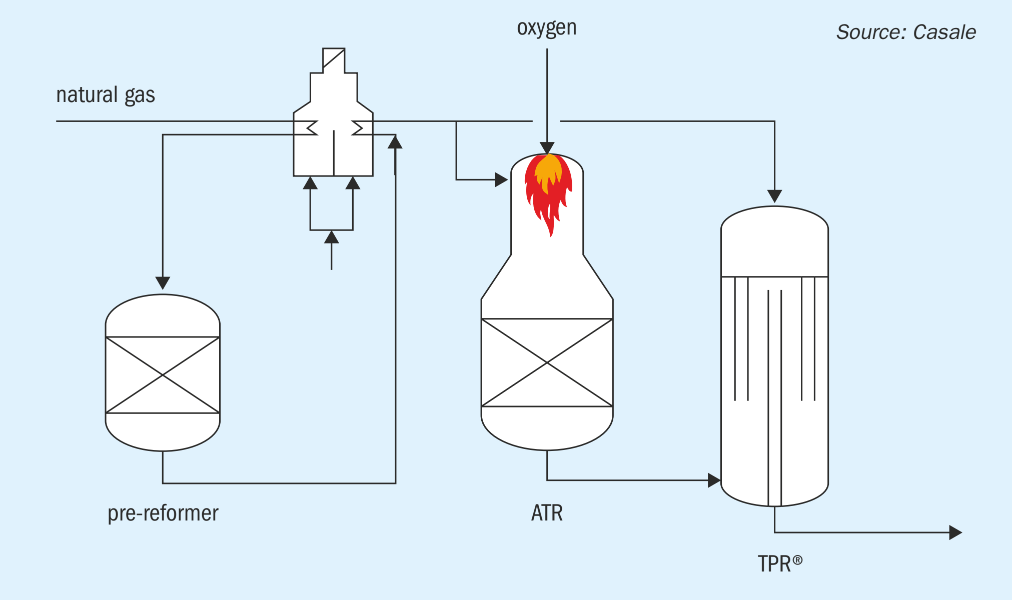
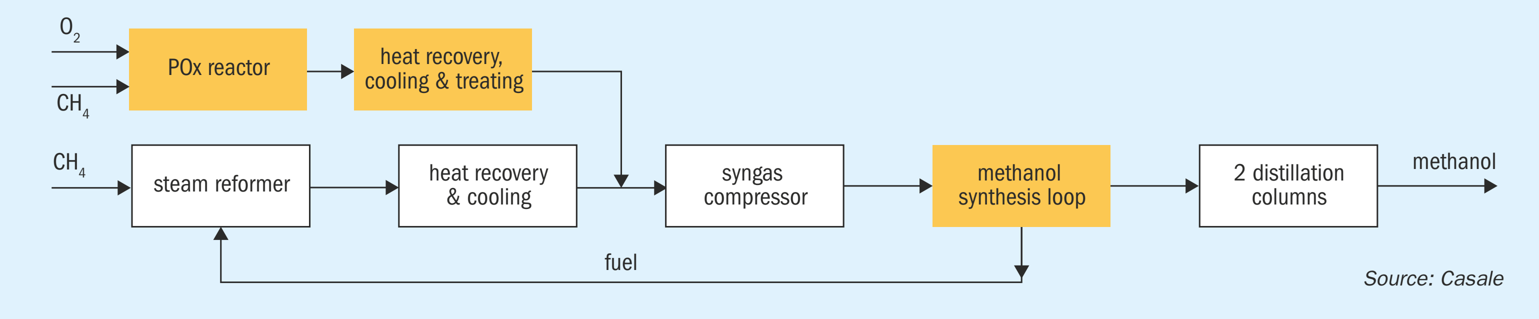


Fig. 7: **Revamping strategy through POx**



With the installation of a POx reactor in parallel to an existing traditional primary reformer (Fig. 7), it is possible to increase methanol production by up to 30% with a single POx unit or to switch the production from the reformer to the POx reactor resulting in a decrease in the natural gas consumption in the range -5% to -15%. In addition, it should be underlined that the specific polished water consumption decreases thanks to the switch from steam reforming to O_2 blown reforming.

The core of this advanced technology is the patented burner, developed using Casale's deep knowledge of combustion and fluid dynamic phenomena to achieve very high combustion efficiency with low energy consumption and negligible soot formation. POx burners are subjected to the harshest conditions and are protected by cooling with a continuous circulation of boiler feed water: accurate design of the water-cooling system is essential to ensure a long and safe operating life when operating in such harsh conditions.

Revamping with POx technology (Fig. 8) has been implemented by Casale with a capacity increase of about 13%, a decrease in specific CO_2 emissions of about 20% and decrease in specific natural gas consumption of about 6% compared to the former plant performances.

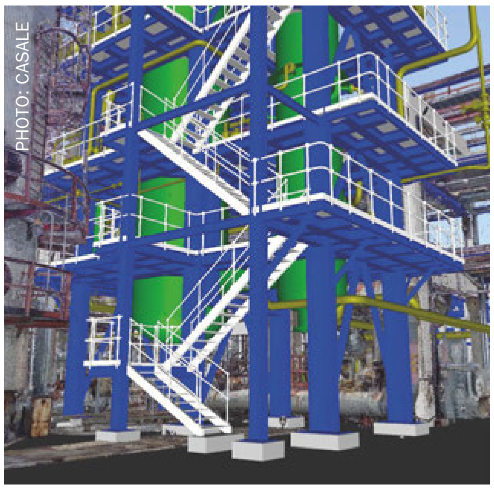


Fig. 8: Syngas generation based on POx (3D model)

To maximise methanol production and, at the same time, to minimise energy consumption, it is imperative to have the highest possible carbon efficiency in the synthesis section. To achieve this goal, Casale has the unique advantage to retrofit the old adiabatic converters with its plate-cooled IMC internals. Casale is, in fact, the only company that can offer an "in situ" retrofit of the synthesis reactor with an isothermal design. Casale is also in the position to revamp and upgrade internal isothermal converter designed by its competitors with its plate cooled technology for capacity increase and energy savings. The modified synthesis section is also made ready to accept the additional and/or more reactive synthesis gas that is generated by POx or ATR. At present, several Casale Isothermal Plate Cooled Methanol Converters, installed though "in situ" retrofit, are on stream with capacities ranging from 400 t/d to 3,400 t/d. Synloop methanol production can be increased by up to 20% while the carbon efficiency can be increased by up to 10%.

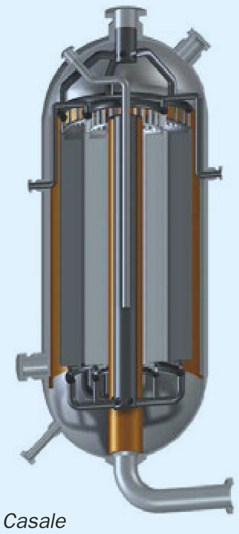
A converter "in situ" retrofit has been successfully implemented in the QAFAC revamping project with the following associated benefits:

- higher plant output with lower specific energy and syngas consumption in the synthesis loop (higher carbon efficiency);
- longer catalyst life;
- higher operational stability and easier control of the reactor.

On its own, revamping with IMC™ (Fig. 9) has been ideal for achieving an immediate increase in capacity from an unchanged make-up gas flow, or the same capacity with a reduced make-up gas flow thanks to its higher carbon efficiency. Furthermore, the additional CO_2 feedstock provided through the new CDR of SMR flue gas has allowed the plant to boost the capacity by an additional 150 t/d: the benefits of IMC™ retrofits are even more impressive if the front end is revamped at the same time for a substantial capacity increase.

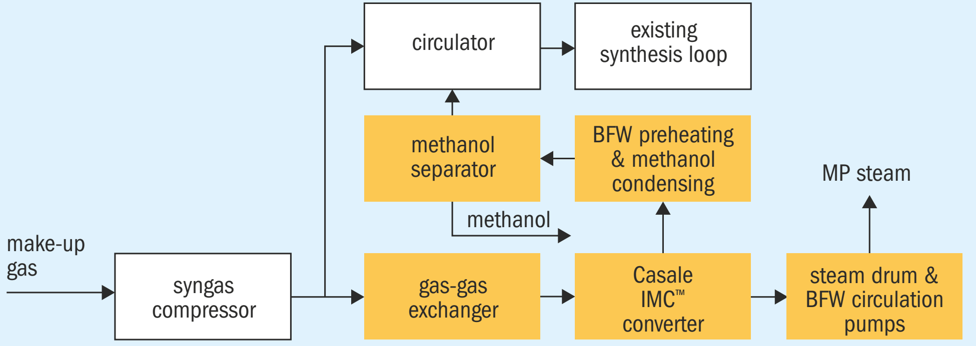
When revamping the main reactor is not convenient, a different way of processing a higher flow of make-up gas is to install a downstream additional converter with its own methanol condensing section.

Fig. 9: **IMC revamping concept for "in situ" retrofit implementation**



Source: Casale

Fig. 10: **Synthesis section revamping with OTR**



Source: Casale

If it is installed in the make-up gas line, it is called "once-through reactor" (OTR) because there is no mass recycle (Fig. 10).

The methanol product obtained in this reactor is separated by condensation. The composition of the gas entering this converter is not optimised and therefore it does not achieve a particularly high conversion efficiency, but it does shift some duty off the synthesis loop, which can be exploited to increase overall production. On account of the gas composition for this specific scheme, the steam-raising configuration is preferred for the IMC converter.

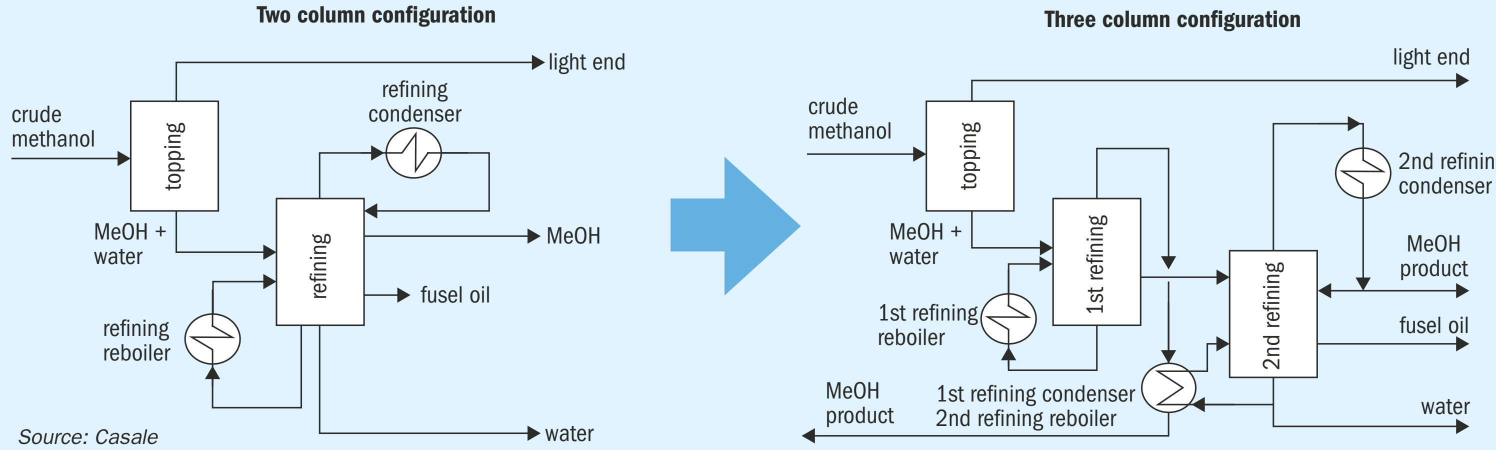
The steam-raising IMC™ reactor in "once-through" mode has also been installed in revamping projects by Casale.

The crude methanol produced in the synthesis loop needs to be purified to reach the contractual grade specification (AA, A, IMPCA, etc.). Final purification is performed in two steps. A topping column separates the lighter compounds from the liquid mixture, while the refining section separates water and higher ends from the pure product, which is sent to storage. For plants of limited capacity (generally lower than 2,000 t/d) only one refining (heavy end column) step is foreseen. For higher capacities, the refining section is divided into two separate columns, one operating under raised pressure (about 7 bar g), the other at atmospheric pressure. This arrangement leads to a significant energy saving compared to the single refining column thanks to the "double effect" concept. The distillation section revamping options should be evaluated to comply with the increased methanol production from the reaction section and/or with the energy saving targets. For that reason, the possibility to increase the methanol production should be followed by any revamping action with the aim to remove the distillation section bottlenecks and increase the relevant nominal capacity.

For moderate capacity increase, the distillation section may already be suitable to process the extra capacity, since typically the original design foresees additional space for future interventions. In case the columns are not suitable for the new load, it is typical to revamp the column internals with high efficiency trays.

For extreme capacity increase or for improving the plant efficiency, Casale proposes the addition of a high-pressure column, where it is not already installed, along with the revamp of the internals of the existing ones (Fig. 11). A high pressure column generally implies the replacement or the integration of the reboiler of the existing atmospheric refining column with a double effect reboiler/condenser: high pressure vapour condensation is used to supply the heat requirements for the second refining column. This modification introduces a significant energy saving too. The strategy can also be applied when the plant is already equipped with three columns introducing the "triple effect" concept. In addition, when the plant is already equipped with three columns, an alternative option is the new fusel oil recovery column: the column is fed with heavy end column fusel oil and part of the heavy ends column feedstock. Following this solution, the bypass of the refining column is sufficient to restore the original heavy ends column operation, removing the capacity bottleneck. ■

Fig. 11: **Distillation revamping concept**



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Flexible co-production of low carbon hydrogen and ammonia

By combining oxygen-blown Lurgi™ autothermal reforming (ATR) technology with Cryocap™ H_2 carbon capture technology, Air Liquide offers an innovative plant configuration to meet the need for a central production facility offering flexible product diversification with hydrogen and ammonia at a scale that satisfies extensive decarbonisation targets.

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Hydrogen will play an essential role in the decarbonisation of industrial applications like refineries and chemical plants, as well as mobility. Based on the specific application and the end point of use (local vs. transcontinental), several hydrogen vectors are discussed – the most popular being ammonia, liquid hydrogen and methanol. Ammonia has been in focus over the last couple of years due to its favourable properties for transport and a proven industrial supply chain. Low carbon or renewable ammonia can be used after an ammonia cracking step as a fuel or feedstock for the chemical industry. Ammonia cracking technology is currently under development and Air Liquide is preparing the start-up and operation of the first industrial pilot plant.

Liquid hydrogen is another viable option to transport low-carbon and renewable hydrogen. Although its physical properties impose certain requirements on the transport (cooling down to -253°C), it is an interesting option as the hydrogen can be readily used without the requirement of additional steps. The hydrogen liquefaction step is an industrially proven technology and the industrial readiness for long-range transport was recently demonstrated by CNOOC and Air Liquide.

Methanol is also being prominently discussed, especially for usage in the shipping industry, for example, it is currently being evaluated in the EU-funded M2ARE project with participation of Air Liquide.

However, ammonia and hydrogen have gained the most traction in recent years and both molecules have their own sweet spots with regard to type of end-use and location. Also, for some projects it is envisaged to produce ammonia for transcontinental shipping and hydrogen as a co-product for local use. In fact, the co-production of both molecules by a shared front end offer an economical benefit by economy of scale, as well as a certain degree of production flexibility – which allows for adaption of market demands.

Air Liquide has developed an innovative plant configuration to meet this need, combining oxygen-blown Lurgi™ autothermal reforming (ATR) technology coupled with Cryocap™ H_2 carbon capture technology. This solution was presented at Nitrogen + Syngas conferences[1,2] in 2023 and 2024 and now following the completed basic engineering and further steps towards industrial realisation, the main benefits and recent advancements of Air Liquide's technology solution are presented.

Air Liquide technology highlights

Air Liquide's unique technology portfolio in the field of low carbon hydrogen production covers all relevant syngas production technologies and a large number of CO_2 capture technologies making it possible to evaluate different techno-combinations in order to select the most suitable and efficient combination. Air Liquide is the only licensor having its own proprietary autothermal reforming as well as carbon capture technologies and provides a one-stop for technology with full integration of the different process units.

ATR

Since the acquisition of Lurgi in 2007, Air Liquide is the sole licensor of Lurgi™ ATR (Fig. 1) technology and a leading technology provider for oxygen blown autothermal reforming with in total more than 45 ATR licenses. The long cooperation with its catalyst partner Clariant ensures reliable operation at stable and high conversion rates. Air Liquide's fully referenced Lurgi™ ATR design is in operation for up to 530 kNm³/h of dry syngas equivalent, which corresponds to a production of approximately 6,000 t/d ammonia.

Air Liquide is also able to match the oxygen requirements of a large scale ATR.


PHOTO: AIR LIQUIDE

Fig. 1: Lurgi™ ATR

As a world leader for industrial gases, Air Liquide can draw upon its extensive design experience and benefits from large amounts of data from industrial operational facilities. Over 4,000 air separation units (ASU plants) have been built for third party customers and Air Liquide operations.

Cryocap™ H_2

Cryocap™ H_2 is a technology which combines cryogenic process technologies and gas separation membranes in a unique Air Liquide proprietary CO_2 capture solution. Cryocap™ H_2 enables carbon capture without solvents or chemicals, effluents or waste, and with negligible steam consumption. In the first step, the shifted syngas from the ATR and downstream CO shift units is fed to a hydrogen pressure swing adsorption (PSA) unit, where it is split into a pure hydrogen product and a low pressure, CO_2-rich tail gas product. The tail gas from the PSA unit is then compressed and fed to the cryogenic section, where the CO_2 is separated from the other components of the PSA tail gas stream by a combination of partial condensation and distillation. The core of the process is based on the partial condensation, as the high purity CO_2 product is first obtained as a liquid and is ultimately evaporated in the main heat exchanger of the cryogenic section at different pressure levels, thereby providing the refrigeration requirements of the separation process.

The non-condensable stream, from the cryogenic section is routed to a series of membrane modules for further separation. The membrane unit comprises two stages of Air Liquide's proprietary MEDAL™ PIX H_2 membranes. Here, the non-condensable stream is separated into two product streams:

- a stream enriched in H_2 that is recycled to the PSA inlet;
- a high pressure off gas stream, containing most of the non-condensable (CO, N_2, H_2, CH_4, and some CO_2), which is recycled to the reforming section.

A direct CO_2 capture rate for this setup can be as high as >99% and brings additional value for reducing scope 3 emissions, which is discussed in detail in the next section.

The application of Cryocap™ H_2 for low carbon ammonia production in an ATR also offers integration options for liquid CO_2 production at marginal additional energy requirements, due to its cold operating conditions[1].

Cryocap™ H_2 has been in commercial operation by Air Liquide in Port Jerome, France since 2015 and is the only cryogenic CO_2 separation technology that has been demonstrated for low carbon hydrogen in an industrial operation.

Air Liquide's integrated in-house PSA technology is referenced in more than 80 own and third party plants.

The experience in membrane design by Air Liquide is based on more than 175 hydrogen systems globally and over 2,900 membrane modules in service.

Low carbon hydrogen and ammonia co-production

The co-production of ammonia and methanol has been known for 20 years and has been done in several locations worldwide. However, the co-production of ammonia with significant amounts of low carbon hydrogen is new in the industry. The conventional ammonia production process via air blown secondary reforming does not offer a straightforward way to branch-off hydrogen as a co-product as nitrogen would have to be removed from the syngas.

Several projects in the past years have envisaged the common production of low carbon ammonia and hydrogen, most of them in the USA and Canada.

As one example, Air Liquide and other stakeholders have agreed to collaborate in the development of a production plant for more than 1.1 million tonnes per year of low carbon ammonia in Houston, TX, USA. The plant will be able to flexibly export a part of the low carbon hydrogen as chemical purity product. Air Liquide will provide the technology and design for the ammonia syngas generation, including the ATR, ASU and Cryocap™ H_2.

Fig. 2 shows a block flow diagram of a production scheme for low carbon ammonia and hydrogen, applying an ATR and Cryocap™ H_2. An ASU provides the oxygen for use in the ATR and the required nitrogen for the ammonia synthesis. Natural gas is desulphurised and then reformed with oxygen from an ASU at temperatures around 1,000°C. The hot reformed gas (syngas) is cooled by raising steam. The remaining CO in the syngas is converted to CO_2 and hydrogen in a CO shift section.

The PSA unit produces a high purity hydrogen from the syngas. The PSA tail gas is treated in the Cryocap™ H_2 unit, where high purity CO_2 is separated in a cryogenic process combining partial condensation and distillation. The remaining gas is separated using membrane technology, preparing an H_2-rich stream and a CO and CH_4-rich stream.

The H_2-rich stream is recycled to the PSA unit to increase the H_2 product or used for hydrogen fuelling in the fired heater. The CO and CH_4-rich stream can be recycled to the ATR or used as fuel in a fired heater.

The water-free CO_2 product is of high purity (>99.9 mol-%) and can be used without further treatment for sequestration, utilisation and even liquefaction.

The CO_2 product is sent to the battery limit for storage or utilisation. The purified hydrogen is split into two portions: the hydrogen product and the portion which is used for ammonia synthesis. The latter is mixed with nitrogen from the ASU to form the syngas for ammonia production and is then fed into the ammonia loop.

This Air Liquide proprietary setup offers a distinctive advantage in carbon emission reduction. In general, the carbon intensity of the hydrogen generation process is classified into three principal categories i.e. scope 1, scope 2 and scope 3 carbon intensity. Scope 1 carbon intensity is governed by the direct emissions of the plant which a process minimises by maximising the direct carbon capture rate. Scope 2 carbon intensity can be minimised by ensuring renewable electricity import (down to 0 kg CO_2/kg H_2). Hence, scope 3 emissions become a significant driver of the overall carbon intensity.

Scope 3 emissions can be classified in the following two main components:

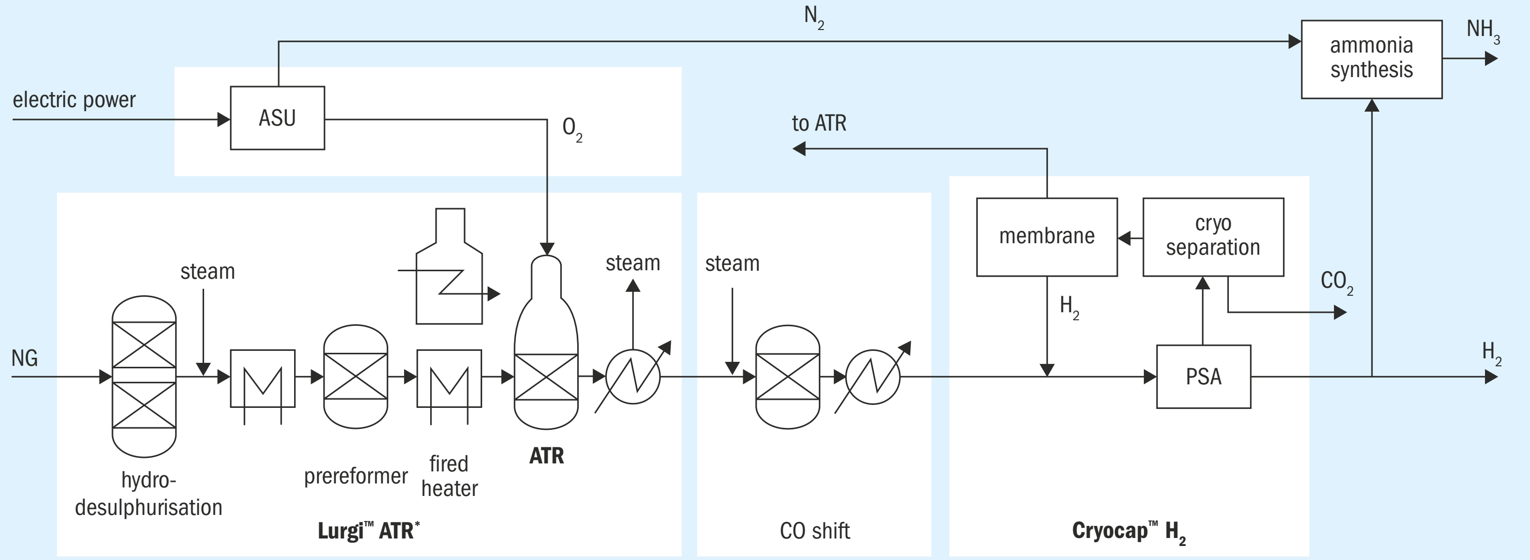
- carbon atoms going with H_2 product as impurity (low-impact parameter);
- carbon intensity of the natural gas fed to the hydrogen plant (high-impact parameter).

In order to produce a H_2 product ready to be exported for downstream use e.g. chemicals industry, refinery, liquefaction or pipeline, the purity requirement is high enough to minimise the scope 3 emission associated with the H_2 product to a minimum (essentially zero or close to zero). Moreover, it is much easier to optimise the product purity level to meet the carbon intensity target.

Hence, effectively, almost the whole contribution of the scope 3 carbon intensity is tied to the hydrocarbon feedstock (typically, natural gas) upstream of the plant. This is also a relatively hard-to-abate section and typically the order of magnitude of specific carbon intensity is much

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

Fig. 2: **Lurgi™ ATR + Cryocap™ H_2 + ASU block flow diagram**



*ATR based solutions: Lurgi Megasyn™ – established in 2002

Source: Air Liquide

higher (e.g. 7-9 kg CO_2e/million Btu LHV of natural gas). Therefore, minimisation of natural gas intake is definitely a crucial driver for all the decarbonisation.

The scope 3 emission reduction is achieved by two specific characteristics of the ATR+Cryocap™ H_2 solution. Firstly, the effective H_2 recovery of the process is significantly boosted by the combination of PSA and Cryocap™ H_2 to >99% compared to ~89% for a standalone PSA, while accomplishing a CO_2 recovery from syngas of >99%. This in turn reduces the natural gas consumption of the process. Secondly, the use of membrane technology enables the recycling of carbon containing syngas components (CO, CH_4) to the ATR section and enhances the process efficiency by carbon recovery.

Also, as no steam is required for Cryocap™ H_2 compared to a state-of-the-art amine wash, less natural gas is required for the steam raising, which can be used in process integration, enabling a higher process efficiency – for example in the setup covering ATR, gas heated reforming and Cryocap™ H_2, which was patented by Air Liquide.

Besides, as an ASU supplies oxygen to the hydrogen plant, from an operating cost as well as scope 2 emission points of view, minimisation of oxygen intake should be of interest as well as it is a direct function of natural gas intake to the plant.

Referring to the points addressed above, Air Liquide's ATR + Cryocap™ H_2 + ASU is a solution providing H_2 and NH_3 production with the lowest achievable carbon intensity and cost of production.

Case study

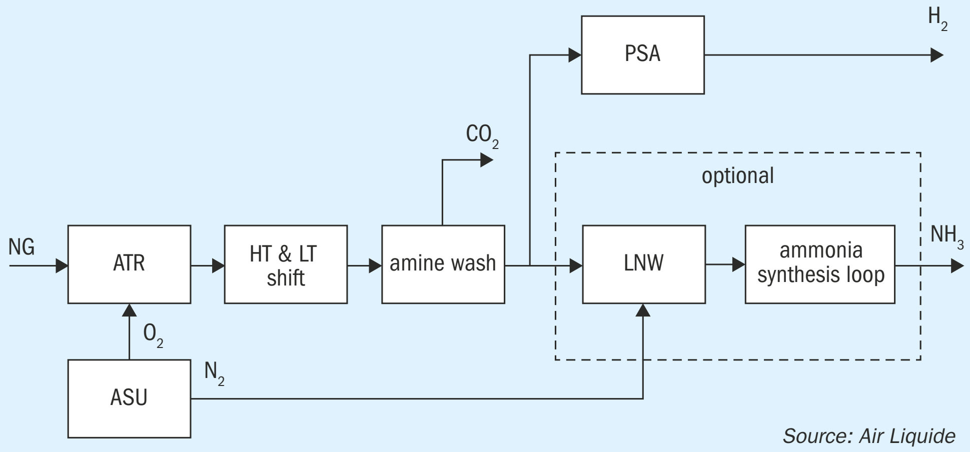
Several case studies for oxygen-blown ATR based production for low carbon hydrogen have been conducted by Air Liquide, covering the envisaged usage of H_2 molecules for:

- chemical industries (> 99.9 mol-% H_2), e.g. hydrogenation in refineries, for liquefaction and transport;
- fuelling purpose (> 95 mol-% H_2), e.g. power plant decarbonisation or cracker decarbonisation;
- ammonia production;
- ammonia-hydrogen co-production.

In general, two types of flowsheets have been compared: a state-of-the-art amine wash carbon capture on the syngas, and Air Liquide's proprietary solution applying Cryocap™ H_2. Fig. 3 depicts the state-of-the-art solution: Syngas is produced by an oxygen-blown ATR, the syngas is shifted in two CO shift units. The CO_2 from the syngas is then captured by an amine wash unit, dried and pressurised to supercritical state before being exported. The decarbonised syngas is then further processed as required depending on the envisaged product(s). For ammonia production a liquid nitrogen wash (LNW) unit is applied for syngas preparation, a PSA is applied for hydrogen production and for co-production both units are used in parallel.

The second flowsheet is based on Air Liquide's innovative solution and is depicted in Fig. 4. The raw syngas derived from the oxygen-blown ATR is also shifted in the CO shift units and then routed to a PSA unit where high purity hydrogen is produced and the PSA tail gas is treated in the Cryocap™ H_2 unit. A CO_2 product is prepared in the cryogenic part before being pressurised to supercritical state and

Fig. 3: **State-of-the-art amine wash carbon capture solution**



Source: Air Liquide

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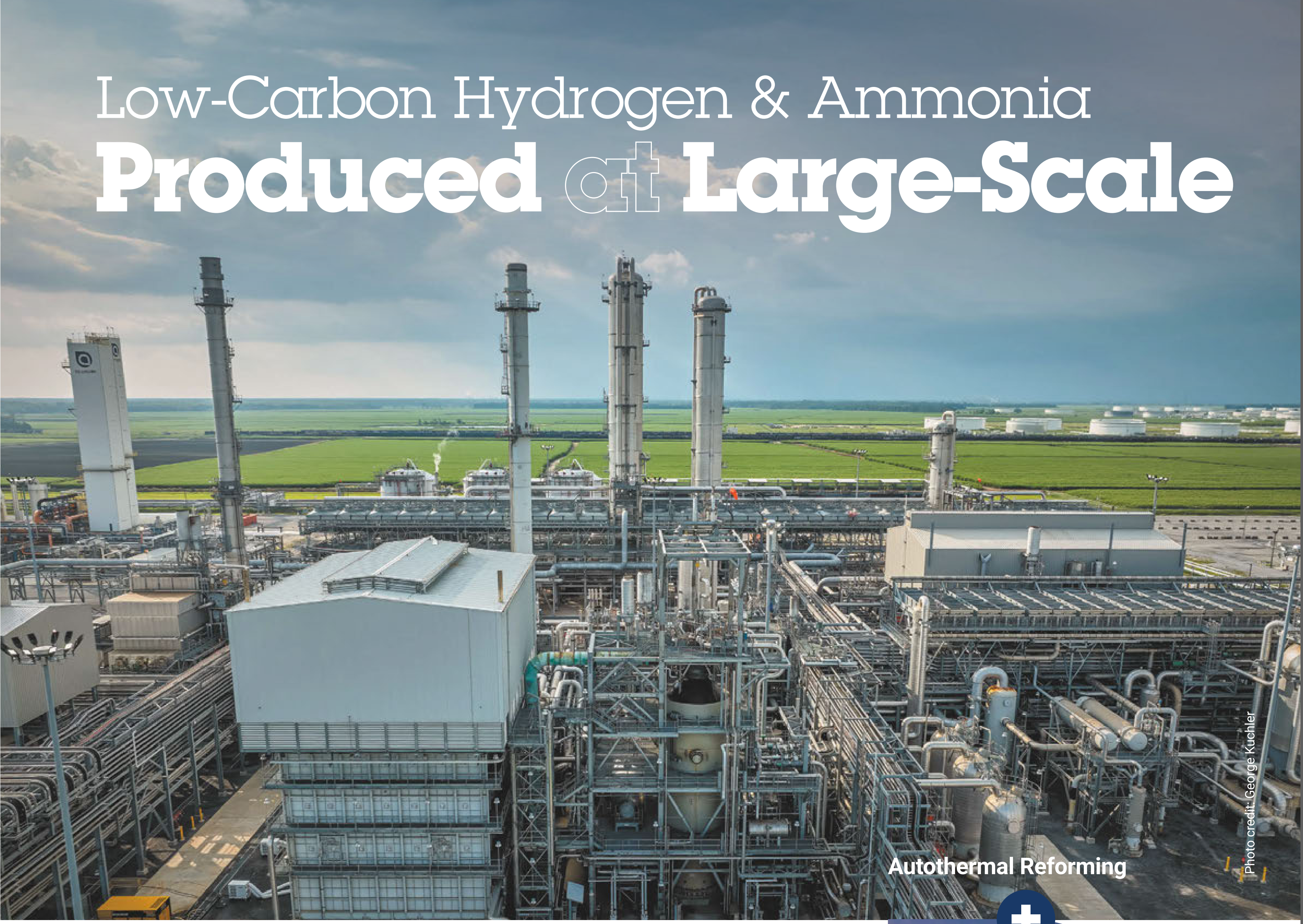
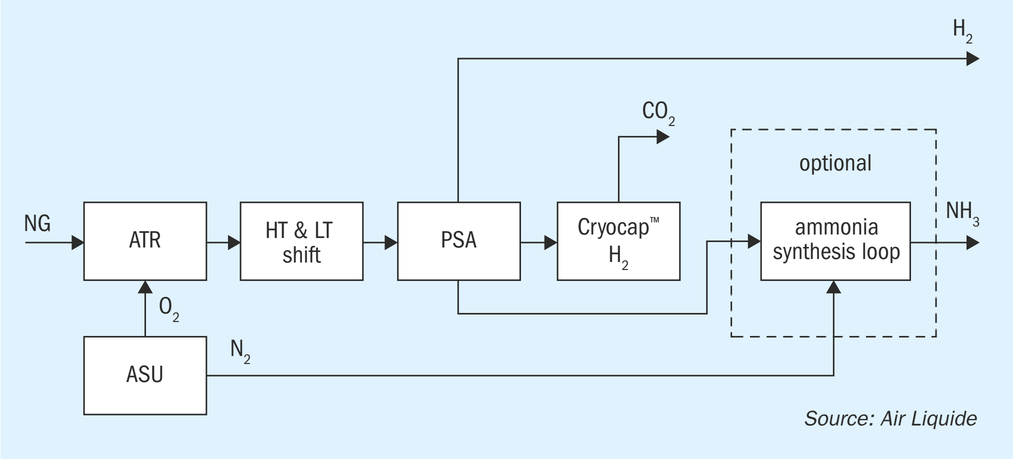


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

valuable gases such as H_2, CO and CH_4 are recycled to the ATR frontend or the PSA.

The further treatment of the hydrogen from the PSA is independent from the envisaged product(s). For hydrogen production, obviously no further treatment is required. For ammonia production, only nitrogen has to be mixed with the syngas. For co-production of ammonia and hydrogen, no additional treatment step is required. This leads to several advantages, which will be further demonstrated in the case studies below.

Fig. 4: **Air Liquide proprietary solution with Cryocap™ H_2**



Source: Air Liquide

Low carbon hydrogen production (chemical grade)

The scenario for the production of chemical grade H_2 (>99.9 mol-%) as the only product is compared in Table 1.

The natural gas and oxygen consumption of the Air Liquide proprietary solution (Case 1A) is reduced compared to the state-of-the-art solution (Case 1B), as the hydrogen recovery is higher due to the membrane based separation step for the PSA tail gas, where H_2 is recovered and routed back to the PSA. Hence less natural gas feedstock and oxygen are required. However, the electrical consumption is increased, as compression of the PSA off gas has to be considered for the Cryocap™ H_2 unit in order to meet the carbon capture rate. However, an intrinsic advantage of the Cryocap™ H_2 is that the CO_2 is obtained at elevated pressure or already liquefied without any increase on electrical duty compared to the amine wash, which delivers the CO_2 at atmospheric pressure and is saturated with water requiring an additional dehydration unit and results in a higher electricity consumption to achieve pressurised supercritical CO_2.

Overall, a significant saving on the operational cost and capital investment can be realised with Air Liquide's solution. The capital investment difference mainly attributes to lower gas/material flow through the process chain reducing the equipment sizes and the high modularisation potential for the Cryocap™ H_2 solution.

While the direct carbon capture rate is the same, the carbon intensity is higher for Case 1B, which is directly linked with the natural gas consumption.

Low carbon hydrogen production (fuel grade)

Fuel grade hydrogen production is applied for example for the decarbonisation of power plants or steam crackers. For this production scheme, a specific point has to be considered in process design: there is no requirement of high purity H_2 as it will be used for combustion only. Hence no dedicated hydrogen purification unit (e.g. PSA) is required from a technical view point. However, the lack of this hydrogen purification leads to a considerable slip of carbon molecules with the product H_2, which will ultimately increase the scope 3 emission from the plant. For fuel grade hydrogen production in this article, the loss of molecular carbon with the product is considered as a direct emission, as the H_2 product is assumed to be combusted leading to emissions to the atmosphere.

Table 1: **Chemical grade H_2 product (>99.9 mole% purity)**

Case	**Case 1A** **ATR + Cryocap™ H_2 + ASU**	**Case 1B** **ATR + amine wash based CO_2 capture + PSA + ASU**
Natural gas consumption	100%	102%
Oxygen consumption	100%	102%
Net electric power consumption	100%	96%
Operational cost	100%	102%
Capital investment	100%	112%
Direct carbon capture rate	99%	99%
Carbon intensity	100%	103%

Source: Air Liquide

Values are normalised on the Case 1A solution, except for the direct carbon capture rate

In Table 2, the parameters for the two flowsheets are compared for fuel grade hydrogen production. For the Air Liquide proprietary solution (Case 2A), a PSA is still included as it is an intrinsic part of the Cryocap™ H_2 and prepares the feed gas. Also the state-of-the-art solution with an amine wash (Case 2B), includes a PSA unit to minimise the carbon losses with the hydrogen product. For the recycle of the PSA tail gas, a compressor is foreseen, to route most of the gas back to the reforming section. As the PSA tail gas is available at close to atmospheric pressure and the reforming section operates typically in the range of 30-50 barg, a significant electricity consumption is added on the state-of-the-art solution. This dilutes the intrinsic electricity consumption difference to the ATR + Cryocap™ H_2 solution.

Although PSA tail gas is recycled and minimum carbon loss is attained, no separation of the carbon molecules and the H_2 is done in the PSA tail gas as there is no membrane foreseen as it is in a Cryocap™ H_2. So the H_2 molecules in the tail gas are run through the ATR reactor a second time, consuming energy. On the other hand, the H_2 molecules in the PSA tail gas in Case 2A, are returned to the PSA and end up in the product. Hence, for the natural gas and oxygen consumption, a clear advantage is apparent for ATR + Cryocap™ H_2 solution and so is reflected in the cost of operation.

For Case 2B*, a H_2 purification unit has not been considered for the ATR + amine wash based solution, leading to lower power

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Table 2: **Fuel grade H_2 product (>95 mole% purity)**

Case	**Case 2A** **ATR + Cryocap™ H_2 + ASU**	**Case 2B** **ATR + amine wash + ASU + PSA + recycle**	**Case 2B*** **ATR + amine wash + ASU + H_2 firing**
Natural gas consumption	100%	102%	103%
Oxygen consumption	100%	102%	103%
Net electric power consumption	100%	96%	89%
Operational cost	100%	102%	102%
Capital investment	100%	112%	105%
Direct carbon capture rate	99.4%	98.9%	95.2%
Carbon intensity	100%	103%	109%

Values are normalised on the Case 2A solution, except for "direct carbon capture rate"

Comparison is based on a defined H_2 flowrate

Case 2B: flowsheet applies a PSA and a recycle of the tail gas to the ATR to meet a stringent carbon capture rate

Case 2B: flowsheet applies no PSA, but firing of product hydrogen in the fired heater to the meet the direct carbon capture rate*

Source: Air Liquide

consumption than Case 2A. However, as discussed above, this leads to higher emissions of carbon via the H_2 product and a lower carbon capture rate. To meet a state-of-the-art threshold direct carbon capture rate of 95%, part of the product H_2 firing is foreseen, which leads to a higher natural gas and oxygen consumption.

Another option for producing a low carbon fuel grade H_2 is to use a methanation instead of PSA. By doing so, the heating / fuel value of the H_2 product is increased as in the methanation reaction the impurities CO and CO_2 are converted with hydrogen to methane. However, this in turn leads to loss of hydrogen, as it is a reactant of the methanation reaction, which leads to a higher natural gas and oxygen consumption. This ultimately increases scope 2 and scope 3 emissions.

In case the product is specified by the heating value (MWh or GJ/h) and not by the product flowrate (t/h or Nm^3/h), then the difference between the cases in Table 2 becomes smaller as there is no additional penalty on H_2 yield anymore. However, to meet a state-of-the-art direct capture rate threshold, operational cost advantage favours the ATR + Cryocap™ H_2 solution.

Low carbon ammonia production

If low carbon ammonia is envisaged, an ammonia synthesis loop as an additional techno-block will be added to the flowsheets. Thanks to the collaboration with KBR, Air Liquide is able to offer a one stop shop solution for fully integrated oxygen-blown ATR-based low carbon ammonia solutions utilising KBR's leadership in ammonia production technology. Together, a unique one-stop solution for the industry is provided, delivering exceptional energy efficiency, reliability, and carbon capture rates of up to 99% in integrated facilities. For the ATR + Cryocap™ H_2 solution (Case 3A), the advantage is that an inert-free syngas is already prepared by the PSA and high purity N_2 is available from the ASU.

For Case 3B, featuring the amine wash based CO_2 capture, typically a LNW unit is foreseen to absorb any oxygenates along with unconverted methane. The liquid nitrogen is supplied by the ASU and in this step, gaseous nitrogen from ASU is also mixed with the H_2-rich gas so that at the exit of the LNW unit a syngas is obtained that is suitable for the ammonia synthesis loop. In Table 3, a comparison of the critical parameters for the two different flowsheets is made.

It can be observed that the difference in the operational cost between the two cases is negligible. The principal reason for that is the ammonia production process is mainly power-driven due to the huge compression duties for the syngas and ammonia refrigeration compressors. Hence, the net electric power consumption does not bring any benefit to the ATR + Cryocap™ H_2 solution (Case 3A). Having effectively the same operational cost, ATR + Cryocap™ H_2 results in lower capital investment cost which leads to net lower levelised cost of ammonia, while achieving the same direct carbon capture rate and total carbon intensity.

Moreover, it is clear from the table that the main contributor of the carbon intensity for Case 3A is the electrical power consumption (scope 2 emissions). The natural gas consumption (scope 3 emissions) is lower for this solution. Hence, if decarbonisation of the power grid is realised, the potential is clearly more for the ATR + Cryocap™ H_2 solution to accomplish the lowest carbon intensity.

Co-production of hydrogen and ammonia

Referring to the above discussions, it is clear that for the production of both chemical grade H_2 and NH_3, ATR + Cryocap™ H_2 solution brings certain advantages. This means for co-production of these two decarbonised molecules, this solution will be even more advantageous. In Table 4, a comparison for critical parameters for the two different cases are illustrated.

For co-production, there is a need to produce a pure H_2 product at one of the process steps. If ammonia production is the objective, in a typical ATR + amine wash based CO_2 capture solution with LNW, there is no pure H_2 production step. Hence, to obtain a co-production scheme, an additional H_2 purification unit (PSA) will be required for the amine wash based solution. This adds capital expenditure to the solution (Case 4B). In contrast, the ATR + Cryocap™ H_2 solution already has an intrinsic PSA step. In other case studies, the application of a PSA instead of a PSA + LNW was evaluated for the state-of-the-art solution. It was observed that the additional compression duty of the PSA tail gas to meet the H_2 and CH_4 recovery from the syngas imposed a large penalty on the setup, making it less competitive compared to a PSA + LNW based setup. This can also be seen in the Case 1B results for chemical grade hydrogen, as this setup serves the same purpose, but without the additional markups for an ammonia loop.

Table 4 shows that, for a co-production scheme where 40% H_2 is being used to produce ammonia, ATR + Cryocap™ H_2 solution brings up the expected advantages from the other scenarios, the power consumption difference between the solutions also gets reduced, while the difference between capital investment cost between the two solutions gets increased favouring the ATR + Cryocap™ H_2 solution even more attributing to the additional H_2 purification unit and thus additional tail gas compression and recycling in Case 4B.

Table 3: **Low carbon ammonia (>99.8 wt-% purity)**

Case	**Case 3A ATR + Cryocap™ H_2 + ASU + NH_3 loop**	**Case 3B ATR + amine wash + ASU + LNW + NH_3 loop**
Natural gas consumption	100%	101%
Oxygen consumption	100%	101%
Net electric power consumption	100%	89%
Operational cost	100%	100%
Capital investment	100%	107%
Direct carbon capture rate	98.5%*	98.5%
Carbon intensity	100%	100%

Values are normalised on the Case 3A solution, except for "direct carbon capture rate"

Ammonia loop with state-of-the-art technology from renowned vendor

** 98.5% was required for this industrial case study, but 99% can be realised*

Source: Air Liquide

Table 4: **H_2 + NH_3 co-production (60% chemical grade H_2 product + 40% H_2 for NH_3)**

Case	**Case 4A ATR + Cryocap™ H_2 + ASU + NH_3 loop**	**Case 4B ATR + amine wash + ASU + NH_3 loop**
Natural gas consumption	100%	102%
Oxygen consumption	100%	102%
Net electric power consumption	100%	89%
Operational cost	100%	101%
Capital investment	100%	116%
Direct carbon capture rate	95%*	95%
Carbon intensity	100%	102%

Values are normalised on the Case 4A solution, except for "direct carbon capture rate"

Ammonia loop with state-of-the-art technology from renowned vendor

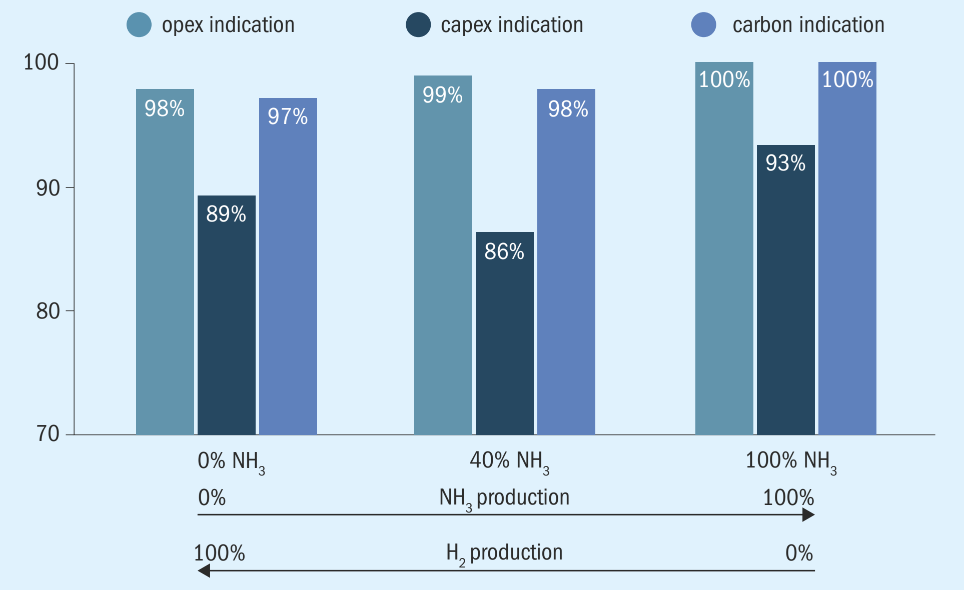
Case 4B includes a LNW and PSA

** 95% was required for this industrial case study, but 99% can be realised*

Source: Air Liquide

Fig. 5 displays the results of the case studies and the overall performance of the Air Liquide proprietary solution versus the state-of-the-art amine wash based setup. It can be observed that if low carbon hydrogen is envisaged as the sole product, the Lurgi™ ATR plus Cryocap™ H_2 solution shows decreased opex and also significantly decreased scope 3 carbon emissions. The capex parameter is remarkably decreased by 11% compared to the state-of-the-art solution, due to the increased H_2 recovery and smaller throughput through the unit as well as the modularised layout. If ammonia and hydrogen are produced, the opex of the Air Liquide solution and the state-of-the-art solution are at the same level, but the capex is drastically decreased as only one common hydrogen purification unit (PSA) is used compared to the state-of-the-art case (PSA + LNW). For the co-production case, the scope 3 emissions are also decreased compared to the state-of-the-art due to the use of Air Liquide's MEDAL™ PIX membranes for carbon recycling and hydrogen recovery. If only low carbon ammonia production is envisaged, the setup based on Cryocap™ H_2 shows a lower capex at comparable operational expenditure and scope 3 emissions.

Fig. 5: **Overview of case studies: Comparison of the flowsheets (100% refers to state of the art setup)**



Source: Air Liquide

Conclusion

Air Liquide is committed to enable sustainable low carbon hydrogen production and offers an innovative production scheme based on the renowned Air Liquide technologies Lurgi™ ATR, Cryocap™ H_2 and ASU.

These three key technologies have a successful industrial track record and can be flexibly integrated by Air Liquide for low carbon hydrogen. In addition, customers benefit from Air Liquide's expertise in EPC and as an owner/operator, drawing on 60 years of experience across the entire hydrogen value chain.

The overall concept is currently underway to industrial realisation in the USA and Air Liquide is ready to supply it to its customers to support their decarbonisation targets worldwide. ■

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Challenges in the conversion to clean ammonia

VK Arora of KPI examines the technical and operational challenges of decarbonising legacy and new ammonia plants, drawing on a European case study of full-scale conversion supported by robust process and integration design. It also presents three US case studies exploring partial strategies, such as green hydrogen blending and oxygen enrichment, to reduce CO_2 emissions and improve throughput. Together, these examples highlight a phased, cost-effective approach to decarbonisation, with blue hydrogen serving as a near-term transitional feedstock.

The decarbonisation of legacy ammonia plants presents notable technical and economic challenges. However, with robust conceptual and process design, coupled with strategic integration planning, the extent of required modifications, and associated capital costs, can be significantly reduced. While these facilities were originally designed for hydrogen sourced via unabated steam methane reforming (SMR), many core systems, such as synthesis loops, compression trains, and heat recovery units, can be adapted to accommodate low-carbon feedstocks, including green and blue hydrogen. This enables a phased decarbonisation pathway, where blue ammonia serves as a transitional step toward fully renewable production. By leveraging existing infrastructure and applying targeted retrofits, operators can pursue a cost-effective and minimally disruptive transition that aligns with evolving regulatory expectations and long-term emissions reduction goals.

Overview of study cases

This article presents four techno-economic evaluations conducted by Kinetics Process Improvements, Inc. (KPI), each offering a distinct perspective on clean ammonia transition strategies. The case studies span full-scale conversions and partial integrations, reflecting a range of plant configurations, regional drivers, and decarbonisation approaches:

Case 1 – Full conversion from grey to clean ammonia

A comprehensive redesign of an existing ammonia synthesis loop for a legacy plant in Europe was undertaken to enable operation exclusively on clean hydrogen, sourced primarily from the European Hydrogen Backbone (EHB) pipeline and supplemented by over-the-fence (OTF) hydrogen from urban solid waste (USW) gasification. The study evaluated major retrofits, including the installation of a new feed purification system to remove trace impurities and the complete phase-out of conventional reforming and CO_2 capture systems. Key regulatory and infrastructure drivers for this full-scale transition are discussed in detail later.

Case 2 – Debottlenecking a new ammonia facility via green H_2 and O_2 integration

At a newly built US ammonia plant equipped with cryogenic purification technology, KPI investigated the injection of green hydrogen and moderate oxygen enrichment to also alleviate specific bottlenecks. These included overloaded arch burners, elevated tube metal temperatures in the steam methane reformer (SMR), and limitations in the cryogenic purifier. The integration strategy aimed to reduce carbon intensity, improve reliability, and achieve a modest increase in ammonia production.

Case 3 – Hydrogen and oxygen integration in a legacy ammonia plant

A legacy ammonia facility explored the integration of green hydrogen and moderate oxygen enrichment using a 20 MW electrolyser system. While the oxygen enrichment pathway was ultimately deemed uneconomical due to the requirement for a dedicated compressor, the plant successfully implemented green hydrogen injection. As an early adopter, the facility capitalised on Inflation Reduction Act (IRA) incentives, achieving a viable business case despite high capital expenditure.

Case 4 – Green hydrogen integration to increase plant capacity

A smaller U.S.-based ammonia plant evaluated the injection of green hydrogen to increase production by approximately 20% while reducing carbon intensity. The plant had already installed a new converter rated at 120% capacity, but was constrained by limited syngas supply from the front end. Key drivers included the high cost of trucked-in ammonia (~20% of total output) and the availability of competitively priced green hydrogen. Multiple nitrogen sourcing options were assessed, with over-the-fence supply emerging as the most cost-effective solution.

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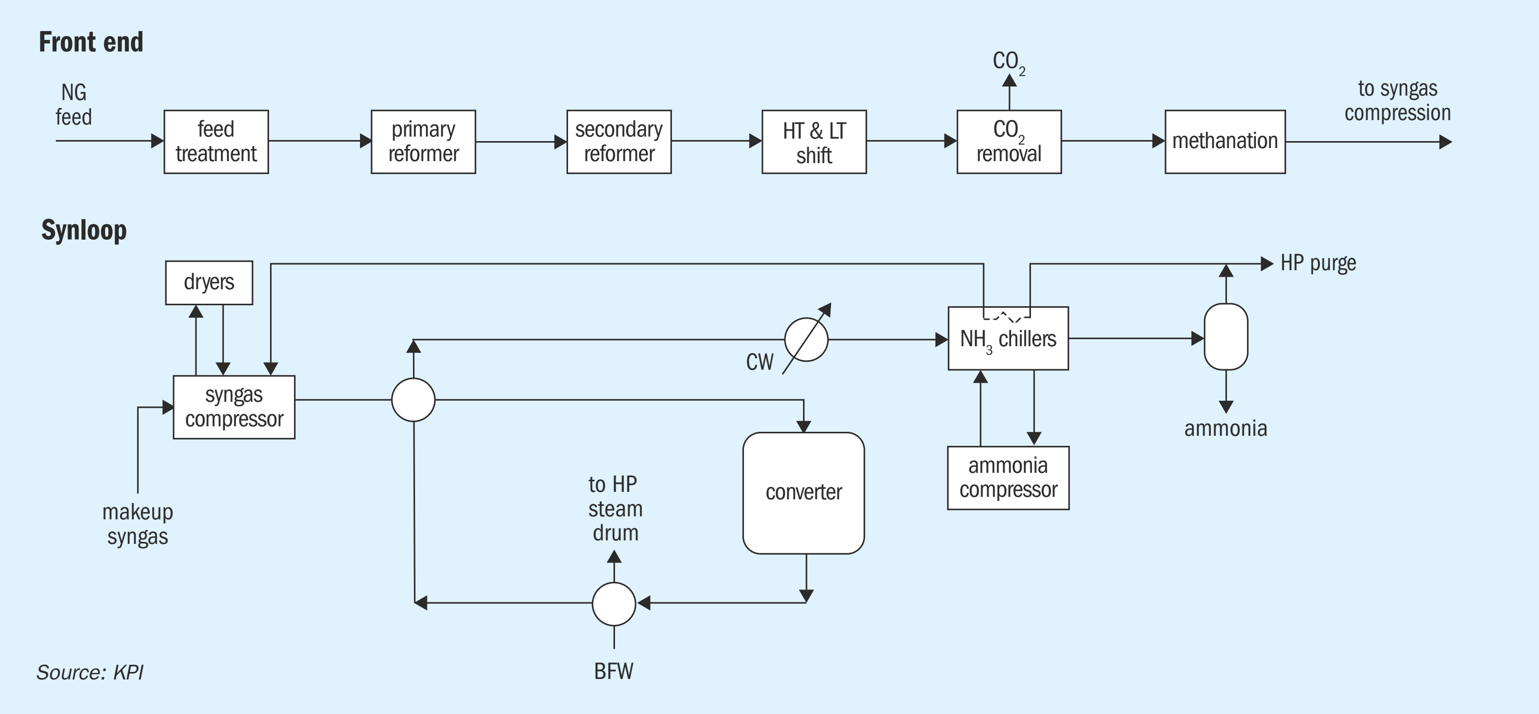
Fig. 1: **Case 1: Existing ammonia plant configuration**



Source: KPI

Case 1 drivers for full-scale conversion at European location

Europe's clean ammonia transition is driven by tightening carbon policy and expanding hydrogen infrastructure. The inclusion of hydrogen under the EU ETS, with carbon prices at €80 to €90/tCO_2, and the upcoming CBAM mechanism are raising the cost of unabated production and imports.

While initiatives such as REPowerEU and the European Hydrogen Backbone are advancing the deployment of electrolysers and pipeline connectivity, high gas prices and funding delays have slowed progress. Still, a phased conversion strategy, anchored in robust conceptual and process design, can minimise facility modifications and reduce capital intensity. For producers, this approach provides a pragmatic path to lower carbon exposure, aligns with regulatory trends, and enables access to emerging low-carbon markets.

Case 1 – Full conversion from grey to clean ammonia

Existing ammonia plant

The facility under study is a legacy ammonia plant constructed in the 1980s, currently operating at approximately 1,765 short tons per day using natural gas as the primary feedstock. The plant follows a conventional process flow scheme, as illustrated in Fig. 1.

The existing steam system is also traditional in design. The syngas compressor turbine is driven by high-pressure (HP) steam, supplied from a header operating at approximately 1,800 psi. Meanwhile, the process air compressor turbine and the ammonia refrigeration compressor turbine are both connected to a medium-pressure (MP) steam header, operating at around 600 psi.

This baseline configuration served as the foundation for evaluating the technical and economic feasibility of a complete conversion to clean ammonia production using low-carbon hydrogen feedstocks.

Hydrogen and nitrogen sourcing

The clean ammonia facility will utilise two distinct hydrogen feed sources:

- OTF hydrogen produced via USW gasification, available from an adjacent third-party supplier;
- pipeline-supplied hydrogen delivered through the EHB network, expected to come online in alignment with the pipeline's phased commissioning schedule.

The USW-derived hydrogen will be available in limited quantities, sufficient to support approximately 35 to 40% of the plant's total ammonia production capacity. The EHB pipeline will meet the remaining hydrogen requirement as infrastructure becomes operational.

Nitrogen feed will be supplied over-the-fence via a dedicated pipeline from a nearby air separation unit (ASU), ensuring consistent purity and pressure for integration into the synthesis loop.

Feedstock quality

The hydrogen supplied via pipeline originates from diversified production sources and contains trace levels of several contaminants that must be addressed before synthesis. Key impurities identified in the feed include: chlorides, sulphur- inorganic compounds, CO, CO_2, O_2, formic acid and formaldehyde.

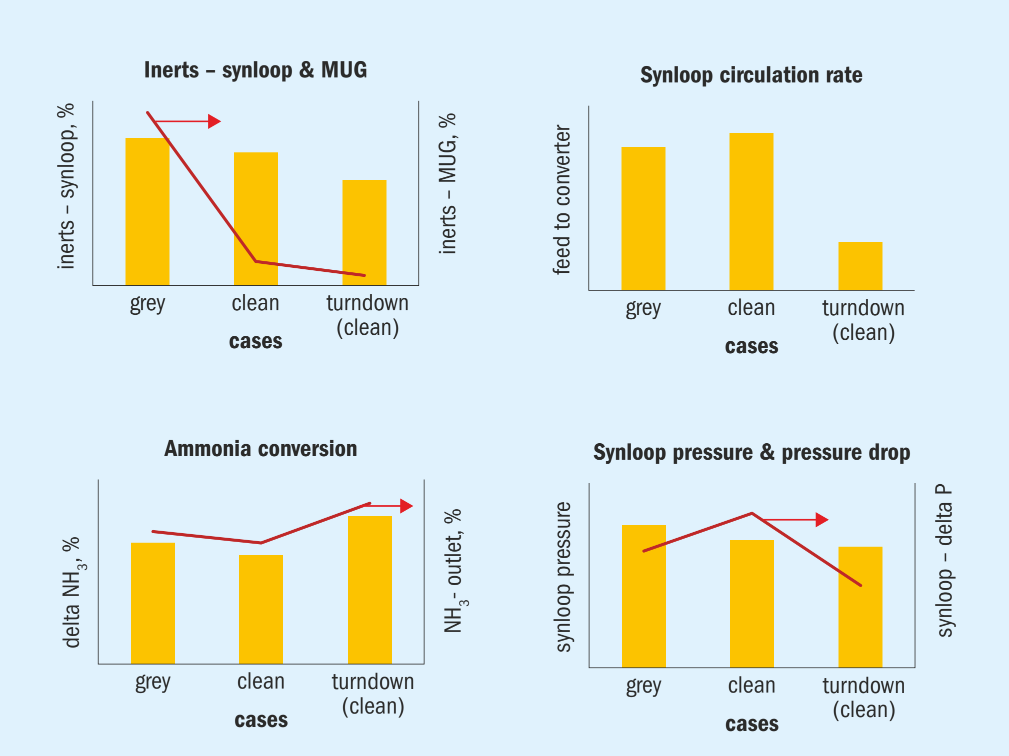
These impurities pose a risk to both catalyst performance and the integrity of downstream equipment. In particular, sulphur compounds and CO are known catalyst poisons, while chlorides can also contribute to corrosion and fouling. Effective purification strategies are crucial for reducing these contaminants to levels compatible with the specifications of ammonia synthesis catalysts and ensuring long-term plant reliability.

Key challenges and mitigation

The listed impurities in the hydrogen are poisonous to the synthesis catalyst and need to be removed well below the acceptable limits. The following challenges were posed for the design of the new hydrogen purification system:

- A viable and cost-effective method for removing formic acid and formaldehyde was not available. Additionally, leading catalyst vendors lacked prior experience with these compounds, and the industry's understanding of their behaviour within the ammonia production process remains limited. A layer of special adsorbent was suggested to be added to the existing dryers to partially mitigate traces of formic acid and formaldehyde.

Fig. 2: **Case 1: Key variables in synloop**



Source: KPI

- Limited degree of H_2 feed preheat (<500°F) due to the unavailability of HP steam. This means that the conventional catalysts used in ammonia plant feed purification cannot be used to remove the impurities. Alternative lower-temperature catalysts were reviewed and carefully configured, incorporating numerous feedback points from different catalyst suppliers.
- To minimise the cost, the existing desulphurisers and methanation vessels were intended to be used.

A limited availability of feed hydrogen for an extended period also posed a challenge for the proper selection of the syngas compressor configuration.

Considering the low turndown requirements for the syngas compressor over an extended period and the cost of additional power consumption in the recycle mode of operation, the cost-benefit analysis suggested using two 50% compressors. Furthermore, it was also determined that the amount of MP superheated steam production within the synloop will permit the operation of one 50% syngas compressor on the steam driver. This combination also provides an added flexibility in the operation with improved reliability.

Challenges of synloop re-rating and re-configuration

The transition of the ammonia synthesis loop from conventional methane-based syngas, typically containing substantial levels of inert components such as argon and methane, to a stoichiometric blend of high-purity hydrogen and nitrogen introduces a suite of complex process and engineering challenges. The virtual elimination of inert materials has a significant impact on both the catalyst bed's thermodynamic equilibrium and kinetics, as well as the overall hydraulic assessment of the synloop. Change in the circulation rate coupled with changes in the temperature profile impacts heat exchanger duties, system pressure drops, and the turndown capability of syngas compressors.

Elevated reactant partial pressures in the feed stream shift the equilibrium conversion, enhancing ammonia yield per pass. However, this gain also requires recalibration of the reactor temperature, pressure profile and rerating to mitigate risks such as catalyst sintering or localised hotspots. A thorough evaluation of equilibrium and kinetics performance, hydraulics of the synloop, and the mechanical integrity of existing equipment, originally engineered for higher inert dilution and different gas compositions, is essential.

KPI undertook a comprehensive re-rating of the entire synthesis loop across all projected operating scenarios, including a detailed kinetics assessment of the converter beds. This resulted in the optimisation of critical operating parameters, including inert concentration, pressure, circulation rate, bed temperature profiles, pressure drop behaviour, heat exchanger loads, and compressor performance (for both syngas and ammonia services). Catalyst bed profiles were further validated through collaboration with all major catalyst suppliers to ensure the desired temperature profiles and ammonia production rates were achievable.

Key variables, including inert levels, circulation rate, ammonia conversion, and operating/pressure drop characteristics, were mapped across both normal and turndown modes for clean ammonia production and benchmarked against baseline grey ammonia operations as shown in Fig. 2.

In addition to process refinements, the configuration was adapted to accommodate superheated steam generation for the compressor drivers. This involved replacing the existing high-pressure boiler feedwater exchanger with a new medium-pressure steam generator coupled with a superheater.

New plant configuration

In the revamped configuration, the majority of the front-end equipment from the legacy ammonia plant is decommissioned. However, several components, including the existing desulphurisers, methanation vessels, and selected heat exchangers, were successfully repurposed within the new feed purification unit designed for blended hydrogen and nitrogen streams. Major modifications to the synthesis loop (synloop), illustrated in Fig. 3, include:

- reconfiguration of the syngas compression system with two new 50% capacity compressors, one steam-driven and the other motor-driven, for operational flexibility and improved turndown performance;
- Installation of a medium-pressure (MP) steam generator and superheater by replacing the high-pressure boiler feedwater (HP BFW) exchanger within the synloop;
- addition of a new feed preheater in the purification section, utilising steam to optimise the feed temperature before synthesis.

Steam system

The redesigned steam system is thermally balanced to minimise external steam import. MP superheated steam is generated within the synloop and used to drive one of the new syngas compressors.

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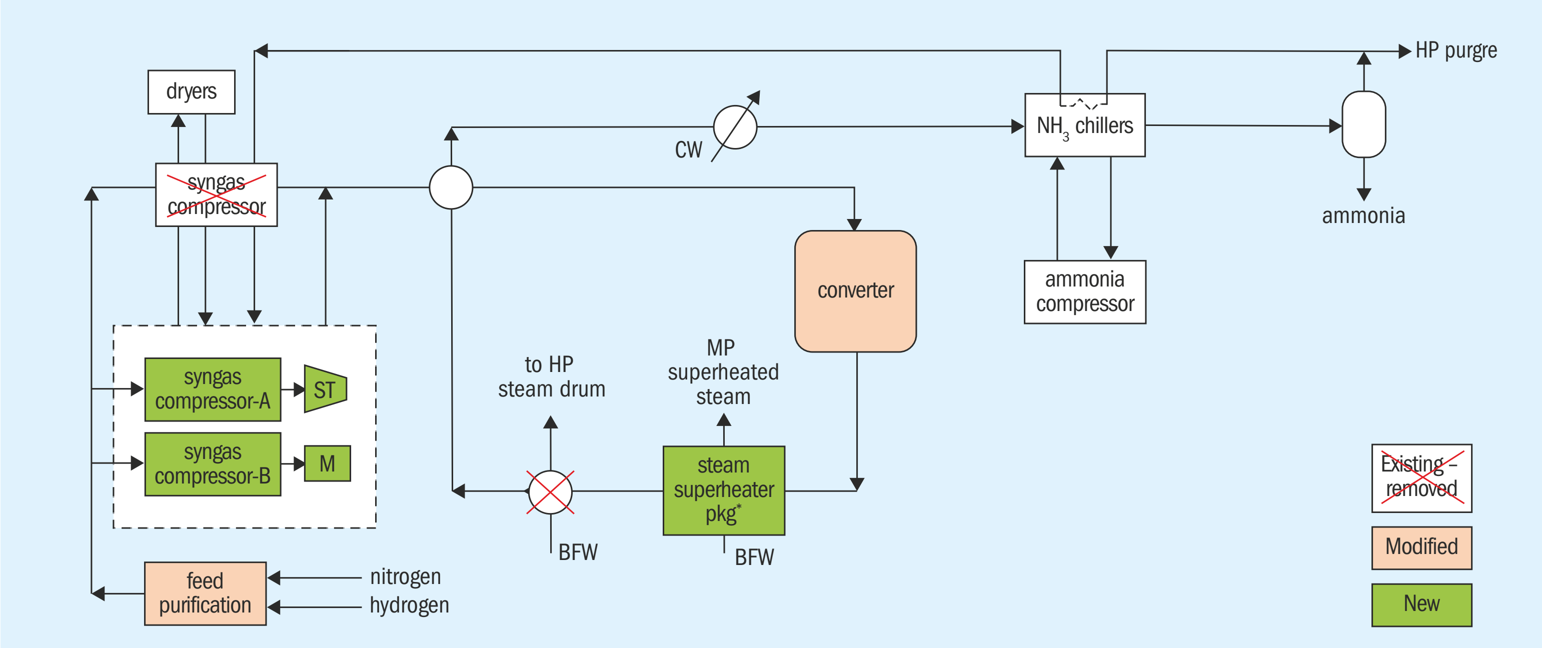
Fig. 3: **Case 1: New configuration synloop**



Source: KPI

**Steam superheater pkg includes an integrated BFW preheater, steam generator, and steam superheater*

The ammonia refrigeration compressor turbine is also powered by MP steam, ensuring efficient energy utilisation across the cycle. A minimal amount of steam is imported for a well heat-integrated purification section.

Specific energy consumption

The specific energy consumption for clean ammonia production is estimated to be approximately 16% lower than that of the existing plant (on a higher heating value basis). This figure accounts for the energy content of the hydrogen feed, power required for nitrogen production, steam import/export credits, and auxiliary power consumption (e.g, compressors and pumps).

Carbon emissions

Scope 1 carbon emissions for the clean ammonia configuration are projected to be less than 0.2% of those from the existing plant. For reference, the current facility emits approximately 1.8 tonnes of CO_2 per tonne of ammonia produced. This dramatic reduction underscores the decarbonisation potential of complete hydrogen substitution and process electrification.

Economic justification

The economic rationale for complete conversion to clean ammonia production is reinforced by a convergence of regulatory, financial, and infrastructure developments across Europe. Stringent environmental policies, notably the tightening of the EU Emissions Trading System (ETS) and the phased implementation of the Carbon Border Adjustment Mechanism (CBAM), are driving up the cost of carbon-intensive production. With carbon prices exceeding €80 to 90 per tonne of CO_2 and free allowances set to diminish, legacy ammonia plants face mounting compliance costs.

Simultaneously, the expansion of hydrogen infrastructure, including the European Hydrogen Backbone, is improving access to low-carbon hydrogen at scale. These developments, combined with funding mechanisms such as the EU Innovation Fund and national-level incentives, significantly enhance the financial viability of clean ammonia projects.

In this context, the studied facility's transition to clean hydrogen feedstock, sourced from both over-the-fence gasification and the EHB pipeline, offers a compelling long-term business case. The project has already advanced into the detailed engineering phase, supported by favourable policy alignment, infrastructure readiness, and a clear pathway to mitigate carbon risk and achieve market differentiation.

Case 2 – Debottlenecking a new ammonia facility via green H_2 and O_2 integration

This US-based ammonia plant, operating at approximately 2,800 short t/d (~115% of nameplate capacity), features a modern configuration that includes a cryogenic purifier for removing inert gases and excess nitrogen from the syngas stream. During the initial evaluation, KPI identified several systems operating beyond their design limits, most notably the cryogenic purifier and the arch burners. Overfiring of the arch burners posed a reliability risk to the radiant tubes. At the same time, the overloaded cryogenic purifier resulted in increased purge gas losses to the fuel system, thereby reducing overall energy efficiency.

As part of a broader decarbonisation initiative, the facility proposed installing a 20 MW electrolyser to integrate green hydrogen into the process. The primary objective was to reduce carbon emissions and leverage the IRA incentives to establish a viable economic case. Given the limitations of the arch burners and cryogenic purifier, KPI recommended a combined strategy: injecting green hydrogen downstream of the purifier, along with moderate oxygen enrichment.

Key findings from the study:

- Arch burner firing could be reduced by ~9%, bringing operation well within design limits.
- Radiant tube outlet temperatures decreased by ~34°F, with even greater reductions in tube metal temperatures, enhancing reliability and extending tube life.
- Cryogenic purifier loading was reduced, resulting in lower inert gas content in the make-up gas and a corresponding decrease in purge rate.

- Post-combustion CO_2 emissions were reduced by ~9%. Additional CO_2 emissions from the auxiliary boiler (used to offset a minor MP steam shortfall) were fully accounted for in the net emissions balance.
- Feed and fuel consumption decreased by ~0.3 million Btu/ST compared to the base case.
- Oxygen injection was deemed feasible without a dedicated compressor based on commercial precedent. However, if a separate compressor were required, the economic viability of oxygen enrichment would be compromised.

Current status

The electrolyser project is currently on hold due to uncertainty surrounding the long-term availability of IRA incentives.

Case 3 – Hydrogen and oxygen integration in a legacy ammonia plant

This legacy U.S.-based ammonia facility, operating at 1,800 short t/d, evaluated the partial integration of green hydrogen and oxygen from a 20 MW electrolyser system to reduce carbon intensity and modestly increase production. The study, conducted by KPI, shared similar objectives with Case 2, though without the added benefits of cryogenic purification.

The project drivers were:

- Initiate decarbonisation through partial integration of green hydrogen.
- Gain operational experience with green ammonia production technologies.
- Leverage federal and state incentives under the IRA to establish a viable business case.

Integration strategy

The plant investigated injecting green hydrogen downstream of the methanator, along with moderate oxygen enrichment. However, the requirement for a dedicated oxygen compressor significantly increased capital and operating costs, rendering the oxygen enrichment pathway economically unfeasible.

Implementation and outcomes

Despite shelving the oxygen integration, the facility successfully implemented green hydrogen integration using the 20 MW electrolyser system. As an early mover, the plant was well-positioned to capitalise on IRA and state-level incentives, enabling a commercially viable transition. The project also yielded valuable operational insights into the handling and integration of green hydrogen within a legacy ammonia framework.

Case 4 – Green hydrogen integration to increase plant capacity

This US-based ammonia facility, currently operating at 550 short t/d, features a high-pressure synthesis loop (>4,000 psi) and reciprocating compressors. The plant recently installed a new, high-efficiency converter rated for approximately 120% of its nameplate capacity. However, the front-end reforming section remains unmodified. To capitalise on the converter's latent capacity, the plant pursued a third-party offtake agreement for green hydrogen, aiming to expand production without major front-end upgrades.

The project drivers were:

- Replace ~100 short t/d of trucked-in ammonia with on-site production to reduce logistics costs.
- Leverage IRA incentives to lower carbon intensity and improve project economics.
- Utilise existing downstream capacity to minimise capital investment and operational disruption.

Integration study

KPI conducted a detailed evaluation of green hydrogen integration strategies to support an additional 100 short t/d of ammonia production. The study also assessed nitrogen supply options, including front-end upgrades and on-site generation via PSA and cryogenic systems.

Key findings

Over-the-fence nitrogen supply emerged as the most cost-effective solution, offering the lowest capital expenditure, minimal production loss, and the shortest turnaround time.

The integration strategy avoids overloading the existing reformer and compression systems, enabling a streamlined capacity increase.

Current status

While technically viable and economically attractive under current policy frameworks, the project is under review due to uncertainty surrounding the long-term availability of IRA incentives. Alternative pathways are being explored to maintain project momentum.

Conclusions

- The complete conversion of legacy ammonia facilities, particularly across Europe, offers significant potential, driven by stringent environmental regulations, rising carbon costs, and the development of emerging hydrogen pipeline infrastructure.
- For the complete conversion of Case 1, a careful and comprehensive assessment of the synloop, particularly of the converter, must be conducted to determine new optimum operating parameters for different scenarios, ensuring compliance with the maximum permissible temperature limits of the catalyst and materials and minimising the purge.
- For the complete conversion of Case 1, the syngas compressor configuration and the type of driver selection should be based on a lifecycle cost-benefit analysis, considering the frequency and duration at turndown rates, and accordingly, the steam system should be balanced to minimise the import.
- Moderate, targeted oxygen enrichment represents a technically and economically feasible retrofit. It preserves mechanical integrity and does not require additional compression systems, as commercially demonstrated. However, if the plant insists on adding a dedicated compressor, then the oxygen enrichment option is not economically viable.
- Applied selectively, oxygen enrichment mitigates primary reformer constraints by lowering radiant tube metal temperatures and reducing arch firing loads. This results in improved operational reliability, modest gains in ammonia yield, and lower post-combustion CO_2 emissions.
- The strategic injection of green or blue hydrogen downstream of cryogenic purification units provides critical relief for bottlenecked systems. This improves overall ammonia plant efficiency and enhances reliability by reducing excess purge gas losses to the fuel system.
- Although technically viable, integrating electrolyser-based green ammonia into existing plants remains commercially infeasible without robust support mechanisms such as tax credits, carbon pricing, or premium pricing for clean ammonia. ■

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Reforming furnace tube failure results in fire

This article describes an unusual tube failure incident which resulted in fire escaping the furnace box during normal operation of a hydrogen plant. **Ken Wohlgeschaffen** of Chevron Products Company shares the sequence of events leading up to the incident, the extent of damage caused by the incident, and most importantly the causes and lessons learned from this incident to prevent recurrence.

Most instances of reforming furnace tube failures occur during transient conditions such as start-up or shutdown when the risk of overheating tubes is the highest. This incident occurred during normal operation of a world-scale side-fired steam methane reforming furnace of a 1960s vintage hydrogen plant.

The incident

The first indication there was a problem was a high fuel gas pressure alarm. Several tube effluent temperatures had failed and the control system responded by firing up the furnace. Flames were observed coming out of the furnace near the location of a burner manifold (Fig. 1). Fuel gas to the burners was reduced, and natural gas feed was pulled. The plant was set to steam-only mode.

Fig. 1: Fire escaping the furnace box

Visual inspection of the interior of the fire box revealed that refractory on the wall had been knocked off. The fire box wall was glowing red on the inside and outside (Fig. 2a) due to the damaged refractory. A leaking tube could be seen with the jet flame clearly impinging on the furnace wall (Fig. 2b). The flame impingement had caused refractory to fall off the furnace wall onto a burner below, deflecting the flames through the burner air inlet above the walkway.

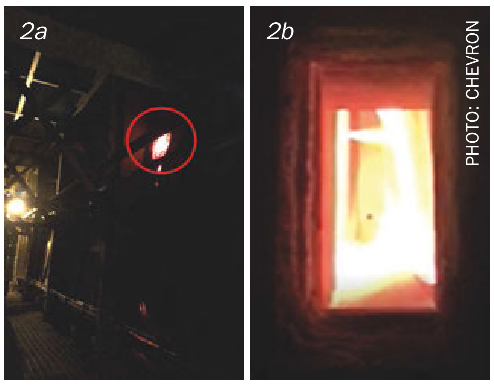

Fig. 2a: Hot spot outside furnace wall (L),
Fig. 2b: Jet flame impinging on furnace wall (R).

The steam flow eventually dropped off below the minimum flow limit causing a full plant trip (Fig. 3).

Upon inspection it was found that a radiant section tube had a crack approximately 5 inches (127 mm) in length and ¼ inch (6 mm) wide (Fig. 4). The tube was bulging about 6 feet (1.8 m) above the closest burner located on the lower level, or approximately one third the length of the tube from the bottom of the tube.

Incident investigation findings

The tubes were newly installed during a major turnaround several years prior. After that start-up a tube in this same section of the furnace had failed near the bottom of the tube outside the extreme heat zone. Destructive testing revealed manufacturing defects or voids in the material resulting in premature failure of this new tube. During the subsequent major turnaround a tube

Fig. 3: **Process trend showing steam flow and natural gas FCV output**

Start Time: 07/08/17 12:50 AM
Span: 4.00
Units: Hours
End Time: 07/08/17 04:50 AM
Scale Left: All
Scale Right: All
Type: Linear

		Legend	Value Name		Description	Default Units	Current Value	@ 07/08/17 03:02 AM	Display Units	Units Category	
☑	●				GAS FEED OP	%	63.84	-6.90	%	All	☐
☑	○				STEAM FEED	MPPH	62.27	18.42	MPPH	All	☐

Source: Chevron

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PHOTO: CHEVRON

Fig. 4: Photograph of tube crack and bulging

Lessons learned

1. Recognise that, with a loss of several layers of protection (the "Swiss cheese effect"), it is possible for a reforming furnace radiant section tube leak to result in fire escaping the furnace fire box.
2. Recognise the risks associated with furnace tube failures, understand what safeguards are needed to minimise them, and ensure that they are in place and working.
3. Follow up on incident investigation action items in a timely manner.
4. Take tube wall temperature measurements routinely.
5. Do not normalise deviation, in this case hot tubes.
6. Use the right tools for the job, in this case a good combination pyrometer and data logger.

crawler inspection was performed to identify early signs of creep damage or thinning. No abnormalities were found.

The possibility that this most recent tube failure occurred because of a manufacturing defect like the one which occurred many years prior could not be ruled out since destructive testing of the failed tube could not be done. However, the probability of this to be a manufacturing defect is low because manufacturing defects tend to be found in the far ends of the tubes or the tube welds rather than near the middle of the tube. Furthermore, this failure would likely have occurred much sooner after start-up, as was the case with the previous tube failure.

Temperature data was reviewed. A few years earlier the catalyst supplier measured tube wall temperatures and found one tube to be running close to the creep limit. This tube which had been identified was closely monitored to ensure it was well below the creep limit. Later on the routine tube wall temperature surveys were discontinued.

A survey was conducted by the catalyst supplier much later on which identified tubes with wall temperatures above the creep limit. Adjustments were made immediately to reduce the tube wall temperature. It is unclear how long these tubes were running at elevated temperatures.

As a result of the investigation it can be concluded that to prevent safety incidents of this nature, hydrogen and ammonia plant operators should: train their personnel on the importance of routine tube temperature monitoring; conduct routine tube temperature surveys; use appropriate equipment for tube temperature monitoring; and have in place a robust process for communicating and managing the identification of hot tubes. ■

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