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Number 392

November | December 2024

nitrogen+syngas

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Australia's nitrogen industry

Coal as a feedstock

Cryogenic storage for green ammonia

Revamping urea plants

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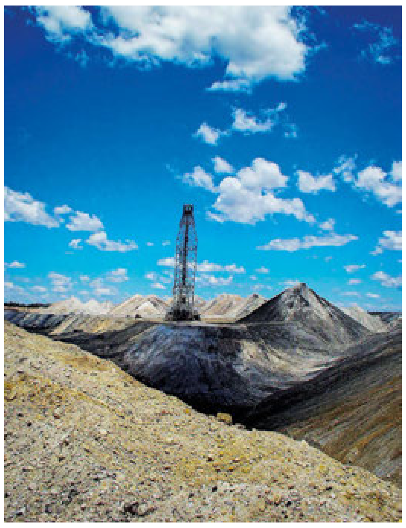

Cover: Dragline at a coal mine in Queensland's coal basin, Australia
Tracie Louise / istockphoto.com

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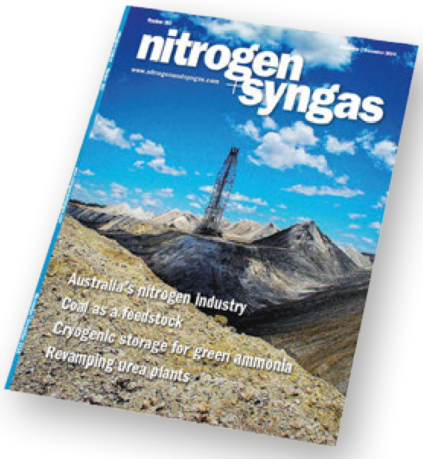

Political threats loom large

While underlying supply and demand criteria continue to set floors and ceilings for nitrogen and other syngas derived products, political events as ever have the potential to derail all calculations. While much attention has focused on the US election, the escalating crisis in the Middle East continues to have the potential to threaten fertilizer trade in multiple ways. As this issue was going to press, Israel had just launched its retaliatory missile strike on Tehran, on October 26th, the latest in a series of tit for tat attacks between Israel and Iran, in particular an Iranian missile strike on Israel on October 1st. The Iranian government appeared to be downplaying the results as "limited", but said that it considered itself "entitled and obligated to defend itself".

One of the potential scenarios is an Iranian attempt to blockade of the Straits of Hormuz, the narrow stretch of water between Oman and Iran that is the transit route for significant quantities of nitrogen, sulphur and phosphates. Around 31% of global urea exports, or 16.4 million t/a, are shipped from producers in the Arabian Gulf, west of the Strait of Hormuz. For ammonia the figure is 3.16 million t/a, or around 18%. Hormuz is also a major choke point for global energy flows, and one that the Islamic Republic of Iran has a history of highlighting. Iran threatened to shut Hormuz in 2019 and again in 2011/12, and during the Iran-Iraq war of the 1980s, the so-called 'tanker war involved 168 attacks by Iranian forces and 283 by Iraq. Around a third of global liquefied natural gas (LNG) and a quarter of the world's crude oil passes through the strait, which is just 21 miles wide at its narrowest point and stretches between an Omani enclave on the Musandam peninsula and mainland Iran to the north. Iran has seized multiple vessels in the strait this year and last, suggesting some were "linked to Israel".

"Regional tensions have already caused urea prices to spike in early October..."

One of the issues for Iran is that it is itself a major exporter of ammonia and urea, and indeed has been exporting high quantities this year, most of it going to Brazil, Turkey or other countries in the region. Urea exports were over 450,000 tonnes in September 2024, up 12% year on year, taking the annual total to 4.4 million tonnes for Q1-Q3 this year, up 18%. Iran also exported 580,000 tonnes of ammonia for Q1-Q3 2024, with more than 80% destined for India. Iranian ammonia exports are up 28% this year so far.

Regional tensions have already caused urea prices to spike in early October, with Brazilian c.fr prices reaching $395/t, up $30/t. Offer prices into India have also increased. Demand in India is expected to provide a floor for urea prices in the short term and an escalation in the Middle East points to potential upside.

There are two key risks to fertilizer markets from the current escalation in the Middle East. The first is a repeat of the 'war-risk premium' that was last seen in June 2019. While there is a possibility of marginal arbitrage opportunities as a result, the production costs of Arab Gulf producers remain among the lowest in the world. This would make a lower Middle East f.o.b. netback more likely, but it would be unlikely to upend markets. However, if vessel movements out of Hormuz were compromised for a sustained period, a significant proportion of nitrogen, phosphate and sulphur trade would be at risk. ■

Richard Hands, Editor

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Price Trends

In October, ammonia benchmarks were more or less stable across the board. West of Suez, supply from Algeria was constrained by an ongoing turnaround at one of domestic player Sorfert's production units. Still, demand from NW Europe remained quiet, although CF was set to receive a 15,000 tonne spot cargo from Hexagon some time in November, reportedly sourced somewhere in the region of $530/t f.o.b. Turkey. While regional supply appeared tight, steadily improving output from Trinidad and the US Gulf could alleviate recent pressures, with many players of the opinion that Yara and Mosaic could agree a $560/t c.fr rollover for November at Tampa as a result.

East of Suez, Middle East exports remained constricted with maintenance works at Ma'aden's No.3 unit still ongoing. The producer had anticipated moving 125,000 tonnes in October, with 60% of that total originally lined up for India. Buyers there continued to resist higher c.fr offers, with phosphate fertilizer producers seemingly holding back on raw material purchases until further clarity on latest phosphoric acid supply contracts was given.

Further east, tonnes continued to move out of Indonesia, where Trammo picked up a formula-priced spot cargo from Mitsubishi for loading from Luwuk. Elsewhere, spot appetite in South Korea and Taiwan, China remained absent, with importers negotiating their 2025 supply contracts. In China, domestic prices moved down in line with inland urea benchmarks, with both imports and exports confined to a minimum.

In urea markets, with India expected to float another tender to secure tonnes for December, Middle East values shot up another $20/t. SIUCI sold a November cargo at $390/t f.o.b. with further trader interest reported at $385/t f.o.b. With other markets generally very quiet, this demand was believed to emanate from traders looking to position for the next Indian tender. News of an IPL tender in India came hot on the heels of RCF confirming letters of intent for 560,000 tonnes.

Nigeria saw some further f.o.b. sales with Dangote placing another cargo, but there was no real clarity as to whether the price had traded once again in the low $350s/t f.o.b., or if a cargo had been sold at $355/t f.o.b. Top-off tonnes were reported sold at $405/t f.o.b. by AOA, a high price considering most October cargoes from the Algerian producer were expected to head to Latin America. Sorfert has few tonnes to offer as its production is in mid-turnaround but a price of $410/t f.o.b. was being asked for small volume sales into Europe. Egyptian prices were fairly solid with November priced at $410/t f.o.b., but there was no rush to buy or sell.

In Brazil buyers recognised the tightness in the global supply market, but this is partly as a result of the armada of vessels headed in their direction. Prices were assessed at $380-385/t c.fr, but with limited liquidity. Weather and finance issues, poor crop prices also contributed to the lack of buying interest as well as the healthy import line-up. Urea prices in NOLA slipped all the way back to $325/st f.o.b.

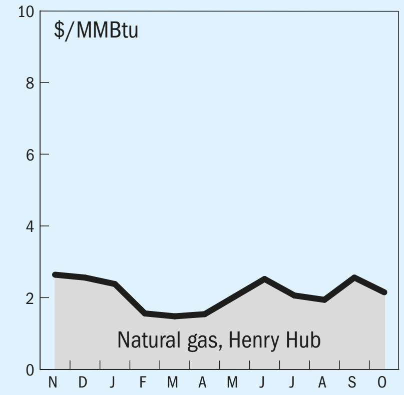
Table 1: **Price indications**

Cash equivalent	mid-Oct	mid-Aug	mid-Jun	mid-Apr
Ammonia ($/t)				
f.o.b. Black Sea	n.m.	n.m.	n.m.	n.m.
f.o.b. Caribbean	520	440-500	360	435
f.o.b. Arab Gulf	350-430	320-350	320-330	270-300
c.fr N.W. Europe	600-610	550-575	450-460	460-470
Urea ($/t)				
f.o.b. bulk Black Sea	320-330	305-325	340-350	250-260
f.o.b. bulk Arab Gulf*	350-370	290-335	280-350	275-290
f.o.b. NOLA barge (metric tonnes)	330-339	305-316	300	285-305
f.o.b. bagged China	253-261	n.m.	n.m.	300-31
DAP ($/t)				
f.o.b. bulk US Gulf	550-570	550-570	550-570	550-570
UAN (€/tonne)				
f.o.t. ex-tank Rouen, 30%N	265-270	240-245	260-265	230-240

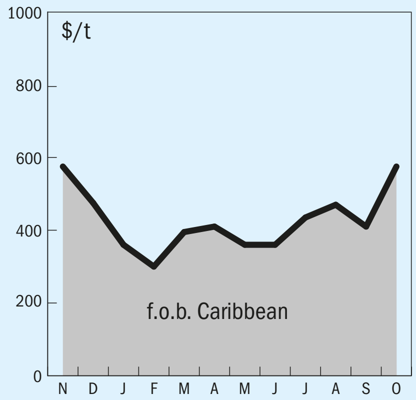
*Notes: n.a. price not available at time of going to press. n.m. no market. * high-end granular.*

END OF MONTH SPOT PRICES

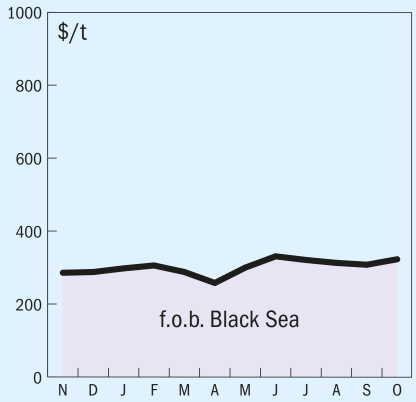
natural gas



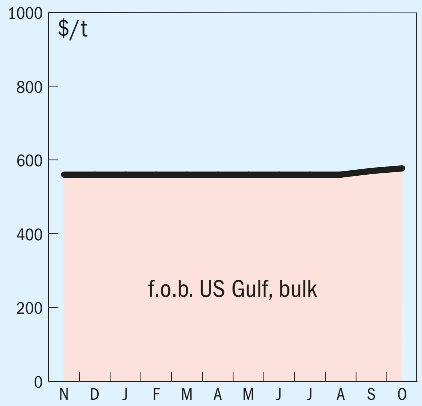
ammonia



urea

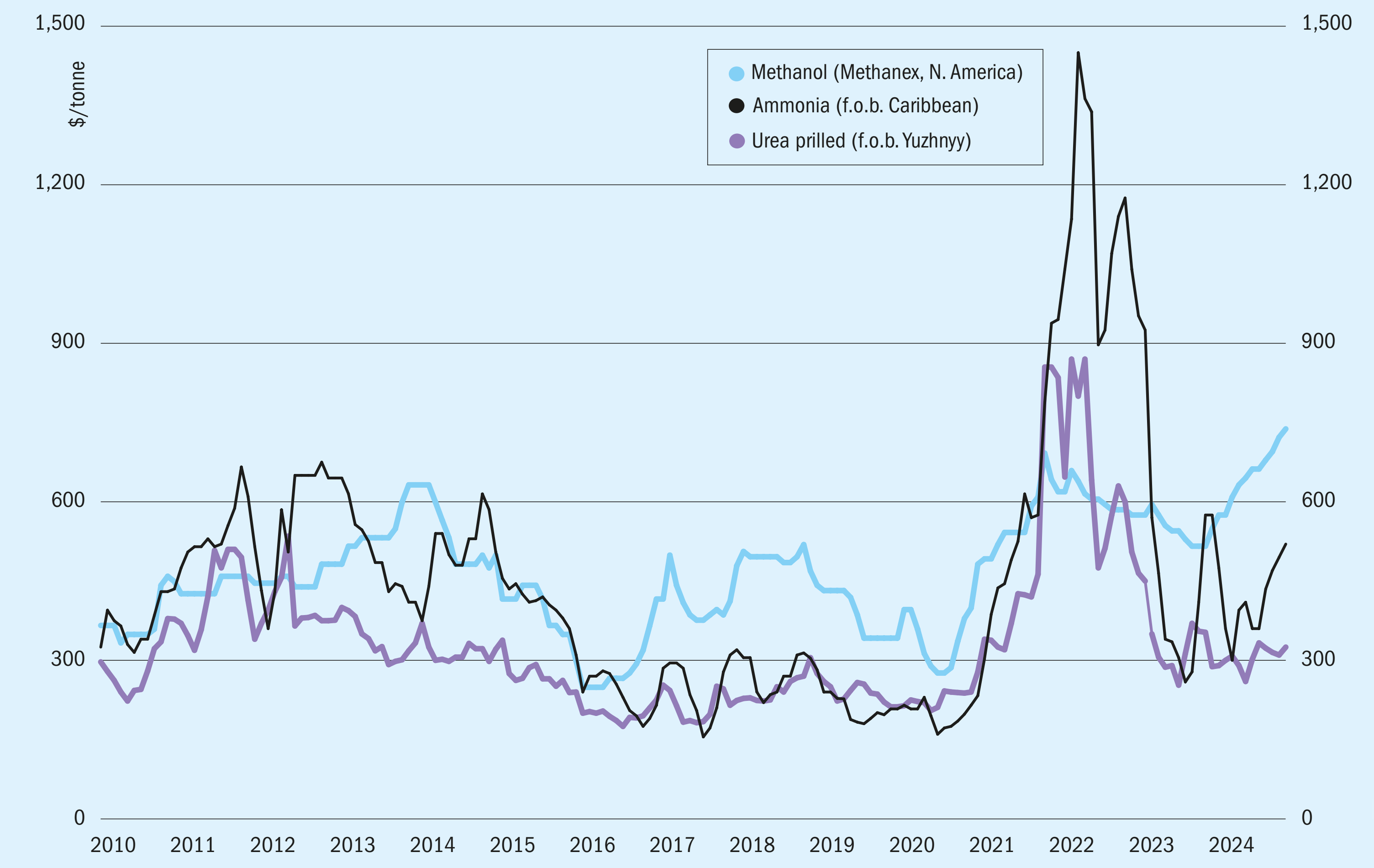


diammonium phosphate



Market Outlook

Historical price trends $/tonne



Source: BCInsight

AMMONIA

- Ammonia prices could remain stable for the duration of October, with any further increases likely to be capped by a lack of demand. The outlook for November is more positive for buyers, with prices set to ease off once turnarounds at key export hubs are concluded.
- Ammonia prices have been supported through 2024 Q3 due to supply constraints in key regions, including the Middle East, the Caribbean, and North Africa. Curtailments and production slowdowns at export hubs, combined with seasonal domestic demand in the US Gulf, have led to tighter availability, pushing up prices in the short term.
- Forthcoming capacity additions, such as the Taman trans-shipment complex in the Black Sea and new US Gulf capacity in 2025 Q1, are expected to pressure prices lower, especially as downstream merchant demand is unlikely to provide strong support. This could lead to further downside than currently expected for 2025.

UREA

- The short term outlook remains firm despite the absence of any significant purchasing activity in Brazil or Europe and NOLA prices sliding again. The prospect of India stepping back into the market without any sign of Chinese exports resuming seems sufficient to keep the upward trajectory on track.
- Upwards price catalysts were absent in 2024 Q3 – usually a peak demand period – due to cautious buyers and weather delays. However, prices maintained steady levels, with sellers able to withhold downwards price pressure through the absence of China.
- Price declines are likely to continue in the medium term, despite limited capacity additions in 2024–26. This is because of excess existing capacity combined with the return of China. Prices are expected to undergo more pressure from 2027 as more capacity commissions globally between 2027–29.

METHANOL

- Methanol markets have tightened due to production outages and cutbacks. Methanex has switched production on Trinidad from its larger Atlas plant to the smaller Titan unit, removing 700,000 t/a of production. Prices have moved upwards accordingly.
- In the medium term however demand is expected to be boosted by higher olefin prices, boosting China's MTO sector, a key consumer of methanol.
- The port of Rotterdam has reported renewable methanol sales eight times higher than last year as shipping companies move towards greater use of low carbon methanol as a bunker fuel. In a report in September the Methanol Institute said that extensions to the EU Emissions Trading System will be sufficient to eliminate the price premium of sustainable methanol to conventional, oil-based bunker fuels, putting their costs on a comparable footing.

Nitrogen Industry News

QATAR

New urea complex for Mesaieed


PHOTO: QAFCO

Qafco's existing complex at Mesaieed, Qatar.

QatarEnergy has announced its decision to build a new, world-scale urea production complex that will more than double Qatar's urea production. The project is aiming to construct three ammonia production lines which will supply four new world-scale urea production trains in Mesaieed Industrial City. Total capacity for the new complex is projected to be 6.4 million t/a, more than doubling Qatar's annual urea production from about 6 million tons per annum currently to 12.4 million tons per annum. Production from the project's first new urea train is expected before the end of this decade.

The announcement was made by Saad Sherida Al-Kaabi, the Minister of State for Energy Affairs, and president and CEO of QatarEnergy, during a press conference held at the company's headquarters in Doha. Al-Kaabi said: "We have been producing ammonia and urea in Qatar for over 50 years. Today, we are expanding our experience and further solidifying our position by this unprecedented mega-project that will make the State of Qatar the world's largest urea producer, playing a crucial role in ensuring food security for hundreds of millions of people around the globe, day after day. Developing this project in Mesaieed Industrial City will ensure the optimum utilisation of the excellent existing infrastructure for the petrochemical and fertilizer industries, including the city's export port, which is one of the largest fertilizer and petrochemical export facilities in the MENA region. It will also establish Mesaieed as the urea production capital of the world." ■

UNITED STATES

ADNOC to partner ExxonMobil on new low carbon ammonia facility

ADNOC has signed an agreement to take a 35% equity stake in ExxonMobil Corporation's proposed low-carbon hydrogen and ammonia production facility in Baytown, Texas. The facility aims to help reduce greenhouse gas emissions across hard-to-decarbonise sectors, including industry, energy and transportation, meet rising demand for lower-carbon fuels. Contingent on supportive government policy and necessary regulatory permits, the facility is expected to be capable of producing up to 1 bcf/d daily of low-carbon hydrogen, with approximately 98% of carbon dioxide (CO_2) removed and sequestered, generating more than 1 million tonnes of low-carbon ammonia per year. A final investment decision (FID) is expected in 2025 with anticipated startup in 2029. The facility will leverage advanced carbon capture and storage technologies to reduce emissions associated with hydrogen production.

Sultan Ahmed Al Jaber, Minister of Industry and Advanced Technology and ADNOC managing director and group CEO, said: "This strategic investment is a significant step for ADNOC as we grow our portfolio of lower-carbon energy sources and deliver on our international growth strategy. We look forward to partnering with ExxonMobil on this low carbon-intensity and technologically advanced project to meet rising demand and help decarbonise heavy-emitting sectors."

Darren Woods, ExxonMobil Chairman and CEO, said: "We appreciate His Highness Sheikh Khaled bin Mohamed bin Zayed Al Nahyan's support for this groundbreaking partnership. This is a world-scale project in a new global energy value chain. Bringing on the right partners is key to accelerating market development, and we're pleased to add ADNOC's proven experience and global market insights to our Baytown facility."

OCI completes sale of Clean Ammonia project to Woodside

OCI Global says it has successfully completed the sale of its 1.1 million t/a Clean Ammonia project under construction in Beaumont, Texas to Woodside Energy Group for $2.35 billion on a cash-free debt-free basis. OCI says that the closing of the transaction "marks a significant milestone in OCI's strategy to unlock value for shareholders". OCI has recently raised $11.6 billion from the sales of Fertiglobe, IFCO, OCI Methanol and OCI Clean Ammonia. As part of the agreement, OCI will continue to manage the construction, commissioning, and startup of the facility through provisional acceptance, and is targeting production of first ammonia from 2025 and lower carbon ammonia from 2026 using carbon capture and strorage.

Loan guarantee for Wabash Valley ammonia project

The US Department of Energy has agreed a loan guarantee of up to $1.56 billion to Wabash Valley Resources to help finance a commercial-scale waste-to-ammonia production facility using carbon capture and sequestration (CCS) technology at West Terre Haute, Indiana. The project will repurpose an industrial gasifier to use petroleum coke while permanently storing carbon dioxide to produce 500,000 t/a of ammonia for the nearby Corn Belt, contributing to both food security and climate goals.

The loan will form part of a total investment of $2.4 billion that Wabash Valley Resources will secure for the project through private investment.

Mitsubishi to buy stake in low carbon ammonia project

Mitsubishi says that it has signed a preliminary agreement for purchasing a stake in ExxonMobil's hydrogen and ammonia project in Baytown, Texas. The announcement is seen as signalling the beginning of negotiations rather than their conclusion, with details of the exact size of the stake and volumes for any offtake agreements expected to be confirmed in 2025. With a view of beginning operations in 2029 the facility's output of 1.0 million t/a of blue ammonia will become part of Japan's decarbonisation efforts while providing heavy industry like steel the necessary volumes to maintain power generation and process heat activities.

Dan Ammann, president of ExxonMobil Low Carbon Solutions, said: "We look forward to furthering our leadership position, alongside Mitsubishi Corporation, to advance low-carbon hydrogen and ammonia globally, helping the world achieve a lower emission future."

Japanese refining company Idemitsu Kosan is also a partner in the joint venture and has agreed to take part of the offtake. Together with Mitsubishi the two companies are exploring the feasibility of converting one of its liquefied petroleum gas terminals in western Japan into an ammonia terminal.

Cronus receives permit for ammonia plant

Cronus Chemicals LLC says it has received a construction and air permit from the US Environmental Protection Agency (EPA) for its new ammonia plant in Tuscola, Illinois. The facility will use proprietary Uhde-thyssenkrupp Industrial Solutions technology to produce 950,000 st/a of ammonia. Cronus says that its strategic location, surrounded by three interstate gas pipelines, ensures access to ample natural gas resources, leading to competitive pricing and operational efficiency. Demand for ammonia continues to outpace supply in the US, and Illinois is the largest consumer of agricultural ammonia.

"We are thrilled to announce the receipt of the EPA Construction and Air Permit, a critical milestone for the project and our commitment to providing reliable, locally produced Ammonia," said Erzin Atac, Cronus Chemicals CEO. "We expect our new plant, in the heart of the highest consumption region in the country will alleviate the shortage as well as the increasing supply concerns of local farmers and industrial users."

DENMARK

Green ammonia plant operational

A 5,000 t/a green ammonia plant has come onstream at Ramme in Denmark, entirely from solar and wind energy. The developers, Topsoe, Skovgaard Energy and Vestas, say that this will prevent 8,200 t/a of carbon dioxide emissions by optimising the fluctuating power feed from the plant's solar panels and wind turbines to the electrolysis and ammonia synthesis loop based on these fluctuations, and improving cost-effectiveness throughout the process. The project has received €11 million ($12 million) from the Danish Energy Technology Development and Demonstration Program.

EUROPEAN UNION

Fertigolbe to supply renewable ammonia from 2027

Fertiglobe has been selected as the winning bidder to supply renewable ammonia to the European Union following a pilot auction by H2Global, an initiative funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). Abu Dhabi-based Fertiglobe, a strategic partnership between ADNOC and OCI Global, has committed to supplying renewable ammonia starting at a potential 19,500 t/a in 2027 (subject to actual production start date and supply availability), with volumes potentially scaling up to 397,000 t/a cumulatively by 2033, at a delivered contract price of €1,000/t.

Ahmed El-Hoshy, Chief Executive Officer of Fertiglobe, said: "This award marks a significant milestone for Fertiglobe in advancing sustainable ammonia production and a further critical step towards a final investment decision for Egypt Green Hydrogen, expected in H1 2025. Our selection as the winning bidder in H2Global's pilot auction underscores our leadership in supplying low-carbon products and our commitment to shaping a more sustainable future, and I appreciate the work of our incredible team to make this award possible. We are leveraging this vital program which makes our investment in sustainable ammonia economically viable, supporting critical decarbonisation technology, while maintaining our disciplined growth strategy."

The German government has committed €4.43 billion to H2Global's 'double-auction' mechanism implemented by Hintco to facilitate the rapid expansion of renewable hydrogen and derivative products. The 'double-auction' model, whereby buyers and sellers actively participate, aims to bridge the difference between the high prices at which hydrogen is currently being traded on the global market, and the lower prices at which it can be sold on and be used in economically viable ways at regional level. H2Global says that the auction demonstrates that renewable ammonia can be imported into the EU at attractive prices with targeted support being offered to the most competitive international projects.

Timo Bollerhey, Chief Executive Officer of Hintco and co-creator of H2Global said: "This auction result is a strong indication of the market potential of renewable hydrogen and its derivatives. The energy transition requires value for money, workable solutions – and this first pilot auction has demonstrated that financial and procurement innovations like H2Global's mechanism not only work but are needed to create thriving markets that motivate and mobilise private finance."

RUSSIA

Lukoil to build urea plant at Budyonnovsk

Interfax reports that Lukoil has conducted a ground breaking ceremony for the construction of an ammonia-urea complex at the Stavrolen plant, a 100% subsidiary of Lukoil in Budyonnovsk, Stavropol region. The complex will take natural gas from Lukoil Group's gas fields in the Northern Caspian region as feedstock. According to the government of Stavropol Krai, urea production will be 1.75 million t/a. The project is planned to be implemented within five years.

"For the region, the construction of a new ultra-modern production facility is of strategic importance. This is not only additional tax revenues, but also about 600 new jobs. The industrial facility will help strengthen the associated infrastructure - road, utilities, social. It is important that the investor paid special attention to compliance with all environmental safety standards," Interfax quotes the governor of the region Vladimir Vladimirov.

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New urea plant for Arctic

Russia's Azot Group signed a memorandum of understanding with AEON and VEB to build a urea and potassium nitrate plant at Vorkuta in the northern Komi Republic by 2031. Projected capacities are 1.2 million t/a of ammonia, and 1.7 million t/a of urea, at a total investment cost of $2.2 billion. Finished products will reportedly be shipped along Russia's Northern Sea Route, meaning an additional 200 km of railway and a port in Ust-Kara, will need to be constructed, both of which will require an additional $1.1 billion worth of investment, according to Komi governor Vladimir Uiba.

EGYPT

Stamicarbon to revamp urea plant

Maire Tecnimont subsidiary Stamicarbon has won the design and process package contract for the modernisation and expansion of the urea plant at Delta Fertilizers and Chemical Industries in Talkha. As part of the revamp, Stamicarbon will increase the urea plant's production capacity from 1,725 t/d to 2,250 t/d by implementing a highly energy-efficient design. The project will reduce steam consumption by 35% and cooling water usage by 16% by using high-pressure steam three times instead of twice, leading to energy savings compared to traditional carbon dioxide removal methods. The contract also includes the licensing and design of a new urea granulation unit with a capacity of 2,250 t/d, using Stamicarbon's liquid solution granulation technology. The Egyptian government is aiming to develop and expand the Delta Fertilizers plants, a subsidiary of the Holding Company for Chemical Industries, with a total investment estimated at $400 million. Earlier this year, German company thyssenkrupp signed a contract with Delta Fertilizers and Chemical Industries to rehabilitate and operate the existing ammonia production complex at Talkha.

KIMA to build new AN plant

Industrial services provided Bilfinger has been awarded the engineering, procurement and construction contract by Egyptian Chemical Industries (KIMA) for a major chemical and fertilizer plant at Aswan. The plant will produce 600 t/d of nitric acid per day, which will be transformed into 800 t/d of granulated ammonium nitrate fertilizer.

PHOTO: RAVINDRA HERAEUS

Ravindra Heraeus' Udaipur headquarters, India.

"As a worldwide exporter of chemical products, this new plant is crucial for growing our production capabilities in Aswan," indicates Abdel Meguid Heguazi, CEO of KIMA. "By the end of 2027, it will allow us to produce 800 tons of granulated ammonium nitrate in fertilizer quality per day, which will be delivered to clients locally and around the world. We trust that Bilfinger will be the perfect solution partner to represent us in all project phases along the way and to make sure that we meet our targets most efficiently."

ROMANIA

Potential sale of Azomures plant

Swiss-based Ameropa, owner of the Azomures fertilizer plant in Romania, is reportedly considering its sale due to high gas prices which have forced periodic shutdowns of the plant over the past couple of years. Azomures says that it is in discussions with Romanian chemical producer Chimcomplex "to explore ways to unite the chemical industry in Romania, to build a globally competitive force supported by strategic energy resources to supply farmers in Romania." Romanian largest chemical group, Chimcomplex, owned by local businessman Stefan Vuza, confirmed in a note to investors on October 8 the existence of preliminary discussions related to taking over Azomures.

INDIA

Iffco to launch micronutrient dosed urea solution

India's Iffco has launched a new 'nano' urea solution dosed with 'nano' zinc and copper micronutrients after receiving permission from the government to market it. The company hopes that it will displace granular urea in India's fertilizer market. Nano urea uses small particles of urea only 20-50 nanometres in size, resulting in much faster breakdown in the soil and an 80% increase in the availability of nitrogen to the plant, resulting in higher nutrient use efficiency.

Offtake deal for green ammonia plant

Indian ammonia storage and transportation company Mysore Ammonia has signed a distribution offtake deal with Avaada for the supply of around 100,000 t/a of green ammonia. Avaada is developing a green ammonia plant with a capacity of 500,000 t/a at Tata Steel's SEZ industrial park in Gopalpur, Odisha which is planning to come onstream in 2027. The memorandum of understanding was officially signed between Avaada Green Fuels Private Ltd, a subsidiary of Avaada Group, and Mysore Ammonia and Chemicals Ltd at Avaada's headquarters in Mumbai. Commenting on the MoU, Vineet Mittal, chairman of Avaada Group, said, "The signing of this MoU with Mysore Ammonia is a significant milestone in our journey towards sustainable energy solutions. It underscores our unwavering commitment to advancing the production of green fuels like green ammonia in India, which is crucial for driving the transition towards a low-carbon economy. Leveraging our cutting-edge technology and expertise, we aim to support industries in significantly reducing their carbon footprint and fostering environmental stewardship."

Torrent to build green ammonia plant

Indian power company Torrent Power has signed a memorandum of understanding with the Gujarat state government to develop a 5 GW solar and wind-based power plant in Dwarka district. The company has committed to investing $6.9 billion towards the development of a total of 10 GW of renewable energy capacity in Gujarat by 2030. Part of the power will go towards feeding a 100,000 t/a renewable ammonia production plant in Gujarat, supported by an investment of $860 million.

Samir Mehta, Chairman of Torrent Group said: "As one of India's largest private sector power utilities, Torrent Power stands committed to contributing to the nation's renewable energy journey… This commitment not only underscores our dedication to advancing green energy solutions but also highlights the fact that our business operations are aligned with national priorities. We thank the Government of India for its futuristic policies and creating an enabling environment to foster growth of the sector."

Ravindra Heraeus acquires Arora Matthey's catalyst and recycling site

Ravindra Heraeus has acquired the business of Arora Matthey in Vizag, India including over 70 employees. Heraeus says that via the acquisition, customers in chemicals and pharmaceuticals industries will benefit from Heraeus' range of precious metals catalyst and recycling technology.

"We are very excited to take over the business. Arora Matthey has long standing relationships with customers and we are committed to continue providing them with leading catalyst and recycling solutions", said Shailesh Choksi, Managing Director at Ravindra Heraeus. The company already produces heterogenous precious metal catalysts at its main site in Udaipur. "This allows us to further expand our footprint to an advantageous location in south India, in line with our commitment to provide support close to our customers." The acquisition follows several significant investments in the company's main site in Udaipur in expanding its pyrometallurgical and wet chemical recycling capacities and capabilities.

GERMANY

Yara opens new ammonia import terminal

Yara International has officially opened its new ammonia import terminal in Brunsbüttel, on the North Sea and Kiel Canal. The company says that this location makes it an ideal hub for enabling the hydrogen economy in Germany. With the new terminal, Yara has the infrastructure to enable imports of up to 3 million t/a of low-emission ammonia to Europe.

"As the world's largest shipper and distributer of ammonia, Yara Clean Ammonia is in a pole position to secure low-emission ammonia supply to Germany, at competitive prices. With its leading global ammonia position, Yara can help kick-start the German hydrogen economy, laying the ground for a net zero future," says Hans Olav Raen, CEO Yara Clean Ammonia.

Demand for low-emission ammonia in Germany is expected to increase significantly in the coming years. The Federal Ministry for Economic Affairs and Climate Protection estimates that up to 70% of future national ammonia requirements will have to be imported by 2030. After this, the volumes will be even higher.

RWE and AM Green sign green ammonia supply deal

German RWE Supply & Trading has signed a memorandum of understanding (MoU) with AM Green Ammonia (AMG), a subsidiary of the Indian AM Green Group, for the long-term supply of green ammonia from the latter's production sites in Kakinada and Tuticorin. The deal outlines the supply of up to 250,000 t/a of green ammonia. Initially, 50,000 t/a of green ammonia will be produced at the Kakinada site, with the remaining volume of up to 200,000 t/a to be sourced from Tuticorin. According to RWE, AMG's ammonia manufacturing facilities will be powered entirely by carbon-free energy sources such as solar, wind and hydroelectric power, and the produced ammonia will meet EU standards for Renewable Fuels of Non-Biological Origin (RFNBO) as defined in the Renewable Energy Directive (RED III). Deliveries of green ammonia from AMG's sites are expected to start by 2027.

ANGOLA

Another green ammonia project

Angola's national oil company Sonangol has signed an agreement with energy companies Conjuncta, CWP and Gauff for the development of the Barra do Dande green hydrogen project. As part of the project, Barra do Dande will produce up to 1,200 t/a of ammonia for export to the European market. The facility will feature the installation of 600 MW of renewable energy capacity – generated from hydro-electric power sources.

SOUTH KOREA

KBR to partner in floating ammonia plant study

Engineering and construction services company KBR has been awarded a conceptual study contract for floating blue ammonia production from South Korean shipbuilder Samsung Heavy Industries. The project will use KBR's blue ammonia technology, suitable for offshore production, and leverage Samsung's expertise in the design of large floating vessels. KBR says that the concept would deliver a sustainable platform for its clients to achieve their energy transition objectives with greater flexibility.

"We are proud to collaborate with SHI for this strategic project and provide our low-carbon blue ammonia process technology solution to develop this first-of-its-kind floating ammonia production facility," said Jay Ibrahim, KBR president of sustainable technology solutions.

CANADA

Fortescue abandons green ammonia project

Fortescue has informed the Environmental Assessment Office of British Columbia province that it is formally withdrawing from work on a green ammonia project at Prince George, and from the environmental assessment process. In a letter, Fortescue said that it is prioritising "projects in locations with favourable green energy policies and affordable and reliable renewable energy."

The $2 billion project would have required 900 MW of hydroelectricity to produce sufficient hydrogen to make 700,000 t/a of green ammonia, representing almost 90% of the output of a projected new C$16 billion dam and power station in the region.

Syngas News

UNITED STATES

Methanex buys OCI Global's international methanol business

Methanex Corporation has entered into a definitive agreement to acquire OCI Global's international methanol business for $2.05 billion. The transaction includes OCI's interest in two world-scale methanol facilities in Beaumont, Texas, one of which also produces ammonia. The transaction also includes a low-carbon methanol production and marketing business and a currently idled methanol facility in the Netherlands.

"This is a unique opportunity to create value by acquiring two highly attractive North American methanol assets that will further strengthen our global production base and we expect it will be immediately accretive to free cash flow per share," said Rich Sumner, President and Chief Executive Officer of Methanex. "The Beaumont plants benefit from access to North America's abundant and favourably-priced supply of natural gas feedstock, and are expected to increase our global methanol production by over 20%."

Nassef Sawiris, Executive Chairman of OCI, added, "We are pleased with the opportunity to achieve a significant ownership position and are highly confident in Methanex's ability to create enduring value for shareholders. As the global leader committed to safety and operational excellence, we identified Methanex as the natural owner of OCI Methanol at the outset of our strategic process, which we initiated in the spring of 2023."

Methanex says that the acquisition enhances its asset portfolio with highly attractive assets in a low-risk jurisdiction that has an ample and economic supply of feedstock natural gas. It also expects to achieve approximately $30 million of annual cost synergies from lower logistics costs and lower selling, general and administrative expenses. OCI's ammonia production, while modest compared with its methanol production, also provides Methanex with a low-risk entry into a new and synergistic commodity in an adjacent and complementary segment to methanol with similar feedstock-based advantages.

OCI's assets include a methanol facility in Beaumont, Texas with capacity of 910,000 t/a of methanol and 340,000 t/a of ammonia, and a 50% interest in a second methanol facility also in Beaumont, Texas, operated by the joint venture Natgasoline LLC. Natgasoline was commissioned in 2018 and has an annual capacity of 1.7 million t/a of methanol, of which Methanex's share will be 850,000 t/a. There is also a methanol facility in Delfzijl, Netherlands with capacity to produce 1 million t/a of methanol. This facility is not currently in production due to unfavourable pricing for natural gas feedstock.

Closing of the transaction is expected in the first half of 2025, subject to regulatory approvals.

SAUDI ARABIA

Chemanol awards methanol plant expansion project

Chemanol has awarded the engineering, procurement and construction (EPC) services contract for the expansion of its methanol plant in Jubail to US energy engineering and construction company McDermott. The contract value was not disclosed, but the project is due for completion in 4Q 2027. Chemanol said in a statement that the project "represents a major step forward in increasing the energy efficiency of the asset while expanding its capacity and ultimately bringing value to the company's shareholders."

Ali Abdulaziz Alturki, Chairman of the Board of Chemanol, said: "We are thrilled to work on this important project with McDermott which not only contributes to Chemanol's sustainability and growth plans but also paves the way for more long-term strategic collaborations with McDermott."

Chemanol is an integrated producer of methanol and chemical derivatives and is also one of the world's largest formaldehyde and derivatives producers situated in a single location, with a total annual production capacity of 1 million t/a.

PHOTO: CHEMANOL

Chemanol's existing site, Al Jubail.

NORWAY

Solution for large-scale green hydrogen production

Nel ASA's EPC partner Saipem has launched IVHY™ 100, a scalable modular 100 MW green hydrogen solution leveraging Nel's technology. It has been designed to be scalable and modular to facilitate the installation and commissioning of large-scale systems and is powered by Nel's alkaline electrolysers, which have demonstrated robustness, durability, and energy efficiency. The project is part of a collaboration between the two companies, where Nel, as the technology provider, will offer its alkaline and PEM (proton exchange membrane) electrolyser technology as well as ancillary technical services, and Saipem, as the engineering service provider and EPC contractor, will be responsible for the basic design, detailed engineering, procurement and construction of the overall green hydrogen facilities.

SWEDEN

Worley to provide FEED for green methanol facility

Worley has entered into an agreement with Liquid Wind to provide preliminary front-end engineering design for Uniper's NorthStarH2 green methanol facility in Östersund. The facility, which is being developed by Liquid Wind on behalf of Uniper, aims to produce over 100,000 t/a of methanol to help decarbonise shipping and chemical industries. Worley says that its focus during the pre-FEED will be on the balance of the plant, which encompasses all supporting systems and infrastructure necessary for the facility's operation.

Jan Narvestad, Senior Vice President, Nordics, commented: "We're excited to collaborate with Uniper and Liquid Wind to unlock the potential of the NorthStarH2 project and help balance the global dependence on fossil fuels."

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

AUSTRALIA

Contracts awarded for concentrated solar-powered green methanol plant

Vast Renewables, along with German partner Mabanaft, has awarded international engineering group Fichtner and German e-fuels developer bse Methanol contracts to commence pre-front-end engineering and design work for the Solar Methanol 1 project. The facility, to be located near Port Augusta in South Australia, is to include a 10 MW electrolyser capable of producing 7,500 t/a of green methanol. The facility will be powered by a co-located 30 MW concentrated solar thermal plant using Vast's CSP technology to generate zero-carbon electricity and industrial process heat.

NIGERIA

Brass methanol project signs feedstock agreement

Brass Fertilizer Petrochemical Company Ltd (BFPCL) has reportedly closed a gas sales and purchase agreement with the Nigerian National Petroleum Company and Shell Petroleum Development Company JV. The agreement brings the $3.3 billion project closer to financial closure and execution. BFPCL has also recently signed agreements with the China Road and Bridge Corporation for construction of the Brass industrial park, methanol plant, and gas gathering pipelines, and has secured a joint venture agreement with COSCO Shipping Lines for 16 new 50,000 tonne methanol-powered vessels, valued at approximately $900 million. The ships will transport methanol and other products from the Brass Methanol Plant to global destinations. Brass is being part financed by Chinese investors. Including Bohai Chemical Industries Group and the China Africa Development Fund. Financial closure for the project is expected by December 31, 2024.

EUROPEAN UNION

EU regulations will boost value of methanol in shipping

A new white paper prepared for the Methanol Institute by Dr Jeroen Dierickx, an energy and fuel expert at iDefossilise, has concluded that the FuelEU Maritime Regulation and EU Emissions Trading System (ETS) will create a level playing field for bio- and e-methanol, making them economically competitive compared to fossil marine fuels. Under the EU's Fit for 55 regulatory package, vessel operators are incentivized to transition to these sustainable fuels through significant penalties levied on continued fossil fuel use. For fuel producers, the regulations offer a stable, long-term framework from 2024 to 2050, paving the way for secure investment opportunities in the maritime sector.

Gregory Dolan, CEO of the Methanol Institute, said: ''The study confirms the profound impact of regulations on the demand for methanol as a marine fuel. The findings indicate that the emerging EU regulatory framework is robust enough to enhance the business case for low-carbon and renewable methanol fuels and fuel blends, supporting the transition to a sustainable maritime industry.''

Assessment of biogas roll-out

The European Biogas Association (EBA), in collaboration with experts in biogas and methanation technologies, has published its first assessment of the rollout of 'e-methane' in Europe. It hopes that the synthetic renewable fuel will play a key role in Europe's electricity grid, scaling-up biomethane production in the coming years, and enabling innovative synergies between biogases and hydrogen production in the future energy mix. In the methanation process, renewable hydrogen produced from excess renewable electricity combines with biogenic CO_2 from raw biogas to produce e-methane, which can be stored in the gas grid.

According to the white paper there are currently 35 operational plants, 33 of which are fully renewable. Germany leads the way with 14 facilities. Additionally, 20 new e-methane plants are either planned or under construction in Europe, signalling further growth in the sector. Over the past eight years, e-methane production capacity in Europe has increased from 20 GWh per year to 449 GWh per year. Projections indicate that by 2027, this capacity will nearly reach 3,000 GWh per year, equivalent to 0.27 billion cubic meters (bcm). Finland, Germany, and Denmark are pioneering this rollout, with the largest production capacities.

GERMANY

Biomass balanced ammonia

Evonik and BASF have announced an agreement for the first delivery of BASF's ammonia BMBcert^{TM} grade. BASF says that the product offers Evonik a solution with a product carbon footprint at least 65% lower than conventional products. BASF says that it applies a biomass balance approach to replace fossil resources at the beginning of the production process with certified biomethane from biowaste raw materials which are attributed to the product. The mass-balanced product is certified according to ISCC PLUS standards. In addition, BASF is using electricity from renewable sources for the manufacture of the ammonia, further reducing its carbon footprint.

Evonik plans to incorporate the lower carbon ammonia into its production of sustainable products like polyamide for applications like shoe soles, sunglasses, gas pipes, safety-related automotive parts and many more. "We are excited to partner with BASF to source ammonia with a reduced carbon footprint for our eCO products. This collaboration underscores our commitment to environmental stewardship and our ability to innovate in a rapidly changing market", said Silvia Torrado, Global Procurement Director for Base Petrochemicals at Evonik.

VIETNAM

NextChem to upgrade hydrogen plant

NextChem says that its hydrogen technologies licensing subsidiary KT Tech has been awarded the licensing and the process design package for a new hydrogen production unit by the Binh Son Refining and Petrochemical Joint Stock Company as part of a larger upgrading and expansion project at the Dung Quat Refinery in Vietnam. KT Tech will design the new hydrogen production unit with a capacity of 22,676 Nm3/h, leveraging its proprietary technology. This technology, which is part of its NX ReformTM hydrogen technology portfolio, enables cost-effective hydrogen production and offers the potential to reduce the carbon footprint by incorporating CO2 capture technology, with flexibility in feedstock and capacity. The technology is based on proven and widely adopted steam methane reforming. Once the project reaches the construction phase, KT Tech will also supply the proprietary equipment for the steam methane reforming process.

Alessandro Bernini, CEO of NerxtChem's parent group Maire, commented, "We are proud of this important achievement, which confirms our excellent track-record in upgrading existing production plants to enhance efficiency and achieving lower consumptions, thanks to our leading technological know-how and unparalleled process engineering capabilities."

People

Sachin Nijhawan has been appointed as the new CEO of thyssenkrupp nucera US, and **Juergen Grasinger** was named Chief Operating Officer to advance the company's international growth strategy and expand its global leadership in the manufacturing and supply of hydrogen production technology. Based out of the thyssenkrupp's Houston office, Nijhawan will be responsible for the business activities of the US operations.

Commenting on the appointment, thyssenkrupp nucera CEO Werner Ponikwar, said; "Sachin brings to our US team the right blend of expertise and commercial relationships to advance our international growth strategy and continue our market leadership in the large and growing hydrogen market."

Grasinger's expanded role as COO will see him ensure continuity across all operations and processes to meet the needs of thyssenkrupp's blue-chip customers and large-scale clean energy projects. Ponikwar added: "Together, Sachin and Juergen have the full support and resources of thyssenkrupp nucera and its advisory board, and we are excited for the path forward as we jointly collaborate to unlock the huge market potential for driving towards decarbonisation and climate neutrality."

The Methanol Institute (MI) has announced the appointment of a new team to lead its European operations from its Brussels office. Effective immediately, the team will be spearheaded by **Tim Eestermans** as Managing Director Europe, **Dr. Richard Burchill** as Director for Research Strategy & Knowledge Exchange Europe, and **Rik Servais** as Director for Government Affairs & Institutional Strategy Europe. Their primary focus will be on strengthening MI's engagement with European Union institutions and managing MI's relationship with the International Maritime Organisation (IMO). Notably, MI has recently achieved Consultative Status with the IMO, marking a significant milestone for the organization.

Eestermans is a seasoned leader with over 25 years of experience in governmental and corporate settings across Europe, Asia, and the Middle East. Burchill is an expert in international and EU law, with nearly 30 years of experience in navigating international organizations, including the UN system. Servais offers over 20 years of specialised knowledge in EU government relations, having worked at the heart of EU decision-making in Brussels. Gregory Dolan, CEO of the Methanol Institute, said: "We are thrilled to introduce the new leadership team for our Brussels office. Their extensive experience and deep expertise will be invaluable as we continue to foster critical relationships within the European Union and the International Maritime Organisation. Their leadership marks a new chapter for MI, and we are confident that their combined skills will drive our mission forward with renewed vigour."

Ben Iosefa, Methanex executive and chair of the MI Board of Directors, said: ''The European Union plays a pivotal role in shaping regulatory and policy frameworks that impact the global methanol industry. Our new team in Brussels is uniquely positioned to enhance our engagement with EU institutions and advocate for policies that support our mission. Their collective expertise will be instrumental in navigating the complex European landscape and advancing our strategic objectives. With our growing membership of 100 global entities, this leadership team will be instrumental in driving our continued growth and amplifying our impact.''

Topsoe CEO **Roeland Baan** has been recognised for his leadership of efforts to steer dramatic technological advances in how we can efficiently produce clean hydrogen and other next-generation fuels by being named one of the 50 executives on Forbes' Sustainability Leaders List, which highlights "those audaciously driving the innovative and scalable solutions the world needs". Since joining Topsoe as President and CEO in 2020, Baan has led the company's nearly 3,000 employees across a dozen countries in rewriting the future of clean fuels production.

Calendar 2025

JANUARY

21-23
7th International Conference Fertilizers 2025: Eastern Europe, VIENNA, Austria
Contact: Chem-Courier
Email: conf@wfmeasterneurope.com

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

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

FEBRUARY

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

MARCH

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

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

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

APRIL

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

MAY

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

Plant Manager+

How to solve stripper efficiency issues (part 3)

In Part 3 of this series on stripper efficiency issues, we continue the discussion on some some of the many causes of lower stripper efficiency. Here we discuss liquid divider fouling and bad installation of liquid dividers.

Liquid divider fouling

A perfect liquid divider system on the top tubesheet of the stripper is vital to achieve a higher stripper efficiency. Each liquid divider contains a number of liquid divider holes, which distribute the liquid from the reactor evenly over the complete surface at the top of the stripper tube. This assures that the solution flows as a falling film downwards inside the tube. Any tubes with clogged liquid divider holes will receive less liquid and will need to be compensated by the other tubes, which will receive more and potentially too much liquid. Furthermore, the tube(s) with less liquid load will have a lower flow resistance to the up-flowing gas than the tubes with more liquid load. This will result in maldistribution of the gas and the CO_2 feed, a lower stripper efficiency and higher corrosion rates in certain tubes.

It is important that all the liquid from the reactor flows through the holes in the liquid dividers at the top of the stripper. In this way, the liquid dividers act like a filter in the high-pressure urea synthesis section. Fouling of the liquid distributor holes can be caused by several factors: oil, fibres, foreign materials, iron- and chromium-oxides or a combination of these.

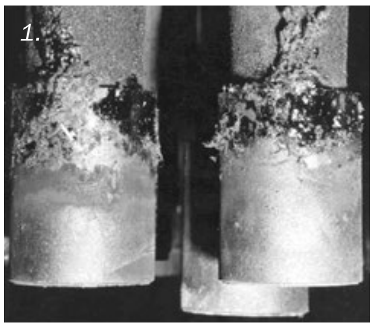

Photo 1 shows an example of oil fouling of the liquid dividers. This was a major issue in the early years after the invention of the CO_2 stripper, when design plant capacities were relatively small and reciprocating CO_2 compressors were applied. The oil from the CO_2 compressors caused fouling in many urea plants resulting in a heavy tar type of fouling caused by the temperatures and the stripping effect of the gas. Major efforts were made to find solutions: Stamicarbon discovered that certain oils were more prone to cause fouling than others and specified which oils were preferred in these compressors. Another solution was the development of a dry seal system developed in China as there are still many small urea plants in operation in China with reciprocating CO_2 compressors.

Oil can also originate from the oil seals of reciprocating high-pressure ammonia pumps as well as from the ammonia feed from the ammonia plant. Jo Eijkenboom, at a time when working for Stamicarbon, developed the water seal system for reciprocating high-pressure ammonia pumps, which is now applied by all vendors. Note that the reciprocating high-pressure carbamate pump operates with a water flush system of its stuffing boxes.

Fibres can originate from the packing rings of the stuffing boxes in reciprocating compressors and pumps, especially at end of lifetime conditions.

Nowadays, with larger design plant capacities one typically sees integrally geared or centrifugal CO_2 compressors and centrifugal high-pressure pumps.

Fines and scaling can also cause clogging of the liquid distributor holes. These fines are typically iron- and chromium-oxides and are a result of the unavoidable passive corrosion rate of ammonium carbamate on the austenitic and super-duplex materials of construction applied. Active corrosion with its much higher corrosion rates can also cause these fines. In addition, fines resulting from grinding during a turnaround will oxidise and form these fines. Note that nickel forms a reaction with ammonia and remains dissolved in the solution. Photo 2 shows examples of the fouling at the top of the stripper caused by these fines. The fines can typically be removed relatively easily and it is advised to remove them when they complicate the proper installation of the liquid dividers on the stripper tubes.

Bad installation of liquid dividers

Another cause for low stripper efficiency is the bad installation or bad quality of the liquid dividers. Low stripper efficiency can also be caused by cross cut end attack corrosion at end of lifetime conditions, see photo 3, which shows a normal liquid distributor on the left and a liquid distributor at end of life on the right.

Stamicarbon and Alleima have solved this issue with Safurex® Degree° liquid distributors. This material is fabricated via the Hot Isostatic Pressing (HIP) method, which results in an isotropic and fine-grained microstructure, improving corrosion resistance and also enhancing the material's mechanical properties at low temperatures.

Bad installation procedures can damage the gasket and/or the bottom of the liquid distributor causing leakages between the liquid divider and the tube end resulting a lower stripper efficiencies as shown in photo 4. ■

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

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

Australia's nitrogen industry

An ammonium nitrate industry geared around producing explosives for the mining sector is now being joined by a major urea project and a number of renewables-based products for export of green ammonia.

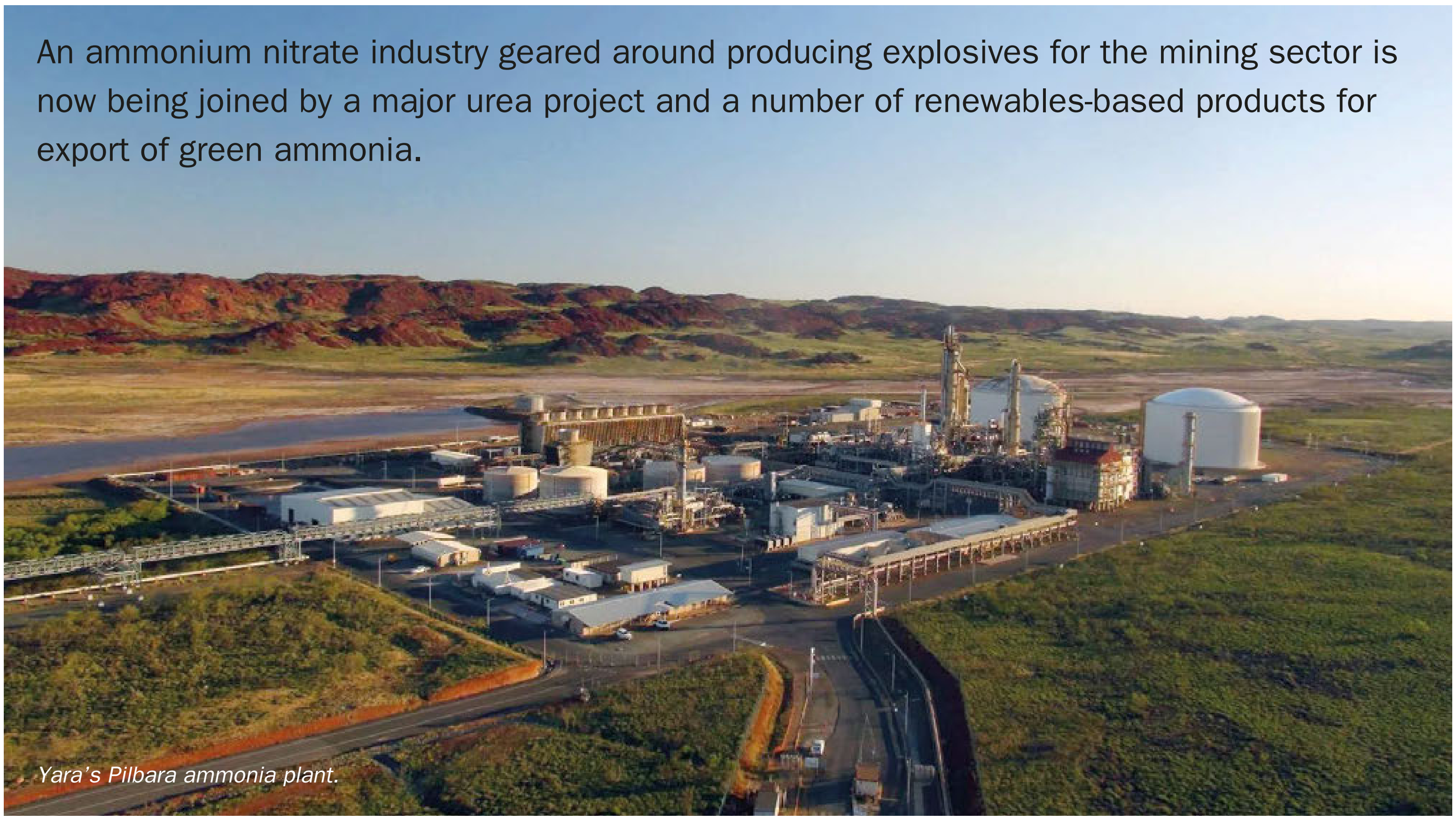

PHOTO: YARA

Yara's Pilbara ammonia plant.

Australia is a country rich in natural resources but relatively sparsely populated. For this reason, the country's nitrogen industry has long been dominated by the ammonium nitrate industry, primarily for commercial explosives as 'technical' grade AN (TAN), for Australia's large and growing mining industry. TAN is mixed with a variety of substances, often fuel oil to form ANFO – the most widely used explosive worldwide. Australia is actually the world's second largest market for commercial explosives, with only China consuming more, and consumption is growing rapidly due to expansions in coal, iron ore, gold and other mining operations. In 2023, Australia consumed 2.3 million t/a of TAN, or just over 13% of all TAN globally. It is also the third largest producer of TAN – Russia still takes the top spot over China and Australia. In 2023 Australia produced 2.2 million t/a of TAN, leaving it a slight net importer. In addition, CSBP Wesfarmers produces around 250,000 t/a of UAN solutions at Kwinana for fertilizer use, but the bulk of Australian AN production goes to the explosives industry. Consumption of explosives continues to grow, but at relatively modest rates, with an AAGR of 1.4% forecast over the next four years.

Nitrogen fertilizer use in Australia comes mainly as urea. Total nitrogen fertilizer use was 1.57 million tonnes N in 2023, 87% of which was consumed as urea (3.0 million tonnes product). Another 250,000 tonnes of urea was consumed in technical uses, mainly as diesel exhaust fluid. However, domestic production of urea ceased in 2022 with the shutdown of IncitecPivot's Gibson Island plant. Since then a number of new projects have been under development to feed Australia's urea needs, but Australia has had to rely upon imported urea to meet its fertilizer and DEF requirements.

The coal industry

Mining uses for AN have traditionally been dominated by Australia's large coal industry. Australia is the fifth largest coal producer in world, with production running at 455 million t/a in 2023, although little of this is consumed domestically, with almost 75% of it exported, primarily to China and Japan. Although China's coal use continues to climb, it is levelling off as the government attempts to move to cleaner and lower carbon energy sources, while an unofficial import ban on metallurgical coal imports, and the global Covid-19 pandemic have all impacted Chinese coal consumption.

Meanwhile, Australia is also under pressure to reduce domestic coal consumption. Coal was responsible for 65% of domestic energy production and 53% of electricity production in 2023. However, governments have been slow to take steps to reduce consumption, and indeed subsidised energy prices during the disruption following the Ukraine invasion. Overall, Australian domestic coal production is relatively flat.

Global coal production is expected to peak in 2023 at 6.9 billion t/a. Declines in coal production are expected to be driven by China and the US as coal is replaced in the fuel mix by renewables. But in the medium term, TAN demand for coal remains moderately stable at around 6 million t/a, with demand increases from India and a modest increase in Australia offsetting decreases from China and the US.

Other mining

Other major consumers of AN are iron ore and gold mining. Iron ore production was 945 million t/a in 2023, and iron ore and concentrates exports represented 20% of Australia's exports last year, with China again the main destination (85% of exports), for use in steelmaking. Unlike coal, iron ore production continues to increase, with projections that it may reach 1.2 billion t/a by 2030, including new projects and expansions at Onslow, Jimblebar and Western Range in the Pilbara region of Western Australia. Once again however there are potential challenges from Australia's major market, as China increases steel recycling and moves towards direct reduced iron (DRI) for steelmaking, which requires higher grade ores than those from the Pilbara. Nevertheless, there are moves by Australia's iron ore producers to address carbon intensity issues. Rio Tinto is investigating a low-carbon ironmaking process, BioIron, and is also partnering BHP and BlueScope in a pilot electric smelting furnace for iron using renewable power and DRI process technology. At present, TAN demand growth for iron ore production in Australia is expected to be driven by 200 million t/a of new capacity commissioning by 2027, and this will represent the largest slice of new TAN demand in Australia.

As far as gold is concerned, production is anticipated to decline from 2026, primarily driven by the depletion and closure of existing mines, coupled with a notable scarcity of investments in the exploration of new mining opportunities. This trend is expected to significantly curtail the emergence of fresh gold production capacities in the medium term.

Nitrogen producers

The Australian nitrogen industry has seen considerable consolidation over the past couple of decades, leaving it mainly in the hands of three major companies; IncitecPivot, CSBP and Orica, though Yara also has a significant presence via the Pilbara Nitrates project.

IncitecPivot

IncitecPivot was formed from the merger of Incitec Fertilizers and Pivot Ltd in 2003. Both companies had considerable interests in phosphate production, but Incitec also had an ammonia plant at Gibson Island, in Queensland. From there the company has grown by acquisition, buying Southern Cross Fertilizers in 2006 and explosives manufacturer Dyno Nobel in 2008. Southern Cross was formerly the fertilizer arm of the Western Mining Corporation (WMC), with ammonia, urea and phosphate production at Phosphate Hill, Queensland. Incitec Pivot also inherited a 50% share in Queensland Nitrates at Moura, a joint venture currently shared with CSBP.

From Dyno Nobel the company also inherited a new ammonium nitrate project at Moranbah in Queensland, which Dyno Nobel dropped in 2007, but which Incitec Pivot has decided to proceed with after a re-evaluation following their purchase of Dyno Nobel. The 330,000 t/a TAN complex including ammonia and nitric acid plants was completed in 2012.

IncitecPivot also operates a major phosphate plant at Phosphate Hill, Queensland, the largest fertiliser plant in Australia. It includes an ammonia plant with a capacity of 1.0 million t/a which feeds ammonium phosphate production at the site, though production is currently running at around 75% of capacity, with rail and gas supply issues and flooding all remaining concerns. Indeed, IncitecPivot has discussed selling or closing the plant, though a potential sale to Indonesia's PT Pupuk Kalimantan Timur fell through in July. In the meantime, an investment project to replace some of the gas feed with solar power for hydrogen electrolysis is under way.

In addition to these, IncitecPivot also owns the Gibson Island plant in Brisbane, south-east Queensland. Gibson Island has the capacity to manufacture 300,000 t/a of ammonia, 280,000 t/a of urea and 200,000 t/a of ammonium sulphate, and is close to major fertilizer markets in southeast Australia. However, the plant was closed in 2022, with IncitecPivot citing high feedstock gas prices as the primary reason, leaving Australia without domestic urea production. The site subsequently became the subject of a major green ammonia project in partnership with Fortescue to generate 70,000 t/a of hydrogen from electrolysis, which might have allowed an expansion of ammonia production to up to 400,000 t/a, using solar energy. However, a final investment decision at the end of 2023 was pushed back three times this year over issues of electrolyser costs and sourcing sufficient electricity, and in April Fortescue entered negotiations with the government over reducing energy costs, and at present the project looks unlikely to proceed.

Orica

Orica was founded from ICI's Australian division, and the company also bought up ICI Explosives worldwide when it was spun off by the parent company in 1997. It is now the largest seller of commercial explosives in the world. In Australia, Orica have an ammonia-ammonium nitrate facility at Kooragang Island near Newcastle, New South Wales, again sited close to major fertilizer consuming regions. There is 360,000 t/a of ammonia capacity, using natural gas, with three downstream nitric acid trains producing a total of around 330,000 t/a of acid. This then feeds 400,000 t/a of TAN production for the mining industry. The NSW state government is looking to develop a 'hydrogen hub' in the Hunter Valley nearby, with 55 MW of electrolyser capacity to start up in 2026, growing to 1 GW over the subsequent decade. Some of the hydrogen is earmarked for green ammonia production at Kooragang Island to help decarbonise production.

Orica also has a site at Yarwun, near Gladstone in Queensland, with three nitric acid plants, two ammonium nitrate trains producing emulsions, and 95,000 t/a of sodium cyanide production. AN output is around 500,000 t/a. Orica recently announced a project to halve greenhouse gas emissions from the site by installing tertiary N_2O abatement technology at two of the nitric acid plants.

CSBP

CSBP is part of the Wesfarmers group (originally the Western Australian Farmers Cooperative). It has grown to become one of Australia's largest companies, with interests in retail, mining and insurance as well as fertilizers and chemicals. CSBP's main nitrogen facility is at Kwinana near Perth in Western Australia, with a capacity of 255,000 t/a of ammonia, as well as downstream nitric acid and ammonium nitrate production. The site was expanded in the 2010s with a third nitric acid/AN train, bringing total AN capacity to 780,000 t/a. They also own half of the Queensland Nitrates TAN plant at Moura in Queensland.

Queensland Nitrates

Queensland Nitrates Pty Ltd (QNP) is co-owned by CSBP and IncitecPivot (via Dyno Nobel). It operates an integrated TAN facility near Moura in central Queensland, approximately 160 kilometres west of Gladstone at the southern end of the coal-rich Bowen Basin. The facility is designed to produce 220,000 t/a of technical ammonium nitrate for use in mining operations and comprises an ammonia plant, a nitric acid plant and an ammonium nitrate plant.

Like many other Australian nitrogen operations it has studied using solar energy to crack water into hydrogen for ammonia production. A feasibility study on 3,500 t/a of hydrogen production to generate 20,000 t/a of green hydrogen was completed in 2020, sponsored by the Australian Renewable Energy Agency (ARENA), though no decision to proceed has been taken.

Pilbara Nitrates

In order to monetise the gas resources of the northwest shelf, the Western Australian government pushed for the development of a chemical complex in the Pilbara region. Development proceeded initially on an ammonia-urea complex by the Australian based Plenty River Company, with Indian development money from Chambal Fertilizers and Chemicals. However, the project saw issues with costs and infrastructure, and land rights issues with local native peoples groups, leading to Chambal – which had been hoping to export the ammonia to India - to withdraw from the project. Once resolution on these was achieved the project metamorphosed into Burrup Fertilizers, a joint venture between Indian entrepreneurs Pankaj and Radhika Oswal and Norwegian fertilizer major Yara, which took a 30% minority stake. The 760,000 t/a nameplate capacity plant (it has run at 840,000 t/a for some time, however), licensing KBR technology, came onstream in April 2006.

However, concerns were expressed by Yara over financial improprieties, and the Oswals defaulted on a loan to the Australia and New Zealand Bank (ANZ), leading to the enforced sale of their share of the company. The holding was eventually split between Yara and gas supplier Apache Energy Ltd, which had also been in dispute with Burrup over gas contracts, but Yara subsequently bought out the Apache share in 2015, and now runs Yara Pilbara Fertilizers Pty Ltd as a wholly owned subsidiary. A joint venture downstream technical ammonium nitrate plant – Yara Pilbara Nitrates - was completed in 2015 in 50-50 partnership with Orica, which markets the AN produced at the site. The downstream capacity includes 760,000 t/a of nitric acid and 965,000 t/a of AN solutions.

More recently, plans for a green hydrogen feed to the ammonia plant at Pilbara have come from the Yuri Renewable Hydrogen to Ammonia Project, in conjunction with Engie and Mitsui, which is looking to add a 640 t/a hydrogen stream from 10 MW of electrolyser capacity fed by solar energy, along with associated battery storage. This would generate 3,600 t/a of green ammonia as part of the output from the plant. Completion is due for 4Q 2025 at a cost of A$87 million.

Table 1: **Ammonium nitrate plants in Australasia**

Company	Location	Capacity (t/a)
IncitecPivot	Moranbah	330,000
Orica	Kooragang Island	430,000
	Yarwun	570,000
Queensland Nitrates*	Moura	220,000
CSBP	Kwinana	260,000
	Kwinana 2	260,000
	Kwinana 3	260,000
Yara Pilbara Nitrogen	Pilbara	965,000
Total		**3,295,000**

**Queensland Nitrates is 50% owned by Incitec Pivot, 50% by CSBP.* *Source: CRU*

Feedstock

Feedstock for the ammonia plants which feed AN and ammonium phosphate production comes from natural gas. Australia is a gas-rich country, and has extensive deposits of gas offshore of the northern coast. However, while some of these are near major mining areas, they are on the opposite side of the country to major fertilizer consuming regions in the southwest and southeast. Trans-Australia gas pipeline infrastructure also remains limited due to the huge distances involved, especially in the east-west direction. This effectively cuts the country into three regions: Western Australia; Northern Territory; and the east – Queensland, New South Wales and South Australia. It means that the major eastern markets do not have access to the rich gas production regions of the northwest. Thus while Australia is one of the largest global exporters of LNG from the northern gas basins, only just behind the US and Qatar in terms of volumes, little of this gas finds its way to the southeast, leading to shortages and higher prices, particularly as the government tries to discourage coal-fired power generation. But government intervention in energy markets, including a price cap on gas, has discouraged new investment in gas production in the southeast, leading to long term supply gaps, and even the possible construction of an LNG import terminal at Kembla in New South Wales – although this project's future remains uncertain.

Australia's labour government has set the country a target of generating 82% of its electricity from renewable sources by 2030, which may ease some of the pressure, but in the interim the pressure on ammonia plants in Queensland remains, and Gibson Island may not be the last to close.

New projects

There have been a number of urea project proposals to meet Australia's domestic fertilizer needs, currently filled by imports. Burrup Nitrates had plans for a urea plant as a follow-on development from

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the ammonia plant at Pilbara, but the company's collapse led its successor Yara to focus on TAN instead. More recently, Strike Energy touted a 1.4 million t/a ammonia-urea project – 'Project Haber'- using natural gas at a site 350km north of Perth in Western Australia, with Koch in negotiations for the offtake of the plant, but this project has since mutated into an 85MW power plant proposal instead after local gas reserves turned out to be lower than anticipated.

Another new company, NeuRizer, was working on a 1.0 million t/a ammonia-urea project at Leigh Creek, South Australia, with front end engineering design completed in 2023 and offtake agreements in place. The project was to be based on coal gasification, bypassing the gas issue, with carbon capture and storage to produce 'blue' ammonia for urea production. However, in January the company said that an unnamed strategic partner had pulled out of the project, and that it was on indefinite hold for now.

The last man standing is Perdaman's Project Ceres gas-based ammonia-urea plant, backed with money from Abu Dhabi-based Mubadala. This A$6.4 billion (US$4.3 billion) project is destined for a coastal site near Karratha in the Burrup Strategic Industrial Area in the north of Western Australia, and is slated to produce 2.3 million t/a. Perdaman has signed an offtake agreement with IncitecPivot, who will market and sell the urea under a 20-year agreement. The plant is ideally sited to sell urea overseas into Asian markets or to the Australian domestic market and intends to split its output between the two. Though delayed by environmental permitting from its originally planned 2020 start date, site work on the project began in May 2024 and the plant is scheduled for completion in 2027.

Green ammonia

Over and above these conventional projects however, Australia's abundant sunshine has also encouraged a number of developments for producing green ammonia in Australia. In addition to the side streams to existing plants mentioned above (or entirely replacing the existing feed in the case of Gibson Island) there are a number of standalone green projects, often looking towards Japan's desire to import green ammonia to co-fire at power stations. In June, the Australian government gave a boost to this via its Future Made in Australia budget measures, which have allocated more than A$15 billion of funding support for green hydrogen.

PHOTO: YARA

Orica's Kooragang Island complex, Newcastle, New South Wales.

One of the largest projects under development, Allied Green Ammonia, has proposed a large-scale (950,000 t/a) renewables-based hydrogen and green ammonia facility on the Gove Peninsula in the Northern Territory, with front end engineering design by Tecnicas Reunidas beginning in 3Q 2024 and a final investment decision in 4Q 2025. Topsoe would license ammonia technology for the project and Trammo has been lined up for offtake.

Australian mining giant Fortescue had been planning a green hydrogen and ammonia project at a sustainable development hub at Darwin in Australia's Northern Territory, but confirmed in June 2024 that this project had been shelved.

The North Queensland Clean Energy Project (HYNQ) says that it will produce renewable hydrogen and ammonia using over 1 GW of electrolyser capacity, powered by solar and wind energy. Current members of the consortium include Idemitsu Australia, Queensland state government-owned CS Energy and local developer Energy Estate. Pre-FEED activities were completed on schedule in Q3 2023 and FEED is now under way, with a FID scheduled for 2025.

Climate Impact Corporation (CIC) said in July that it plans to develop two projects in Australia, based on its modular hydrogen production technology. Each project will feature a 10 GW "network" of off-grid modules, incorporating renewable energy generation, water extraction from the ambient atmosphere, and a 2.5 or 5 MW electrolyser to produce renewable hydrogen. The first project (named Green Springs) would be sited south of Tennant Creek in the Northern Territory, and produce more than 500,000 t/a of green hydrogen. The second Australian project will be in South Australia.

Meanwhile, the East Kimberly Clean Energy Project is looking to use 1 GW of solar energy to generate hydrogen for 250,000 t/a of green ammonia production at Kununurra in the north of Western Australia by 2029 at a cost of A$3 billion.

The Western Green Energy Hub (WGEH) is a development including Korea Electric Power looking at a very large scale hydrogen and ammonia hub at Mirning Country near Eucla in Western Australia. Phase 1 would use 50 GW of wind and solar power to produce 330,000 t/a of hydrogen for 1 million t/a of ammonia production, but subsequent phases could take this to 3.5 million t/a of ammonia. WGEH is a consortium made up of InterContinental Energy (46%), CWP Global (44%) and Mirning Green Energy Limited (10%), the commercial entity of the Mirning Traditional Lands Aboriginal Corporation. The project is aiming at a FID in 2027.

All of these projects remain highly speculative of course, and the demise of Fortescue's Darwin project and the delays to its Gibson Island project are indicative of the difficulties in getting these projects off the ground. Allied Green Ammonia looks the most promising, but it remains to be seen how it will fare against real world economics. ■

Coal-based nitrogen capacity

In spite of increasing environmental concerns over the use of coal as a feedstock, it continues to provide around one quarter of the world's ammonia. But in a world that is decarbonising, is there still a future for coal-based capacity?

Coal was the original feedstock for man-made nitrogen production. When Carl Bosch of BASF first scaled up Fritz Haber's ground-breaking ammonia synthesis process at Oppau near Ludwigshaven in 1913, it was in a world where coal was the dominant fuel for the industrial revolution and the source of most chemicals. That first plant used coal from the nearby mines at Oppau and, as Figure 1 shows[1], coal dominated the early life of the synthetic nitrogen industry, with some inroads from hydrogen generation via water electrolysis using hydro-electric power, beginning with Norsk Hydro in Norway, and later naphtha-based production from the rapidly growing oil industry.

But natural gas proved to be a cheaper and more tractable feedstock, requiring less pre-processing and swapping a cumbersome gasification reactor for a steam methane reformer (SMR). It allowed the scale-up of the ammonia process during the 1940s and 50s to plant sizes of 1,000 t/d and beyond, until by the 1970s it had become the dominant way of producing ammonia and downstream nitrogen products, a status that it still retains today.

Nevertheless, coal still had its adherents. In countries where natural gas was scarce and coal abundant, it could still be a much cheaper feedstock, particularly if used at large scale, in order to reduce the relative capital cost per tonne of expensive gasification sections. Figure 1 shows a resurgence of coal as a feedstock during the 1980s and 90s, as gas began to be used more and more in the power sector, driving natural gas prices upwards in North America, Europe and East and South Asia. This resurgence was however based in just a few countries where the economic conditions made coal attractive, particularly China, but also including Vietnam, India, South Africa and even the United States, which had pioneered gas-based production, but which also had major coal producing regions. Indian coal proved technically challenging for the gasifiers of the time, and in the US the sudden fall in gas prices caused by the fracking boom in the 2010s made life economically difficult for the coal-based plants there also, but China and Vietnam continue to operate coal-based capacity, and indeed China has become almost synonymous with coal-based ammonia production, with coal representing almost 80% of domestic ammonia production, and China representing 97% of all coal-based ammonia production worldwide.

PHOTO: DAKOTA GASIFICATION

The Great Plains Synfuel Plant, North Dakota

China

China is the world's largest coal producer, mining around half of the world's coal and consuming just over half (55%). China's ammonia industry grew on the back of coal gasification, initially using fairly simple fixed-bed atmospheric pressure UGI gasifiers, which use air and steam rather than oxygen for the gasification process. While this makes them relatively cheap, it also means that they operate very inefficiently, and can only use high quality anthracite coal as feedstock. These plants, often small scale (<300 t/d) in the early days of China's ammonia industry, proliferated across the country until there were several hundred in operation, many of them feeding ammonium bicarbonate production.

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However, as China opened up economically in the 1990s, they faced competition from overseas ammonia producers, often using low cost natural gas in locations such as the Middle East. This led to a second wave of Chinese domestic production, some of it using natural gas in locations such as Hainan Island, and most of the rest switching to more modern fluidised bed or entrained bed gasification processes at larger scales (>1,000 t/d) and able to use cheaper bitumen or lignite coals. The wave of new Chinese ammonia plants meant that by 2018, around half of Chinese coal-based ammonia capacity was based on more modern gasification techniques, and many of the smaller and less efficient plants had shut down.[2]

From about 2015, China's government took a decisive strategic turn, trying to pivot the economy from its previous concentration on industrial capacity towards consumer spending, and shifting towards more ecologically friendly policies, cleaning up the country's major air pollution problems and moving to more sustainable use of energy. This has impacted on the ammonia and downstream fertilizer industry, leading to much stricter emissions limits and the closure of some of the most polluting plants, again often older capacity, or restriction of their operation during certain times of year, such as winter when major cities can be blanketed by smog. At the same time, however, China has continued to build coal-based capacity, replacing older and dirtier plants with more efficient and modern ones.

> **"China has continued to build coal-based capacity, replacing older and dirtier plants with more efficient and modern ones..."**

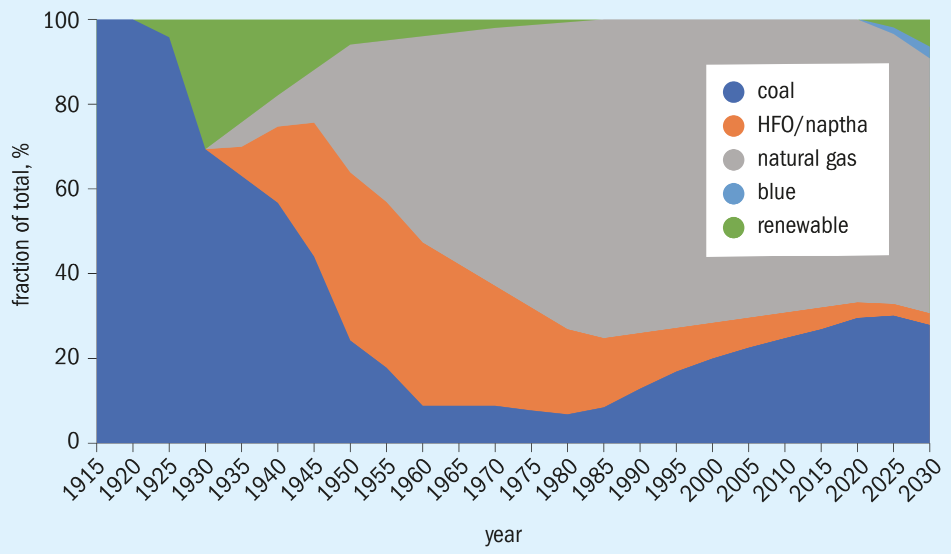
India

India built two coal gasification-based ammonia plants during the 1970s at Ramagundam and Talcher, but these suffered operating difficulties due to the high ash content of Indian coal (35-45%) and were closed down in the 1990s. India, like China, is a gas-poor but coal-rich country, and various plans for more ammonia capacity based on coal gasification were advanced over the decades, but the experience of the two 1970s plants acted as a brake on these developments. A new large scale (2,200 t/d ammonia, 3850 t/d urea) coal gasification-based ammonia plant at Talcher was proposed as long ago as 2007, and finally approved by the Modi government in the 2010s, but disputes over coal supply and the Covid-19 pandemic have slowed the project, and it has still not yet commissioned, though construction, being conducted by China's Wuhuan Engineering, is said to be close to completion. The plant will blend the local coal with 25% petroleum coke as feedstock in order to reduce its overall ash content. Once again, though, the plant's troubled history seems to have functioned to put off new coal-based developments until the current plant can demonstrate that it works.

Indonesia

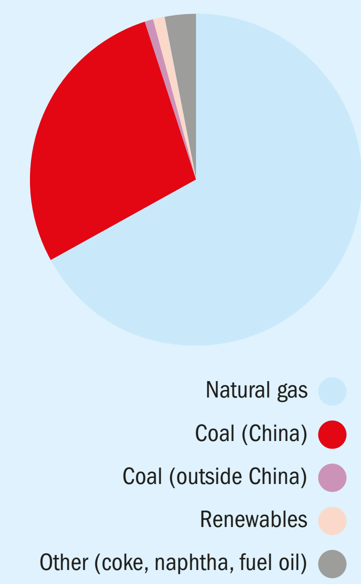
Indonesia operates a considerable amount of gas-based ammonia capacity across the archipelago. But the country is also a major coal producer, mining 687 million tonnes in 2022, or around 8% of the world's coal, and coal generates around 45% of all energy used in Indonesia. The country has tried to developing two coal gasification projects, aimed at methanol production rather than ammonia. The first was to be built at Tanjung Enim, and was originally a collaboration between Air Products, state-owned coal producer Bukit Asam and national oil firm Pertamina. It would use 6 million t/a of coal to generate 1.4 million t/a of dimethyl ether (DME) via syngas and methanol steps, to replace imports of LPG. In 2022 Air Products inked a similar deal with Bakrie Group companies, PT Kaltim Prima Coal and PT Arutmin Indonesi for a coal-based methanol plant at Bengalon, East Kalimantan. However, Air Products exited both projects earlier this year, as Pertamina, which would have taken the offtake from the first plant, reportedly had cold feet over coal prices and the project's economics, and the status of both projects now remains very uncertain.

Figure 1: **Historical ammonia production by feedstock and expected production to 2030**



Source: Rouwenhorst[1]

Fig. 2: **Ammonia production by feedstock**



Source: IFA, CRU

PHOTO: HENAN XINLIANXIN CHEMICAL

Coal-based ammonia production in China

Emissions concerns

Looming large over all coal-based developments these days is the spectre of carbon emissions. Even the most efficient Chinese bituminous coal-based ammonia production generates on average 2.0-2.1 times as much carbon dioxide as an average natural gas-based plant. This means that there is pressure on existing coal-based capacity to 'clean up' its operation. The Great Plains Synfuels Plant at Beulah, North Dakota, which generates 400,000 t/a of ammonia from coal, is moving to carbon capture, utilisation and storage (CCUS). Sasol's major coal gasification site at Secunda in South Africa is facing challenges with the company's commitment to a 30% cut in carbon emissions by 2030 and may be scaled down or closed. Even China is beginning to introduce an emissions trading scheme – albeit at a low carbon price at present – which will affect the economics of coal-based production. At the moment, it seems almost inconceivable that any new coal-based plant could be built outside of China without incorporating CCUS, and existing plants are likely to move to CCUS or greener feedstocks, or face closure.

> **"There is pressure on existing coal-based capacity to 'clean up' its operation..."**

Within China, there are projects to convert some coal-based production to partial renewable feeds. A 20,000 t/a pilot plant came onstream near Chifeng City in Mongolia earlier this year developed by Envision, and the second and third phases of this project, planned for 2025 and 2028, are proceeding. Last year, Topsoe signed an agreement with Mintal Hydrogen Energy Technology as technology provider for a new green ammonia plant in Baotou, Inner Mongolia, in the heart of China's coal-based ammonia production. The new plant will be the first 'dynamic' green ammonia plant in China, using technooogy which allows for considerable turn-down rates, allowing production of down to 10% of normal capacity. The first phase will have a 100% capacity of 1,800 t/d, with expected start of production in 2025 and will replace local coal-fired production. Inner Mongolia has considerable potential for wind energy, and China also has large scale domestic electrolyser production, bringing down capital costs. Overall, there are some 9 million t/a of renewable ammonia capacity under development in China, with perhaps 4-6 million t/a possibly in operation by 2026. In addition to this, in June 2024 the National Development and Reform Commission (NDRC) announced a new 'ammonia industry special action plan' with a target of 13 million t/a of CO_2 emission reduction from the sector by 2025, mostly through the retirement and retrofit of older, more inefficient facilities. China has been pushing energy efficiency, fuel switching and renewable feeds rather than CCUS for its ammonia capacity because it has less experience and expertise in the latter.

The end of coal?

China remains the main bastion of coal-based ammonia capacity, and nowhere outside of China are there active projects in developing new coal based ammonia plants. China's governmental decisions will in effect decide the future of coal-based ammonia, and while the sheer volume of ammonia produced by coal in China means that it will be with us for some years to come, there is now a major government push on conversion to renewable feeds, efficiency improvements and the replacement of the remaining older gasifiers with more modern ones. There will be a long tail of production as it gradually closes or switches, but it looks as though the writing is on the wall for coal as a means of generating ammonia. ■

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Nitrogen+Syngas 2025

A look at the forthcoming Nitrogen+Syngas Expoconference, to be held from 10-12 February 2025, in Barcelona

CRU's 38th Nitrogen+Syngas Expoconference will be held on 10-12 February 2025 in Barcelona. The most respected technical event for the global nitrogen and syngas community offers an ideal platform for industry professionals to connect, do business and learn about the latest innovations in operations, technology, process and equipment. The annual meeting attracts a global audience of producers, licensors and materials and equipment providers representing an unparalleled opportunity for business networking and peer-to-peer knowledge sharing.

The most comprehensive agenda covering the entire nitrogen and syngas value chain is now available to view online, featuring 80 papers covering 25 subject areas – an increase of 5 on 2024, including a record 21 presentations from plant operators; and a full day of investment and commercial presentations. The industry-leading technical agenda showcases the latest technical advancements in operations, technology and product diversification – helping nitrogen and syngas producers working in both new projects and existing plants to optimise their processes. With a significant focus on energy efficiency, carbon capture and GHG emissions, dedicated sessions focusing on innovations in digitalisation and future fuels; and a training morning dedicated to plant safety and reliability.

Operator involvement

This year there is a particular emphasis on the involvement of operator companies, with a 3 hour Monday morning operator training session, and technical presentations from a record 21 operating companies, including Sorfert, OCI NV, MOPCO, and the Fauji Fertilizer Company.

Technical showcases

Monday morning will feature the usual technical showcases, shorter presentations by leading technology companies describing their product offerings. These will include:

Belleli Energy – applications of low alloy steels in high pressure equipment. Within the last decade use of enhanced 2.25 Cr 1.0 Mo low alloy steel has been reconsidered in case of pressure equipment designed for temperatures significantly below its ASME Code allowance (i.e. 454°C), such as in ammonia plants, allowing for wall thickness reduction, and inherent weight, though in order to grant such mechanical properties specific care must be taken be taken in design of the appropriate quality heat treatment, inherent final post weld heat treatment parameters and fabrication conditions.

BASF-OASE® connect, a digital platform for gas treatment applications. This platform provides various customer support like access to a knowledge centre with training material, analytical data, OASE® digilab and a simulation tool. The latter can be preset with plant specific settings and is the key element for analysis and for optimisation of plant operation.

WIKA Alexander Wiegand SE & Co. KG – a newly designed optical sensor technology which can be used in processes with higher media temperatures up to 600°C and potentially above. Current widely used technologies methods of pressure measurement stop at a media temperature of 400°C when measuring in direct media contact.

Paralloy – OMEGA technology for profiling interior diameters of reformer tubes, enhancing the thermal performance of the tubes using standard reforming catalyst. This application is retrofittable for all steam reformer designs and is reversable. Combining OMEGA with Paralloy's range of micro- alloyed materials can provide additional synergie.

Commercial sessions

Monday afternoon will be devoted to the commercial session, where experts from CRU and other companies will present a snapshot of the state of markets and trends, and a summary of issues facing the industry. A highlight will be a keynote presentation by Sorfert on decarbonising the industry, followed by a keynote panel on the transformation that the nitrogen and syngas industries are going through, as well as a CRU assessment of the potential for low emission ammonia and hydrogen production.

Technical sessions

The technical sessions which will be run on Tuesday and Wednesday include 64 presentations in 3 parallel streams, covering a wide variety of topics. Important issues which will be covered include plant reliability and integrity; greenhouse emissions reduction; CO_2 removal and carbon capture and utilisation; ammonia as a hydrogen carrier and ammonia 'cracking'; the energy transition and future fuels; and novel technologies and applications. A fuller list of topics to be covered is summarised below:

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Expoconference

Barcelona cityscape

PHOTO: ALEXANDER PASARIC/PEXELS

LIST OF SESSIONS

10th February

- Investment And Commercial Programme
- Operator Training – Identifying Hazards With Green Ammonia/Urea Production
- Technical Showcases

11th February

- Plant Reliability & Troubleshooting
- Green Ammonia Technology
- Ghg Emissions Reduction
- Urea Plant Design
- Nitric Acid: Catalysts And Equipment
- Ammonia, Methanol And Urea Operations
- Urea Plant Safety Technology
- Nitric Acid And Ammonium Nitrate Technology And Plant Reliability
- Sustainable Fertilizer Production
- Co_2 Removal And Carbon Capture And Utilisation
- Digitalisation: Technology And Innovation
- Fertilizer Finishing

12th February

- Urea Plant Safety And Integrity
- From Green Ammonia To Green Hydrogen – The Journey
- Energy Transition And Future Fuels
- Urea Production: Matreials Of Construction
- Ammonia And Methanol Plant Operations And Optimisation
- Low Carbon Hydrogen Production
- Decarbonising Urea Production
- Ammonia Plant Operations
- Asset Integrity

Investment in industry infrastructure

Monday morning's commercial session, investment in industry infrastructure, is a C-level meeting serving as an exclusive networking platform. Supported by the largest asset owners and leading names in industry infrastructure investment, the conference will welcome institutional investors, fund managers, asset owners and asset managers, investment banks, Government representatives, consultants and advisers representing the global hard-to-abate nitrogen and syngas industries. This agenda is designed to provide a comprehensive overview and updates of the regulations, opportunities and challenges in industry infrastructure investment, focusing on decarbonisation and sustainability efforts.

Hydrogen, ammonia, methanol and urea are providing novel solutions in energy security and in net-zero energy transition, food security as well as future fuels. By 2050 demand for low-carbon hydrogen is expected to reach 350 million tons per annum. Investments needed in developing the hydrogen infrastructure alone is estimated at $12 trillion between 2025 and 2050.

Topics:

(i) Navigating the global net-zero investment landscape – outlook for 2025 and beyond
- EU policy and regulatory framework: What supporting schemes and incentives are there for investors?
- Are the new rules setting a level playing field for investment in hard-to-abate industries
- Key challenges revised: uncertainty, market limitations, transparency, and greenwashing

(ii) Unlocking the potential – focus on future assets
- What are the current allocations in emerging asset classes like ammonia and hydrogen
- Global projects pipeline: Where are the new frontiers?
- What is your risk threshold?
- Financing the energy transition

(iii) Fostering investment in emerging assets.

(iv) The future of the ammonia supply in *Europe*

Presenters and panel sessions will include Pensions Europe, Société Generale, ING, GIZ, Oxford Energy Institute, and the Ammonia Energy Association.

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Financing green plants

With a large number of green ammonia projects under development, financing remains the greatest hurdle to getting ventures off the ground.

In order to decarbonise the industry, ammonia production is going to have to move to various forms of green and blue production over the next 20-25 years. Indeed, if ammonia is also used to transfer hydrogen atoms from place to place, and to provide a relatively clean burning fuel for the shipping industry, as well as a side stream for coal fired power stations as various Asian countries are planning, then not only will the present and future fertilizer and industrial demand need to be converted, but possible as much again new capacity need to be constructed.

Unsurprisingly, project activity has therefore been intense in the past couple of years, with dozens of new projects being announced, from small scale pilot studies and side streams to huge complexes intended to provide large scale production. However, the final step, to final investment decision and project construction, remains elusive, with many projects running into trouble with tying down financing.

Substantial capital will be required to develop this new industry. Estimates range from $80-300 billion from now until 2030, and the IEA estimates up to $2.5 trillion will be needed for low-carbon hydrogen production alone out to 2050. Broadly speaking, project finance can come from three sources; government grants, raising debt from banks, and issuing equity. Where the project sponsor is a government agency or state-owned company, there is often a kind of hybrid of all three.

Debt

Incurring project debt means convincing a bank (or more likely a consortium of lenders) to risk money on a scheme. In order to grant the loan the lender is likely to require assurances in terms of mitigation of risks; commercial, technical and political. Reduction of risk reduces the cost of servicing debt, which can be make or break for project economics. Guaranteed offtake agreements from a creditworthy customer can be vital in this regard, as they signal guaranteed income stream for the project. This is also why greening existing uses for hydrogen/ammonia may be most attractive to lenders, as the customer base already exists for fertilizer or industrial uses, whereas, e.g. demand from shipping companies still remains speculative at present, which has been the downfall of several projects this year.

Political risk

As noted recently by the Ammonia Energy Association, global policy ambitions aim for 11 million t/a of low-emission hydrogen by 2030 – already 3 million t/a down from last year, while projects reaching a final investment decision only account for 3.4 million t/a. The AEA remarks that: “clear policy actions are required to drive demand.” EU mandates for low carbon aviation and shipping fuels and other incentives are helpful in this regard, as are the financial incentives provided by the US Inflation Reduction Act, but whether the latter would survive a Trump presidency remains an open question.

Technical risk

Building large scale low carbon ammonia plants has a degree of technical risk, though the individual parts are often well understood. Electrolysis is a mature technology, as is ammonia synthesis, but coupling ammonia production to a variable power input is a technical challenge that licensors are currently grappling with. Conversely, blue production from existing plants with the addition of carbon capture, utilisation or storage has lower upstream risk, but large scale CCUS has technical challenges with the acidity of high pressure CO_2 on process equipment. Then there is logistics. One of the reasons that ammonia has come to dominate low carbon hydrogen production is to lower the technical risk, as large scale hydrogen storage and transport remains difficult and expensive, while for ammonia it is already an existing and well understood industry. At least until some track record has been demonstrated, lenders will have a heightened concern about completion risk, and may require completion guarantees.

Government finance

Government finance can be very helpful in guaranteeing capital costs and, via loan guarantees, particularly from export credit agencies or development banks, in lowering the cost of capital for projects, but generally it is limited in availability and usually it will require at least matching funding from private interests. A permissive tax environment or guaranteed offtake from government agencies can often be more important than one-off grants.

Equity

Equity issue is only really an option for state owned entities or existing large private companies with a demonstrable track record of project development, particularly oil, gas or fertilizer majors. They have the ability to fund projects from equity, even if the economics are uncertain, or the project risk is high, rather than relying on bank lending, provided that they believe in the fundamentals of the project.

Project ownership models

Ownership models can be a way of spreading risk across project partners to make a project more attractive overall. For example, a company that owns the production facilities may enter into tolling arrangements with its customers, whereby the customer is responsible for the supply of the inputs (e.g. electricity and water), and will pay a tolling fee to the project developer to produce the ammonia. This insulates the developer from variable supply costs and provides for a predictable revenue stream that would support the financing. ■

PHOTO: AICHE

2024 AIChE Ammonia Safety Symposium

Venkat Pattabathula, a member of the AIChE Ammonia Safety Committee, reports on the American Institute of Chemical Engineers' (AIChE) Safety in Ammonia Plants and Related Facilities Symposium held in San Diego on 8-12 September 2024.

San Diego, venue for this year's symposium.

The Ammonia Safety Committee is dedicated to improving the safety of plants that manufacture ammonia and related chemicals, such as urea, nitric acid, ammonium nitrate, and methanol. The conference's objective is to improve the safety performance of the ammonia industry. This is achieved by sharing information on incidents, safety practices, and technology improvements in presentations and open discussions.

From 9th–12th September 2024, 340 engineers from more than 30 countries and 100 companies attended the AIChE's 68th Annual Ammonia Safety Symposium at the Manchester Grand Hyatt in San Diego, CA, USA. Attendees who participated in the symposium included plant managers, production managers, safety managers, process/reliability engineers, and everyone responsible for the safety and performance of ammonia plants or handling facilities. Worldwide experts discuss the latest advances in the safe production and use of ammonia, as well as case studies and lessons learned at these symposiums.

Ammonia as an energy carrier

This year's keynote speech: 'Ammonia as an energy carrier :scaling risk' was presented by Rob Stevens, Sector Lead for Green Fuels at Topsoe Power to X. Rob looked towards a future where ammonia's use in energy applications, including as a marine fuel, as a power plant co-fuel, and as a hydrogen carrier could total up to 10-30 million t/a by 2030, and 100-300 million t/a by 2050, the latter more than doubling the size of the ammonia market by that time. Methanol could also see similar growth if it were widely adopted as a bunker fuel. In both cases, grey production will continue to predominate by 2030, but blue and green production is expected to produce the bulk of both chemicals by 2050.

Rob discussed the makeup of ammonia safety incidents in the US and EU by industry and root cause, and whether a new use case (maritime fuel handling and use) at large volume could also lead to an upwards scaling in ammonia safety incidents. The ARISE (Ammonia Response in Sea Emergencies) programme is looking at ammonia releases in a marine environment, to improve risk assessment and assist the maritime sector and regulators towards a safe deployment of ammonia as an alternative fuel. Other studies are looking at ammonia pipelines. But he stressed the importance of industry involvement in helping the maritime industry to develop procedures and safety documentation, via the AIChE Ammonia Safety committee, Ammonia Europe, TFI, and the Ammonia Energy Association.

PHOTO: AICHE

2024 AIChE Ammonia Safety Committee
Front: Ahmed Esmael Rahimi (Qatar Fertiliser Company), Venkat Pattabathula (SVP Chemical Plant Services), Kristina Balch (Dyno Nobel), Seshu Dharmavaram (Air Products), Mohamad Noueiri (Yara), Marc Gilberston (East Dubuque Nitrogen Fertilizer)
Back: Federico Zardi (Casale SA), Ashutosh Shukla (FFI), Samuel Okulaja (Nutrien), Lari Bjerg Knudsen (Topsoe), Klaus Noelker (thyssenkrupp Industrial Solutions AG), John Brightling (Johnson Matthey), Mark Schroeder (Koch), Taylor Archer (Clariant), Umesh Jain (KBR), Eugene Britton (CF Industries).

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Safety incidents

The key safety-related papers were:

1. Primary reformer riser transitional assembly failure

In 2023, Nutrien's Trinidad number 4 ammonia plant had an abnormal temperature profile in the primary reformer, along the number 3 riser. Shortly after, a fire was seen emanating from the primary reformer penthouse and the plant was shut down. Subsequent analysis revealed flaws in welds from a 2009 turnaround, where modifications also left a gap in the refractory which was filled with compressed ceramic (Si/Al) fibre with a higher silicon content than that recommended. It is suspected that process gas, H_2 and CO bypassed through the slip joint compromised the insulation and exposed the flawed weld to the process. The suspected bypass of the process gas exposed the transition cone to carburisation temperatures above 480 °C (900 °F), which manifested in shallow pitting, reduced ductility and toughness and subsequent cracking. Elevated temperatures and the riser's subsequent bowing added more stresses on the already compromised weld, contributing to thermally induced fatigue cracking and subsequent loss of containment. It was determined that insufficient quality assurance and control (QA/QC) during the installation of the 2009 transition cone were the primary causes of the failure. Temporary repairs were conducted to return the plant to service during the 2023 outage to replace all rise transitional assemblies (RTAs) during the next scheduled turnaround. Improvements in RTA design, including eliminating the Inconel 800HT liner slip joint and dissimilar metal joints when designing future replacements, will prevent such failures in future.

2. Fire beneath a reforming furnace

An unexpected fire occurred two weeks after the startup of a hydrogen plant following a major plant turnaround. The fire occurred beneath the furnace box due to the loss of containment from a radiant section process gas tube. Damage was limited to instrumentation at the bottom of the furnace, including the actuator on the waste heat boiler temperature control (internal bypass) valve, refractory, and the furnace structure. Fortunately, no one was injured as no one was in the area when the fire occurred, and actions were immediately taken to shut down the plant and extinguish the fire safely.

Investigation found that the bottom flanges were not tightened adequately to ensure tight closure while in operation. The evidence indicated the contractor assigned to tighten the bottom flanges did not execute their standard work practice, with quality issues on flange closure details. The investigation team also found two completely loose studs on one flange and one completely loose stud on three other flanges that were worked on during the turnaround and were all outside the fire zone. The quality control processes were inadequate in identifying the compromised enclosure tightening. The shutdown contractor appeared to have not executed their own QA process to audit whether their enclosure practice was utilised or that the bolts were insufficiently tightened. The QA process relied on the contractor's audit practice, which only involved a spot audit of the contractor's records.

Subsequently, the contracting company has developed a certified training program to familiarise all levels of workers with contractors' procedures, including a bolting training program and competency training assessment for its workers. The operator has also enhanced its own in-house Quality Assurance process with defined roles and responsibilities.

3. Hydrogen assisted cracking (HAC) in an ammonia synloop

Hydrogen assisted cracking (HAC) may occur in low alloy steel welded components in hydrogen service. It is normally seen in the heat-affected zones of equipment operating at high hydrogen partial pressure (>7 MPa/1015 psi) and operating wall metal temperatures (>250°C). This phenomenon can be considered a type of hydrogen embrittlement, resulting in the formation of cracks. The presence of ammonia can be a detrimental factor for crack nucleation, possibly promoted by nitriding and internal (thermal) stresses. Yara's complex at Sluiskil in the Netherlands has suffered a number of HAC incidents in recent years.

In 2019, during a scheduled turnaround of one of the ammonia plants, the second synthesis loop converter was inspected for internal corrosion, nitriding and hydrogen-assisted cracking (HAC) according to the risk based inspection (RBI) plan. Several cracks were found, mainly between the manway and the top head. Cracks were uniformly distributed along the weld seam with a depth of about 40% of the total thickness. The reactor was taken out of service and bypassed as no repair option was possible. The converter was a hot-walled type, and the operating conditions were in the range of susceptibility for HAC.

In 2020, during a scheduled turnaround of the second ammonia unit, an unexpected crack was found during the weld inspection between the ammonia converter (R406) and the waste recovery boiler (E416). This could have potentially led to a leakage of syngas with safety risks. The configuration of the failure of the waste heat boiler object with the indication of the cracked weld. The site has multiple boilers with the same design and one spare unit, so a preventive replacement and maintenance strategy is in place. The boiler object of the failure was removed – by cutting the welded connections – in 2012 from the third ammonia unit and installed in 2014 in the second unit after some repair activities at the workshop. As a lesson learned and mitigation action for future projects and on-the-field welded connections and repair, the internal Yara post-weld heat treatment (PWHT) technical standard was updated to include specific requirements for installing thermocouples at the inner surface of thick components during the treatment.

In 2023, during normal plant operation, a hot spot in the insulation of the outlet nozzle of the E516 waste heat boiler connected to the ammonia converter of the third unit (R507) was noticed by an operator, indicating a possible leak of syngas. The plant was shut down, and the inspection confirmed the presence of a trough-wall crack in the circumferential weld between the outlet nozzle and the connecting outlet pipe. An improper PWHT procedure resulting in non-acceptable hardness levels and the detrimental impact of other degradation mechanisms, such as nitriding, considerably reduced the resistance to HAC of these pressure equipment.

A detailed analysis of the operating conditions and the definition of specific minimum pressurisation temperature curves, considering the amount of available hydrogen and the geometry of the equipment and operating loads, have been identified as the best approach to mitigate the risk of HAC in combination with a proper inspection plan involving advanced NDT techniques. However, the recent experiences within Yara proved that this degradation could be difficult to predict and prevent with proper in-service inspection. For these reasons, Yara's internal procedures have been updated to increase quality control on the manufacturing and repair action, such as strong prescription PWHT and hardness checks.

4. Secondary reformer waste heat boiler tube rupture

Ammonia Kujang's 1A plant experienced significant failure events in the secondary reformer waste heat boiler, where the tube ruptured during two successive startup attempts. Both cases led to boiler feed water (BFW) flooding in the high-temperature Shift (HTS) catalyst bed. Total replacement of the HTS catalyst was required after the first event, whereas efforts to heat up more slowly following the second event restored the HTS catalyst performance. The team decided to repair and re-install the damaged tube bundle and amended the plant shutdown procedure to include a leak test of the WHB, steam superheater and HTS effluent BFW pre-heater to make they are in good condition and to prevent catalyst being submerged by boiler feed water. Startup has emphasises the importance of controlling the temperature rate increase at the inlet of the WHB, with a new temperature rate indicator at the inlet installed to prevent similar failures from taking place in the future.

5. Catalyst overheating due to feed preheat coil failure.

On 18 March 2023, Ammonia Kujang 1A faced operational disruptions due to a vacuum system issue, causing speed fluctuation in all compressors and subsequent shutdown of the back-end section. Control measures stabilised the air and natural gas compressors, but overheating in the HTS and LTS catalyst bed increased the temperature up to 1010 °C and 515 °C respectively, prompting a total plant shutdown while no interlock was triggered. Inspection revealed damages, including coil fracture and catalyst breakdown due to overheating caused by air exposure and water submersion.

Considering the extreme increase in catalyst bed temperature, the decision was taken to initiate a total shutdown of the facility for a thorough analysis. During the shutdown process, a high-level alarm was triggered in the HTS effluent knock-out drum, necessitating the implementation of manual drainage in the field. The condensate exhibited a dark brown colour, with analysis confirming that it had a PO4 content of 16 ppm. The existing interlock system had not adequately mitigated the risk of feed preheater coil failure, the risk of which is substantial, especially in aging plants. The failure of the feed preheater coil unit led to extreme overheating of the HTS-LTS catalysts and resulted in an 18-day shutdown of Ammonia Kujang 1A.

To prevent similar incidents in the future, several programs have been implemented, including the addition of a low flow feed gas sensor downstream of the feed preheat coil, feed preheater coil replacement; ensuring that all pressure gauge indications in the vacuum system can be read correctly and regularly maintained; routine checks of piping in the vacuum system; and a review of the existing interlock system for potential unmitigated risk.

6. Failure of primary reformer tubes

PT Pupuk Kujang also suffered a fire in the primary reformer of their ammonia 1B plant in 2018. Pupuk Kujang suspected a rupture in a primary reformer tube and, based on this condition, decided to shut down the ammonia 1B plant. Upon inspection, it was discovered that there was a rupture between the catalytic tube and the bottom reducer. Out of the 192 tubes, one tube was ruptured, three tubes had more than 4% creep, and the rest showed no visual indications. These tubes have been in service since October 2004, approximately 14 year. Pupuk Kujang's root cause analysis indicated that the rupture of the primary reformer tube was caused by creep initiated by a hot spot in the primary reformer tube. Field measurement results indicated a significant increase in tube wall temperature, which reached a peak of more than 922 °C. High temperatures on the tube catalyst induced carbon formation on the catalyst's active sites, causing metal sintering. This led to further catalyst deactivation, which worsened the tube wall temperature.

The most effective method to prevent primary reformer tube failure is by thoroughly examining the composition of natural gas entering the primary reformer and adjusting operating parameters based on the data. Tube wall temperature of the primary reformer tube need to be checked to verify the burner adjustment. Good teamwork between the operations, process engineers, and maintenance teams was key to achieving optimum operating parameters and smooth operation. Since primary reformers in the Ammonia 1B plant primarily run at full loads and above design production rates, it is important to still operate within the design envelope without exceeding the design parameters.

7. Syngas compressor oil-seal failure with fire

On 6 March 2023, at 7 pm, an electrical blackout occurred at the Cubatão 2 production complex, causing the shutdown of all production plants simultaneously. Subsequently a fire was observed in the ammonia plant at the atmospheric vent of the synthesis gas compressor oil reservoir. Firefighting actions were initiated and eventually succeeded after the compressor's gas intake valve could be closed. After evaluating the operational conditions, it was decided to initiate a cold production shutdown to maintain the ammonia plant, correct the damage caused by the lack of electricity, and assess the potential damage caused by the fire.

A failure analysis study was carried out using the fault tree method. The results indicated no damage to the compressor and seals, and it became clear how the fire had occurred by comparing the operational data under normal conditions versus upset conditions and linking the main events from the blackout until the end of the emergency. With the loss of the barrier fluid and the pressurisation of the oil system with synthesis gas coming from the compressor's internal pressure, gas escapes together with oil through the atmospheric vents, creating conditions conducive to the start of a fire. The high concentration of hydrogen in the synthesis gas coming into contact with the various heat sources and hot surfaces close to the vent of the oil reservoir (turbines and pipes with damaged insulation) likely caused the leaking gas to ignite, allowing the fire to start.

Short term remedial actions included rerouting atmospheric vents that may contain synthesis gas to suitable locations, i.e. from oil reservoirs and coupling covers and degassing the entire oil inventory with thermo-vacuum equipment. Longer-term actions included installation of a water mist firefighting system connected to a fire detection system, a hydrogen detection sensor and a nitrogen smothering system in the oil tank, installation of an automatic surge control system, and re-evaluation of steam and power supply during different upset and emergency scenarios.

Round table

On Day 4, a round table Session was held, which provided open exchange and discussion through brief presentations from panellists, followed by a question-and-answer session on topics of interest such as ammonia converter catalyst issues; the future of AI in ammonia plant operations; and improving CO_2 removal system operational efficiency with AI.

Next year's Symposium will be in Atlanta, Georiga, USA, on 7-11 September 2025. ■

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Making RFNBO compliant ammonia competitive

One of the key challenges of producing RFNBO (renewable fuels of non-biological origin) compliant ammonia is managing the intermittency associated with renewable energy sources for hydrogen production. Furthermore, the additional costs associated with managing this intermittency can be significant. In this article, **Dr Solomos Georgiou** of AFRY Management Consulting explores those additional costs as well as potential ways to achieve cost savings and make RFNBO-compliant ammonia production competitive against conventional 'grey' ammonia.

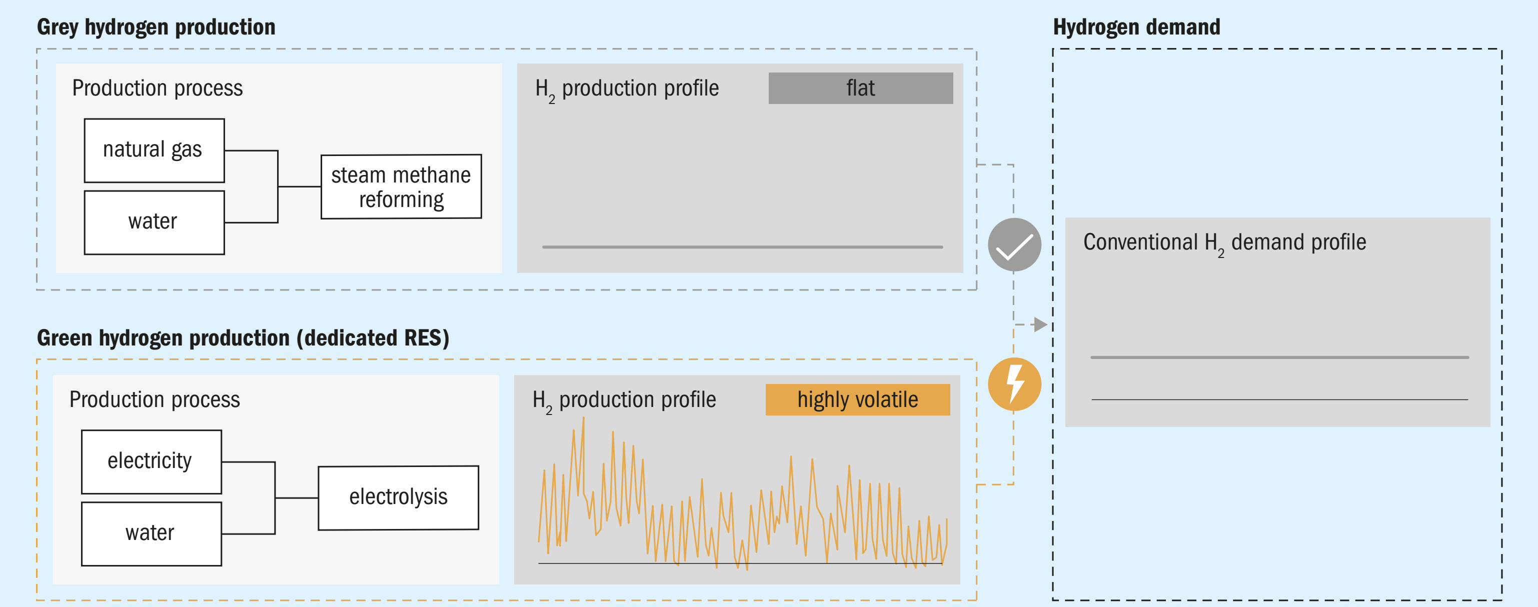
European policies require industrial use of hydrogen to be 42% RFNBO compliant by 2030 and 60% by 2035. This puts the future of ammonia in Europe in the hands of 'green' (i.e. RFNBO) hydrogen production, which raises a number of challenges. Perhaps the biggest is managing the intermittency associated with renewable energy sources (RES).

Green hydrogen production often requires the direct use of electricity from renewable energy sources such as solar and wind. The intermittency of the electricity source and the subsequent hydrogen production profile leads to significant volatility when compared to the conventional way of producing hydrogen using steam methane reforming (SMR); in other words, 'grey' hydrogen. At the same time, the conventional demand profile for hydrogen is generally flat (or very defined) as it is driven by the downstream industrial process (Fig. 1). As a result, for green hydrogen to be comparable to SMR in meeting offtake demand profiles, it requires flexibility solutions and/or ways to minimise the volatility of hydrogen production. Importantly for the competitiveness of green hydrogen, this needs to be done in a cost-effective way.

In this article 'green' and 'RFNBO' is used interchangeably. Similarly, 'grey' and 'SMR-based' are also used interchangeably.

With sufficiently large hydrogen storage, supply and demand in a green hydrogen-based system can be balanced, and offtaker demand profiles could be met. However, having a very

Fig. 1: **Grey vs green hydrogen production (illustrative).**



Source: AFRY

large hydrogen storage capacity can be prohibitively expensive and practically infeasible (e.g., due to available space); thus, making it uncompetitive against existing hydrogen supplies.

AFRY has analysed the cost competitiveness of green hydrogen against SMR, using AFRY's proprietary Hydrogen Optimisation Tool. This tool uses mathematical optimisation programming techniques to minimise the levelised cost whilst satisfying the constraints/requirements set, either on the supply side or the demand side. The tool has capabilities to enable key drivers and insights to be determined regarding the production of hydrogen and its derivatives. It is worth noting that in this article only a small fraction of the tool's capabilities is used.

To quantitatively assess the impact of key factors AFRY has analysed several illustrative case studies that are summarised in Fig. 2.

As a base case, an ammonia production system utilising 100% RFNBO compliant hydrogen whilst simultaneously optimising only hydrogen storage capacity has been modelled. This results in significantly more expensive ammonia production than a SMR-based system. More specifically, the levelised cost of ammonia production (LCOA) of a SMR hydrogen-based system is 79% cheaper than the RFNBO hydrogen-based system in the base case (Fig. 3a). The single biggest cost element in LCOA of green ammonia is hydrogen storage, which, in the base case requires a very large capacity and is the only optimisation considered.

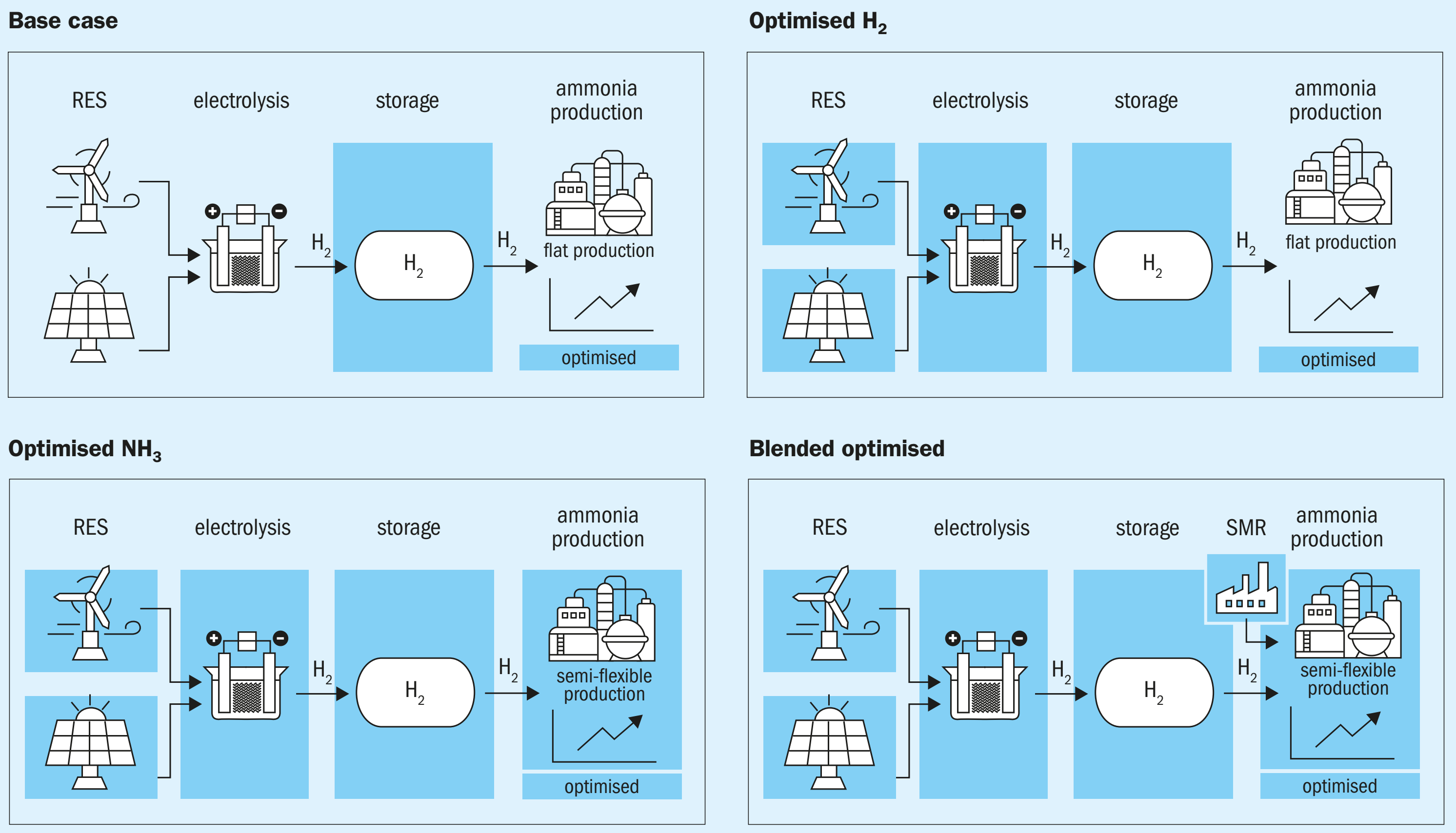
This demonstrates how uncompetitive green hydrogen-based ammonia can be when only considering the optimisation of hydrogen storage. It is necessary, therefore, to consider the optimisation of other components' capacity and operation for hydrogen production. In this case study, the key components considered are solar PV, onshore wind, electrolyser and hydrogen storage.

Co-optimisation of renewable energy sourcing, electrolyser, and hydrogen storage ensures that appropriate resources are used cost efficiently leading to improvements in the cost competitiveness of green ammonia. In the illustrative case study here, a 58% decrease in LCOA was achieved through co-optimisation (Fig. 3b). In addition, hydrogen storage requirements decreased to a more reasonable level. Even though it is still about double the cost of a grey hydrogen-based system, it is a significant cost reduction that could close some of the cost gap between grey and green ammonia.

Although traditionally ammonia production has been considered a relatively inflexible process (possibly because it was not needed when using SMR), introducing some flexibility could help reduce the overall levelised cost of production. Even assuming existing ammonia production technology with limited flexibility, a further 14% LCOA decrease can be observed whilst still meeting the same annual ammonia demand, despite the need to have a slightly larger ammonia production plant (Fig. 3c).

If some technology improvements are assumed aimed at increasing the flexibility of ammonia production e.g., by relaxing its operational limits, additional cost savings of 26% are seen compared to the system with optimised hydrogen production (Fig. 3c). Furthermore, hydrogen storage capacity requirements also decrease through the enhancement of ammonia production flexibility. In summary, the greater the flexibility of ammonia production the better green hydrogen production can cope with the volatility in renewable power generation. By this point, ammonia production based on fully green hydrogen has significantly reduced and approaches the cost of grey hydrogen-based ammonia, closing the gap to only 48%. This is a significant cost saving

Fig. 2: **Optimisation cases considered**



Source: AFRY

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compared to the gap of the base case and optimised H_2 case at 376% and 100%, respectively.

However, industrial offtakers do not necessarily need 100% RFNBO to comply with the relevant European obligations. Therefore, AFRY has examined the impact of blending grey hydrogen with green hydrogen whilst still meeting the 42% RFNBO obligation. Hence, industrial offtakers, including ammonia producers, could take advantage of potentially cheaper grey hydrogen and still satisfy their RFNBO obligations.

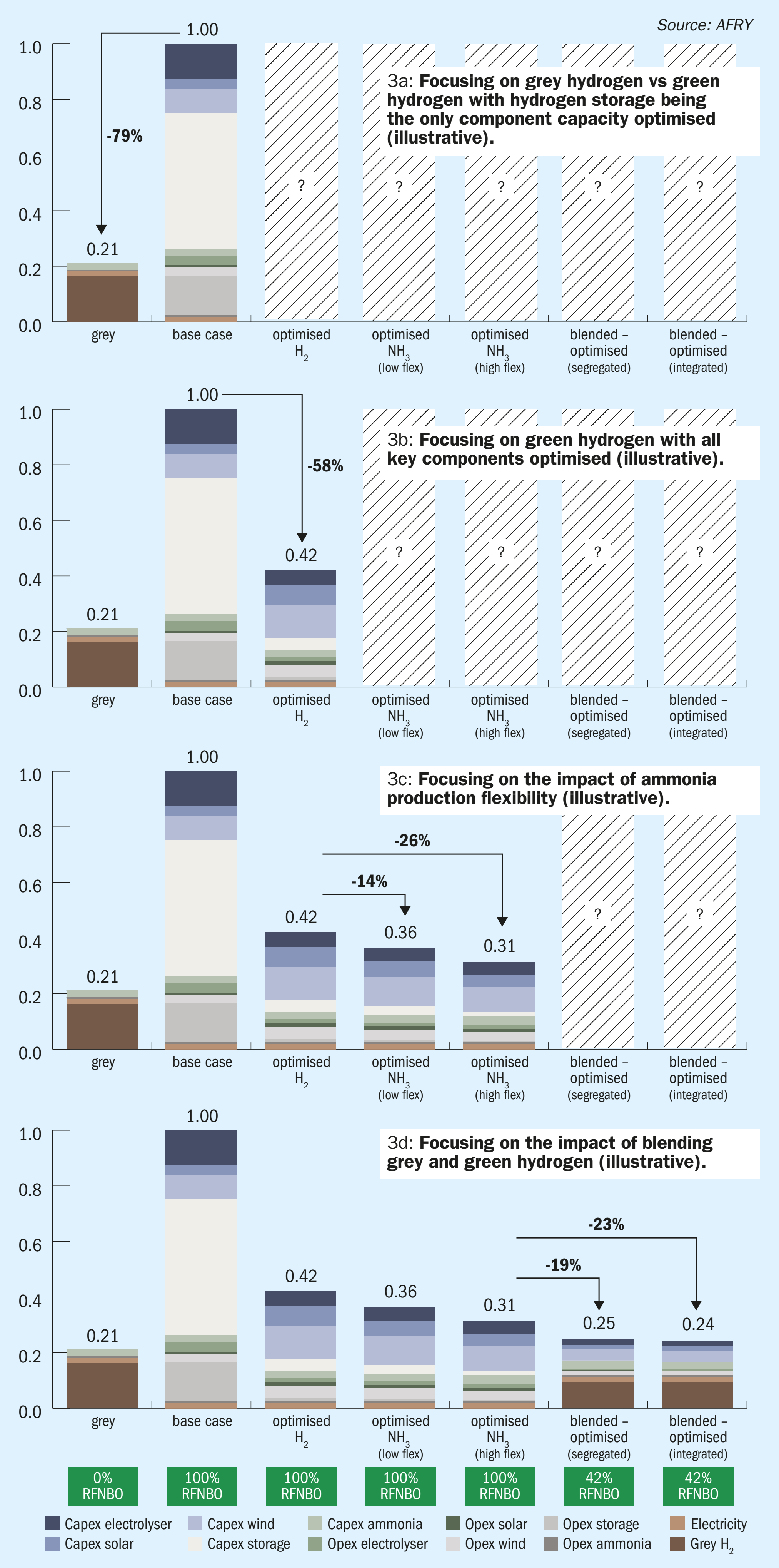
Even assuming that the SMR plant supplying grey hydrogen is completely segregated (i.e. works independently from the green hydrogen production plant), a decrease in LCOA of 19% can be seen compared to the previously cheapest case (i.e. the highly flexible ammonia plant). That is whilst still meeting the 2030 RFNBO obligation of 42% (Fig. 3d).

For a fully integrated system where the SMR and electrolytic production are co-optimised (still within SMR flexibility constraints), the LCOA savings increase to 23% (Fig. 3d). Therefore, despite flexibility constraints of SMR, there could be additional savings through the integration of grey and green hydrogen production. Cost benefits from co-optimised grey-green integrated systems could potentially be even greater in less flexible ammonia production systems. Furthermore, a less obvious benefit achieved from co-optimisation is achieving this level of cost savings with a smaller increase in ammonia production capacity. This potentially avoids a significant increase in capital expenditure while still achieving a decrease in LCOA.

The analysis presented here demonstrates how the optimal selection of technologies and solutions can significantly improve the competitiveness of RFNBO compliant ammonia. In the case studies considered in this article, optimisation across the key components results in a system that could comply with the 2030 European RFNBO obligations whilst being only 14% more expensive than grey ammonia. Therefore, the funding gap to be covered by subsidies and/or a voluntary green premium by offtakers has significantly shrunk making the compliance with RFNBO policies more achievable.

In summary, yes, ammonia production using green hydrogen can be expensive; yes, ammonia production using green hydrogen might have its technical challenges; but optimal and project tailored solutions could potentially make RFNBO compliant ammonia attainable and competitive.

Fig. 3: **Levelised cost of ammonia (LCOA)**



Cryogenic storage for green ammonia

Stamicarbon, in collaboration with KT Tech, has developed a cryogenic energy storage system, named GALCES™, for green ammonia plants that addresses the intermittency challenges of renewable energy supply. The technology not only supports the sustainability goals of the ammonia production industry but also contributes to broader energy market stability and efficiency.

Deepak Shetty, Luca Amicucci, Nikolay Ketov, (Stamicarbon) and Paolo Mazzara (KT Tech)

Green ammonia is crucial for sustainable fertilizer production, as well as an energy vector for storage and transportation. From a volumetric, storage, and shipping perspective, green ammonia represents the optimal investment as an energy carrier. According to the IEA, the demand for ammonia for new applications by 2050 is projected to be twice as high as the demand for its current applications. To address the environmental impact of traditional ammonia production and meet the growing demand, Stamicarbon, the nitrogen technology licensor of MAIRE S.p.A., has developed the NX STAMI Green Ammonia™ technology.

Managing the intermittency of feedstock produced with renewable power is essential to ensure consistent ammonia production. Stamicarbon, in collaboration with KT Tech, a subsidiary of MAIRE S.p.A., has developed an integrated process and cryogenic energy storage system: GALCES™. This system effectively mitigates the fluctuations in renewable energy supply, enabling the design of stable, efficient and sustainable ammonia production processes.

Integration of these advanced technologies enhances the efficiency of green ammonia production and contributes to the broader goal of reducing greenhouse gas emissions in the energy and fertilizer sectors.

Ammonia supply chain

There is already a globally established infrastructure for transporting ammonia. Each year, approximately 18 to 20 million tonnes of ammonia are transported from production centres to destinations around the globe using specialised vessels known as ammonia carriers or ammonia tankers. The shipping infrastructure not only includes these specialised ships but also encompasses terminals and ports equipped with storage facilities and loading/unloading systems specifically designed for handling ammonia.

PHOTO: STAMICARBON

Green ammonia plant 3D model.

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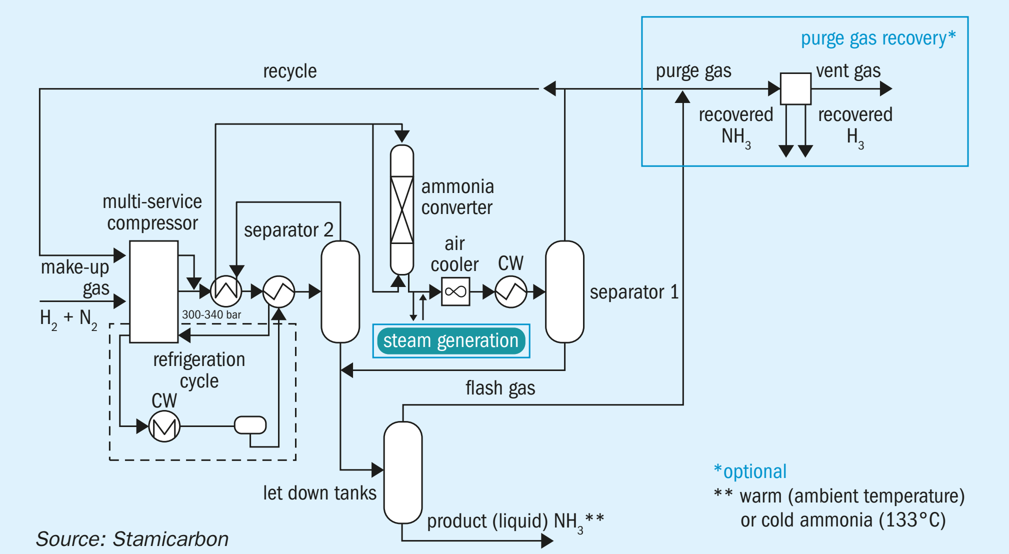
Fig. 1: **NX STAMI Green Ammonia™ process diagram**



Source: Stamicarbon

Ammonia can serve both as a hydrogen carrier and as a direct carbon-neutral fuel. Its combustion or utilisation in fuel cells does not produce CO_2 emissions, thereby not requiring the need for cracking it back into hydrogen. However, the challenge lies in producing green ammonia, which requires generating hydrogen from renewable energy sources or via a carbon-neutral production process that eliminates CO_2 emissions.

NX STAMI Green Ammonia™ process

The NX STAMI Green Ammonia™ technology utilises a high-pressure synthesis loop, which operates at over 300 bar, making it suitable for small and medium-sized plants (50-500 t/d). This high-pressure system reduces equipment size, leading to capex savings of about 25-30%. The process integrates water electrolysis for hydrogen production and air separation for nitrogen generation, making it a fossil fuel-free process.

The ammonia synthesis loop (Fig. 1) has been modified to optimise the layout for plants that rely on green feedstock. The make-up gas for the ammonia synthesis unit, containing hydrogen and nitrogen, is produced from the upstream electrolyser and nitrogen generation unit, then compressed to a pressure of over 300 bar by an electrically driven multi-service reciprocating compressor. The same compressor is responsible for recompressing the recycle stream containing the unconverted gas and managing the refrigeration loop, as well as delivering cold ammonia if required. The high pressure of the synthesis loop allows for single-stage ammonia condensation using cooling water, eliminating the need for a dedicated refrigeration compressor, thus minimising equipment count. Over 70% of ammonia is recovered in separator 1, while the remaining 30% of the uncondensed ammonia is condensed in separator 2, placed upstream of the converter to protect the catalyst by removing contaminants (mainly water) from the make-up gas.

Due to the high pressure, the reactor and catalyst volume can also be reduced. The ammonia converter used in the NX STAMI Green Ammonia™ process is a single-bed axial-flow converter with a tubular design. The feed is pre-heated using the exothermic ammonia synthesis reaction on the catalyst side to a temperature required for adequate catalytic activity. The start-up heater is integrated into the ammonia converter to ensure optimal heat integration during start-up. In addition, a purge gas recovery system, as well as steam generation, can be integrated, if required.

Depending on the capacity, the plant uses overall about 25–250 MW of power, and its footprint is about 15 × 30 m for smaller scale plants and 50 × 50 m for larger scale plants. Depending on the location and available plot space, the plant can also be a modular design which further reduces its footprint.

This technology can be designed for stick-built/modular and decentralised production, allowing for medium-scale, local plants that can be scaled up over time. This approach not only makes fertilizer production more sustainable but also enhances local supply chain resilience by reducing dependence on imports.

Addressing intermittency challenges

Green ammonia production can be viable in many areas where renewable energy is abundant and demand for fertilizer or marine fuel is high. For optimal performance, green ammonia production requires a stable power supply, preferably from hydro, geothermal, or reliable renewable grid electricity. However, there are limited locations where those stable sources are available due to geographical constraints.

In many locations, the available renewable sources are wind and solar, which are intermittent by nature and thus pose significant challenges in plant design. These include daily variations in energy supply, which can affect the stability and efficiency of ammonia production. The daily cycles of an off-grid green ammonia plant can vary significantly, sometimes between 0% to 100% energy availability, leading to several operational issues.

One of the main challenges is linked to the cyclic loading and fatigue phenomena. The process equipment, particularly the synthesis loop, experiences stress due to daily pressurisation and depressurisation cycles in combination with temperature fluctuations. This induces cyclic fatigue (CF), characterised by small elastic strains over numerous cycles, which can lead to degradation of material properties and potential failure.

Equipment design also faces significant challenges. The frequent daily start-ups necessitate additional electrical heater duty, impacting its design and the durability of the syngas compressors. This frequent starting and stopping can accelerate wear and reduce the operational lifespan of the equipment.

Another issue is related to the catalyst management. During standby/shutdown periods, extra nitrogen is required to maintain positive pressure in the ammonia converter. Additionally, hydrogen must be supplied, preventing oxidation of the catalyst and maintaining its reduced state.

Start-up times are another critical factor. Daily restarts involve building up pressure and temperature, which can result in production losses and pose health, safety, and environmental (HSE) risks for several hours each day. These risks must be managed carefully to ensure safe and efficient operations.

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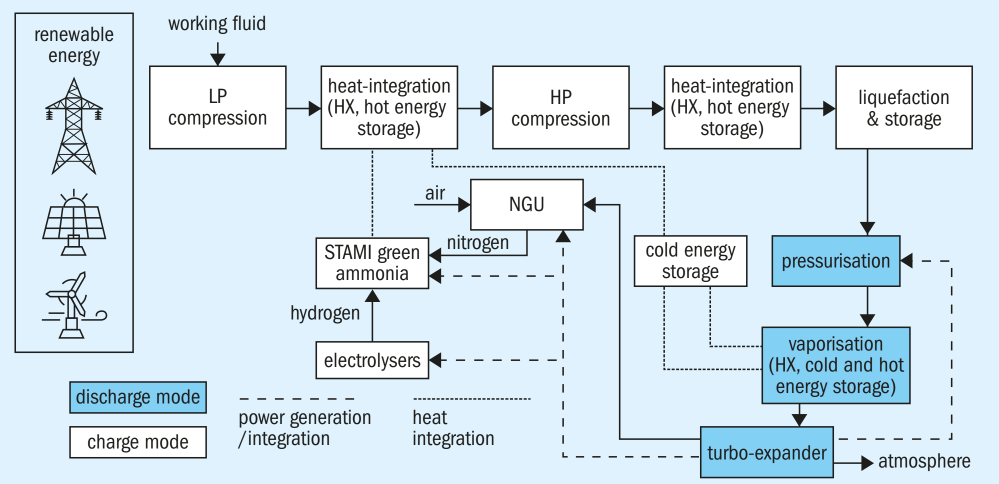
Fig. 2: **GALCES™ block flow diagram**



Source: KT Tech

Cryogenic energy storage

To address this challenge, Stamicarbon, in collaboration with KT Tech, has developed a cryogenic energy storage system: GALCES™. This technology represents a significant advancement in managing the intermittency of renewable energy sources. It offers a systemic integration of energy storage and ammonia production, leveraging cryogenic systems for enhanced efficiency.

The GALCES™ concept involves the physical transformation of a cryogen fluid, directly connected to renewable energy source (RES) aiming to achieve long energy storage times without the need for Li-ion batteries or hydrogen storage. It utilises standard, "off-the-shelf" industrial equipment such as compressors, turbo-expanders, pumps, heat exchangers, hot and cold storages and liquefier based on the Claude cycle.

The block diagram (Fig. 2) summarises three distinct processes: charge, storage and discharge. During periods of excess renewable electricity, called charge mode, the working fluid is compressed in the LP and HP compressor before being liquified in the liquefaction section. The liquid cryogen is then stored in cryogenic tanks at around ambient pressure. During charge mode, the plant is operated at full load. During periods when renewable electricity is not available, discharge mode, the liquid cryogen is pressurised, re-gasified and expanded through a turbo-expander to generate electricity, which is then used to run the electrolyser, nitrogen generation unit (NGU), and green ammonia unit. During the discharge mode, the plant is operated at partial turndown, avoiding the necessity of a deep turndown and associated challenges as described in the previous section.

Both the heat of compression and cold thermal energy from regasification are stored and, together with heat integration using excess heat coming from the ammonia plant, the overall efficiency is greatly enhanced. Additionally, air is integrated with the NGU where a concentrated nitrogen stream is produced as a feedstock for the green ammonia plant.

GALCES™ boasts several key features that enhance its functionality and efficiency in green ammonia production. One of the primary advantages is its ability to maintain a stable plant load operation at various capacities, which ensures continuous production regardless of fluctuations in energy supply. This stability is crucial for the consistent output of green ammonia.

Additionally, GALCES™ technology eliminates the need for additional electrolyser capacity or expensive storage solutions for hydrogen and nitrogen. This reduction in required infrastructure not only decreases capital expenditures (capex) but also simplifies the overall production process, making it more cost-effective and efficient.

The seamless integration of GALCES™ with renewable energy sources makes it a viable solution for off-grid green ammonia production. By leveraging proven engineering solutions, GALCES™ ensures high reliability and maintainability, providing a robust and efficient system for sustainable ammonia production. This deep integration with renewable energy systems positions GALCES™ as a key technology for the future of green ammonia, enabling continuous and efficient production even in areas with intermittent renewable energy supplies.

Economic and commercial aspects

GALCES™ technology offers a streamlined approach for the development of small standalone off-grid green ammonia plants that can be directly connected to renewable energy sources. Its design incorporates additional sections to the process unit based on historically proven engineering solutions for air processing, ensuring reliability and efficiency.

One of the significant economic advantages of cryogenic energy storage system is the capability to install and operate most of the add-on facilities in an over-the-fence mode. This flexibility allows for easier integration and operation without the need for extensive on-site infrastructure modifications, reducing initial setup costs and complexity.

Furthermore, GALCES™ technology has the potential to benefit from analogous applications in the power grid energy market. The integration into power grid systems can provide mutual advantages, leveraging its efficient energy storage and management capabilities to stabilise and enhance power grid operations, while also supporting the continuous production of green ammonia.

Overall, the economic and commercial benefits of a cryogenic energy storage system position it as an attractive option for green ammonia production, improving overall profitability and offering a combination of cost-effectiveness, operational flexibility, and integration with renewable energy sources.

This technology not only supports the sustainability goals of the ammonia production industry but also contributes to broader energy market stability and efficiency.

Conclusion

Green ammonia technology, particularly NX STAMI Green Ammonia™, integrated with GALCES™ technology, offers a sustainable solution to the challenges posed by traditional ammonia production methods.

With the ability to address the intermittency of renewable energy, cryogenic energy storage ensures continuous and reliable green ammonia production, marking a substantial step forward in enabling sustainable technology solutions. ■

Reference

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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

Conversion into hybrid ammonia plants

One challenge of a green revamp by stepwise injection of green hydrogen into existing ammonia/urea complexes is to cover the nitrogen demand for the ammonia synthesis while stepwise reducing the front-end load, usually by applying a cost-intensive air separation unit (ASU). thyssenkrupp Uhde GmbH has developed an advantageous concept whereby, instead of an ASU, the nitrogen gap is closed by the introduction of pretreated reformer flue gas back into the ammonia process, with the side effect to also enhance CO_2 production.

Johannes Distler and Dr. Sebastian Jung (thyssenkrupp Uhde GmbH)

The fertilizer industry is at the start of a feedstock transition towards low-carbon or even carbon-free (green) production, which will have considerable impact on plant owners. A "green revamp" by stepwise injection of green hydrogen into an existing ammonia/urea complex is a promising way to reduce the carbon footprint of the assets and provide new business opportunities. However, this feedstock transition requires consideration of certain boundary conditions.

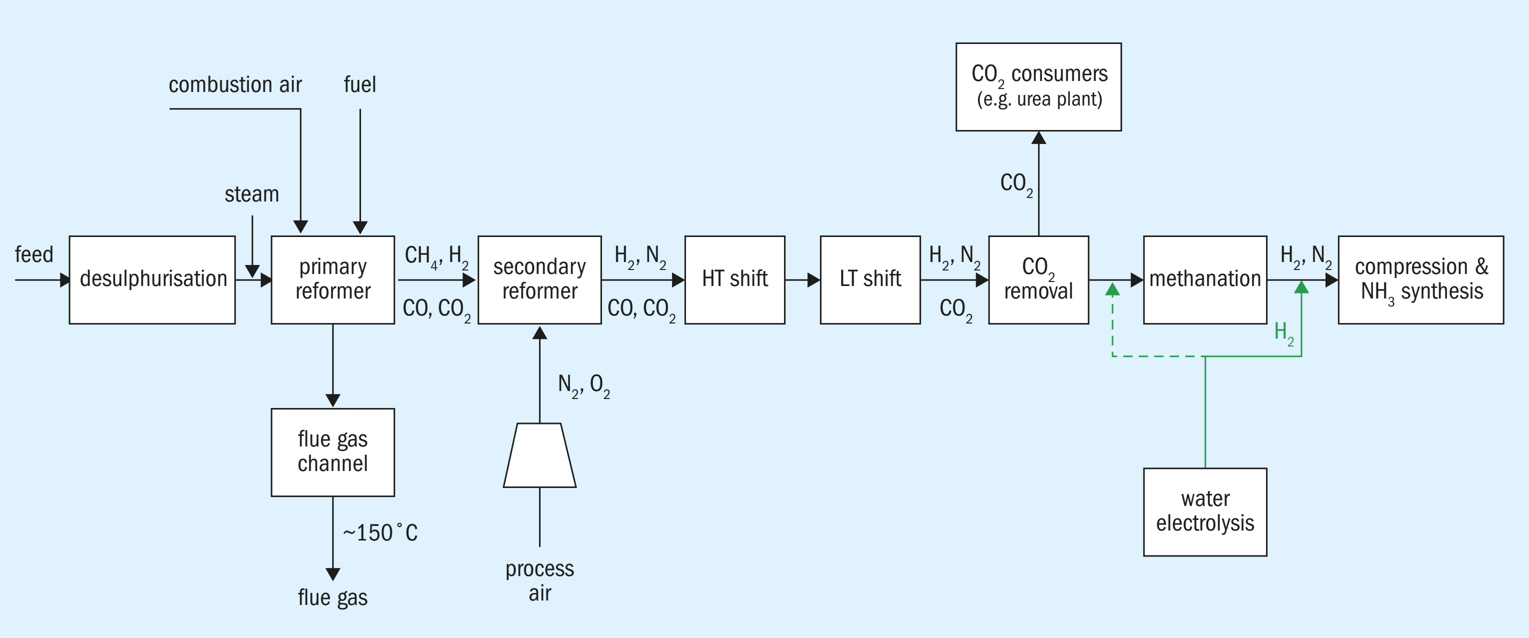
Green hydrogen injection into an existing ammonia plant can be generally utilised for two revamp possibilities:

- replacement of natural gas by maintaining the production capacity (i.e. decarbonisation);
- additional ammonia production.

In both cases, where one operation mode does not necessarily rule out the other, the conventional natural gas-based (grey) plant will be converted into a hybrid (grey/green) ammonia production and the green hydrogen injection can be increased stepwise to increase the green share of the production. Considering the demand in the market for sustainable fertilizers and/or green ammonia as an energy carrier, this conversion is the most viable and fast-track way compared to the construction of an entirely new plant.

The main subject of this article is the decarbonisation of the ammonia plant (i.e. natural gas replacement and reduction of carbon footprint) with the goal to realise the green revamp without major hardware modifications within the process plant, particularly by avoiding the need for an air separation unit. This is feasible by the careful check of certain boundary conditions.

Fig. 1: **Conventional ammonia plant with green hydrogen injection**



Source: thyssenkrupp Uhde

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 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

Boundary conditions

For the decarbonisation of the plant, the focus is mainly on the plant front-end (synthesis gas production) where the green hydrogen is usually injected upstream of the syngas compression as shown in Fig. 1.

Depending on the hydrogen profile, the application of intermediate hydrogen storage may be necessary, as the operational flexibility of the plant, especially of the reformer section, is limited. The required minimum size of the storage can be studied as a first step.

The tie-in point for the green hydrogen can be upstream of the syngas compressor or the methanation unit (to remove possible O_2 traces in the green hydrogen stream). Since the green hydrogen is inert-free, there is already a positive impact on the syngas compression load and the ammonia synthesis.

For the replacement of natural gas and therefore for the load reduction of the front-end, the following three main boundary conditions were identified:

- **Steam production/superheating**: The heat recovery for steam production and pre-heating takes place mainly after the secondary reformer and in the flue gas channel. The high-pressure steam demand is nearly constant since the load of the major consumers like the syngas compressor and the CO_2 compressor remains unchanged.
- **N_2 supply**: Nitrogen is usually injected with the process air. The N_2 demand remains unchanged since the production capacity will be maintained.
- **CO_2 supply**: Carbon dioxide is separated from the syngas in the CO_2 removal unit and in most cases there is an attached urea plant which requires a constant CO_2 supply as feedstock. As a matter of fact, less natural gas feed leads to less CO_2 production. In case of no CO_2 consumers, this boundary condition remains unconsidered.

Table 1: **Effect of stepwise increase of green hydrogen injection on boundary conditions**

	10-15%	15-30%	30-50%	100%
HP steam production	Load reduction in primary reformer with less feed/fuel consumption leads to less heat recovery for steam production/superheating. This deficit can usually be balanced with increased firing and auxiliary boiler(s).		Additional heat sources necessary by e.g. auxiliary burners in the convection bank or electrical heaters.	Replacement of steam turbines with electrical motors and complete front-end to be shut down.
N_2 supply	Covered by constant process air supply to secondary reformer, whereas the maximum outlet temperature of the secondary reformer to be carefully checked.	Additional nitrogen source required (e.g. air separation unit)		
CO_2 supply	Nearly linear reduction of CO_2 supply by increasing decarbonisation. Minimum off-take of the consumers needs to be verified and availability of alternative CO_2 sources to be checked.			

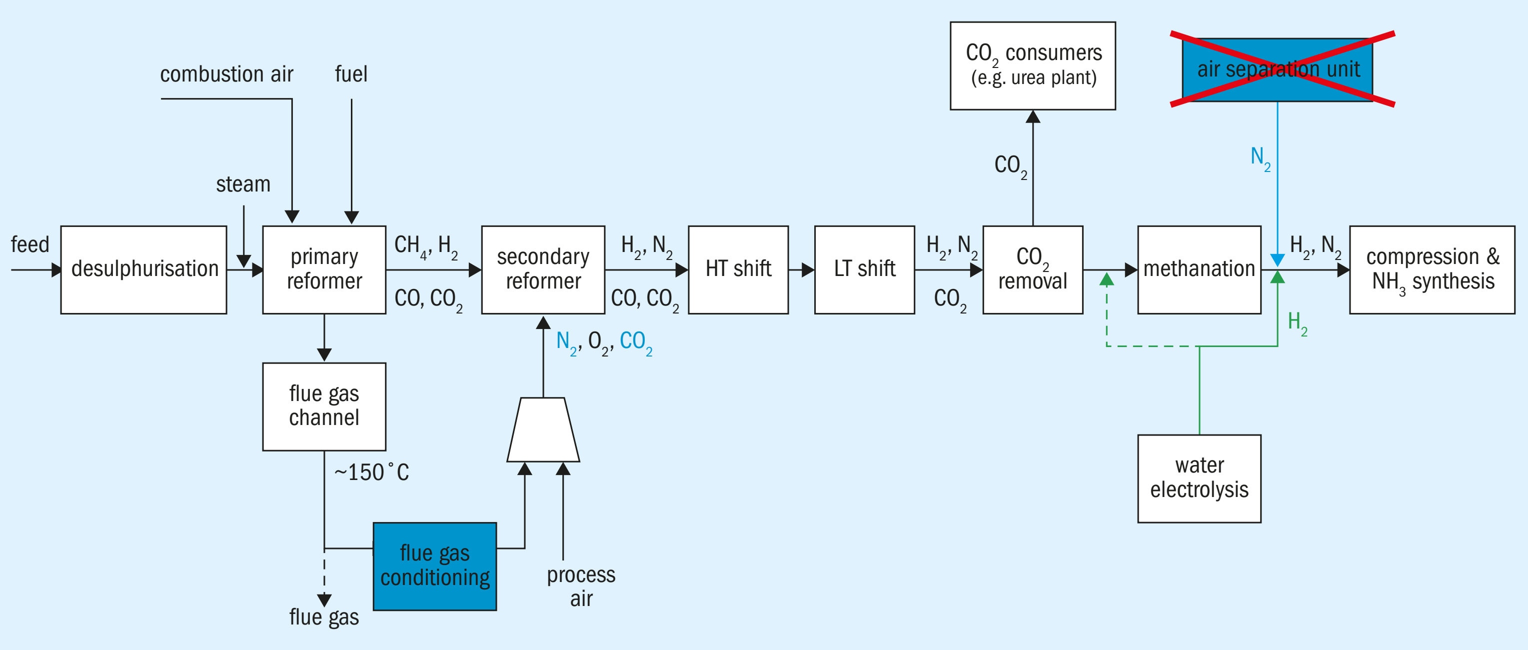
Source: thyssenkrupp Uhde

Increasing decarbonisation

Based on several decarbonisation projects, Table 1 shows the findings that could be detected by the stepwise increase of green hydrogen injection with respect to the above-mentioned boundary conditions.

Looking at Table 1, decarbonisation rates of >30% cannot be handled without hardware modifications and the deficits in N_2 and CO_2 supply become more severe. Additionally, the required amount of green hydrogen will likely be the bigger issue

Fig. 2: **Hybrid ammonia plant with flue gas recovery**



Source: thyssenkrupp Uhde

looking at the limited availability for the time being. For instance, the decarbonisation of a 1,200 t/d ammonia plant by 30% requires an electrolysis capacity of 140-150 MW.

However, the decarbonisation of the fertilizer complex < 30% is more realistic and is manageable without major hardware modifications in the process plant and only the N_2 and CO_2 supply needs to be addressed.

Focusing on the N_2 supply, an ASU is usually applied as a necessary source which always represents the main cost driver of the green revamp. As an alternative, thyssenkrupp Uhde has developed a concept to close the nitrogen gap by utilising the reformer flue gas as described in the next section.

Table 3: **Pros and cons of flue gas recovery vs. ASU for N_2 supply**

	Flue gas recovery		Air separation unit	
Investments costs	Approx. 50% less capex compared to an ASU.	green		red
Plot space	Compact design with significantly less plot space and installation within the complex close to the reformer section usually possible.	green	High plot space demand and placed outside of the complex.	red
Power demand	Approx. 50% less power demand.	green		red
Operational flexibility	Better flexibility expected and required N_2 to be regulated by adjustment of flue gas stream flow.	green	Less flexibility expected. A booster compressor is necessary as the outlet pressure of the ASU is usually much lower than the pressure at tie-in point.	amber
CO_2 supply	Positive impact on CO_2 production and CO_2 deficit can be reduced.	green	n.a.	red
Water management	Water content in the flue gas can be reused after treatment as demin/ cooling water.	green	Slightly higher cooling water demand	amber

Source: thyssenkrupp Uhde

Nitrogen supply by flue gas recovery

The reformer off-gas which is normally released into the atmosphere has the following typical composition as shown in Table 2.

The concept is to utilise the high nitrogen content of the reformer flue gas and introduce a part of it together with the process air into the ammonia process. As shown in Fig. 2, a flue gas conditioning/treatment step is necessary to remove the impurities to allowable levels before entering the process air compressor.

The flue gas needs to be cooled and cleaned accordingly, so as not to harm the catalysts in the process and the downstream equipment, where the main focus is the removal of the SOx traces in the flue gas stream. N_2O or NOx traces in the stream are not critical from a catalyst point of view as these components will break down into N_2 and H_2O in the reducing environment of the secondary reformer. Furthermore, the water content in the flue gas stream will be significantly reduced by condensation, which is beneficial for the process air compressor load and, after appropriate treatment, this water can be used as demin or cooling water.

"The fertilizer industry is at the start of a feedstock transition towards low-carbon or even carbon-free production."

The cleaned flue gas stream replaces part of the process air and the mix enters the process air compressor. Even though the new CO_2 component in the stream increases the molar mass, the load impact on the process air compressor is negligible due to the above-mentioned removal of the water content in the flue gas.

There is a further important benefit of this concept because the flue gas is also an additional CO_2 source which enters the process and is washed out in the existing CO_2 removal unit. Hence, the inevitable CO_2 deficit is also significantly reduced.

A wet scrubber process with a caustic solution as neutraliser is one possible technology for flue gas conditioning/treatment. It is well-referenced and widely used in other industries with even more severe applications.

Table 2: **Hybrid ammonia plant with flue gas recovery**

Components	mol-% dry
N_2	86
O_2	3
Ar	1
CO_2	10
Total dry	100

Source: thyssenkrupp Uhde

Comparison of flue gas recovery vs. ASU for N_2 supply

The pros and cons of flue gas recovery versus an air separation unit for nitrogen supply is summarised in Table 3.

For their implementation, both concepts are add-on solutions which don't require long plant shutdowns. The erection works can be carried out mostly during running operations and only the tie-ins have to be done during a scheduled shutdown.

Summary

The decarbonisation (i.e. replacement of natural gas) of an ammonia plant is a complex exercise where the N_2 deficit and the CO_2 deficit (in case of required feedstock for attached plants, e.g., urea plant) are the limiting factors for decarbonisation rates up to ≈30%. thyssenkrupp Uhde has developed a cost-effective concept to address these deficits by utilising the reformer off-gas and feeding it into the process after appropriate cleaning.

Flue gas cleaning/conditioning is widely used in other industries and can be considered as proven technology. This concept has overwhelming advantages compared to nitrogen supply from an expensive air separation unit and flue gas recovery has the further advantage of also reducing the inevitable CO_2 deficit. ■

Introducing ammonia flow-induced corrosion

In recent years, extensive and severe internal attack has been observed of carbon steel equipment and lines in aqua ammonia service at several Yara manufacturing sites across the globe. In all cases, the damage has a distinct flow-accelerated corrosion (FAC) signature which challenges the current understanding of FAC. All features typically observed for this kind of damage mechanism, that seem to be specific to the NH_3 recovery section of ammonia plant, are reported. Upgrading the material of construction for this unit, will solve this failure mode, but a leak would potentially generate health and safety problem for the release of ammonia.

Giulio Paci, Roy van Lier, Rodney Babwah and Stefano Cavalleri (Yara)

Extensive, severe internal corrosion has been observed in carbon/low-alloy steel equipment and piping in aqua ammonia service at several Yara manufacturing sites around the world in recent years. Whereas this itself is remarkable in the sense that such steels are widely used as construction materials for ammonia[1] it has come as an even greater surprise that in all cases the damage had a distinct flow-accelerated corrosion (FAC) like signature.

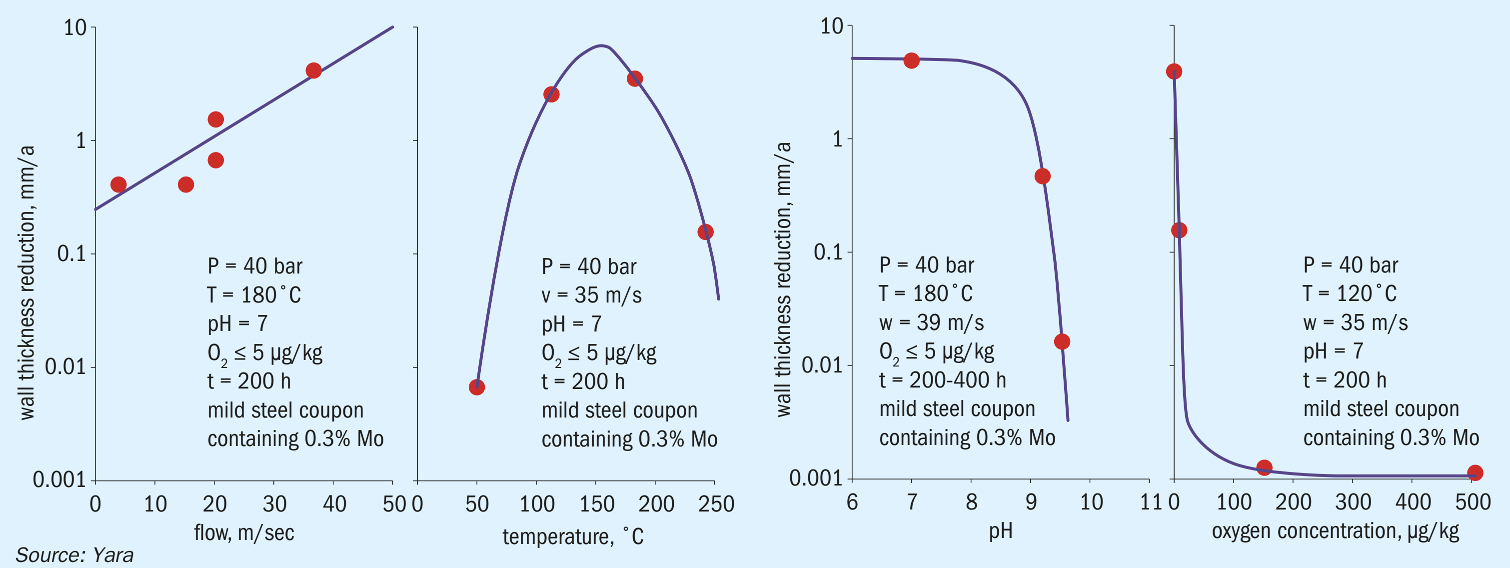
Historically, FAC used to be referred to as erosion-corrosion[2]. It is one of the most important and dangerous failure modes in water-steam cycles.

FAC is an electrochemical-mechanical damage mechanism that manifests itself both in single phase and two-phase forms. In addition to steel grade/composition and geometry in general there are a number of system parameters known to play a key role in "conventional FAC". These system parameters and their effects are illustrated in Fig. 1.

It should be noted that nowadays a trace amount of molecular oxygen is considered beneficial to combat FAC with ferrous metallurgy. For a comprehensive overview of the current under-standing of FAC in steam systems the reader is referred to reference 3.

In the authors' view, the damage that has occurred in aqua ammonia loops in Yara plants suggests a potential FAC knowledge gap, especially with regard to pH. Indeed, the pH of ammonia-

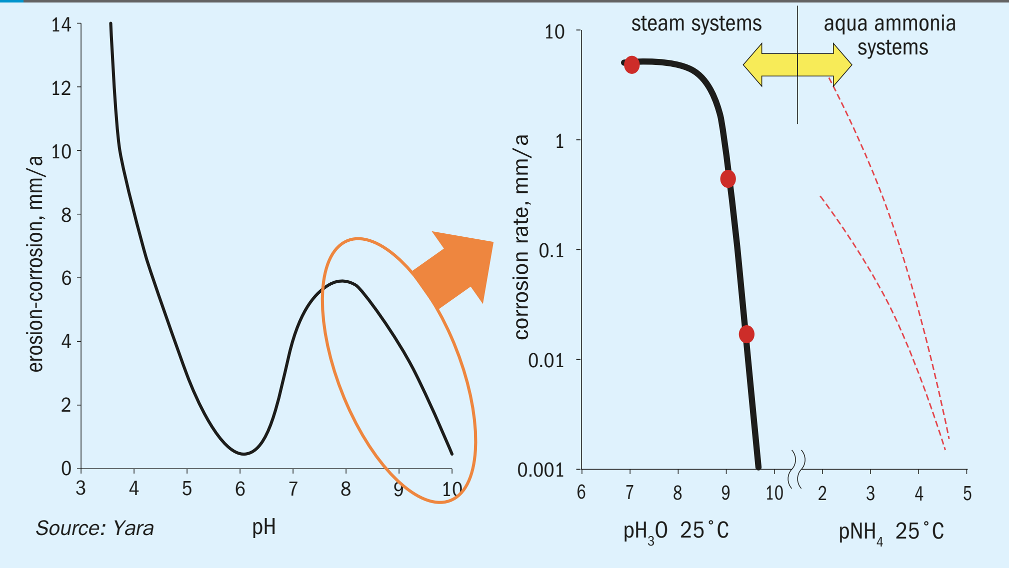
Fig. 1: **Influence of flow velocity, temperature, pH and oxygen concentration on FAC of carbon/low-alloy steel**



Source: Yara

This article is a consolidated and edited version of Yara contributions to the IAPWS Conference on Film-Forming Substances in Prato, Italy, March 2024, and the AIChE Symposium on Safety in Ammonia Plants and Related Facilities in San Diego, California, USA, September 2024.

Fig. 2: **Erosion-corrosion rates as a function of pH/pH$_3$O and pNH$_4$ (left graph from Ref. 7)**



Source: Yara

water mixtures containing up to say 25% ammonia is obviously far above the value of 9.8 (at 25°C) which is generally considered sufficient to arrest FAC in a steam system.

In this regard, concentrated solutions of NH_3 in water are probably better characterised using pNH$_4$, because ammonium ion rather than hydronium is the dominant acidic species in aqua ammonia[4]. Whereas pNH$_4$ values can be calculated using software such as PHREEQC[5,6] they cannot readily be measured.

Extrapolation of the pH graph in Fig. 1 leads to the interpretation shown in Fig. 2. Unfortunately, at present insufficient reliable data points are available to establish the actual location of the curve on the far right side.

Interestingly, the worst damage found in aqua ammonia systems, just like with "conventional FAC", occurs at a temperature of ~150°C (300°F) – see temperature graph of Fig. 1. Following extensive discussions with specialists, notably Dr. Barry Dooley of Structural Integrity Associates, Yara hereby introduces ammonia flow-induced corrosion (AFIC) to describe the FAC-like damage encountered in aqua ammonia systems. In this way, any confusion with FAC as defined in the context of the power industry is avoided.

Damage locations

Fig. 3 shows the areas in the ammonia stripping/recovery section of a typical ammonia plant flowsheet where AFIC has been observed in Yara:

- bottom of absorber – with two-phase flow and high turbulence;
- nozzles on shell side of heat exchangers and first tube rows – due to flashing or fluid impingement;
- inlet nozzle and shell of stripper on opposite side – because of high turbulence and impact.

Experience has shown that a double pipe design heat exchanger is especially susceptible to AFIC.

Case description

On April 28th, 2022 a serious incident occurred at a Yara manufacturing site. This involved loss of containment (LoC) from the ammonia stripper, fortunately without any harm to people present in the plant at that time.

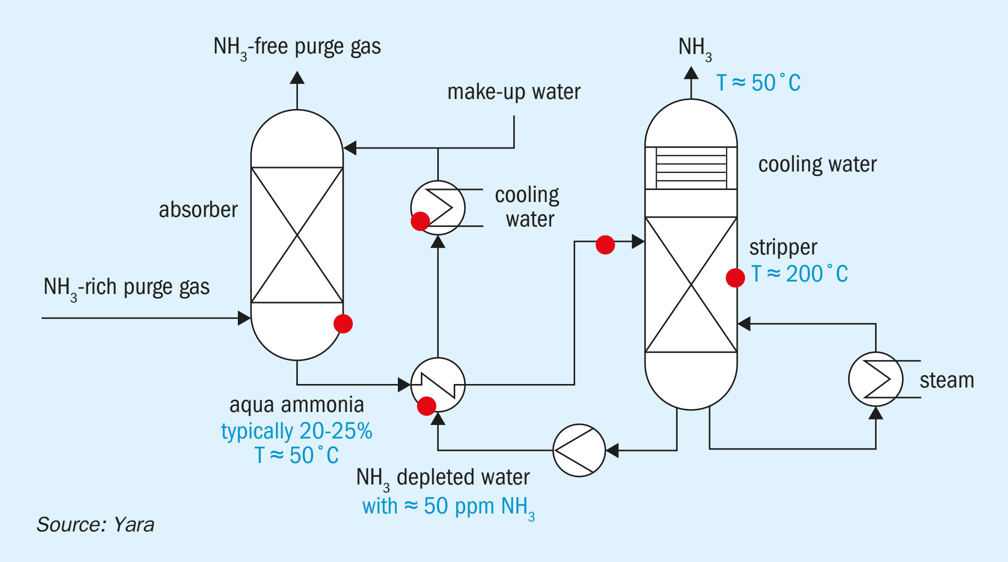
The liquid distributor was found to be completely dislodged from the column through the rupture opening arising from the incident. It was located some 12 m (40 ft) away from the stripper. The event could potentially have caused severe physical injury to personnel in the vicinity of the failed equipment. A release of ammonia to the environment also occurred in the period until the unit was stopped.

Plant operations responded to the event by first identifying the area in which the incident occurred via the distributed control system (DCS) and then promptly shutting the unit down. Investigation into the incident commenced on May 4th, 2022. Given its severity, site management requested a comprehensive root cause analysis (RCA) to identify the main cause(s) of the failure and define possible mitigation actions.

The investigation team consisted of local staff from process, operations, maintenance, and inspection departments. Experts from Yara's central support team were also involved in the RCA as well as an independent third-party company. The mandate of the team and the goal of the investigation was to:

- determine and document the sequence of events, as well as all other information, circumstances, and conditions that were considered to have contributed directly and indirectly to the incident;
- review and comment on emergency response actions and performance;
- deep-dive into technical, organisational, and human aspects of importance to the incident;
- identify non-conformity with respect to regulations and company requirements related to the incident;
- identify preventive actions and recommend corrective actions for the site.

Fig. 3: **Locations affected by AFIC in aqua ammonia systems**



Source: Yara

The rupture of the shell of the stripper occurred immediately beneath the middle flange and to the west of the liquid feed nozzle (Fig. 4). At the instant of rupture, the distributor tray (below the nozzle) was propelled outwards, possibly colliding with the internally projected liquid feed line. The liquid feed line (2 in Sch 160 pipe) was found to be significantly thinned and was warped/twisted consistent with impact from the distributor tray. This led to the decision to remove and replace the line. The removed section was subsequently sent to an independent laboratory for failure analysis on June 1st, 2022. Evidence suggested that the feed line was externally corroded by "FAC", to such an extent that the line became perforated between the 10 and 12 o'clock positions, just before the elbow.

From the work done by the investigation team it has been concluded that the ammonia stripper is subject to multiple corrosion mechanisms working simultaneously. The two key types of corrosion identified are:

- primary mechanism: carbon/low-alloy steel corrosion in an oxygen-depleted environment;
- secondary mechanism: FAC-like attack.

The primary mechanism has always existed and is dependent on the steel grade applied under the service conditions. A corrosion inhibitor could be used to mitigate it but there is no historic information about this in the aqua ammonia loop of the plant. Interestingly, corrosion inhibitors apparently are widely used in ammonia heat pump systems, including extremely undesirable sodium (di)chromate[8,9]. Alternative inhibitor chemistries described are:

- "usual suspects": silicates, molybdates, borates, etc.;
- rare earth metal salts (REMS), especially cerium nitrate.

There seems to be no experience with film-forming substances yet.

To gain further insight into the secondary mechanism and to validate the results of the investigation done by the RCA team, an additional failure analysis was contracted to another independent laboratory.

This lab came back with the following statements: "… ammonia-water solutions are not completely inert towards carbon steels, especially at higher temperatures. The corrosion attack is expected to form non-protective magnetite scales. High flowrates can cause these scales to be

Fig. 4: Close view of the failed stripper

continuously removed leading to an accelerated attack. Conventionally, in advanced ammonia absorption systems, a corrosion inhibitor in the form of sodium chromate (Na_2CrO_4) or sodium dichromate ($Na_2Cr_2O_7$) is added … to inhibit the working fluid from reacting with the steel … Sodium chromate is effective for operating temperatures up to about 200°C. While uninhibited ammonia-water is not inert towards carbon steels, the corrosion rate is still expected to be limited at current operating temperatures (up to 154°C). This is in accordance with the observations of the plant that the attack mainly occurred at the locations subjected to the highest flowrates".

The RCA concluded with a review and comparison of the performance of various ammonia recovery strippers across Yara. All of these are made out of carbon/low-alloy steel with (austenitic) stainless steel wetted internal parts (packing, trays etc.). From this study it became clear that they all experienced magnetite (Fe_3O_4) dissolution and redeposition in the form of black powder. However, the extent of integrity issues is variable across the company, from no wall thickness loss whatsoever to multiple occurrences of significant attack.

In addition to the aforementioned replacement of the feed line the entire bottom section of the damaged stripper will be replaced in austenitic stainless steel during the next turnaround. It goes without saying that the tower condition is strictly monitored through non-destructive testing (NDT) and visual inspections.

Closing remarks

The authors of this article are conscious that the surface of AFIC as a failure mode has merely been scratched. It is evident that a substantial effort will be required to further the understanding of its mechanism. In this regard, it is hoped that this article not only raises awareness in the ammonia industry but also generates interest in the academic world.

AFIC should be systematically included in corrosion studies of ammonia plants, with appropriate risk ranking and, where required, modification of equipment and piping inspection plans.

Acknowledgments

The authors wish to thank the management of Yara for permission to publish this paper. The computational work on concentrated NH_3-H_2O systems by Peter de Moel of Omnisys in the Netherlands is gratefully acknowledged. ■

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Revamp activities in urea plants

Urea revamp activities are performed to achieve improvements of the urea plant. Besides the typical capacity increase there are many options to reduce operation costs, increase plant availability or reduce environmental impact. In this article **Marc Wieschalla** of thyssenkrupp Uhde GmbH provides an overview of some of the options from an EPC contractor point of view.

The meaning of revamp is to change something, to make or to design something differently, to improve it. Applied to urea plants the improvement can have very different objectives as listed below:

- increasing production capacity;
- utilisation of CO_2 sources or surplus ammonia;
- reducing operation costs, e.g., by reducing energy consumption;
- improving the environmental impact, e.g., by reducing emissions;
- increasing plant availability and reliability, e.g., through the use of improved construction materials or state-of-the-art technologies;
- production of additional urea products such as AdBlue® or melamine;
- improving operating comfort, e.g., by modernising the control system.

The most common goal is to increase production capacity because the additional output pays off.

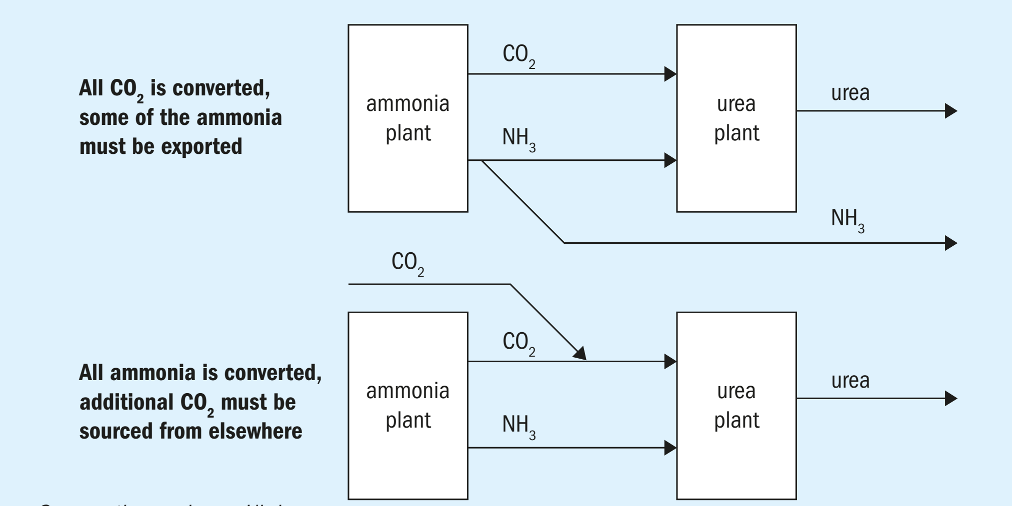
thyssenkrupp Uhde GmbH (Uhde) has more than 65 years of experience in engineering, supply of equipment and commissioning of urea plants with more than 120 plants built worldwide. For urea synthesis, Uhde works with the license of Stamicarbon, optimally combining it with the license of tkFT being preferred for the granulation. Thus, Uhde also offers revamp activities for both processes and additionally for plants using different technology, which can be revamped based on Stamicarbon and tkFT process design packages.

Revamping for capacity increase

The melt plant

For the melt plant, there are five basic concepts for increasing the capacity of a plant. The first is debottlenecking, which can achieve a small increase in capacity of up to 10%. As a rule, the equipment stays untouched and only control valves, pipes and pump impellers are changed or replaced. The bottlenecks can be identified during a plant visit by observing DCS data, checking equipment data sheets and interviewing operators. Based on a detailed recalculation and specification of the identified bottlenecks, the required measures can be detailed. After implementation, the new achievable capacity can be tested and additional bottlenecks identified, if any. Other revamp methods as shown in Table 1 can achieve higher capacity increases of up to 100 % of the original capacity. In these cases, the involvement of the licensor is a must and the replacement, or modifications of static equipment is required.

Fig 1: **Ammonia/CO_2 ratio in an ammonia urea complex**



Source: thyssenkrupp Uhde

The urea granulation plant

The activities involved in revamping the granulation plant can be divided into two types:

- Smaller revamps can achieve capacity increases of up to 15% of the original capacity. Intensive work requiring structural adjustments and welding to equipment is avoided, i.e., the granulator casing and fluid bed coolers are left untouched, as is the material handling circuit. Instead, the new nozzles can be installed in the granulator to provide more urea melt feed. With the additional melt feed, there is more crystallisation heat released to be removed. As a result, the cooling capacity will need to be increased if there is no spare cooling capacity. More cooling can also be achieved by adding additional coolers, e.g., a bulk flow cooler, or by increasing the cooling capacity, e.g., by chilling the water circuit of the bulk flow cooler or by adding chillers in the fluidisation air supply.

Table 1: **Revamp activities in the melt plant for capacity increase**

Method name	Detailed activities	Achievable capacity increase
Debottlenecking	• Add CO_2 sources • Replacement of valves or their internals • Conditioning of CO_2 within CO_2 compression unit • Replacement of pumps or their impellers	up to 10%
More in more out	• Installation of efficient reactor trays • Maximum utilisation of existing design margins • Adding heating and condensation capacity in the low-pressure recirculation unit and the evaporation unit • Install adiabatic flash	10 to 30%
New/double stripper	• Parallel stripper / new bigger stripper • Installation of efficient reactor trays • Installation of parallel LP recirculation and/or evaporation unit • Improvements in desorption unit	30 to 40%
MP add-on	• Installation of efficient reactor trays • Installation of a parallel MP carbamate recirculation unit • Installation of MP CO_2 compressor or modifications at CO_2 compressor unit • Improvements in waste water treatment	30 to 50%
Pool condenser	• Replacing HPCC by Pool condenser • New or additional CO_2 compressor • Installation of a parallel HP stripper • Installation of a parallel LP recirculation unit • Installation of a parallel evaporation unit • Modifications in desorption	50 to 100%

Source: thyssenkrupp Uhde

- Larger revamps are required for higher capacity increases of up to 45% of the original capacity. It requires modifications to the granulator. The existing cooling zones are used as new spray zones by installing additional nozzles and extending the number of melt headers. A new cooling zone is required. This is usually achieved by extending the granulator. Alternatively, a second granulator can be installed. The cooling section must also be enlarged by extending the fluid bed coolers or installing a bulk flow cooler. To ensure sufficient cooling, the fans must convey more air. This can be achieved by installing new atomisation and fluidisation air fans. If the requested capacity increase is on the lower side and sufficient margins can be used, changing the impellers and installing new pads inside the scrubbers with very low pressure drop may be sufficient to avoid the installation of new fans. Typically, however, emissions need to be reduced as well when performing a revamp and, with additional ammonia abatement, pressure drop increases. Consequently, new fans are often required. In order to reduce investment cost a booster fan can be installed. The existing fan is then operated at a higher pressure and less flow as originally designed and the booster fan delivers the resulting difference in flow. Material handling equipment must be adapted to handle the higher granules flow. Spare capacity can be used to keep investment costs low.

Providing additional CO_2 to the urea process

An important question for a capacity increase is where the required feedstock is coming from. This question is particularly important for the CO_2. In a conventional, natural gas based, ammonia and urea plant complex a surplus amount of ammonia is produced, that cannot be consumed for urea production. There is a lack of CO_2 to form urea. This is due to the fact that the production rates of ammonia and CO_2 are normally not independent from each other. In an idealised process where ammonia is produced from pure methane (CH_4), air and water, the ratio of the products CO_2 and ammonia is 1.14 t/t. In a real process, this ratio can be lower or higher, depending for example on the natural gas composition and the losses in the process.

In contrast to that, the urea plant consumes CO_2 and ammonia in a higher ratio of approx. 1.29 t/t (0.73 t CO_2 / t urea and 0.57 t NH_3 / t urea). Hence there is a lack of about 0.15 t CO_2 per t of ammonia if all of the ammonia produced is utilised for urea production.

Exceptions are balanced ammonia plants which are rare. In all plants the CO_2 source in ammonia urea plant complexes is the CO_2 removal unit of the ammonia plant which removes the CO_2 from the synthesis gas of the reformer downstream of the CO shift.

There are several ways to generate the additional CO_2 required for the capacity increase. One of these is to increase production in the CO_2 removal unit of the ammonia plant. Another option is to use a separate unit to collect CO_2 from other CO_2 containing streams such as flue gases. The third option is to import CO_2 from outside the battery limits, if feasible, e.g., from nearby power plants or cement plants.

CO_2 removal unit in ammonia plant

The CO_2 for urea production is normally obtained by separation from synthesis gas in the CO_2 removal unit. The amount of CO_2 can be increased by passing more synthesis gas through this unit. Downstream of the CO_2 removal unit, the excess synthesis gas not needed for ammonia production is withdrawn and fed to the reformer to be used as fuel gas. This system increases the plant's fuel gas consumption and results in a higher throughput and consequently higher outputs in the front-end units for desulphurisation, reforming, waste heat recovery, CO shift and CO_2 removal. On the other hand, recycling part of the synthesis gas to the reformer as fuel leads to a reduction in the natural gas used as fuel. However, overall this increases natural gas consumption. The energy of the additional amount of natural gas is not lost because the higher throughput of the synthesis gas generation units increases steam production. A benefit occurs if this steam can be used e.g., in surrounding plants.

If the additional amount of CO_2 required is small and there is still design margin in the front-end units, the required modifications and cost are minor, as only one let-down for a small synthesis

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

Table 2: **Overview of international and local emission standards for urea granulation plants**

Standard	Ammonia	Dust
IFC (World Bank, 2007)[1)]	< 50 mg/Nm³	< 50 mg/Nm³
EFMA BAT Booklet (2001)[2)]	< 50 mg/Nm³ < 50 mg/Nm³	< 0.25 kg/t < 0.25 kg/t
EU BREF LVIC (2007)[3)]	< 3 - 35 mg/Nm³	< 15 - 55 mg/Nm³
Louisiana (2012)	< 30 mg/Nm³	PM10 / PM2.5 < 8.3 mg/Nm³ < 20 % opacity
Iowa (2012)	BACT[4)]	PM2.5 < 20.96 mg/Nm³ No visible emissions

[1)] *IFC: International Finance Corporation (World Bank Group)*
[2)] *EFMA: European Fertilizer Manufactures Association (today: FE: Fertilizers Europe)*
[3)] *EU BREF LVIC: European Commission, Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals, August 2007*
[4)] *Best available control technology*

Source: thyssenkrupp Uhde

stream to the reformer's fuel gas system is required. If higher CO_2 quantities are required, one of the following options can be considered.

CO_2 removal from flue gas

The flue gas from the reformer and the package boiler contains high amounts of CO_2, making them a potential source of CO_2 for urea production. There are several technologies to recover CO_2 from the flue gas streams. The processes applied to flue gas are based on the same principle of absorption and desorption as the CO_2 removal process from the ammonia plants' synthesis gas. The recovered CO_2 is of good quality (no hydrogen content) and can be mixed with the existing CO_2 stream upstream of the CO_2 compressor. Amines are often used as solvents. These processes are also used for separation of CO_2 from fossil power plants and blue ammonia plants for subsequent sequestration.

Uhde has developed a CO_2 removal process, shown in Fig. 2, to purify such CO_2 streams for use in urea plants. The advantage is that no additional scrubbing agent such as amine solutions are needed, instead ammonia, which is present in the complex, is used. This process requires a high pressure of approx. 150 bar which perfectly meets the requirements of the urea plants for CO_2 injection. This process avoids the need to change the CO_2 compressor. If the capacity of the ammonia plant is also increased this unit can be dimensioned to also consume the additional reformer exhaust gases so that it is not necessary to replace or change the CO_2 removal unit in the ammonia plant. With the help of this unit, a considerable increase in plant capacity can be achieved while at the same time increasing energy efficiency. Critical elements such as the CO_2 compressor can remain untouched.

A CO_2 removal unit is a separate and additional unit that is connected to the flue gas outlet of the reformer or boiler, but does not have many other connections to the rest of the plant. Therefore, the installation of such a unit as part of a revamp can be done quite easily.

On the other hand, the investment costs are relatively high and there are operating costs for solvent regeneration, steam and electricity for pumps and flue gas fans. In addition, the solvent losses must be constantly compensated for by adding fresh chemicals.

CO_2 from direct air capture

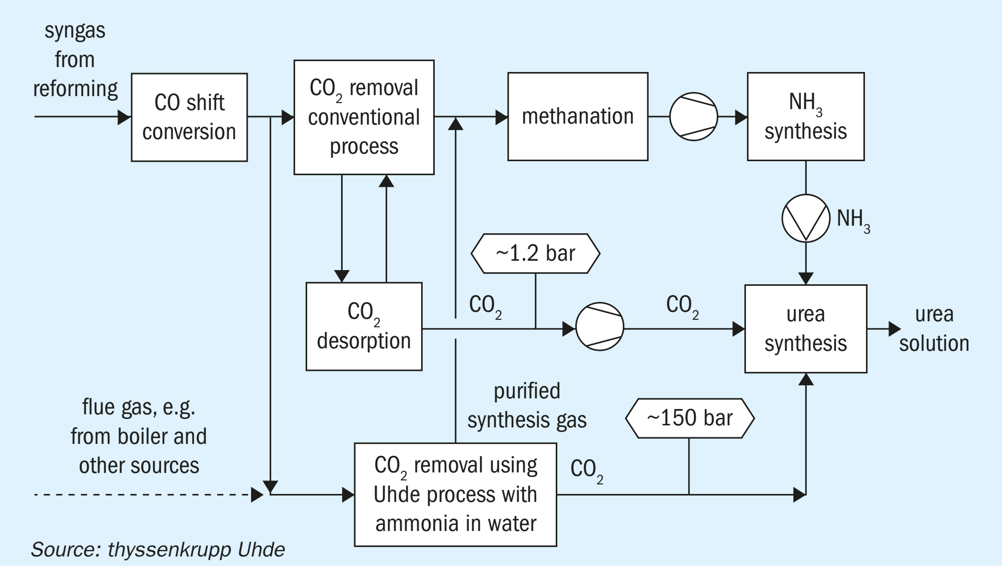
Another emerging option for supplying CO_2 is the direct air capture process (see Fig. 3). The CO_2 is removed from air and added to the CO_2 supply to the urea plant, e.g., on the suction side of the CO_2 compressor. The available processes are currently in the upscaling phase and the available systems only allow small increases in production of approx. 1 %, while the investment costs are still high. In the long term, direct air capture will offer the possibility of producing green urea, which only releases the amount of CO_2 during dissociation that was previously captured from the air. The second feedstock must of course be green ammonia.

Emission reduction

In recent decades, ammonia and urea dust emissions in urea plants and their reduction have become a challenge. The focus has been on continuous emissions, but emissions resulting from upset operation of the plant as well as accidental emissions have also come into focus. As a result, laws and regulations as well as local conditions, customer requirements and international standards have become more stringent. Older plants often do not comply with the new regulations. Table 2 shows some of the current requirements of the various international and local standards.

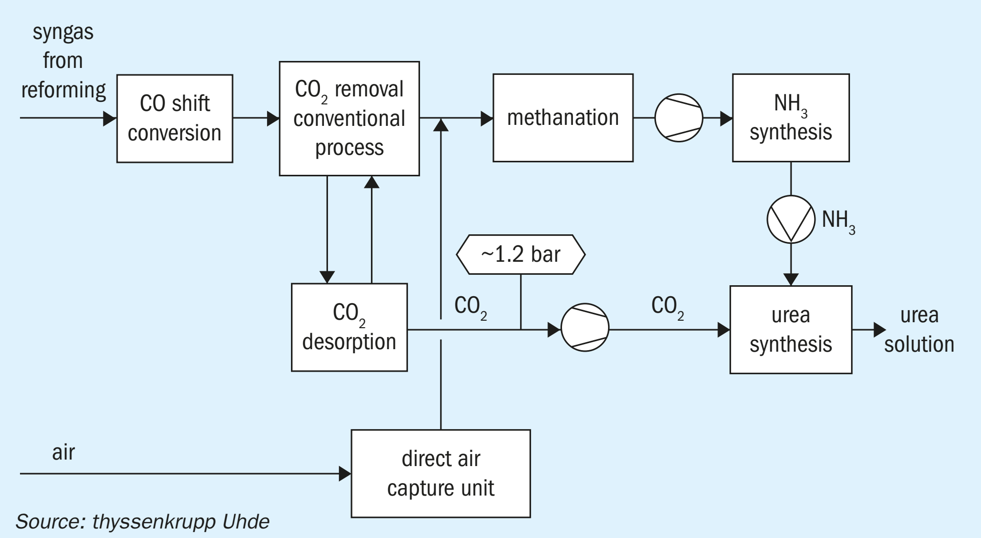
In a urea plant that produces granules, there are usually three emission points: Although the emissions from the two absorbers in the melt plant (see Fig. 4) only amount to approx. 4 to 6 kg/h of

Fig. 2: **Adding a CO_2 removal unit using Uhde's proprietary ammonia scrubbing**



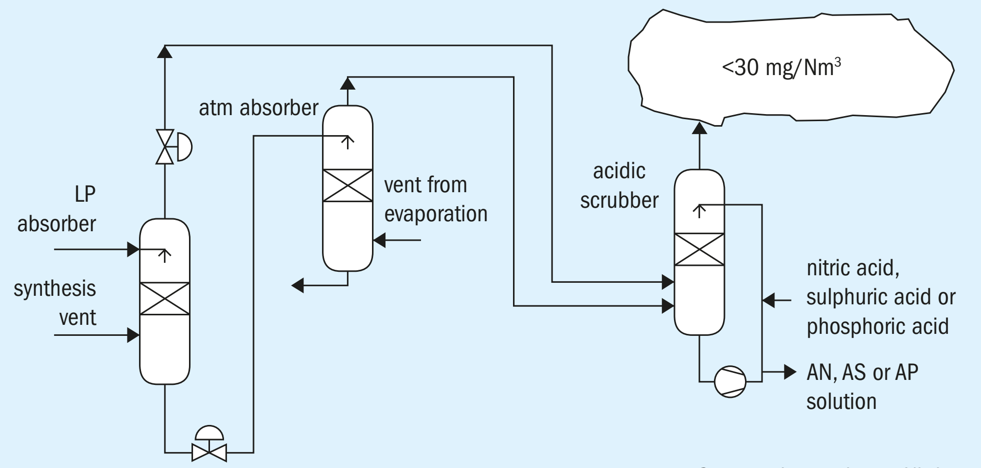
Source: thyssenkrupp Uhde

Fig. 3: **Adding CO_2 which is removed from air by means of a direct air capture process**



Source: thyssenkrupp Uhde

Fig. 4: **Ammonia emissions from sources in the melt plant treated with acidic scrubbing**



Source: thyssenkrupp Uhde

ammonia, the concentration limits are far exceeded due to a very low total throughput. The emissions from the granulation stack (see Fig. 5) amount to approx. 80 to 90 kg/h of ammonia, but the large volume of air dilutes the concentration to approx. 100 mg/Nm³.

State-of-the-art scrubbers for ammonia and dust reduction with water and acid solutions (see Figs 4 and 5) now meet even the strictest regulations. In existing plants, these technologies can be added by replacing the inner pads or trays of the existing scrubber, installing a dedicated acidic scrubber or replacing the scrubber with a new combined dust and ammonia scrubber. The decision is made based on the actual emissions achieved with the old scrubber system, the total new pressure drop and the required changes to the air system, e.g., the exhaust fan. Due to the lower pressure drop of the new scrubber pads, there are cases without the need to replace the fan. Either an increased impeller is sufficient, or a small booster fan can be installed.

Uhde has built new plants in the US with scubbing technologies complying with the local standards shown in Table 1. The scrubbers achieved ammonia emissions of 11.1 mg/Nm³ (EPA 9 method) and dust emissions of 0.86 mg/Nm³ (EPA 5 method).

Since acidic scrubbers are part of many new build plants, their use is well known. Three types of acid have proven themselves for ammonia reduction:

- nitric acid
- sulphuric acid
- phosphoric acid

On contact with the gaseous ammonia, ammonia salts are formed which leave the scrubber either as an ammonium nitrate solution, ammonium sulphate solution or ammonium phosphate solution. The ammonium nitrate solution can be used in a UAN or ammonium nitrate plant. If sulphuric acid is chosen, the solution can be concentrated and sent to the granulator together with the fresh melt from the melt plant. When granulated together with the fresh urea the sulphur content is smaller (0.1 wt-%) but nitrogen is still high, more than 46 wt-% (fertilizer grade). Due to the corrosivity of the free sulphuric acid, the granulator material of construction must be 316/316L, but most plants are built of 304. Alternatively, a crystalliser can process the resulting solution to produce ammonium sulphate fertilizer. If phosphoric acid is used, MAP or DAP can be produced from the solution. The choice of acid is therefore mainly influenced by three factors:

- availability of acid;
- processability of the resulting ammonium salt solution;
- the construction material of the granulation plant.

Improving plant availability

In addition to overhauling systems that have reached end of life, replacing certain equipment with overall new concepts can increase plant availability. One example is the use of a so-called self-regulating pump as a melt pump to supply the granulator. The main feature of this pump is that it can be operated with almost zero suction head (NPSH = 0 m). Therefore, it can be installed close below the second stage evaporator in the melting plant.

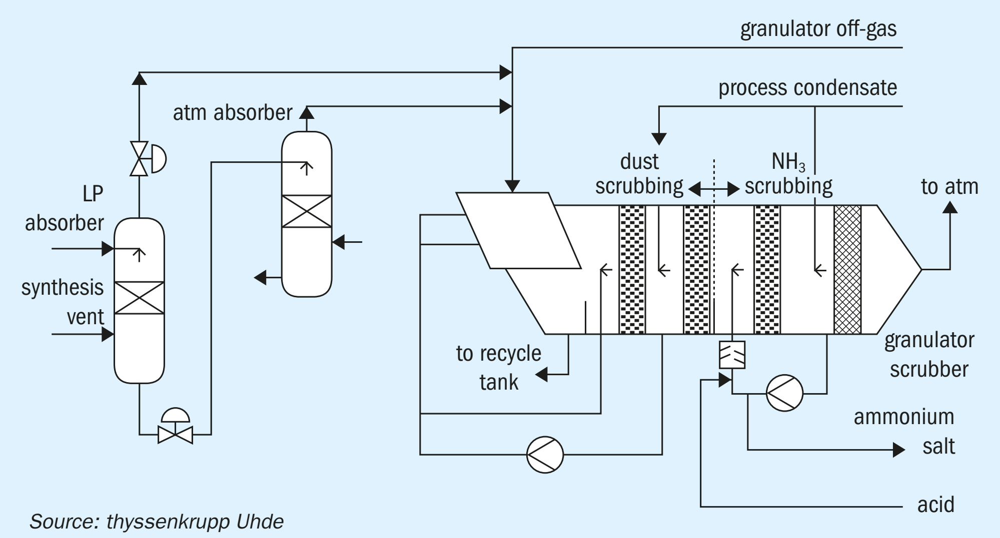
The fact that the self-regulating pump does not require a NPSH leads to a couple of advantages.

Due to the close distance to the evaporator, the pipe length on the suction side is shortest. Because the pump can be installed at a level higher than ground level, there is no need to route the pipe up and down, instead it can be directly connected to the granulators melt header at the same level. This also keeps the pipe length short. The pump takes the flow as it gets it. This feature prevents level build up on the suction side. All this leads to low residence times of the hot urea melt resulting in minimised biuret formation.

A further advantage of the self-regulating characteristic and the fact that no NPSH is required is that no level control or even pump protection is necessary. This avoids shutdowns of the downstream plant which would otherwise be triggered by a low suction level, e.g., specifically plants with a granulation, and UAN and/or a DEF unit in which the solution feed to the evaporation is varied from time to time.

In order to place the pump in the centre of the structure and achieve the required pump characteristic, the connecting pipes must be designed according to the requirements of the pump. Special vent lines and height requirements must be taken into account. Uhde holds the patent rights to apply this pump in a urea synthesis plant.

Fig. 5: **Common treatment of the off gases from the melt plant and granulator in a state-of-the-art horizontal type scrubber**



Source: thyssenkrupp Uhde

How to approach a revamp

Fig. 6 shows an ideal overview of how a revamp can be approached. Basically, there are four steps. It starts with a study which results in the process concept and a first idea of the cost is derived. If a more precise cost estimate is required, the EP/C contractor must already be involved at this phase. Detailed concepts can then be considered. Examples of questions to be clarified are: where do the required utilities come from and how can the higher quantities be achieved at the source? Is there enough space available to place new structures? How can the revamp be carried out to minimise downtime?

In the second phase the basic engineering is carried out on the basis of the licensor's process design package (PDP) and concepts of the EPC contractor. In this phase the first equipment is purchased (proprietary equipment, critical equipment and equipment with long lead times). In the third phase the detail engineering is performed, and all remaining equipment is purchased. This phase is usually performed by the EP/C contractor. Agreed parts of the phase, e.g. the purchasing, can also be done by the client. It ends with the construction and commissioning of the new parts of the plant. While construction is usually carried out by the contractor or with the contractor's support, there are more options for commissioning. If the customer is very experienced, they may only need advisory services. If the customer is not so experienced, Uhde also offers complete commissioning services together with the support of the licensor.

Input of the contractor

It is often assumed that everything is fixed when the process concept is selected and the licensor's process design package has been supplied. However, an experienced contractor can contribute valuable detailed concepts for adapting the process design package, as shown in the following two examples.

A suitable spare parts philosophy must be defined by the contractor. A perfect example in urea plants is the spare parts philosophy for the high-pressure pumps, which are quite expensive. It is important to work with the customer to find the best spare philosophy that is suitable for their opex and capex needs. However, the information obtained

Fig. 6: **Revamp execution schedule**

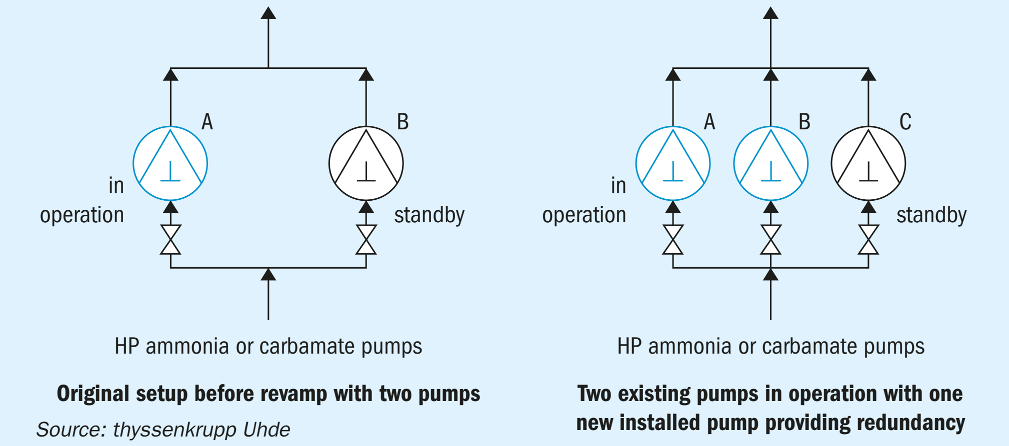
	1a	1b	2	3	4
Project phase	Revamp study	Revamp study	Basic engineering	Detail engineering	Construction commissioning, start-up
Main activity	Process concept, first cost estimate	More accurate cost estimate, consideration of specific requirements	Equipment specifications, P&IDs, layout and civil engineering, engineering of process details, purchasing of long leads/critical/proprietary equipment	Piping and equipment design, procurement of equipment, engineering of details arising from vendors input	Construction and pre-commissioning, adjust plant parameters, commissioning
Responsible	Urea licensor	EP/C contractor	EP/C contractor	EP/C contractor; procurement by EP/C contractor or by client	EPC contractor; or client together with EPC contractor assistance Commissioning by or with assistance by EPC contractor and or licensor

Source: thyssenkrupp Uhde

as part of the PDP is sufficient to provide equipment specifications for different pump capacities required for the various possible spare part concepts. This enables the contractor to develop the solutions. The left side of Fig. 7 below shows a typical arrangement of the high-pressure pumps in the urea melt plant. The following three philosophies are possible:

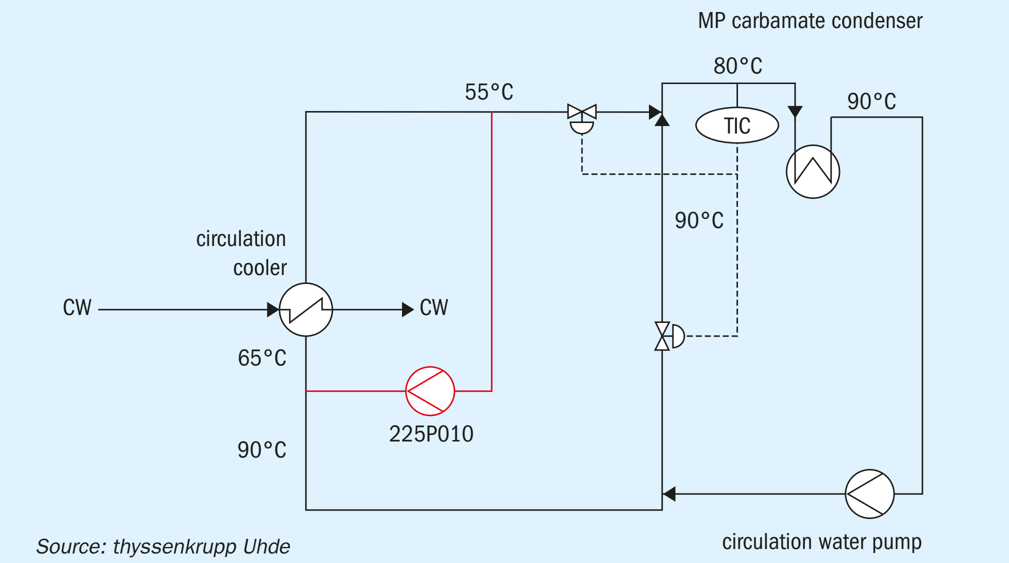
- Keep existing pumps without modification. Both pumps must be in operation to achieve the required flow after the revamp. No spare pump is available. This is the option with the lowest capex costs but has high opex.
- Replace the two existing pumps with new ones, each capable of handling the increased flow after revamp. Only one pump will be in operation and the other one in standby, providing redundancy. This solution has the highest capex cost, but the lowest opex cost, as each pump is designed for the new operating point.
- Install a third pump alongside the existing pumps that can handle the entire flow during operation and keeping the existing two pumps has the following advantages. Either the new pump is in operation, or the two old pumps are in parallel, thus achieving redundancy. As only one new pump needs to be ordered, this is the solution with the lowest capex costs to achieve redundancy. When the newly installed pump is in operation, this solution also has low opex, while higher operating costs only occur during the times when the two existing pumps are in operation. However, this solution requires an available area to install the additional pump.

Fig. 7: **Standby philosophy for high pressure pumps**



Source: thyssenkrupp Uhde

Fig. 8: **Closed cooling water loop of the medium pressure (MP) carbamate condenser with additional circulation loop (red) to reduce fouling**



Source: thyssenkrupp Uhde

Another example where the contractor can contribute is in the detail of the cooling water loop. In a so-called MP add-on, an additional section is added to the existing plant, which is operated at medium pressure of approx. 20 bar. In this section, unreacted carbamate is removed, which cannot be converted to urea in the high-pressure synthesis unit after capacity increase. As the removed carbamate is gaseous and needs to be recycled back to the HP synthesis, it is condensed in the MP carbamate condenser, then pumped. The heat of condensation is removed by cooling water. To prevent the carbamate from crystallising, the cooling water is controlled to 80°C. The outlet temperature of the cooling water is around 90°C. In this specific example, the customer stated that they had noticed increased fouling in the cooling water loop of the high-pressure scrubber and the low-pressure scrubber that were installed in the originally built melt plant. These two scrubbers and their cooling water loops are comparable to the loop of the new MP carbamate condenser. Fouling occurred in the plate heat exchanger, which is intended to condition the closed cooling water loop. Due to the high cooling water temperature and the resulting high wall temperature in the plate heat exchanger, the tendency for fouling is increased.

As part of the revamp, this design was improved by installing an additional pump as shown in Fig. 8, which generates a secondary circulation around the plate heat exchanger and reduces the inlet temperature to the plate heat exchanger by mixing the hot return water with already tempered water from the outlet of the heat exchanger. Scaling the ratio between two flow rates by scaling the size of the additional pump results in a certain mixing temperature which is reduced to such an extent that the tendency of fouling is significantly reduced.

In the specific case of this example, the same modification was made to the cooling water loop of the high-pressure scrubber and the low pressure carbamate condenser. As a result, better performance and higher availability of the entire plant was achieved.

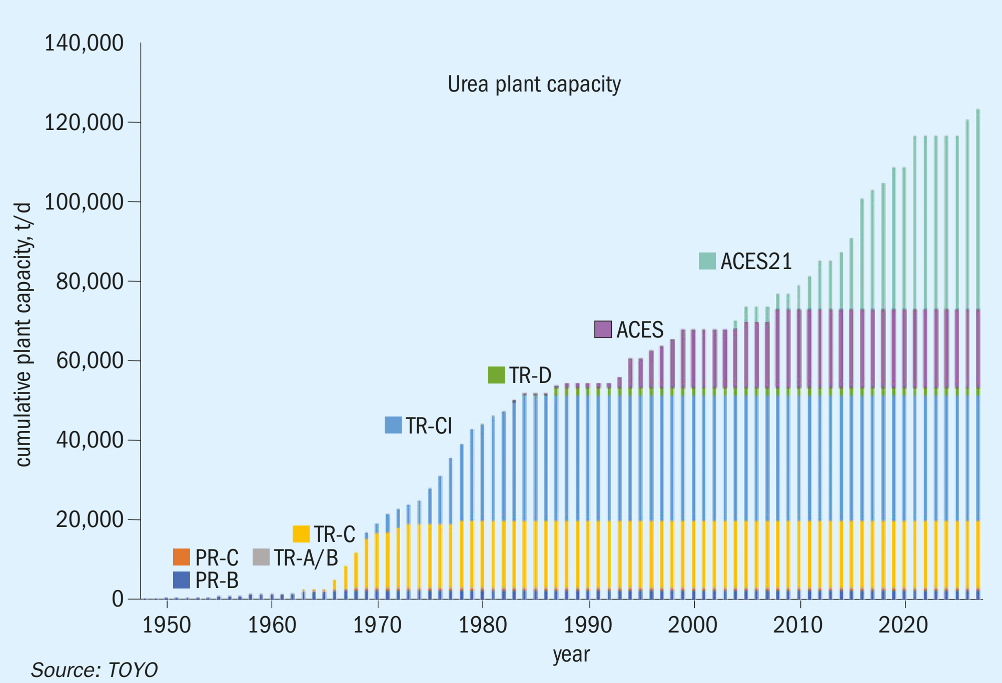
In summary, there are different ways to conduct a revamp for a urea plant. An ideal way is that the licensor provides reliable consumption data for raw materials and utilities in an early phase. Based on this data the contractor can provide further detailed input at an early stage and evaluate the commercial feasibility of the revamp. Based on the reliable emission figures, contractors can check for any change of existing environmental permits, if required, or provide and consider further detail changes. To achieve the best outcome for customers, it is essential that all parties involved work together and provide important information at all phases of the revamp. ■

Revamping to optimise performance and sustainability

Revamping aging urea plants with the latest urea technology brings many benefits. Not only can greenhouse gas emissions be reduced, but the overall performance and sustainability of these facilities can also be optimised. **Hiroo Kunii** of Toyo Engineering Corporation discusses TOYO's approach to urea plant revamping.

Toyo Engineering Corporation (TOYO), a global leading engineering contractor and urea process licensor, has developed its proprietary urea processes since the development of the partial recycle process in the 1950s. Using its expertise, advanced technology and novel thinking, TOYO established ACES21™ in the late 1990s and has since been awarded 18 ACES21™ projects, including three 4,000 t/d urea projects in Nigeria which are the world's largest single-train urea plant. Fig. 1 shows the cumulative capacity of urea plants using TOYO's urea technology which has now reached approximately 120,000 t/d, corresponding to 40 million t/a and representing around 20% of the current global urea production. The revamping and upgrading of existing, aging urea plants is one of TOYO's key strategies. This article provides a detailed account of TOYO's approach to urea plant revamping.

Fig. 1: **Cumulative capacity of TOYO urea plants**



Source: TOYO

TOYO's revamping experiences

TOYO possesses a diverse array of state-of-the-art technologies for revamping existing urea plants. For example, TOYO has upgraded outdated urea synthesis technologies to its latest processes, converted the final product from prilled to granulated urea, added process condensate treatment facilities, etc. utilising its latest technology. These initiatives are aimed at enhancing energy efficiency (reducing CO_2 emissions), lowering operational costs, increasing the added value of products, and contributing to environmental sustainability. Each project has been carefully planned, effectively implemented, and successfully completed, meeting all objectives and deadlines. Table 1 lists the revamping projects undertaken by TOYO, showcasing the remarkable achievements made worldwide through the application of these diverse technologies.

Upgrading existing vintage plants to ACES21™/ACES21-LP™

This section explains the methods of upgrading outdated urea synthesis technologies to TOYO's latest processes, ACES21™ or ACES21-LP™ [1] as part of the revamping approaches discussed above.

Urea plants employing conventional processes, such as self-stripping and total recycle processes, are widespread globally, with approximately 200 to 300 plants in operation (TOYO estimate). The cumulative capacity of these plants has reached an impressive total of more than 100 million tons per year (TOYO estimate).

Fig. 2 shows the modification scheme for the synthesis section of the conventional total recycle process to convert it to ACES21™ or ACES21-LP™. The

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
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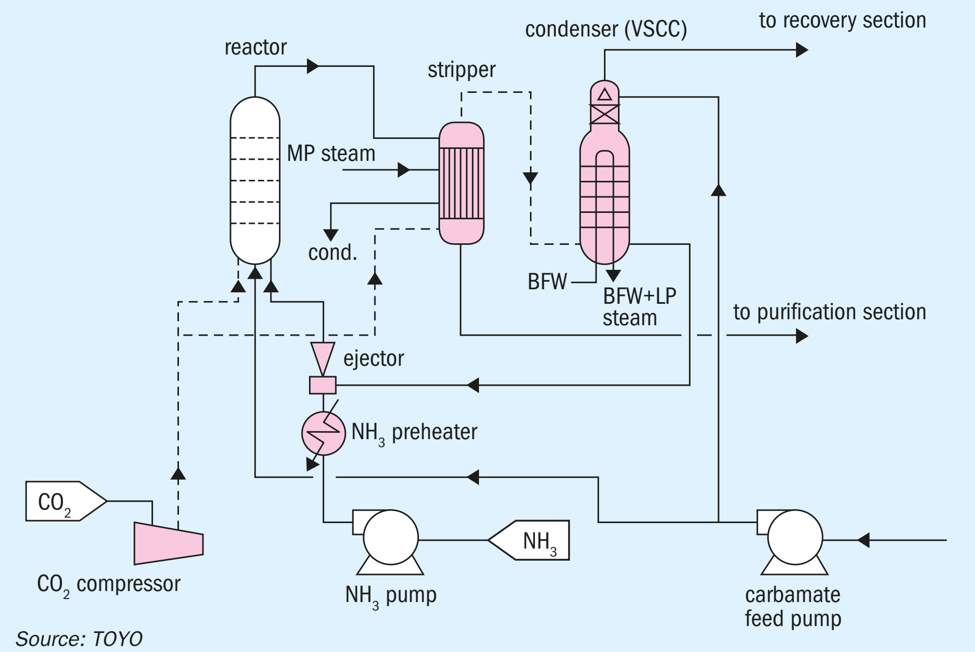
Table 1: **Revamping projects undertaken by TOYO**

Year	Country	Process	Note
1988	Spain	ACES	Upgrading to ACES process from conventional process. Revamping evaporation unit.
1989	India	PCT*	Incorporating process condensate treatment unit.
1991	India	PCT*	Incorporating process condensate treatment unit.
1994	Russia	PCT*	Incorporating process condensate treatment unit.
1994	Indonesia	ACES	Upgrading to ACES process from conventional process.
1995	Indonesia	PCT*	Incorporating process condensate treatment unit.
1995	Germany	Granulation	Converting the product to granulated urea.
1996	New Zealand	Granulation	Revamping granulation unit.
1997	Spain	PCT*	Incorporating process condensate treatment unit.
1998	Brazil	TR-CI**	Revamping synthesis, purification and evaporation unit.
1998	Germany	Granulation	Converting the product to granulated urea.
1998	Pakistan	ACES	Upgrading to ACES process from conventional process. Revamping evaporation unit.
2000	China	Granulation	Converting the product to granulated urea.
2001	India	PCT*	Incorporating process condensate treatment unit.
2002	Japan	PCT*	Incorporating process condensate treatment unit.
2004	China	ACES21™	Upgrading to ACES21™ process from conventional process. Revamping evaporation unit.
2007	Brazil	Granulation	Converting the product to granulated urea.
2008	India	ACES	Revamping synthesis, purification and evaporation unit.

**PCT: Process condensate treatment unit* ***TR-CI: Total Recycle-C Improved process*

equipment illustrated in pink, the stripper/carbamate condenser and HP ejector, is added in the synthesis section; however, the existing reactor can be reutilised as it is. By virtue of this modification, a capacity increase of 50% can be achieved with energy savings of more than 30%, keeping the existing ammonia feed pump and carbamate feed pump without any modification. Replacement or modification of the CO_2 compressor to increase its capacity is an option depending on the revamping concept. In case the purpose is to increase the production capacity or to improve the maintenance frequency of the existing reciprocating compressor, replacement with a new centrifugal type is one solution.

Fig. 2: **Modification scheme of the total recycle process**



Source: TOYO

Strategies for reducing GHG emissions

In this section, the reduction in greenhouse gas (GHG) emissions achieved by applying the latest technologies to enhance the capacity of aged existing urea plants is discussed. TOYO believes that renovating old plants is a crucial pillar of environmental measures in the fertilizer industry. For example, for this study, an existing urea plant with a capacity of 1,620 t/d, one of the standard production capacities in the past, was examined to increase its capacity by 50% (to 2,460 t/d) by implementing advanced technologies and optimising processes. Table 2 shows the typical calculation results of energy savings and CO_2 emissions when upgrading from a total recycle process to ACES21™. It is obvious that a significantly lower carbon footprint is achieved after the revamp. Despite a 50% increase in production capacity, the annual CO_2 emissions for urea production have only increased by 9%, thanks to the latest synthesis technology. Specifically, CO_2 emissions can be reduced by 0.111 t CO_2 / t urea, dropping from 0.393 to 0.282 t CO_2 / t urea.

Revamping old urea plants using the total recycle process with the latest technology, as modelled above, could lead to significant reductions in greenhouse gas emissions. Assuming there are 200 such existing plants worldwide and applying this upgrade to 30% (i.e., 60 plants), and if these 60 plants could maintain a daily production of 1,620 tons without increasing capacity while reducing specific CO_2 emissions from 0.393 to 0.282 t CO_2 /t urea, it could result in an annual reduction of approximately 4 million tons of CO_2 emissions. This significant decrease in emissions shows the environmental benefits of modernising outdated facilities and the contributions to global sustainability from these upgrades. It underscores the importance of using advanced technologies to reduce the environmental impact of industrial activities.

In this context, the evaluation aims to determine whether revamping an existing, aged urea plant offers advantages compared to a grassroots project, specifically from the perspective of CO_2 emissions during construction. Two scenarios are considered: one where a new urea plant with a daily production capacity of 840 t is constructed, and another where the daily production capacity of an existing urea plant is

Table 2: **Typical result of energy saving and CO_2 emissions by revamping**

	Before revamp	After revamp
Capacity, t/d	1,620	2,460
CO_2 consumption, t/a[1) 3)]	413,586	628,038
Energy consumption in boiler and power plant for urea production[4) 5)]		
Gcal/t	1.269	0.913
Gcal/a	709,244	774,863
Crude oil equivalent, t/a (10,000 kcal/kg)	70,924	77,486
CO_2 emission based on crude oil, t/a[2)]	219,439	239,741 (+9%)
Specific CO_2 emission, t CO_2 / t urea)	0.393	0.282

Notes:
[1)] 345 running days per year
[2)] CO_2 emission rate 3.094 t CO_2 / t crude oil is assumed
[3)] CO_2 consumption 0.74 t CO_2 / t urea is assumed
[4)] Boiler thermal efficiency = 85%
[5)] Conversion factor in power generation = 2,646 kcal/kWh

increased from 1,620 t to 2,460 t using the latest technology (an increase of 840 t/d). As shown in Table 3, the CO_2 emissions associated with the manufacturing and transportation of equipment and materials are reduced by 34% in the revamping scenario. While there may be constraints in the revamping scenario due to the restriction of the plot area and the condition of existing equipment and materials, the revamping case offers clear advantages over new construction from the perspective of CO_2 emissions during construction alone.

Next, a comprehensive evaluation of the CO_2 emissions in the revamping scenario has been conducted, considering not only the construction phase but also the 20-year operational period of the plant. The analysis compares two scenarios: one where two old urea plants with daily capacities of 1,620 t and 840 t continue to operate, and another where the older urea plant with a daily capacity of 1,620 tons is revamped using the latest technology to achieve a daily capacity of 2,460 t. As indicated in Table 4, the CO_2 emissions in the revamping scenario are reduced by 28% compared to the scenario where the old plants continue to operate. This revamping scenario focuses on an increase of 840 t/d, allowing the cessation of operations of an older unit with equivalent capacity, which is a high GHG emitter, thereby significantly contributing to the mitigation of global warming.

Thus, as a future trend, it is crucial to enhance the production and energy efficiency of old plants using the latest technologies such as ACES21™/ACES21-LP™, while simultaneously shutting down less energy-efficient plants corresponding to the increased production. Moreover, it is also necessary to increase the upstream ammonia plant's production to match the increased urea production. Given that ammonia plants consume more energy than urea plants, it is imperative to focus on energy efficiency improvements and the transition to blue and green ammonia on the ammonia plant side. This transition involves adopting more environmentally friendly production methods and utilising renewable energy sources, which can significantly reduce the carbon footprint of ammonia production. By integrating these advanced technologies and strategies, the fertilizer industry can achieve a balance between increased production capacity and environmental sustainability. This comprehensive approach highlights the importance of continuous innovation and adaptation in industrial processes to meet the growing demands while minimising environmental impact.

It emphasises the need for a concerted effort to modernise outdated facilities and adopt more sustainable technologies, paving the way for a more sustainable future.

Replacement of urea synthesis equipment

It is worth mentioning simpler revamping projects undertaken by TOYO, which involved the replacement of existing synthesis equipment in urea plants,

Table 3: **CO_2 emission analysis: grassroots vs. revamping project[1)]**

	Grassroots project	Revamping project
Capacity increase, t/d	840	840 (1,620 → 2,460)
CO_2 emission		
Equipment & material[2)], t	28,300	18,200
Transportation[3)], t	3,700	2,800
Total, t	**32,000**	**21,000 (-34%)**

Notes:
[1)] Reference values based on TOYO's internal data, with the construction site located in Southeast Asia
[2)] For manufacturing equipment and material
[3)] For transportation of equipment and material to a construction site

Table 4: **CO_2 emission analysis: status quo vs. revamping**

	Status quo	Revamping
Capacity, t/d	2,460 (1,620 + 840)	2,460 (1,620 → 2,460)
CO_2 emission, t		
Construction phase	0	21,000[1)]
20 years operation-1	219,439 x 20 = 4,388,780[2)]	239,741 x 20 = 4,794,820[4)]
20 years operation-2	114,000 x 20 = 2,280,000[3)]	n/a
Total, t	**6,668,780**	**4,815,820 (-28%)**

Notes:
[1)] Reference values based on TOYO's internal data, with construction site located in Southeast Asia
[2)] Estimated CO_2 emission from 1,620 t/d aged urea plant for 20 years
[3)] Estimated CO_2 emission from 840 t/d aged urea plant for 20 years
[4)] Estimated CO_2 emission from 2,460 t/d revamped urea plant for 20 years

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

Table 5: **Recent experiences of replacement/refurbishment of urea synthesis equipment**

Year	Country	Equipment	Note
1997	Indonesia	Reactor	Replacement
1998	India	Reactor	Replacement
2004	Japan	Reactor	Replacement
2007	India	Carbamate condenser	Technical advisory service
2014	India	Stripper	Technical advisory service
2016	Indonesia	Carbamate condenser	Technical advisory service
2016	India	Carbamate condenser	Technical advisory service
2017	India	Double lining of reactor	Technical advisory service
2020	Indonesia	Stripper	Replacement
2021	India	Double lining of reactor	Technical advisory service
2022	Pakistan	Stripper, carbamate condenser	Replacement
2022	Indonesia	Reactor	Replacement
2024	India	Reactor	Replacement

Source: TOYO

rather than the extensive modifications mentioned earlier. Synthesis equipment in urea plants that has been in operation for over 20-30 years inevitably deteriorates and requires replacement according to the circumstances. Table 5 shows recent records of synthesis equipment renewals. There have been some instances of replacing or refurbishing equipment for both older and latest technologies, including the total recycle process. In these cases, state-of-the-art technology, including the latest equipment models, corrosion-resistant material DP28W™, and the latest high-efficiency baffle plates, have been applied to enhance the reliability and performance of the equipment. These equipment renewal projects often include the dispatch of specialists for on-site installation of internal parts and start-up support as part of the scope of work.

Conclusion

As discussed in this article, TOYO's latest urea technology can be leveraged to enhance and improve the energy efficiency of existing, aging plants, significantly contributing to global GHG reduction. By implementing these advanced technologies, not only can greenhouse gas emissions be reduced, but the overall performance and sustainability of these facilities can also be optimised. As a leading licensor of urea technology, TOYO remains committed to contributing to a sustainable society worldwide, continuously innovating and providing solutions that support environmental sustainability and energy efficiency. ■

Reference

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