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NITROGEN+SYNGAS
ISSUE 387
JANUARY-FEBRUARY 2024

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CRU

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A return to the fold

We are very pleased to be able to tell you that, as of this issue, *Nitrogen+Syngas* magazine has a new publisher. Or rather, an old publisher, as the magazine is now once again part of the CRU Group.

Nitrogen magazine, as it originally began life in 1959, was started by the British Sulphur Corporation, which was in turn acquired by CRU in the early 1990s. Over this time *Nitrogen's* coverage gained first methanol and then syngas more generally as co-products, reflecting the way that the industry was increasingly looking at syngas-based compounds as a part of a portfolio for major gas- or coal-based developments, and particularly the interest that there was – and is – in opportunities for integrating these processes for greater efficiency and more diverse product streams.

In 2007, CRU's Publishing division was spun off as a separate entity, BCInsight Ltd, as CRU sought to focus on its core activities of analysis, consultancy and conferences, but the new company retained the magazine staff who had been working on it for many years, and continued a close relationship with our former colleagues at CRU, liaising especially over CRU's industry conferences.

The current move back to CRU is in part a result of the changing nature of how people seek and acquire knowledge and network in a digitally saturated age. *Nitrogen+Syngas* will now be housed within CRU's new Communities business unit, headed by Nicola Coslett, CEO of CRU Communities, which will seek to strengthen engagement and facilitate knowledge-sharing and networking across the fertilizer and wider chemicals industries.

> **The need for technical knowledge and insights has never been more important.**

The move will also allow us access to CRU's Fertilizer consultancy division, with its unrivalled team of dedicated and highly experienced analysts, enhancing our ability to deliver even more comprehensive and insightful information to our readers. With so many new entrants into the ammonia, phosphate and fertilizer industries, the need for technical knowledge and insights has never been more important.

In the longer term, it will also allow us to make improvements to our product offerings that were beyond the resources of a small publishing company, and we hope to have more news on that in due course. But rest assured that the team writing and publishing the title remains the same as always. Myself and Lisa Connock, our Technical – and now Managing – Editor, and Marlene Vaz, our Sales Manager, will look forward to seeing you under our new guise at CRU's Nitrogen+Syngas conference in Gothenburg on March 4th-6th, alongside our new CRU colleagues. ■

Richard Hands, Editor

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Price Trends

Ammonia prices are expected to remain soft moving through January with little in the way of price support from both a supply and demand perspective. Weakened global sentiment was characterised by news of January's Tampa settlement $100/t down on December at $525/t CFR, with further declines anticipated in Q1 once the Gulf Coast Ammonia (GCA) project comes online. Traders returned to their desks in the New Year and ammonia prices extended losses amid a stable supply outlook and a distinct lack of downstream industrial and fertilizer demand.

The outlook for global urea prices is weak, but a purchase of a million tonnes by India may put a line under recent declines if buyers in Europe and the US are tempted back into the market. Paper markets indicate modestly firmer prices through the first quarter and by the second week of January, a number of Egyptian sales had lifted export prices from Damietta as high as $365/t FOB by 10 January.

December began on a positive note for urea markets with a flurry of Egyptian urea sales and firmer prices for delivery to Brazil, although the increase in values was short lived and piecemeal demand in Europe was insufficient to halt the downward trend. By mid-December buying interest from Brazil had fizzled out, although on 21st December India's NFL floated a new import tender closing on the 4th of January for shipment by 29th February, and sellers breathed a sigh of relief.

Fresh enquiries emerged from Brazil and Europe, along with new sales from Egypt. Business at New Orleans was limited in the last week before Christmas amid little confidence that prices would move higher. On 6th January NFL opened offers revealing that Fertcom was lowest for West Coast India (WCI) at $316.80/t CFR, with Agri Commodities lower on the East Coast India (ECI) at $329.40/t CFR. By 8th January NFL had issued counters at those prices, which will mark a significant decline from an assessment of $340-345/t CFR for delivered prices to India on 4 January.

UAN benchmarks are expected to rise steadily from January through April due to renewed spring demand. Unrelenting wet weather in Europe has curbed farmer applications. Should these conditions persist, anticipated demand may not emerge as expected.

In France, the UAN-30 market has been stable with December prices sitting at €285/t FCA. In line with US UAN markets, demand is forecast to kick in in late January to February and prices should steadily increase through until April to around €325/t FCA. As UAN demand wanes seasonally, prices are expected to decline modestly, rather than slumping.

Traders show little concern over natural-gas storage levels given the mild winter in Europe to date. In addition, prices at the Dutch TTF gas hub fell just below $10/MMBtu for February, boosting margins for UAN producers in the region. Production margins have been benefiting from easing gas costs since October 2023 and the favourable conditions for UAN production are likely to persist for the foreseeable future.

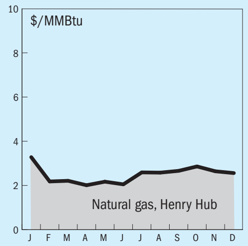
Table 1: Price indications

Cash equivalent	mid-Dec	mid-Oct	mid-Aug	mid-Jun
Ammonia ($/t)				
f.o.b. Black Sea	n.m.	n.m.	n.m.	n.m.
f.o.b. Caribbean	475-575	525-575	260-310	270-340
f.o.b. Arab Gulf	470	445-550	290-320	210-260
c.fr N.W. Europe	535-545	620-680	380-410	355-365
Urea ($/t)				
f.o.b. bulk Black Sea	273-290	320-390	340-400	220-285
f.o.b. bulk Arab Gulf*	298-302	340-405	346-400	240-316
f.o.b. NOLA barge (metric tonnes)	330-334	370-418	390-400	294-310
f.o.b. bagged China	360-370	365-405	370-395	270-340
DAP ($/t)				
f.o.b. bulk US Gulf	560	550-589	573-600	468-506
UAN (€/tonne)				
f.o.t. ex-tank Rouen, 30%N	309-310	284-315	302-324	253-283

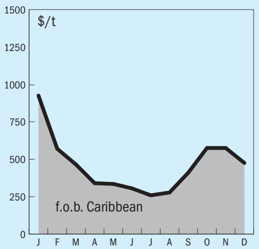
*Notes: n.a. price not available at time of going to press. n.m. no market. * high-end granular.*

END OF MONTH SPOT PRICES

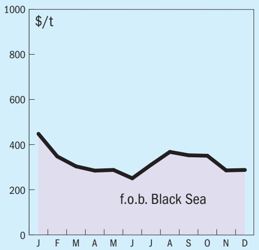
natural gas



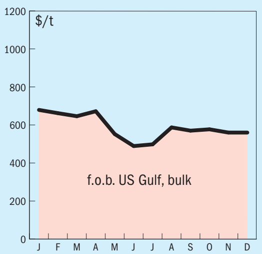
ammonia



urea

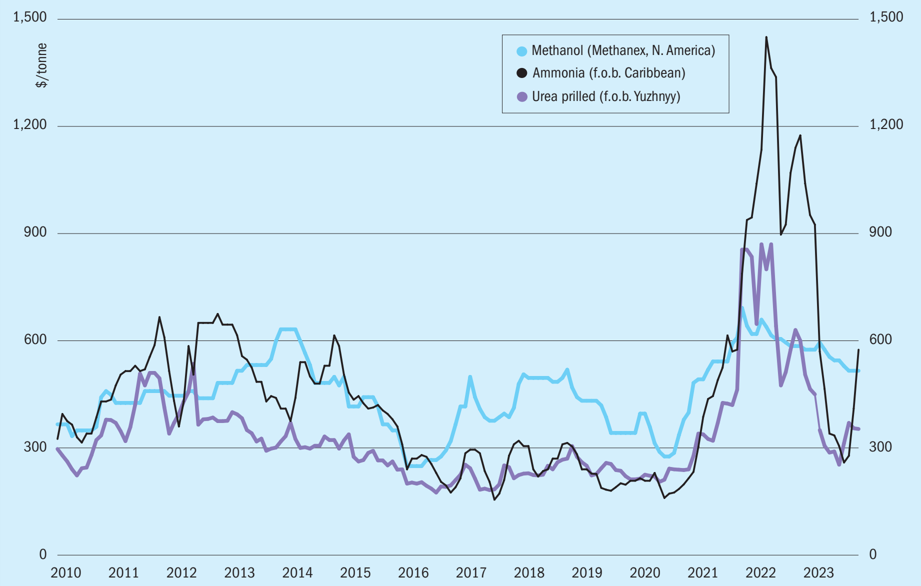


diammonium phosphate



Market Outlook

Historical price trends $/tonne



Source: BCInsight

AMMONIA

- Ammonia prices are expected to remain soft moving through January into February, with little in the way of price support from both a supply and demand perspective. January's Tampa settlement was $100/t down on December at $525/t CFR.
- Further declines are expected in Q1 2024 due to fresh supply, particularly the new Gulf Coast Ammonia (GCA) project.
- Overall the supply outlook for ammonia is stable, with a lack of downstream demand for both industrial consumers and fertilizer producers, leading to further reductions in ammonia prices into the New Year.
- Feedstock costs remain relatively modest in spite of the onset of cold weather in North America and Europe, with Henry Hub spot prices down to just $2.50/MMBtu at the end of December, and even European TTF prices below $10/MMBtu for February delivery.

UREA

- Urea prices have fallen, although the recent Indian tender may put a floor under prices and tempt European and US buyers back into the market. It is believed that the US still needs an additional 1.0 million tonnes of urea. However, with US delivered prices close to f.o.b. offer levels some movement is needed either on the supply or purchase side.
- Brazilian demand for the Safrinha second corn crop, sown in January-March, remains uncertain. Last year the harvest reached record levels, but El Nino drought conditions may slow or delay planting and application. Mosaic says that it expects Safrinha fertilizer demand to be 12% down on last year.
- Paper markets indicate modestly firmer prices for urea through the first quarter and by the second week of January. Egypt has been particularly bullish, with a number of sales lifting export prices from Damietta as high as $370/t FOB.

METHANOL

- On the supply side, Malaysia's Petronas restarted its No.2 methanol plant at Labuan on 27th December, restoring 1.7 million t/a of capacity after several weeks shutdown due to mechanical issues, and keeping southeast Asian prices at their relatively low level of $340/t f.o.b. Other plants have also had unscheduled outages, including several in Iran due to gas supply issues. Methanex's Damietta plant, with 1.3 million t/a of capacity has been down since October because of ongoing gas supply issues.
- Methanol prices have recovered from their low point of Q3 2023 thanks to more stable Chinese MTO production, boosting Chinese domestic demand and imports. However, falling oil prices may impact upon MTO production, and slowing global growth may also impact upon demand for methanol derivatives.

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Nitrogen Industry News

UNITED STATES

OCI to sell Iowa fertilizers to Koch

The Iowa Fertilizer Company plant at Wever

PHOTO: ORASCOM

OCI Global says that it has reached an agreement for the sale of 100% of its interest in its large-scale nitrogen fertilizer subsidiary the Iowa Fertilizer Company LLC, located in Wever, Iowa, to Koch Ag & Energy Solutions for $3.6 billion. Completion of the transaction remains subject to US anti-trust approval and other customary closing conditions. The transaction is expected to close in 2024. Morgan Stanley & Co. International plc is serving as financial advisor to OCI on the transaction. IFCO produced 1.2 million t/a of urea ammonium nitrate (UAN) in 2021 and 700,000 t/a of anhydrous ammonia, as well as 700,000 t/a of diesel exhaust fluid (DEF).

The sale follows a strategic review in March 2023, with the objective of unlocking value for OCI's shareholders. The transaction is expected to enable OCI to explore value added opportunities in energy transition, building on its early mover lower-carbon ammonia and green methanol platforms.

Nassef Sawiris, Executive Chairman of OCI commented: "Today's announcement marks an evolutionary step in our journey to create value for shareholders, and to enhance our focus on efforts in lower carbon initiatives. IFCO was the first world-scale greenfield nitrogen fertilizer facility built in the United States in over 25 years. We are confident that under Koch's stewardship, IFCO will be well positioned for its next phase of growth. Our strengthened balance sheet will support the acceleration of our strategy in the field of decarbonisation projects, driving future growth and supporting the energy transition goals we share with many of our stakeholders, establishing us as a leader in the low carbon space. ■

JAPAN

Approval in principle for ammonia FSRU

ClassNK has issued an approval in principle for an ammonia Floating Storage and Regasification Unit (FSRU) jointly developed by Mitsui OSK Lines and Mitsubishi Shipbuilding. An FSRU is a floating facility designed for liquified gases and equipped with storage tanks and a regasification facility that receives liquified gas on the water, vaporises it and sends it ashore, with the advantage of lower costs and shorter construction periods than those of the equivalent facilities onshore. The new FSRU developed by MOL and Mitsubishi Shipbuilding this time applies this technology to ammonia, and is expected to contribute to the development of ammonia value chain as an alternative carbon neutral fuel.

ClassNK says that it carried out a review of a conceptual design of the ammonia FSRU based on its Part N of Rules for the Survey and Construction of Steel Ships for ships carrying liquefied gases in bulk, Guidelines for Floating Offshore Facilities for LNG/LPG Production, Storage, Offloading and Regasification," and other relevant rules, and examined risk assessment taking into account the results of gas dispersion study.

EGYPT

Agreement to develop green hydrogen project

Saudi-listed ACWA Power has signed a framework agreement, following a memorandum of understanding that was signed on December 7th 2022 to outline the development of the first phase of its green hydrogen/ammonia project in Egypt. Projected capacity will be 600,000 t/a of green ammonia, with an investment in excess of $4 billion, with the intention of scaling up to a second phase with a potential capacity of 2 million t/a. The agreement was signed with the Sovereign Fund of Egypt, the Suez Canal Economic Zone, the Egyptian Electricity Transmission Company, and the New and Renewable Energy Authority in the presence of Dr. Moustafa Madbouly, prime minister of Egypt. The hydrogen will be generated electrolytically from wind and solar plants.

ACWA Power has been rapidly expanding its green portfolio, including its involvement in the NEOM Green Hydrogen Project, a joint venture between ACWA Power, Air Products, and NEOM to create the world's first utility-scale green hydrogen plant in the northwest of Saudi Arabia. The project will be capable of producing 1.2 million t/a of green ammonia. The first wind turbines were delivered to the site in October. On November 27th, the company also broke ground on its second green hydrogen project, in Uzbekistan. The first phase of this project will be capable of producing 3,000 t/a of green hydrogen, with the intention to expand to a second phase. Once the second phase is complete, 2.4 GW of wind energy will power the production of 500,000 t/a of green ammonia. ACWA also signed agreements during COP28 for green hydrogen projects in Jordan and Indonesia.

Marco Arcelli, Chief Executive Officer of ACWA Power said: "As a first mover in green hydrogen, ACWA Power is proud to bring its expertise in this new and exciting market to Egypt. We commend our partners for their bold step into producing the fuel for the future, for which there will be great demand in Europe and the rest of the world. Egypt is well-positioned to become one of the world's top producers of green hydrogen and we are elated to be a part of the country's energy transition."

Fertiglobe ships certified renewable ammonia

Fertiglobe, the strategic partnership between ADNOC and OCI Global says that it has completed the first shipment of the internationally recognised renewable ammonia with ISCC PLUS (International Sustainability and Carbon Certification) certification. The renewable ammonia was produced at the company's facilities in Egypt using renewable hydrogen from its pilot Egypt Green Hydrogen electrolyser and will go into the production of near-zero emissions synthetic soda ash – a key ingredient in laundry powder – for Unilever. The shipment was sent to Tuticorin Alkali Chemicals and Fertilisers in India, who will produce the soda ash for Unilever's India business, Hindustan Unilever (HUL).

Ahmed El-Hoshy, CEO of Fertiglobe and OCI Global, commented: "This shipment is an important milestone for Fertiglobe, a breakthrough in producing and supplying renewable ammonia to the world, and for the ongoing execution of our hydrogen roadmap. As a pioneer in renewable ammonia, we see immense potential in its ability to decarbonize industries and drive the global energy transition. Looking ahead, we are committed to leveraging our state-of-the-art ammonia facilities and global distribution infrastructure to expand our low-carbon ammonia capacity to meet growing demand and further reduce the carbon footprint of our business."

Tecnimont to begin work on KIMA plant

Following the award of the project to build a nitric acid and ammonium nitrate plant by KIMA, Tecnimont says that it has now received the advance payment and authorisation to start engineering works, while the notice to proceed with full engineering procurement and construction (EPC) activities is expected by the end of June 2024. The EPC contract was awarded to a Tecnimont-led consortium for an overall value of $300 million, of which approximately $220 million pertains to Tecnimont.

The plant will replace the older units for ammonium nitrate production at the site, significantly reducing the greenhouse gas emissions thanks to state-of-the-art abatement systems, as well as improving the overall energy efficiency and environmental standards. Once the plant is in operation in 2026, the ammonium nitrate offtake will be used as a fertilizer both by local farmers as well as being exported internationally.

Alessandro Bernini, MAIRE CEO, commented: "We are glad to start this strategic project, which is important for the industrial plans of KIMA as well as for the development of the agricultural activities in the whole region".

Eurotecnica to license melamine plant

Eurotecnica, part of the Proman family of companies, has been selected by Helwan Fertilizers Company for the implementation of a world scale melamine plant based on the company's proprietary Euromel® G5 melamine technology. The facility will have a nameplate capacity of 60,000 t/a, and is scheduled to be commissioned by 2027. It will be strategically located in the vicinity of Helwan district, south of Cairo, ensuring proximity to essential resources and markets, facilitating operations and distribution.

Commenting on the collaboration, Guido Canti, Eurotecnica Sales Manager, said: "We are delighted to join forces for this monumental project. Our technology and expertise align perfectly with HFC's vision for innovation and sustainability. This melamine plant marks a significant step forward for HFC and reaffirms our commitment to providing highly innovative technologies to our customers."

Euromel technology is the leading and most advanced technology for the production of high-quality melamine used in wood-based products, laminates, moulding compounds and fire-extinguishing foams. It delivers zero pollution with no effluents to be treated and no added chemicals, and now can also be green with electricity from renewable sources.

AUSTRALIA

Topsoe signs contract with Allied Green Ammonia

Topsoe has signed a contract with Allied, a developer of energy infrastructure projects, to deliver its dynamic green ammonia technology for Allied's project in Gove, Northern Territory, Australia. The ammonia is intended to be exported from Gove to Southeast Asian markets, where demand for clean fuels continues to grow. Production is planned to start in Q4 2028/Q1 2029, targeting a capacity of 2,500 t/d. Using Topsoe's technology, the CO_2 saved in this project is estimated to be around 1.4 million t/a, compared to ammonia produced from conventional (natural gas) routes. Topsoe is also in discussions with Allied to supply an undisclosed quantity of its solid oxide electrolyser cells (SOECs) to produce green hydrogen.

Kim Hedegaard, CEO Power-to-X, at Topsoe, said: "We are excited to embark on this journey with Allied and to support the growing demand for e-fuels production in Australia. Allied's project is completely in line with our ambition to deliver carbon reduction technologies for reaching net zero. Our dynamic green ammonia solution supports this by enabling the production of e-fuels for energy-intensive industries and long-distance transportation."

Alfred Benedict, Founder & Managing Director of Allied, said: "We are confident that the geographical location and existing infrastructure in Gove in combination with the most energy efficient hydrogen and green ammonia technology will lead to the lowest levelised cost of green ammonia production in Australia. We are delighted to receive strong endorsement from the local Gumatj Corporation and the Northern Territory government, both of whom eagerly support the development of our green ammonia project in Gove."

Topsoe's dynamic ammonia technology adapts the production output of green ammonia in response to fluctuating supply of renewable electricity, enabling the ramping up/down

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of ammonia production bidirectionally at a rate of at least 3% per minute in response to the fluctuating supply of hydrogen to the ammonia plant. Topsoe says that it also brings a significant reduction in capital expenditure and operational expenditure, since hydrogen storage systems can be reduced substantially, or otherwise eliminated.

Uhde to license urea granulation unit

thyssenkrupp Fertilizer Technology has signed a contract with Saipem to license a urea granulation unit in Karratha, Western Australia. The project in Karratha is being built for Perdaman Chemicals and Fertilisers by a joint venture (50/50) comprising Saipem and Australian company Clough. thyssenkrupp Fertilizer Technology will be responsible for the licensing, process design package and supplying the main equipment for Saipem's urea project using its proprietary UFT® fluid bed urea granulation technology, which is responsible for more than 70% of the urea granules produced worldwide.

For this project, thyssenkrupp has been contracted to supply two granulators and two exhaust air scrubbers for the urea granulation unit, which will have a total production capacity of 6,200 t/d.

Vikas Rambal, Chairman Perdaman said: "We are pleased to be building Australia's biggest downstream project, which represents a major investment in the Australian production sector. This state-of-the-art plant will contribute to Australia having a safe and reliable source of high-quality urea, thus supporting the farmers and food producers. The decision in favour of thyssenkrupp Fertilizer Technology as the technology supplier and licensor for this urea project not only speaks for the competence of thyssenkrupp Fertilizer Technology, but also for confidence in the ability of the company to supply reliable solutions for the fertilizer industry."

NORWAY

EU funding for green ammonia project

Australia's Fortescue has received euro 200 million ($219.3 million) from the European Union for its Holmaneset Project, a flagship green ammonia plant in Norway. The plant aims to capitalise on the Norwegian transmission grid's surplus renewable energy and ship the resulting green ammonia to domestic and European markets.

Fortescue Energy CEO, Mark Hutchinson, said, "The Holmaneset Project is a great opportunity for Fortescue, Norway and Europe to develop a significant green energy value chain, and its selection for funding by the EU is a recognition of its significance to global decarbonisation efforts."

The Holmaneset Project has been identified as a priority project by the Fortescue board, who recently approved an early investment decision in the project to see it progress towards front end engineering design (FEED) before being considered for a final investment decision. Fortescue is currently targeting construction to commence in 2025, and operations in 2027, pending final approvals from the board. The EU Innovation Fund Grant will be paid on the completion of specified project milestones, with the first instalment to be paid on financial close.

"The green hydrogen and green ammonia produced near Svelgen has the potential to replace fossil fuels in industries that find it difficult to cut emissions, like long-haul transport, shipping and heavy industry," Fortescue Norway Country Manager Thor Magnus Rovik said.

Maire Group says that its Tecnimont business unit has been awarded the front end engineering and design contract by Fortescue. Tecnimont's scope of work entails the design of electrolyser integration, the air separation unit for nitrogen production, and the ammonia production plant, as well as its storage and ship loading facilities. As part of the agreement, Tecnimont will also submit an engineering, procurement and construction proposal for the realisation of the plant. The facility will produce green ammonia through electrolysers that will use renewable hydro-electric power for hydrogen production. Unlike other renewable energy sources, such as wind and solar, hydropower is stable over time, greatly simplifying the configuration and operation of the plant as well as its efficiency. The plant aims to ship the resulting green ammonia to domestic and European markets, contributing to the decarbonization of hard-to-abate industries. These objectives align with both Norwegian and European ambitions of accelerating the green energy market.

Alessandro Bernini, Maire CEO, commented: "We are proud to support Norway with this new sustainable initiative aimed at decarbonizing hard-to-abate industries, in particular the shipping sector, where ammonia is playing a pivotal role. This project is concrete evidence of our strong positioning in the energy transition thanks to our technology-driven value proposition".

KAZAKHSTAN

New ammonia and urea complex for Aktau

The Kazakh government has said that it is aiming to develop a new ammonia-urea complex at Aktau. Spain's Técnicas Reunidas is working with state-owned KazAzot and KazMunaiGas on developing the project. In a press statement, Kazakh prime minister Smailov said that the introduction of urea production through the construction of the complex would lead to the production of a unique nitrogen-containing fertilizer suitable for various types of soil, marking a significant step forward in the development of Kazakhstan's agricultural sector.

IRELAND

Plans for ammonia fuelled power plant

UK-based Centrica plc and Mitsubishi Power Europe have signed a memorandum of understanding to explore the development, construction, and operation of Europe's first-ever ammonia-fired power generation facility at the Whitegate combined cycle gas turbine (CCGT) power station in Cork. The project is being led by Centrica through its Bord Gáis Energy and Centrica Energy businesses. Bord Gáis Energy's facility at Whitegate would serve as a global demonstration site for ammonia-fired power generation technology, providing insight into the feasibility and scalability of low carbon ammonia as a green fuel and shaping the future of power generation worldwide, with low carbon ammonia being sourced through Centrica Energy's global trading network. Following the signing of the MoU, a project team is being established to commence project feasibility assessments. Upon the successful outcome of this assessment, extensive local stakeholder engagement will commence.

Chris O'Shea, Group Chief Executive, Centrica said: "At Centrica we believe that all energy can be green energy and that this can also improve energy security. This is one of the many projects Centrica is working on to demonstrate how the hydrogen economy could work in practice. In this instance, we hope to be able to show how hydrogen could be stored and transported as low carbon ammonia, delivering cleaner energy for customers at the point of use. Centrica Energy continues to be a pioneer in supporting the development of these new international value chains and we're delighted to have the expertise of our partners in Mitsubishi Power in delivering the project".

INDIA

Ammonia leak at fertiliser plant

Around 60 people have been hospitalised following a leak from an undersea ammonia pipeline operated by Coromandel International near its Ennore plant in Chennai, Tamil Nadu state. Fishermen and local residents reported bubbles from the pipeline site, followed by difficulty in breathing and a burning sensation in the eyes. The leak took place when Coromandel's fertiliser manufacturing unit was preparing to receive an ammonia shipment through its 2.5 kilometre-long (1.5 mile) pipeline. The leak was reportedly contained within 20 minutes. In a press statement, Coromandel said: "As part of routine operations, we noticed abnormalities at 23:30 pm on 26th December 2023 in the ammonia unloading subsea pipeline near shoreside, outside the plant premises. Our standard operating procedure activated immediately, and we have isolated the ammonia system facility and brought the situation to normalcy in the shortest time." The Tamil Nadu government has issued an order mandating that the company carry out appropriate tests after a full repair of its pipelines to completely rule out any scope for further leaks before unloading ammonia from ships.

UNITED ARAB EMIRATES

ADNOC to buy out OCI's stake in Fertiglobe

The Abu Dhabi National Oil Company (ADNOC) and OCI Global have entered into a sale and purchase agreement for the acquisition by ADNOC of OCI's entire majority shareholding in Fertiglobe, the world's largest seaborne exporter of urea and ammonia, and the largest nitrogen fertilizer producer in the Middle East and North Africa, with production facilities in Egypt, Algeria and the UAE. The transaction, which will see ADNOC become the majority shareholder in Fertiglobe, supports the company's ambitious chemicals strategy and its plans to establish a global growth platform for ammonia, a key lower carbon fuel and hydrogen carrier that is expected to play an important role in the energy transition.

Under the terms of the agreement, ADNOC will purchase OCI's 50% + 1 share stake in Fertiglobe at a price of AED 3.20 per share, representing a total purchase price of AED 13.28 billion ($3.62 billion). The agreement also incorporates an earn-out mechanism for FY2024 and 2025, linked to commodity pricing and the free cash flow performance of the Fertiglobe business during the relevant period. Following the completion of the transaction, ADNOC's shareholding in Fertiglobe will increase to 86.2%.

Khaled Salmeen, Executive Director, Downstream, Marketing and Trading Directorate at ADNOC, said: "Working in close partnership with OCI since 2018, we have successfully listed and grown Fertiglobe into the world's largest seaborne exporter of ammonia and urea fertilizers. Today's agreement reinforces ADNOC's long-term commitment to Fertiglobe and our continued focus on delivering growth and maximising value for the company's shareholders. This important transaction supports ADNOC's ambitious chemicals growth strategy and accelerates our plan to establish a global growth platform for ammonia and clean ammonia."

THAILAND

PTT to explore low carbon ammonia

PTT Global Chemical has signed a memorandum of understanding with Mitsubishi Heavy Industries to jointly study the technologies required to develop a large-scale chemical complex that aims to support Thailand's ambition of achieving carbon neutrality by 2050. The collaboration will consider low carbon fuels such as hydrogen and ammonia, as well as carbon capture and storage technologies over the next four years. It has two main objectives; first to compare the feasibility of using hydrogen and ammonia as fuels for gas turbines, as well as CCS technologies to reduce carbon dioxide emissions from power generators; and second to assess how CCS technologies can best be applied and optimised for the steam methane reforming (SMR) process. MHI will support this through providing carbon capture technologies as well as hydrogen combustion gas turbines and ammonia gas turbines.

Osamu Ono, Managing Director of MHI said: "Low-carbon fuels such as hydrogen, ammonia and CCS technologies have great potential in reducing carbon emissions from existing energy infrastructure. MHI-AP is honoured to partner with GC to explore how we can utilise our technology and expertise to reduce carbon emissions from GC's existing business assets and support the establishment of an economically viable large-scale carbon neutral petrochemical plant."

BRAZIL

Petrobras looking to revive UFN III plant

Petrobras has tendered for assessment services for the unfinished construction works on the UFN III ammonia/urea plant in Três Lagoas in Mato Grosso do Sul state, on the Bolivian border. The assessment is aiming to draw up a list of the remaining materials, equipment and services required to complete the plant. Work began on the plant in 2011, being conducted by Sinopec and local firm Galvão Engenharia, but was suspended in 2014 following a dispute with the contractors, at which time the plant was said to be 80% mechanically complete. Since then Petrobras has tried to sell the project, with Russia's Acron interested at one time. However, since the election of president Luiz Inacio Lula da Silva in October 2022, there has been a change in policy, with the sale of the plant halted and instead plans to complete the unit. UFN III has a planned capacity of 2,200 t/d of ammonia and 3,600 t/d of urea, with natural gas to be supplied across the border from Bolivia.

Petrobras has also signed a contract with Unigel Participacoes SA for production of fertilizers at the Sergipe and Bahia plants on a tolling basis. The two companies signed an agreement in June 2023 to consider collaboration in the areas of fertilizers, green hydrogen and low-carbon projects. It has also revealed plans to restart production of fertilizers at Petrobras subsidiary Araucária Nitrogenados (ANSA), which has been idled since 2020. ANSA has 1,300 t/d of ammonia capacity and 1,900 t/d of urea capacity using asphalt residue from the nearby 200,000 bbl/d Presidente Getulio Vargas refinery (REPAR).

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Syngas News

UNITED ARAB EMIRATES

Feasibility study on waste to fuels plant

Maire Group subsidiary MyRechemical has been awarded a feasibility study for the integration of its proprietary waste-to-syngas technology in a large-scale conversion plant that would transform solid municipal waste into 120,000 t/a of sustainable aviation fuel (SAF). MyRechemical would provide the gasification unit to transform solid waste streams into synthesis gas, which would then be converted into low carbon ethanol and then to SAF.

"We are happy to participate in the first waste-to-chemicals initiative in the UAE," commented Giacomo Rispoli, CEO of MyRechemical. "This achievement further confirms our commitment in valorising alternative feedstocks, contributing concretely to the reduction of the carbon footprint in the aviation sector. This happens in a country like UAE where we boast a long-standing presence in the transformation of natural resources, and which is now open to sustainable innovation" ■

UNITED STATES

MyRechemical to license technology for biomass to fuels plant

MyRechemical has been selected by DG Fuels Lousiana to provide the process design package in relation to a sustainable aviation fuel (SAF) facility under development in St. James Parish, Louisiana. The plant, expected to be operational in 2028, will produce 350,000 t/a of SAF derived from biomass and other waste. MyRechemical has been selected as technology licensor in relation to a gasification unit and a gas treatment unit able to process 1,000,000 t/a of bagasse and sugar cane trash and pulp, representing the first step for the SAF production. DG Fuels has established several partnerships and offtake agreements with major global airlines and is currently developing its first SAF facility.

Michael Darcy, DG Fuel CEO and chairman, commented: "We are very happy to formalise our agreement to use the NextChem gasification technology in our first zero carbon SAF production facility. NextChem's superior technology, extremely strong engineering capabilities and unquestioned financial wherewithal makes them the ideal partner in our efforts to decarbonise the aviation industry".

UNITED KINGDOM

Topsoe to collaborate on UK-based renewable natural gas and methanol

Topsoe, has signed a memorandum of understanding with Standard Gas, a decarbonisation technology company, to collaborate on a UK-based project to produce renewable natural gas and methanol from residual waste feedstocks. Under the terms of the MoU, Topsoe will provide the technologies, engineering, equipment items and catalysts that will enable the synthesis gas produced by Standard Gas to be processed into valuable products such as methane and methanol. The process of renewable natural gas production will additionally produce biochar, which captures and removes carbon and can be sequestered in valuable products for the agricultural, construction and environmental industries.

Standard Gas will develop and obtain all appropriate approvals, licenses, funding and offtake agreements needed to implement the project. Standard Gas will either own and operate the potential project or license to a third-party owner.

Peter Vang Christensen, Senior Vice President, Clean Fuels & Chemical at Topsoe, said: "We are thrilled to be working with Standard Gas to address waste management, which continues to be a significant challenge to society. Standard Gas' visionary approach to waste management aligns with our own aspirations to be a global leader in carbon emission reduction technologies. This MoU marks another step forward in our shared commitment to sustainability and environmental stewardship."

Johnson Matthey demonstrates fuel cell recycling technology

Johnson Matthey (JM) has announced the successful lab scale demonstration of its new HyRefine technology for recycling hydrogen fuel cell and electrolyser materials. While there are established routes to recycle the platinum group metals (PGMs), often the ionomer isn't recovered. JM believes that this is the first ever demonstration of a circular process for the PGMs and valuable ionomer together. JM researchers have proven at lab scale that both the PGMs and the ionomer can be recovered and recycled into new catalyst coated membranes – the performance-defining components at the heart of hydrogen fuel cells and electrolysers. Separate experiments have confirmed that the recycled PGM catalysts match the performance of fresh material.

As the hydrogen economy takes off, embedding circularity is critical to conserve precious resources and minimise the environmental impact of manufacturing new hydrogen technologies. Using a purely chemical process, HyRefine offers efficiency and sustainability benefits compared to conventional PGM refining, producing metal with up to a 98% lower carbon footprint than primary (mined) metal. JM is now scaling up this technology to run 50 litre pilot trials in its facility in Brimsdown, UK.

Alastair Judge, JM's Chief Executive, Platinum Group Metals Services, said: "This demonstration of our HyRefine technology is a key step on our path to providing a circular service for our fuel cells and electrolyser customers in the future. It's a fantastic example of how we can leverage our foundational PGM ecosystem, world-leading recycling capabilities and decades of expertise in hydrogen technologies and apply this to embed circularity into the hydrogen economy."

CHINA

Approval for floating methanol plant design

Classification society Bureau Veritas has issued an approval in principle to Wison Offshore & Marine for its floating green methanol plant design. The floating plant developed by Wison will use renewable energy from wind, solar or hydroelectric power and captured carbon dioxide from onshore facilities such as power plants to produce green methanol. Compared with an onshore methanol plant, the proposed floating design has high system integration and a small footprint, and is easy to deploy, highly flexible, and can be stationed away from communities to realise greater safety and environmental protection.

"Future energy utilisation will pivot towards renewable energy and nuclear power. Wison, as a leading clean energy technology and solution provider, is committed to providing efficient integrated solutions for the energy industry. These include floating LNG facilities, onshore standard modular LNG plants, floating wind turbines, floating natural gas to methanol, floating green ammonia and other clean energy solutions," said Zhou Nan, General Manager of WOM's Product Technology Centre.

SINGAPORE

Singapore invites methanol bunker proposals

The Maritime and Port Authority of Singapore (MPA) has invited interested parties to submit proposals for the supply of methanol as a marine bunker fuel in the port of Singapore. The MPA is looking to gather proposals for the implementation of end-to-end methanol bunkering solutions in Singapore from 2025. The goal is to ensure a resilient supply of methanol to meet international bunkering needs given the expected delivery of methanol-capable vessels in the coming years. The proposals cover three areas: methanol supply sources; a methanol bunkering operation model at commercial scale in Singapore; and alternatives to the physical transfer of methanol molecules to Singapore such as mass balancing. MPA will assess the viability of various solutions in the proposals received, which will also inform and shape the development of MPA's methanol bunkering licensing framework.

JAPAN

Agreement on green natural gas

TES and Toho Gas Co., Ltd. have signed a comprehensive agreement to explore the development of a green synthetic natural gas ("e-NG" or "e-methane") supply chain in order to support Japan's decarbonisation goals. As part of this collaboration, both companies will work together to raise awareness of e-NG and design systems such as CO_2 counting rules and financial support as well as the early implementation of e-NG in society, with the aim of achieving carbon neutrality.

Takeo Haigou, Managing Executive Officer of Toho Gas, commented: "Toho Gas has set a goal for carbon neutral including our customer's site by 2050. To achieve this goal, we believe that e-methane will play a key role, and aim to supply e-methane more than 1% of our city gas sales volume by 2030. Toho Gas will accelerate these plans through the collaboration with TES."

Maersk and Port of Yokohama sign methanol supply agreement

Maersk has signed a memorandum of understanding for a potential methanol supply agreement with Mitsubishi Gas Chemical and the municipal authorities responsible for the port of Yokohama. The deal is intended to study ways of supplying methanol and green methanol as marine fuels.

ITALY

Low carbon DME proposal

MyRechemical, part of the Sustainable Technology Solutions business unit led by NextChem, and Dimeta BV have agreed to carry out a study to explore the feasibility of the development of plants to produce renewable and recycled dimethyl ether (DME) from waste, which can be used as a clean-burning fuel, based on MyRechemical's waste-to-chemicals technologies and expertise. The study will assess the regulatory environment and carry out a market analysis of available feedstock and product enhancement in Europe, with a focus on Italy. Based on the results of the study, MyRechemical and Dimeta will work then to define the best development strategy for project implementation. Dimeta, a joint venture between SHV Energy and UGI International, aims to produce 300,000 t/a of DME by the end of 2027, establishing plants in the UK, Europe and the USA.

SPAIN

Plans for green methanol plant

Spanish energy company Cepsa has partnered with C2X, an affiliate of Danish shipping firm Maersk, to build a green methanol plant in Huelva, at a cost of up to $1.1 billion. The proposed methanol plant would have a capacity of 300,000 t/a, making it one of the largest facilities of its kind in Europe. Hydrogen required for the plant's operations will be sourced from another project that Cepsa is concurrently planning – the Andalusian Green Hydrogen Valley, while the carbon source may potentially be forestry residues or even carbon dioxide extracted directly from the air.

FRANCE

Maire awarded pre-FEED contract for Engie biomethane project

Maire SpA says that its Sustainable Technology Solutions business unit, NextChem, has been awarded a contract by Engie SA to carry out a pre-front end engineering design study for the gasification and methanation of waste wood as well as the implementation of a carbon capture unit for the Salamandre project in the Normandy region. This award follows the successful completion of an advanced basic engineering study for waste wood gasification and the syngas purification system to produce second generation biomethane, which was announced in April 2023. NextChem's scope also includes the preliminary evaluation and estimate of the engineering, procurement and construction activities for the full gasification and methanation package of the project, including the relevant utilities and ancillary units, which will be considered as part of the client's final investment decision.

The plant is expected to produce 20 MW equivalent of bio-methane. The methane, produced through pyro-gasification of waste wood, will be injected into the French natural gas grid, representing one of the first industrial projects of its kind in the world.

BOTSWANA

Tender issued for coal to liquids project

In December Botswana Oil opened bidding for the country's coal to liquids (CTL) project, which aims to produce 12,000 bbl/d of synthetic fuels, equivalent to more than 50% of Botswana's annual consumption. The deadline for bids was December 22nd, with submissions to be based on a public private partnership (PPP) model. Investors will be required to design, build, finance and operate the plant based on a turnkey basis with an associated off-take agreement with the state oil firm. The investor would operate and maintain the facility for a period, ultimately transferring ownership to the government of Botswana at the end of this period. ■

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People

Incitec Pivot says that **Mauro Neves de Moraes** has been appointed as Chief Executive Officer and Managing Director from 22 January 2024. De Moraes has leadership experience in the mining and logistics sectors including as Asset President for BHP Mitsubishi Alliance (BMA) in Queensland, Australia and Asset President at BHP's Escondida operations in Chile, the world's largest copper mine.

IPL chairman Greg Robinson said: "Mauro's Australian and international mining, logistics and commercial experience is strongly aligned to our strategy as a global leader in explosives technology and services for the resources sector, and a leading supplier of fertilisers for Australia's east coast agricultural sector. The Board conducted an extensive global search process and is confident Mauro has the leadership capability, strategic insight and customer focus to lead IPL through its next phase of growth. We are confident he will bring a strong focus on performance and on creating long term value for shareholders. We look forward to him joining IPL."

De Moraes said: "I am honoured to be joining IPL to lead the Dyno Nobel and Incitec Pivot Fertilisers businesses. Safety is a priority for me, and IPL's commitment to safety for its people and stakeholders is a strength of its business. I will bring my passion for continuous improvement, high performance and a strong focus on customers as we continue to build this great company. I am looking forward to joining the talented team at IPL."

Greg Robinson also acknowledged the contribution of Interim CEO Paul Victor, "Paul has led our company with passion and commitment through the transition and focused on safely delivering results that are aligned to shareholder and stakeholder expectations. Under Paul's leadership over the past six months, our explosives and fertilisers businesses have made good progress, including delivering strong underlying second-half FY 2023 earnings growth. Paul will resume his role as IPL's Chief Financial Officer following Mauro's appointment and together, they will provide strong leadership for our company."

Omnia Group CEO **Seelan Gobalsamy** has been appointed to the board of the International Fertilizer Association (IFA). "Food security and supply chains have been propelled to the fore in recent years. Climate change is likely to exacerbate the shortfalls in the global food supply system. Joining a global organisation dedicated to solving the interlinked issues of food security, sustainability and employment has never been more important," Gobalsamy commented. "Food security is a fundamental human right and, as a company dedicated to innovation, we bear a responsibility to be at the forefront of solutions. As we navigate an era marked by climate change and a growing global population, [Omnia's] purpose as a business gains even greater significance. We are proud to be actively participating in the creation of a world where every individual has access to sufficient, nutritious food produced on a sustainable basis. Africa has an important role to play in feeding the global population, yet it is also the continent most affected by food insecurity. Omnia's unique knowledge and capabilities in developing cutting-edge solutions that address the complex challenges hindering global food security will be invaluable to our industry.

"We welcome and look forward to working with Seelan Gobalsamy on our board," said IFA CEO Alzbeta Klein.

Waste-to-hydrogen firm Compact Syngas Solutions says that **John Williams** has joined the firm as commercial director. Williams previously worked in business development for Rank, which creates Organic Rankine Cycle (ORC) modules and high temperature heat pumps. His other senior roles included director positions with ORCogen and AE Power International in the Netherlands, and include experience in negotiating RDF supply contracts, working with local authority planning guidelines and power purchase agreements. Compact Syngas Solutions, based in Deeside, Wales, has developed a gasification process that generates hydrogen gas from waste products.

Calendar 2024

FEBRUARY

5-7
Fertilizer Latino Americano, MIAMI, Florida, USA
Contact: Argus Media, Ltd.
Tel: +44 (0)20 7780 4340
Email: conferences@argusmedia.com

MARCH

4-6
Nitrogen+Syngas Conference 2024, TULSA, Oklahoma, USA
Contact: Michelle Bingham, CRU
Tel: +44 (0)20 7903 2159
Email: michelle.bingham@crugroup.com

6-7
European Green Ammonia Summit, DUSSELDORF, Germany
Contact: Marcin Janecki, ACI Europe
Tel: +48 61 646 7047.
Email: mjanecki@acieu.net

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

APRIL

15-17
Nitrogen+Syngas Conference USA 2024, GOTHENBURG, Sweden
Contact: Michelle Bingham, CRU
Tel: +44 (0)20 7903 2159
Email: michelle.bingham@crugroup.com

MAY

20-22
IFA Annual Conference, SINGAPORE
Contact: IFA Conference Service, 49 Avenue d'Iena, Paris, F75116, France.
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

JUNE

6-7
NH3 Event, ROTTERDAM, Netherlands
Contact: Stichting NH3 event Europe, Karel Doormanweg 5, 3115 JD Schiedam, The Netherlands
Tel: +31 10 4267275
Email: info@nh3event.com

SEPTEMBER

9-12
AIChE Ammonia Safety Symposium, SAN DIEGO, California, USA
Contact: Ilia Kileen, AIChE
Tel: +1 800 242 4363
Web: www.aiche.org/ammonia

29 – OCTOBER 4
Ammonium Nitrate/Nitric Acid Conference, MONTREAL, Canada
Email: annaconferencehelp@gmail.com
Web: annawebsite.squarespace.com

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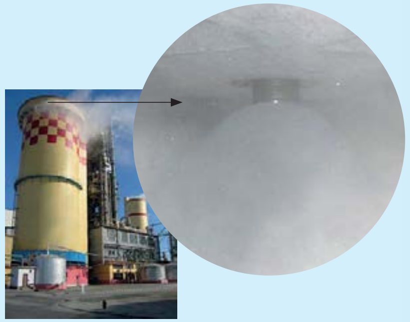
Plant Manager+

Problem No. 71 Fouling and damage of prilling tower air fans

Today some 75% of all urea plants worldwide operate a prilling tower as the solidification and finishing technology. A prilling tower is a large hollow concrete tower in which concentrated urea melt is sprayed from the top via a rotating bucket or static shower heads. The urea melt droplets cool and solidify while falling down some 70-100 m. The heat is removed by ambient air flowing upwards either as a natural draft due to the temperature increase or forced by means of air blowers.

The air gets contaminated with ammonia and urea dust. A major part of the urea dust is a result of the sublimation reaction of ammonia and isocyanic acid which are formed from the urea melt at higher temperatures. This urea deposits on cold spots forming a hard layer, e.g., on the fans of the air blowers in the top of the prilling tower. Learn from this UreaKnowHow.com round table discussion about the possible consequences and solutions of this operational and maintenance issue.



Ali Ançaza of Igsas, Turkey starts up this round table discussion: Our prilling tower air fans experience frequent mechanical failures. What are your experiences, opinions and suggestions regarding issues with the air fans?

Mr. Yusuf Ugur of Igsas, Turkey replies: Please explain what you mean by mechanical failure of the fans.

Ali comes back with more information: Urea dust accumulates on the blower fan blades and in the inner hips. There is a balance distortion in the fan blades. The fan experiences excessive vibrations. Due to the vibrations, there are deformations and cracks. Refer to the pictures.

Prem Baboo, Retired from NFL, India and Dangote Fertilizer, Nigeria and Expert of UreaKnowHow.com shares his valuable experiences: Prilling tower ID fan problems are created due to:

- urea deposition on the blades leading to an imbalance; urea build-up causes vibrations;
- looseness of hanger brackets;
- urea ingress in internal parts of the fan, e.g,. bearing, lubrication points.

The remedies are:

- periodical maintenance is required, circulate grease through extended grease line in the bearing, rotate shaft while purging grease and correctly align;
- perform NDT inspections weekly;
- remove urea deposits from duct weekly;
- inspect ingress parts of the fan;
- balance the fan;
- check all bearing and drive set screws, hold down bolts and motor mounting bolts for tightness;
- check all supporting hanger brackets;
- check suspension nut/washer and clips;
- check hanger rod for any bending.

Yusuf comes back with a question: Are there any chemicals that will prevent the adhesion of the urea on fans?

Prem replies: No chemical is available to protect urea deposition. Simply wash with hot water; only five minutes is required.

Mark Brouwer of UreaKnowHow.com, the Netherlands joins the discussion: What is your opinion about PTFE or some kind of oil? Do You believe that may work on the fan blades?

Naseemce from SABIC Agri-Nutrients Company, Saudi Arabia shares his valuable experiences: Urea dust deposit is the usual cause of the fan becoming rigid or for the bearings to seize. Vibration monitoring is one way to reduce this risk as well as monthly cleaning with hot steam condensate. These are called induced fans and are installed at the top of the tower or dust scrubbers.

Prem replies: Coating with PTFE is absolutely no problem. Typically, the PTFE coating is 35 microns +/- 10 microns. Lower thicknesses can be achieved with good coating practices. This type of coating generally is used for anti-corrosion or electrical insulation. The ID fans used in the prilling tower top is made of 304L.

PTFE coating does not protect from urea deposition.

We use waste oil on the scraper arms in the bottom of the prilling tower. This oil treatment also helps to remove the urea layer more easily. But unfortunately, oil treatment is not suitable for the ID fans.

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Europe's natural gas challenges

As Europe struggles to move away from its previous dependence on imported Russian natural gas, prices have been high and volatile, with a corresponding catastrophic impact upon domestic ammonia production.

PHOTO: TOTAL

The Culzean natural gas field off the coast of Scotland.

Europe has been faced with a huge shake-up in the way that its gas and energy markets work over the past two years, with major implications for the future of ammonia and methanol production across the continent.

Natural gas prices have been something of a rollercoaster over the past few years, beginning in 2020, when coronavirus lockdowns and mild summer weather reduced continent-wide demand for natural gas, leading to low prices. This was followed by surging demand after the easing of lockdowns, combined with a cold winter in 2020-21 which left storage depleted, and then a prolonged period of still air in the summer of 2021 which led to low output from Europe's large wind-powered electricity generation sector. Combined with pandemic-delayed maintenance on gas pipelines from Russia and Norway, and a fire at an electricity sub-station in the UK handling a cross-Channel power cable which left the country unable to import electricity from France and having to rely on gas-based generation capacity, there was already a major spike in European gas prices by late 2021, even before Russia's invasion of Ukraine. However, the onset of war and the subsequent sanctions regime on Russia led to Russian curtailments of natural gas deliveries to Europe, pushing prices still higher. By August 2022 the Dutch TTF gas prices had risen to euro320/MWh (approximately $100/MMBtu). The Nordstream 2 pipeline had already not received certification by the German authorities, and in September sabotage destroyed the Nordstream 1 pipeline across the Baltic Sea.

Dependence on Russia

Europe's problem was that a combination of circumstances had left it extremely dependent upon supplies of gas from Russia in spite of attempt to diversify its supply. Previously a lot of electricity generation had relied upon coal and nuclear based generation, but stricter climate and energy policies had gradually forced the closure of most of the continent's coal-based capacity, and environmental concerns had also led to a winding down of nuclear power generation, particularly in Germany. While there was a corresponding rapid increase in power generation from renewable sources, these are intermittent by nature, meaning that base load generation must rely on natural gas. Gas is also widely used for domestic heating – around 30% of European homes use natural gas for heating.

Europe had long been a collective importer of natural gas. Its own gas fields, mainly in the North Sea, as well as Romania, are mature and in long term decline. There have also been concerns over the Groeningen gas field offshore of the Netherlands, where seismic issues as the gas basin empties have led to a rapid winding down of production there. As a result Europe's gas deficit has grown greater. In 2021, the EU-27 consumed 412 bcm of gas, but only produced 70 bcm, meaning that 83% of its gas requirements were imported from outside the EU in 2021.

Europe imports gas from North Africa and Norway, and there is also rapidly growing liquefied natural gas (LNG) import capacity. However, the continent has a significant infrastructure of gas pipelines connecting it to gas fields in Russia, many dating back decades to when the countries of eastern Europe such as Poland and Romania were part of the Soviet sphere of influence. Germany had also pursued a policy of engagement with the USSR and later Russia – so-called 'ostpolitik' – which had encouraged gas import via pipeline. The consequence was that by 2021, 50% of Europe's gas imports, or just over 40% of all gas consumed in Europe, came from Russia. But for countries like Hungary, that dependence was 95%, and in Germany, the economic powerhouse of the continent, it was 65%.

A new reality

Since February 2022, however, the continent has been forced to come to terms with a new reality. Just as Europe and the US have tried to put economic pressure on Russia via sanctions, so Russia has put pressure on Europe by curtailing gas supplies. Of the five major pipelines that run from east to west, three have been shut down. The Soyuz pipeline across Ukraine was closed in May 2022 by Ukraine, as much of the pumping infrastructure was in Russian-occupied territory. The Yamal-Europe pipeline also closed in May 2022 after Moscow halted gas flows to Poland and sanctioned the firm that owns the Polish section of the pipeline. The second stage of NordStream pipeline across the Baltic had already been on hold due to delayed German certification, and then the first state was destroyed by underwater sabotage in September 2022, with both sides casting blame at the other. Only the Blue Stream pipeline across the Black Sea to Turkey and the Brotherhood pipeline across Ukraine into Hungary remain operational, the latter at much reduced flow rates as a favour to Hungarian president Victor Orban, who has been much friendlier to president Putin than his neighbours. The contract covering that pipeline's operation will expire in December 2024, however, with neither side willing to extend it, and it is unclear to what extent ad hoc agreements to keep it running will be possible.

The consequence of these restrictions is that Russian deliveries of gas to the EU dropped to 27 bcm in 2023, as compared to 167 bcm in 2021, and may yet fall still further.

Policy response

The response by European authorities has been a duel pronged approach of managing demand and looking for alternate sources of supply. Pipelines from Norway and Algeria have been running close to capacity, but to make up the shortfall Europe has turned to imports of liquefied natural gas (LNG). EU imports of LNG surged by 60% in 2022, and have risen another 8% in 2023. The US has been a key supplier, with around 9 million t/a of new long term supply contracts signed in 2022, as well as Qatar and Nigeria. Prior to February 2022 the EU had 21 operational LNG import terminals and one mothballed. Since then it has crash-built and opened a further six. LNG import capacity was 160 bcm in 2021 but has risen to 200 bcm in just two years, and projections are that it could be as high as 350 bcm by 2030 if all current and planned projects come to fruition.

Capacity is one thing, however, and actual physical imports another. EU figures show that while 2023's LNG imports were at a record level, they only reached 141 bcm. Most of this (40%) came from the United States, with Qatar and – ironically – Russia supplying around 13% each. Russia's LNG exports were not subject to sanction and so have been a workaround for both producers and consumers. Overall the EU imported 302 bcm of gas in 2023, down from 326 bcm in 2022. LNG imports have been helped by the fact that the global LNG market is in a period of oversupply, keeping prices lower.

The other side of the coin is demand, and in order to make its gas go further, the EU has tried to manage demand to reduce import requirements. Some of this has been assisted by weather – a mild winter in 2022-23 certainly helped. The EU also managed to fill its gas storage capacity during 2022 ahead of that winter, and storage levels have been high going into the winter of 2023-24, helping to keep pricing down. Storage levels at the end of December 2023 were 86.5% of capacity according to Gas Infrastructure Europe, a record level for December.

High gas prices in 2022 also helped reduce demand, particularly among industrial consumers who were forced to cease operations, more on which in a moment. Overall EU gas demand fell by 56 bcm in 2022 (around 13%), and by another 7% in 2023, and most of this fall in demand has come from the industrial sector, which represents around 20% of European gas demand. Around 2/3 of this is represented by three sectors: pulp and paper, chemicals (including syngas-based chemicals) and non-metallic minerals, all of which have seen drastic declines in consumption. Overall, the International Energy Agency (IEA) estimated that about half of the decline in industrial gas demand in the EU27 in 2022 came from production curtailment and about 30% from switching to alternate fuels, with the remaining 20% coming from efficiency gains, import substitutions, and milder weather.

Pricing

European gas prices rose precipitately in 2022, both due to the supply crunch going into the year and then concerns about Russian supply from February onwards, with peak pricing reached in August 2022. To mitigate the effects of energy prices on both households and firms, EU governments were forced to adopt several fiscal support measures in the form of energy tax abatements, energy price ceilings, and fiscal transfers to vulnerable parts of the population. These measures inevitably burdened governments' finances: European countries allocated over €650 billion between September 2021 and January 2023 to address the impact of the energy crisis.

However, since then the combination of supply switching, demand curtailment and

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clement weather over 2023 has meant that European gas prices have fallen steadily, down to around $10/MMBtu for the Dutch TTF price in December 2023, a drop of 45% over 4Q 2023 to its lowest level since early 2021, and comparable to winter pricing across most of the 2010s.

In spite of a cold snap in Europe in January, European gas supply remains relatively comfortable, and the LNG market remains fairly well supplied, with 60 new LNG vessels due to be commissioned in 2024. The main factor that could push prices up is the ongoing disruption to shipping in the Red Sea due to missile and drone attacks by Houthi rebels. This has forced Qatari LNG tankers to divert around the Cape of Good Hope, adding to travel time and shipping costs. A more worrying prospect might be the further widening of the conflict in Gaza. If Iran were drawn into the conflict and LNG tankers were prevented from leaving the Straits of Hormuz, through which Qatar alone shipped 108 bcm of LNG in 2023, prices could reverse dramatically. Absent that, though, Europe looks to have dealt with its gas supply crisis for now.

Ammonia production

Europe's ammonia production was badly affected by the record gas prices in 2022. By the time that prices peaked in August 2022, it was estimated that around 70% of ammonia production capacity across the continent had been idled. This coincided with ammonia prices of over $1200/tonne in Europe, especially as supplies from the Black Sea were virtually halted. Even though Russian fertilizers were not subject to sanctions, the closure of the ammonia pipeline to Odessa put a halt to most Russian ammonia exports. High European ammonia prices drew in imports from all over the world, especially the US.

Since then, the fall in gas prices over the past year have brought ammonia production costs down towards $500/t for European producers, but this is still high compared to market rates, and while some capacity has restarted, it remains an open question as to how much of the European ammonia industry will survive the current crisis. Fortunately the ammonia market has been in a relatively well supplied condition, with several new plants starting up, and this has allowed European fertilizer producers to save money by closing ammonia plants and importing it instead to feed downstream urea and ammonium nitrate production. One notable recent casualty of this was CF Industries, which late last year closed down its last remaining ammonia plant at Billingham, and the site is now reportedly importing ammonia from the US.

However, many end use plants without easy access to import ports have also closed. Table 1 shows European ammonia production and imports over the past few years. As can be seen, total Western European ammonia production has been falling, reaching 14.8 million t/a in 2021, down from 16.1 million t/a in 2020, but this figure fell to 10.8 million t/a in 2022. Full figures for 2023 are not yet available, but likely to be comparable to 2022. But at the same time, imports have not increased dramatically, showing that many producers have chosen to simply idle plants.

Table 1: Western European ammonia production and net imports, million t/a

Year	Production	Net imports
2017	16.9	2.9
2018	16.3	3.1
2019	15.8	3.6
2020	16.1	3.2
2021	14.8	3.8
2022	10.8	3.2

Source: IFA

The outlook for 2024 and beyond

There still seems to be no sign of the war in Ukraine stopping, although the failure of major offensives by both sides during 2023 have let it settle into a grim stalemate. Nor does either side seem to be inclined to negotiate to bring fighting to a halt at present. The only sign of war weariness is among the western nations backing Ukraine, although the EU is on the verge of signing a deal to approve $55 billion in funding for Ukraine if Hungary can be placated, and the UK recently agreed to increase its military aid to £2.5 billion in 2024 ($3.2 billion). The US Congress is still arguing over a $60 billion aid package to Ukraine as it has become tied up with other concerns such as Israel, Taiwan and funding for US border controls in what is now a mammoth $110 billion spending bill. Nevertheless, aid of some kind is likely to be approved. The difficulty for Ukraine may come if November delivers a Trump presidency far more sceptical of spending money to keep Ukraine fighting. Indeed, some have suggested that this is precisely what president Putin is relying upon to rescue him from the impasse he has created.

What this means is that for the moment Europe will continue to be gas constrained, although rapidly increasing LNG import capacity and lower demand mean that gas prices are unlikely to return to their peak of 2022. Nevertheless, on LNG markets Europe must compete with Asian economies like India and Japan, and while European gas deregulation means that gas prices in Europe are no longer substantially linked to oil prices, many LNG contracts still are, which also makes Europe vulnerable to oil price shocks. In general LNG imports are the most expensive form of gas, and this is likely to keep European gas relatively expensive compared to other locations.

This of course has a knock-on effect on the ammonia industry, and much of European production is likely to be towards the upper end of the cost curve, potentially make it seasonal or encouraging further closures and the import of ammonia from overseas.

There is of course a drive in the ammonia industry towards sustainable or lower carbon production, and this has driven a large number of projects for green and blue ammonia production, especially in Europe. However, from a cost point of view blue ammonia projects, which tend to be the larger tranche of new production, are still based on natural gas feedstock, and with the added cost of carbon capture and storage are likely to struggle just as much as conventional ammonia production in Europe. Green projects tend to have higher production costs still.

There may be some relief for this once the Carbon Border Adjustment Mechanism becomes established. The CBAM began its transitional phase on 1st October 2023, with the first reporting period for importers ending on 31st January 2024. Placing what amount to environmental tariffs on imported ammonia may help European producers to compete and encourage further blue and green production. At the moment, however, the future looks difficult for European ammonia producers and a corresponding opportunity for producers in the US, which could become a net exporter of ammonia this year. ■

Russian nitrogen capacity and exports

In spite of nearly two years of western sanctions, Russian exports of nitrogen fertilizer have recovered almost to pre-war levels, while high prices led to record earnings in 2022.

With huge reserves of natural gas, Russia has long been one of the world's largest producers of ammonia and downstream nitrate fertilizers and chemicals. In 2021, Russia accounted for 12% of ammonia production globally, as well as 14% of urea and that year it was also the world's second largest ammonia producer (after China) and the largest exporter. In 2021, Russia exported 4.4 million tonnes of ammonia, representing 30% of all traded ammonia.

Initially it was assumed that the imposition of stringent sanctions following the invasion of Ukraine in February 2022 would led to a major drop in Russian exports of ammonia, urea and ammonium nitrate. Although fertilizer products were not themselves subject to sanctions, the closure of the trans-Ukraine pipeline to the Black Sea at Yuzhnyy, near Odessa, and banking and financial sanctions which made payments difficult were expected to dramatically reduce shipments of fertilizer to the west.

As we discuss elsewhere in this issue, the major impact in 2022 was upon natural gas prices in Europe, with a knock-on effect on European ammonia production. By August 2022, ammonia prices were at $1,200/t and around half of Europe's downstream nitrogen production was idled. Russian ammonia exports were indeed affected, and reduced to low levels during 2022. The UN Food and Agriculture Organisation says that Russian ammonia exports fell by 76% in 2022 compared to 2021. However, exports of fertilizer from Russia declined only by around 15% overall in 2022, according to the Russian Fertilizer Producers Association, and the much higher prices that were being achieved, particularly on the nitrate side in Europe, meant that export revenue for fertilizers actually increased by 70% in 2022 in spite of this. The direction of exports did change substantially, however, with a substantial increase in supplies to India, Southeast Asia, and the Middle East, primarily Turkey. Ironically, the shutdown of EU fertilizer production meant that EU countries also increased their purchases of nitrogen fertilizers from Russia, mainly exported via the Baltic Sea.

Prices began to drop in the last quarter of 2022 and across 2023, and European production began to return. Nevertheless, Russian exports in tonnage/volume terms increased in 2023. Transit of ammonia from Togliatti Azot to Yuzhnyy formed part of the talks around the Black Sea grain export agreement between brokered by the UN between Russia and Ukraine. However, talks collapsed

Quotas

Russian exports have been restricted not just by sanctions by also by domestically imposed export quotas. Russia had imposed fertilizer export restrictions back during the gas price spike of 2021-22, aimed at keeping sufficient volumes of fertilizers in the domestic market. While the quota for urea was above the normal seasonal export amount, the quota for export of Russian AN for the six months from December 1st 2021 was just 744,000 tonnes; less than half the amount that would usually be exported over that period. This was followed in January 2022 by a complete ban on AN exports during February and March, later extended to April. On May 1st exports were allowed again, but the quotas from late 2021 were back in force, and these were extended from July 2022 to December 2022, with only 8.3 million tonnes (product) of nitrogen fertilizers and 5.95 million tonnes of complex

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fertilizers permitted to be sold overseas; approximately 60% of what would normally be shipped pre-sanctions. Sanctions continued through 2023; in May 2023 a total export quota of 16.3 million tonnes was agreed for the six months to the end of November. The restrictions were again extended from December to May 2024, setting the quota for the six month period at 16.95 million tonnes, including 9.81 million t/a for nitrogenous fertilizers and 7.14 million t/a for complex fertilizers. The Russian Fertiliser Producers' Association has proposed replacing quotas with a licensing system, but the Russian government has decided to stick with the quota system for now. Russian domestic fertilizer demand rose by 20% in 2021 and 2022 according to the Russian Fertilizer Producers Association.

Changing trade patterns

With transit through the Black Sea subject to severe restrictions and the port of Sevastopol subject to intermittent Ukrainian air attack, Russia is trying to rapidly develop new export port capacity in other locations along its coastline. At Ust-Luga, west of St Petersburg on the Baltic Sea, where a major fertilizer export terminal has been under construction to join existing dry bulk and container export capacity, capacity is being expanded from 7 million t/a to 8 million t/a by JSC National Transport Company, part owned by EuroChem with the addition of 1 million t/a of ammonia export capacity.

On the Sea of Azov, a tributary of the Black Sea, the port of Tuman is being developed by Uralchem for ammonia export at a cost of $825 million. First ammonia is due to be shipped this year, with the project completing in 2025 with a final export capacity of 2 million t/a of ammonia and 3 million t/a of urea. Finally, a terminal to handle fertilizers is to be built in Primorsk Kray in the Russian Far East as part of the Nakhodka mineral fertilizers plant project, one of the major investment projects currently under development in the region.

Nitrogen production

Russia is a key player in the ammonium nitrate market. In 2021 it produced 12.3 million t/a of ammonium nitrate and 550,000 t/a of calcium ammonium nitrate, of which it exported 4.3 million t/a of ammonium nitrate (1.5 million tonnes N), which represented almost 50% of the international market. Production was at a similar level in 2022, but exports dropped to 2.8 million t/a.

On the ammonia side, Russia produced 19.9 million t/a in 2021, the bulk of it consumed domestically for downstream fertilizer production, which dropped to 17.0 million t/a in 2022. Exports fell from 4.4 million t/a in 2021 to 1.7 million t/a in 2022 due to the closure of the pipeline across Ukraine. Morocco and Turkey were the main recipients in 2022, but a substantial amount also reached Europe.

Russian urea production was 9.8 million t/a in 2021, and exports were exports in 2021 were 7.0 million t/a. This made it the world's single largest urea exporter, with around 18% of the global market. Urea production actually increased in 2022 to 10.4 million t/a, and exports to 8.3 million t/a, with Brazil and India the main recipients, but again substantial volumes travelling to Europe.

Russia also exported around 2.2 million t/a of urea ammonium nitrate (UAN) in 2021. This became a bone of contention that year when CF Industries brought a case before the US International Trade Commission alleging that UAN solutions from both Russia and Trinidad had been illegally "dumped" (i.e. sold at below the notional cost of production and export) on the US market. However, no countervailing duties were imposed, and UAN exports were still 2.0 million t/a in 2022.

Thanks to its abundant natural gas reserves, in recent years Russia had been engaged in a number of expansion projects. New urea production began at Metafrax's AUM plant at Gubakha in 2023, with 300,000 t/a of ammonia and 500,000 t/a of urea capacity, as well as 40,000 t/a of melamine production. In Novgorod, Acron commissioned a new 700,000 t/a urea line in 2023, taking the company's total urea capacity to 2.4 million t/a. KuibishevAzot completed work on a new nitric acid and 760,000 t/a ammonium nitrate plant last year.

There was also a new ammonia-urea production line under construction at Kingisepp in the Baltic for Swiss-based EuroChem. The 1.4 million t/a plant was being built by Tecnimont using KBR and Stamicarbon technology, and due for completion in 2024, but Tecnimont ceased work on the plants in 2022 and the matter is now embroiled in a legal dispute between Tecnimont and EuroChem.

Though not quite in Russia, Grodno Azot in Belarus has been debottlenecking its number 3 and 4 ammonia plants at Grodno. The company says that the upgrades will increase ammonia production to 2,100 t/a, with an additional 310,000 t/a of capacity, most of which will be used to expand downstream production of urea and UAN.

New production

In spite of sanctions, there are also still ongoing plans for new production. In the Far East of Russia, a new fertilizer plant is under development at the port of Nakhodka, near Vladivostok, at a cost of $6.3 billion. The complex includes both methanol and nitrogen fertiliser production, including 1.8 million t/a of methanol in phase 1 and 3 million t/a of urea in Phase 2. The company says that its cash production costs per tonne will be among the lowest in the world. The project is supported by Russian state-owned banks, local authorities and the federal government. Phase 1 (methanol) is scheduled for completion in 2025, with urea production to follow later.

Further down the line, Ammoni has plans to develop new capacity at its existing site at Mendeleevsk in Tatarstan, including a new ammonia and urea train using a lower energy process. Production capacity will be 1.2 million t/a of ammonia and 1.75 million t/a of urea. The new train is planned to be commissioned in 2027-8.

KAO Azot also has plans for large scale ammonia and urea production; 1.2 million t/a of ammonia and 1.4 million t/a of granular urea. Also planned at the site is production of 50,000 t/a of liquid carbon dioxide and 250,000 t/a of granulated ammonium sulphate (250,000 tonnes per annum).

Russia also has plans to develop green hydrogen production for export, primarily aimed at Europe as the continent attempts to decarbonise, with up to 2 million t/a of hydrogen generated via nuclear power or renewable energy to be exported by 2035. There are also plans for blue hydrogen production using carbon capture and storage. Russia is targeting Europe and Asia as key export markets. It plans to create at least three hydrogen clusters – in the northwest for European exports, the east for Asian supplies, and the Arctic for domestic consumption and potential exports. ■

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HIGHLIGHT 3
Nitrogen+Syngas 2024 Conference preview

NITROGEN+SYNGAS
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Gothenburg city in Sweden

CRU Nitrogen + Syngas 2024

Join us at CRU Nitrogen + Syngas 2024 in Gothenburg, 4-6 March, for a truly global gathering of the nitrogen and syngas community, where leading producers and technology experts will gather to connect, share knowledge, exchange ideas and learn about the latest developments in operations, technology, process and equipment.

The Nitrogen + Syngas 2024 Conference and Exhibition will take place 4-6 March at the Gothia Towers, in Gothenburg, Sweden. As one of the most respected technical events in the industry, CRU's Nitrogen + Syngas conference has a proven track record of bringing together senior technical professionals from across the nitrogen and syngas value chain to share experiences and best practices. Now in its 37th year, the conference represents one of the largest gatherings for the global nitrogen and syngas industry - spanning ammonia, urea, melamine, methanol, syngas, hydrogen, nitrates, nitric acid, and fertilizers.

The conference runs alongside an exhibition of world-class process, materials, equipment and technology solution providers who bring invaluable expertise to the audience. Ample networking and meeting time is scheduled throughout the agenda to maximise interaction for business networking and peer-to-peer knowledge sharing.

As the industry strives to meet the transition to renewable energy sources and to achieve sustainable and profitable plant operation the 2024 agenda will address the challenges of decarbonisation and help operators to unlock the full potential of their plants.

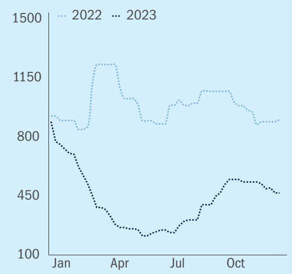
The 2024 agenda

This year's comprehensive agenda with a record 83 papers will feature industry insights from CRU's nitrogen analysts and other industry experts on the first day of the conference followed by two days with a three-track streamed agenda showcasing the latest technology, process, materials and equipment developments that are driving operational efficiency, sustainability and reliability for nitrogen and syngas producers. With a significant focus on energy efficiency and low-emission technologies for blue and green ammonia, hydrogen and methanol production, there will also be dedicated sessions focusing on innovations in digital tools for process design, production, plant monitoring, and operator training as well as a dedicated workshop on low carbon projects.

Chris Lawson, Head of Fertilizers at CRU sets the scene for this year's event:

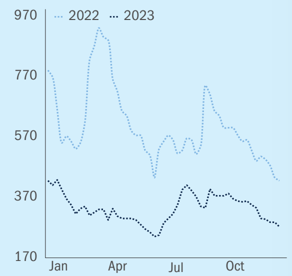
"Nitrogen prices have crashed back to reality after soaring in 2022. But market fundamentals remain dynamic and price volatility has reared at multiple points over the past year. Producers and project developers are excited for the changing long-term structure of the industry. European players face an almighty challenge as gas prices remain high and policy evolves to penalise high carbon intensity production and imports. Geopolitical risk is at an all-time high. Investment is flowing into the US on the back of the inflation reduction act, but uncertainty over policy stipulations lingers over final investment decisions. New end markets are evolving. There has never been a more important time for the nitrogen and syngas industry to gather and discuss the market and what the future holds. Join this market leading event to get the most actionable takeaways on nitrogen, ammonia, hydrogen and syngas."

Fig 1: **Ammonia f.o.b. Middle East spot, $/t**



Source: CRU

Fig 2: **Urea granular f.o.b. Black Sea spot, $/t**



Source: CRU

For more information about the event, visit www.nitrogensyngas.com

Technical programme highlights

A selection of abstracts from the 2024 technical programme

Sustainable maritime transportation: Reducing emissions from ammonia-fuelled ships

Enercat

Ammonia has emerged as a promising green alternative to marine fuels due to its zero-carbon potential. However, the combustion of ammonia can produce nitrogen oxides (NOx) emissions, nitrous oxide (N_2O) emissions and ammonia (NH_3) emissions from the engine alongside various vents related to storage and use.

While selective catalytic reduction for NOx abatement is already being used on numerous vessels using standard vanadium-titania catalyst, N_2O emissions are still be addressed as they could completely offset the benefit of using a zero-carbon fuel.

Enercat has investigated the potential of zeolite catalysts for the abatement of NOx, NH_3 and N_2O emissions from NH_3-fuelled engines in combined or multi-staged beds and will share their findings.

H_2 Magallanes: A journey to future of green ammonia

TotalEnergies

TEH2, a new joint venture between Total Energies (TTE) and EREN Groupe has assessed the technical constraints and economic evaluation of developing a massive green ammonia plant in Magallanes, Chile. The study looked at the impact of intermittency and its effect on the green ammonia chain in terms of sizing, operability, energy efficiency and GHG emissions. The green ammonia chain consists of renewable onshore wind farms, electrolyser hubs, hydrogen pipelines, gaseous hydrogen storage, ammonia plant and export terminal of liquefied NH_3. Different ammonia export solutions have been evaluated.

Energy reduction at Yara urea plant in Ferrara Italy

Yara Belgium SA/NV

Yara will discuss two projects showcasing how to revamp and improve the energy efficiency of existing plants. The first is a joint project with Casale to reduce the urea plant process consumption by installing heat recovery, optimising the main process parameters and the steam network, reducing the steam imports from the CO_2 compressor steam turbine and stop venting LP steam. The second is a project involving replacing the CO_2 compressor steam turbine (condensing type) with a counterpressure type, integrated in the ammonia steam network. The results obtained after project implementation in 2015/2016 led to more than 40% reduction of the total energy consumption per GJ/t urea.

In-service monitoring of heat exchanger tube wall thickness

Schoeller-Bleckmann Nitec (SBN)

SBN's patented sensor technology provides up-to-the-minute data, facilitating a shift from fixed preventative maintenance to a more adaptive, condition-based strategy. Consequently, decisions regarding costly and time-consuming plant shutdowns can be driven by actual data instead of relying on time-based estimates. This presentation showcases two distinct patented sensing systems based on ultrasound and fibre optic technology, designed for continuous monitoring of individual heat exchanger tube wall thickness in high pressure, high temperature operating conditions.

Maximising the storage of liquid ammonia in large-scale flat bottom tanks

Linde GmbH, Linde Engineering

As the use of liquid ammonia continues to expand beyond the fertilizer industry to an attractive hydrogen and energy carrier, there is a growing demand for even larger storage sizes, nearing those of LNG. This presentation will review the currently built and planned ammonia storage tank sizes. Starting with a summary of the available storage concepts and state-of-the-art design features for these tanks it will then discuss how they relate to the maximal storage capacities. This includes an in-depth look at current regulation, design solutions, material selection and maintenance requirements.

Ammonia cracking by Technip Energies

T.EN Netherlands

Technip Energies will introduce a low energy intensity ammonia cracking technology, building on decades of experience in hydrogen production and ammonia cracking. The proposed technology is a combination of high heat recovery and a commercially proven cracking catalyst. While traditional cracking technologies make use of high-grade process heat to generate steam, the proposed ammonia cracking concept offers the possibility to utilise high-value heat to provide additional ammonia cracking efficiency and energy savings, as well as reduce operating costs, by reducing the firing duty.

Reducing primary energy costs through pioneering advances in heat exchange applications

Solex Thermal Science

The energy involved in the production of fertilizers represents one of the industry's most significant operating costs. The IFS (International Fertiliser Society) has singled out several areas of the fertilizer production process where operators have opportunities to reduce their consumption of fuel gas, notably through the recovery of waste heat from existing process loops. This presentation will focus on how both plate- and pipe-based heat exchanger can be used as waste heat recovery mechanisms that subsequently improve the energy management practices of today's fertilizer producer. Real world examples will demonstrate how this technology is actively decarbonising industrial process operations worldwide.

Mechanical design of ultra low energy reactor for large capacity urea plants

Stamicarbon

Stamicarbon successfully introduced the Ultra-Low Energy (ULE) reactor concept with the commissioning of two ULE urea plants in 2021. Both plants had a nameplate capacity of 2,334 t/d. Leveraging on the excellent corrosion resistant properties of Safurex, the mechanical design of the ULE reactor features a double bundle connected to an internal tubesheet. This concept is only suitable for plant capacities of up to 2,500 t/d urea plants. For plant capacities above 2,5000 t/d, Stamicarbon has developed a new design and the first large capacity ULE plant with a name plate capacity of 3,850 t/d was licensed in 2022. In this presentation the conceptual design of the new ULE pool condenser will be highlighted. ■

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Methanol synthesis using renewable energy

Toyo Engineering Corporation (TOYO), a global leading engineering contractor, has developed g-Methanol® technology. Methanol, traditionally produced from fossil resources, is now gaining attention for synthesis using carbon dioxide and hydrogen from renewable sources. This article explores methanol synthesis technology and the challenges in utilising renewable energy sources.

To achieve carbon neutrality by 2050, there is a significant emphasis on capturing, utilising, and storing carbon dioxide (CO_2). Methanol, traditionally derived from carbon-based resources like natural gas and coal, has been widely used as a chemical product and fuel. Recently, there's been a shift towards methanol synthesis from CO_2 and hydrogen from renewable sources. In Japan, methanol is attracting attention as a raw material for chemicals, mainly through ARPChem (Artificial Photosynthesis Chemical Process Technology Research Association) as well as e-fuel. This article explores methanol synthesis technology and the challenges related to using renewable energy.

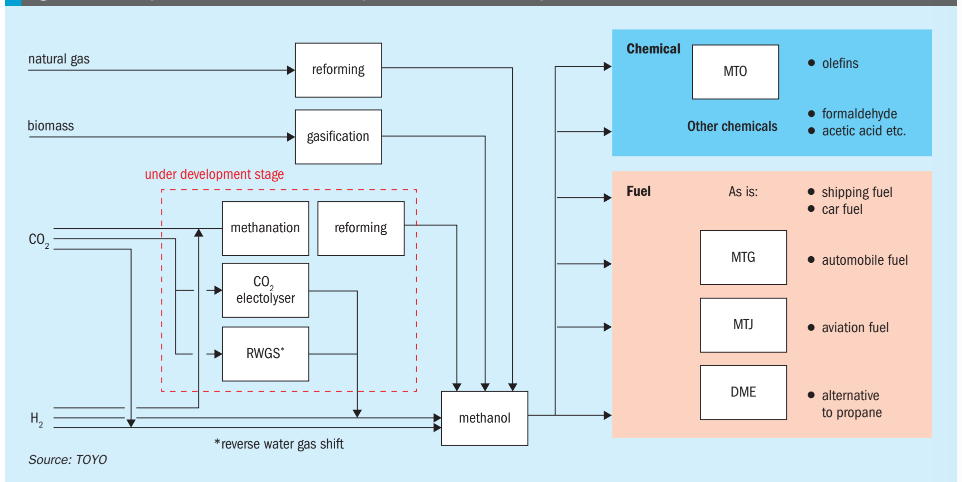
Demand for methanol globally and in Japan

Methanol, consumed globally at 92 million tonnes annually, serves mostly as a raw material for chemicals (70%) and as fuel (30%)[1]. Traditionally sourced from natural gas, recent focus has shifted to low-carbon alternatives like biomethanol and CO_2-derived methanol using renewable sources (Fig. 1). These variants maintain quality while reducing the carbon footprint of production. By using low-carbon methanol, existing applications can cut CO_2 emissions without altering processes or facilities. Furthermore, in the fuel field, where CO_2 emissions reduction is urgently needed, low-carbon methanol can be directly used as marine and automobile fuels. Additionally, fuels through processes such as MTG (Methanol to Gasoline) and MTJ (Methanol to Jet), can be deployed as automobile and aviation fuels that can be directly dropped into existing infrastructure without requiring a revamp.

In the chemicals sector, olefins have so far been produced in China from coal-derived methanol by MTO (Methanol to Olefins). Low-carbon methanol could offer a clean route for olefin production. In addition to its conventional use, the promising expansion of methanol as a fuel is expected to rise dramatically to 500 million tonnes by 2050, marking a fivefold increase from 2020[2].

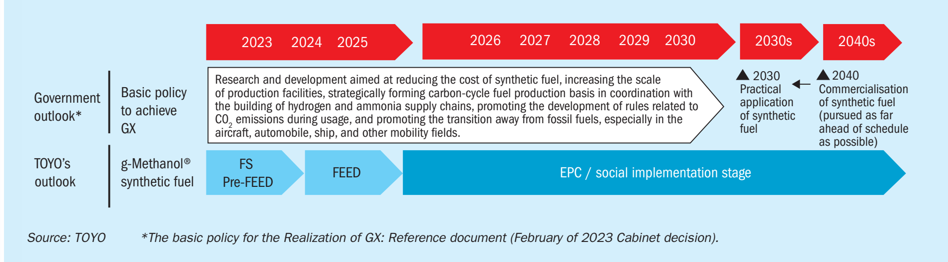
In Japan, the carbon recycling roadmap was updated by Japan's Ministry of Economy, Trade and Industry (METI). Methanol is highlighted as a key substance for chemicals and fuels. The national policy, announced in February 2023, outlines the future promotion of synthetic fuels as part of the GX realisation strategy, aiming to transition towards a carbon-neutral society using existing infrastructure and CO_2 utilisation (Fig. 2). As hydrogen costs from renewable sources decrease, synthetic fuels are expected to gain traction. Japan targets commercialising these fuels by 2030 and aiming for widespread use by 2040, prioritising early adoption. In particular, methanol has already been commercialised as a marine fuel, and since the market can be shifted to aviation fuel in the future, CO_2 methanol is expected to be implemented in society at a relatively early stage.

Fig. 1: **Methanol production routes and development into downstream products**



Source: TOYO

Fig. 2: **Roadmap for the introduction of synthetic fuels**



Source: TOYO *The basic policy for the Realization of GX: Reference document (February of 2023 Cabinet decision).

Methanol synthesis from CO_2 and H_2 from renewable sources

TOYO's g-Methanol® process

TOYO is developing a low-carbon methanol process called g-Methanol®, utilising CO_2 and hydrogen from renewable sources, as shown in Fig. 3. The hydrogen is generated through electrolysis using renewable energy.

Fig. 4 shows a typical scheme for a CO_2 methanol plant. The reforming process in the conventional natural gas scheme is replaced by a water electrolysis facility and a CO_2 recovery facility, while the conventional schemes are applied to the synthesis and distillation sections. In terms of overall yield, the inputs are renewable energy, water, and CO_2, making it a low-carbon process compared to methanol derived from fossil resources.

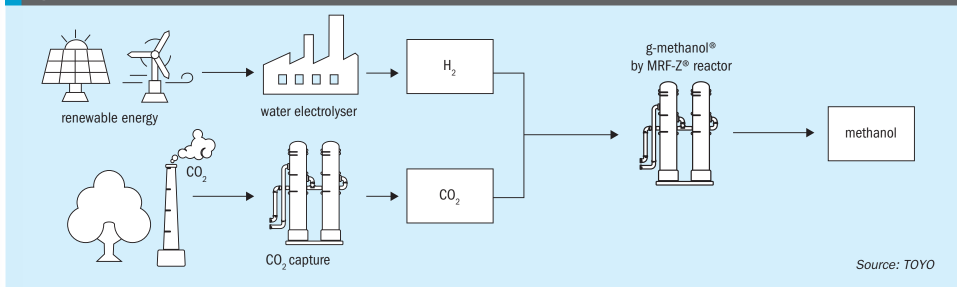
Methanol synthesis reactor

Catalytic reactors in methanol plants play an important role in utilising their catalytic properties and improving process performance.

TOYO's MRF-Z® reactor was initially demonstrated in Japan, with a 50 t/d pilot plant established in 1985. The largest production facility to date is 3,000 t/d. It is feasible to design a single system capable of handling 5,000 t/d class in this case for conventional methanol. The history of MRF-Z® reactor scale-up to date is shown in Fig. 5.

The MRF-Z® reactor recovers reaction heat as steam (Fig. 6). Synthesis gas enters from the top, spreads outward, then moves radially through the catalyst bed towards the central pipe (radial flow). Reaction-generated heat is recovered by circulating boiler water through cooling tubes in the catalyst bed, generating steam at saturation temperature and pressure. Control over catalyst bed temperature is achieved via steam pressure and inlet gas temperature.

Fig. 3: **g-Methanol® concept[3]**



Source: TOYO

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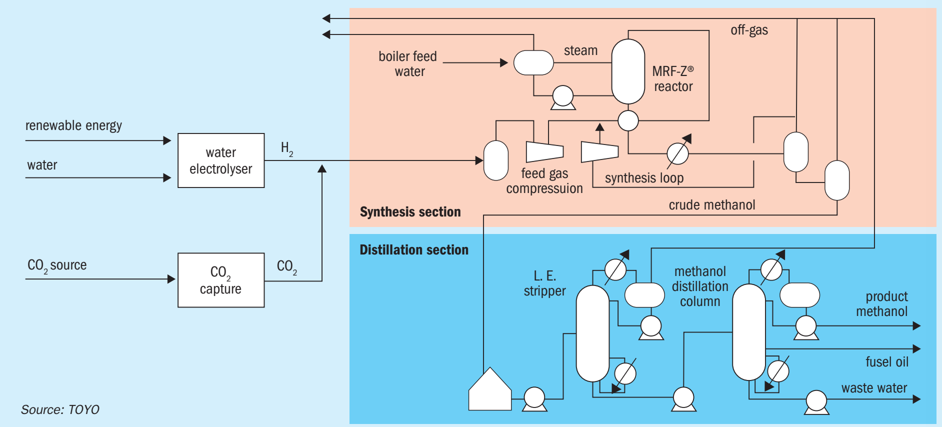
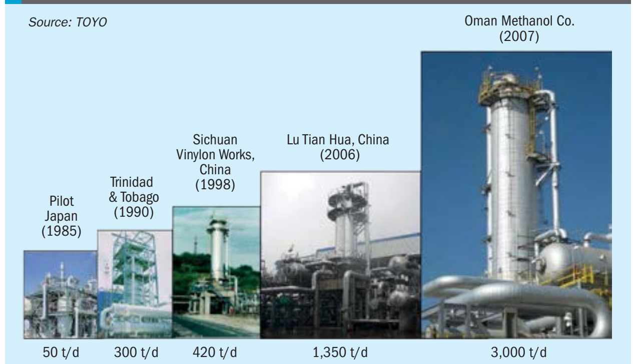
Fig. 4: **Methanol synthesis plant from H_2 and CO_2 (TOYO method)**[3]



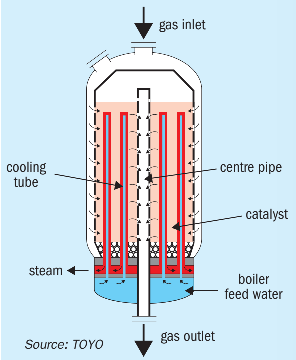
Source: TOYO

Fig. 5: **History of MRF-Z® scale-up**[3]



Source: TOYO

Fig. 6: **MRF-Z® reactor structure**[4]



Source: TOYO

The MRF-Z® reactor offers the following advantages:

- The reaction heat generated by the methanol synthesis reaction can be recovered as medium-pressure steam through a cooling pipe and used in the process.
- By facilitating cross-flow of the gas over the cooling tube, a high heat transfer coefficient between the syngas and the cooling tube can be achieved, allowing for a reduction in the heat transfer surface area of the cooling tube.
- By arranging the cooling pipes at appropriate intervals, the reaction path in the methanol synthesis reactor can be placed on the maximum reaction rate line of the methanol synthesis reaction, maximising the methanol production per unit volume of catalyst. As a result, the size of the reactor can be reduced, making it easy to scale up (Fig. 7).
- Synthesis gas flows in a radial flow to reduce the pressure drop in the catalyst bed and thus reduce the power of the synthesis gas compressor.
- Simplified catalyst removal through the centre pipe saves time and manpower.

The MRF-Z® reactor suits exothermic methanol synthesis due to its adaptable surface area and temperature control. Its features align well with current catalyst limitations, expected to have shorter lifetime due to by-product water, necessitating more frequent replacements.

Challenges when using H_2 from renewable energy sources

In conventional methanol production plants from fossil resources, a stable supply of raw materials allows for relatively straightforward continuous operation. In contrast, when generating hydrogen using renewable energy, the flow of hydrogen needed for methanol production fluctuates with variations in electricity generation due to day-night cycles and weather conditions. To ensure a consistent supply of renewable energy, the ideal approach involves purchasing grid power with green certificates or combining multiple renewable energy sources such as solar, wind, and pumped storage. However, practical implementation faces challenges on both regulatory and cost fronts. TOYO has been working on developing a system that is flexible enough to cope with fluctuations in the amount of electricity generated from renewable energy sources.

TOYO has developed MethaMaster™ software to optimise the configuration of plant equipment based on the power generation profiles of each plant (Fig. 8). This software enables simulation of the plant's average production, operating rate, shutdown frequency, etc., by inputting TOYO's g-Methanol® process performance, cost information of each facility, etc., in addition to the power generation change profile. Based on the results, the plant configuration and capacity of each facility are considered, and an optimised average methanol production cost, LCOM (levelised cost of methanol), is determined.

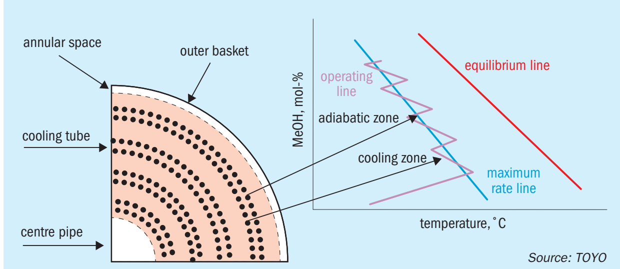
Compared to a system with a plant receiving stable power, additional facilities are needed:

- During periods when renewable energy is sufficiently supplied, facilities for storing electricity through batteries or producing and storing hydrogen are employed.
- During periods of insufficient renewable energy, such as during the night, power generation facilities like hydrogen gas turbines are utilised to continue operations at low loads.

Fig. 9 shows an example of this plant configuration.

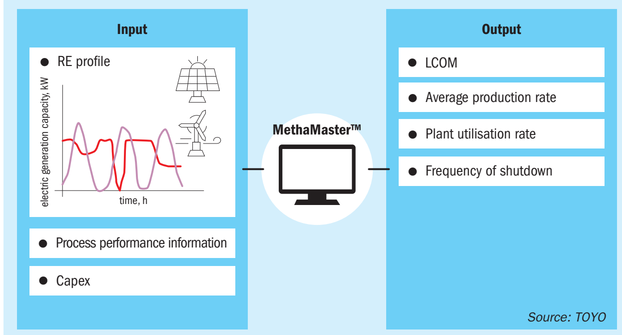
Integrating renewable energy complicates facility capacity planning. Unlike traditional plants aligned with steady supply and demand, renewable energy introduces factors like variable power generation patterns and the methanol plant's flexibility in managing load changes. Capacity decisions must now consider both demand and the specifics of renewable energy and methanol synthesis processes to handle operational fluctuations.

Fig. 7: **Cooling tube arrangement and maximum reaction rate line**[4]



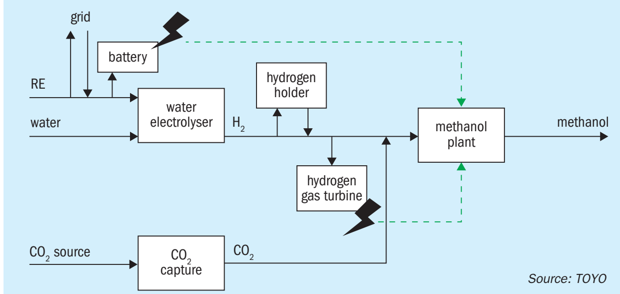
Source: TOYO

Fig. 8: **The MethaMaster™ concept**



Source: TOYO

Fig. 9: **Typical plant configuration when power supply is variable**



Source: TOYO

Conclusion

This article focuses on low-carbon methanol production technology using renewable energy, exploring how fluctuations in power generation affect plant design and production costs. Methanol synthesised from CO_2 and hydrogen from renewable sources holds significant promise in achieving a carbon-neutral society and early adoption of synthetic fuels. Its capacity to handle substantial CO_2 volumes, technological maturity, and versatility across various markets underscore its potential. ■

References

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End-to-end digitalisation

Ekaterini Yamalidou, Satish Baliga, Jeffrey Feng, Amudha Narasimhan, Raimon Marin, Paolo Brunengo (KBR)

KBR offers an end-to-end digitalisation solution specifically designed for green ammonia plants to balance the available renewable resources and consistently deliver the lowest levelised cost of green ammonia (LCOA). This article outlines some of the key modules of the KBR end-to-end digitalisation solution developed to overcome the challenges in green ammonia operation and achieve best in class, safe and reliable plant operation.

KBR's K-GreeN® Technology

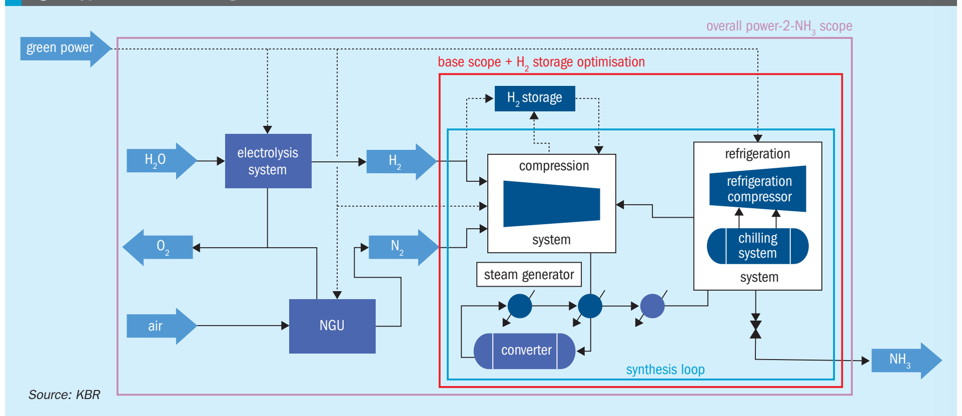
KBR has developed the K-GreeN® technology, which consists of a fully integrated solution for the synthesis of green ammonia via electrolysis of water to produce green hydrogen, separation of air to produce nitrogen and the KBR's proprietary Haber-Bosch process to produce ammonia. The KBR design can accommodate different electrolysis technologies such as alkaline, PEM and SOE electrolysis, the latter bringing attractive integration opportunities and significant overall efficiency improvements.

The KBR ammonia synthesis section is a proprietary design with proven unmatched reliability and lower energy consumption at lower capital cost (due to lower equipment count). In developing its K-GreeN® concept, KBR has leveraged on its past 75+ years of experience in designing ammonia plants, from very small capacity (4 t/d) to the largest single train capacity (6,000 t/d). Flexibility is paramount to most of the green ammonia facilities, KBR has extensive experience in flexible design and operation and has already designed and operated loops between 20% and 100% without changing the process, and with some alterations 10% turn-down is possible. Fig. 1 exemplifies a typical block flow diagram for generic green ammonia plants.

The advantages of the K-GreeN® process scheme are:

- well-proven design;
- reduced number of optimised and modularised design of the high-pressure equipment, in particular the converter and the chilling system, reducing capex and construction time;
- KBR's horizontal converter, design well-proven since 1971;
- unitised chiller combining the feed/effluent exchanger, several chillers, and the compressor knock-out drums into one piece of equipment;
- steam generation, superheated steam generation making loop energy efficient;
- no start-up boiler required;
- reduced opex due to lower loop pressure drop;
- reduced maintenance cost associated with fewer equipment pieces;
- robust, reliable steam generation and superheating with process gas.

Fig 1: **Typical block flow diagram for K-GreeN®**



Source: KBR

KBR solution for green ammonia plants

The availability of renewable energy, unstable by nature, causes significant fluctuations in hydrogen production, hence the synthesis loop operation may not receive a stable supply of hydrogen as required for reliable, efficient operation of the green ammonia plant. Moreover, the front end (electrolysis plant) and the back end (ammonia synthesis loop) have different dynamic responses to variations in the availability of renewable energy and different times for reaching steady state. Specifically, the ammonia synthesis loop needs longer time, several minutes or even hours, to respond to hydrogen availability variations and reach new steady state operating conditions. Therefore, it is desirable to proactively and dynamically compensate for continuous and rapid energy availability changes to ensure stable and reliable operation of the ammonia synthesis loop.

KBR offers an end-to-end digitalisation solution specifically designed and developed for green ammonia plants, which enables reliable and stable operation, while minimising the levelised cost of green ammonia (LCOA). The solution is made up of modules which can stand alone but are also appropriately interconnected and synergetic.

This article outlines some of the key modules of the KBR end-to-end digitalisation solution for green ammonia plants.

KBR Investment Optimizer

KBR offers conceptual design services, aiming at optimising LCOA for the overall plant, including the electrolysis system. The KBR Investment Optimizer is a tool which identifies the optimum size of each section for given plant location conditions and given renewable energy or hydrogen profile. The Investment Optimizer has embedded actual operating parameters which ensure realistic unit sizing and comprehensive LCOA calculations. The user can view the sizing and economic results of the design scenarios graphically on a graphical user interface.

KBR Operational Digital Twin

The KBR green ammonia plant digital twin covers the entire green ammonia plant. It receives a power generation profile as input and simulates the plant operations, including the electrolyser front end and the ammonia synthesis loop back end.

The integrated dynamic simulation model is the means to evaluate the response of ammonia production to the periodic fluctuations of renewable energy sources. Based on the analysis of different steady state and transient scenarios, the operation envelop of each equipment unit is established, and the overall control strategy is optimised to achieve robust response.

The KBR green ammonia plant digital twin is used as a design assurance tool to:

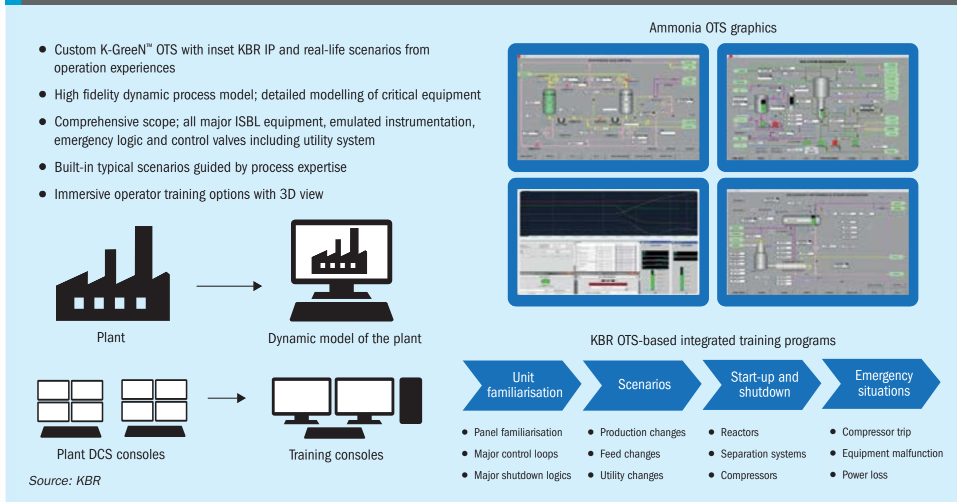
- identify the best type and configuration of the electrolysis unit;
- size the hydrogen storage;
- verify control strategies for the ammonia plant and the interconnecting systems;
- identify additional instrumentation required;
- establish operation boundaries for critical equipment.

Moreover, it is used to mimic start-up and shutdown sequences for the entire production chain and turndown and ramp-up rate of synthesis loop and critical utility systems. Through what-if analysis, it can also be used to minimise the risk of cascade trip during minor process disturbances.

KBR Advanced Process Control (APC)

The KBR APC solution covers the entire green ammonia plant, including the production of hydrogen and nitrogen in the front end and the production of ammonia in the back end synthesis loop, and achieves an optimised operation with respect to production and energy usage, while considering variations in

Fig 2: **Outline of the KBR OTS for green ammonia plants**



Source: KBR

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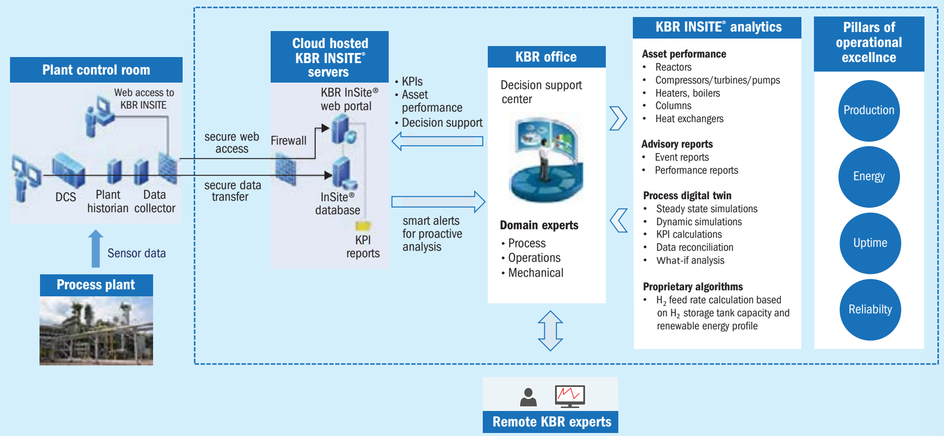
Fig 3: KBR INSITE® functional diagram



Source: KBR

the renewable energy availability and hydrogen storage capacity. It calculates the control setpoints to minimise process fluctuations and operate the plant closer to its equipment and process constraints in a stable and reliable manner.

The main KBR APC objectives are:

- satisfy offtake contracts;
- optimise hydrogen production while balancing the forecasted renewable energy supply with the hydrogen storage availability;
- minimise the fluctuation in the ammonia plant production due to fluctuations in the hydrogen supply ;
- minimise energy consumption.

Additional benefits of the APC include:

- standardisation of operation;
- increase in plant reliability and safety;
- allowing operators to focus more on process monitoring than on the minute-by-minute control of the plant.

KBR operator competency development program

KBR offers operator training simulators (OTS) as well as full operator competency programs for green ammonia plants. The KBR OTS for green ammonia plants (Fig. 2) embeds KBR's deep domain knowledge as a leading ammonia technology licensor.

The KBR OTS covers the entire plant and offers the following benefits:

- promotes faster and more efficient process unit start-ups by enabling operations staff to repeatedly practice the complete start-up procedure from empty and ambient conditions to full production;
- develops a deep understanding of the process unit operations and interactions between interconnected sections of the unit;
- tests operating procedures before they are used on the actual plant and thus identifies and eradicates any deficiencies;
- evaluates, standardises, and monitors operator performance within and across shifts;
- trains the operations team on the identification, diagnosis and management of abnormal situations that may occur during plant operations and may impact production;
- builds strong cooperation between shift supervisors, panel operators and field operators;
- greatly reduces the time required to train a new operator to a board-certified level - reduction from 2-3 years to 6-12 months may be expected.

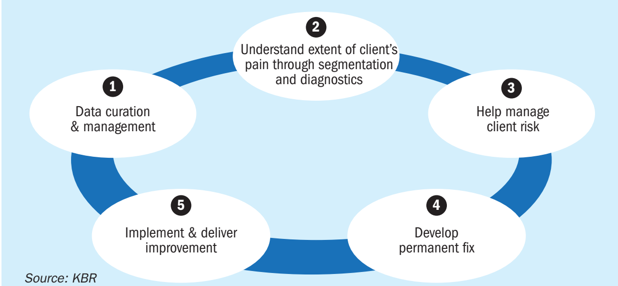
The green ammonia plant is required to maintain smooth operation of the synthesis section considering the variation in hydrogen generation, based on renewable power availability, hydrogen storage capacity etc.

In addition to the high-fidelity OTS solutions, KBR also offers an integrated training service (ITS) program specifically for green ammonia plants, designed to maximise the value that its clients derive from the OTS. The KBR ITS includes an OTS-based integrated training guide and customised training modules for the green ammonia process, as well as training scenarios focusing on the dynamic nature of the process.

KBR INSITE® for green ammonia plants

KBR INSITE® is a market-leading, cross-industry digital platform that enables cloud-based real-time monitoring and diagnostics services aiming to optimise the performance of green ammonia plants (Fig. 3). It uses a combination of web-enabled visualisation dashboards and innovative tools based on first-principles, artificial intelligence (AI), and machine learning (ML) to unlock the value of near real-time sensor data and create an accurate digital representation of the process plant. Backed by KBR's deep process domain knowledge, KBR INSITE® offers a uniquely differentiated service that leverages in-house or remotely located subject matter experts to provide proactive and timely guidance and decision support to plant operators.

Fig 4: KBR intelligent asset management function overview



Source: KBR

Physics-based models are utilised to estimate inherent asset health and performance parameters such as heat exchanger fouling, catalyst activity, compressor and pump efficiency, and turbine power. AI/ML based anomaly alerts are triggered from within KBR INSITE® to provide advance notification to operators of impending abnormal or sub-optimal deviations in process or equipment behaviour. In addition, these AI/ML modules are also leveraged to make ahead-of-time forecasts of process behaviour and mean-time-to-failure of critical rotating equipment. Process experts analyse these alerts and predictions to rapidly identify the root cause of active or evolving operational problems, and then proactively recommend mitigating actions to minimise and even eliminate unplanned disruptions to plant operations.

Moreover, KBR INSITE® utilises smart alerts based on proprietary statistical algorithms for tracking deviations from normal equipment behaviour that can cause metal fatigue and impact the mechanical integrity of equipment.

The ability to capture and reuse past lessons and best practices, and effectively combine expert knowledge within a blend of digital solutions provides plant operators the opportunity to achieve operational excellence across all phases of the plant life cycle and for safely driving their plant operations closer to optimum targets for longer periods, while maintaining critical equipment at peak levels of efficiency, availability, and reliability.

KBR INSITE® dashboards offer:

- process schematic view of the plant with real-time access to operations data;
- KPI dashboards for visualising real-time data as well as aggregated data;
- plant hierarchy tree-structure for drill-down, navigation, content search, and alarm propagation;
- advanced trending capability to study interactions between key variables;
- secure, cross-platform, role-based access including from mobile devices;
- intelligent alerts to flag current or predicted excursions of KPIs from targeted values;
- built-in, real-time calculation engine and analytical tools for real-time KPI evaluation and overall equipment effectiveness;
- direct access to all stored content and documentation such as operation manuals, user manuals, data sheets, and best practice manuals.

KBR Intelligent Asset Management

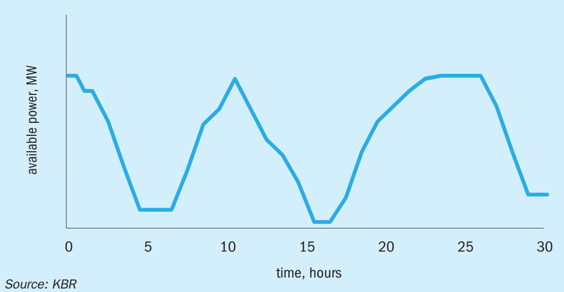
KBR's INSITE® Intelligent Asset Management (IAM) can accurately predict and maintain appropriate inventory levels of spare parts and ensure operational, maintenance and insurance requirements without overstocking. It can reduce inventory levels, release significant working capital, and enable better decision-making during maintenance and operations. The business objective is to maintain maintenance, repair and operations (MRO) materials and spare parts using a risk-based approach MRO, which aligns business risk with holding cost to optimise inventory levels to reduce or eliminate stockouts whilst at the same time achieving the lowest cost of ownership.

Fig. 4 provides a function overview of KBR Intelligent Asset Management.

IAM leverages cutting edge AI/ML technology on a scalable cloud platform to:

- intelligently extract and curate material and bill of materials (BOM) data at scale and pace from tag data, materials and BOM rich drawings, un-intelligent drawings and documents not available in searchable and analysable electronic format, which is frequent in older, mature plants;
- manage vast data sets in a single hierarchical plane on the cutting-edge AI/ML platform;
- harmonise material master descriptions through the ability to learn and recognise attributes in text strings and split into reconcilable data using a standard class model;
- identify excess, obsolete and duplicate materials and bills of materials, produce clean and enriched lists with optimised min/max levels and quantifies gaps and risks;
- minimise the number of discrete suppliers, by converting original equipment manufacturers to original component manufacturers;

Fig 5: Sample power availability profile



Source: KBR

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- identify accurately interchangeability and minimise the number of suppliers and associated contractual burden;
- identify maintenance plans and work orders which are not fully resourced with materials;
- identify critical high-risk areas and recommend solutions along with hidden/latent insurance spares.

Use case – optimising green ammonia plant production

A case study for green ammonia production using renewable power is presented here, to demonstrate the value of the KBR digital twin and the KBR APC in optimising the production of a green ammonia plant with an assumed nameplate capacity of 1,500 t/d.

A sample power generation profile having a high degree of variability is shown in Fig. 5.

This power availability profile is fed into the KBR digital twin and the KBR APC. The APC processes the profile input and decides at each point the optimum actions to be taken across the plant.

The graph in Fig. 6 shows the expected ammonia production based on operator action to adjust plant setpoints, so as to maintain continuous ammonia production given the power availability profile.

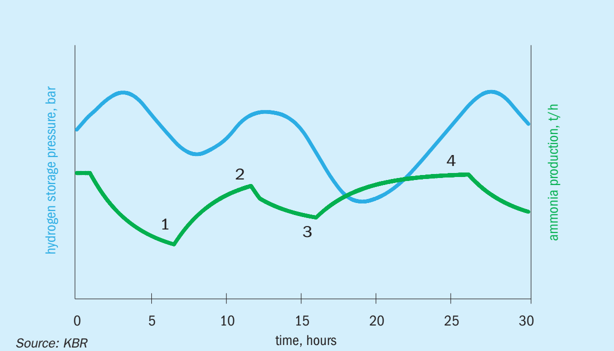
Points 1, 2, 3 and 4 on the green curve in Fig. 6 represent changes in the flow controller setpoint enforced by the operator. With operator action, the plant runs within design parameters avoiding undesired shut down situations due to low or lack of availability of renewables. The total ammonia produced during the 30 hours period is about 89% of the nameplate production over the same period. The plant runs continuously, but not necessarily at the optimum production efficiency levels.

Fig. 7 demonstrates the capability of the KBR digital twin as part of the KBR OTS to train the operators through various scenarios, such as high variability in renewable power generation, modification of constraint limits as well as adapting to unforeseen events during operation, to evaluate operator actions and to forecast the plant's response to those actions.

The next scenario shows how through proactive action deployed by the KBR APC, ammonia production can be improved beyond what could be achieved by an operator.

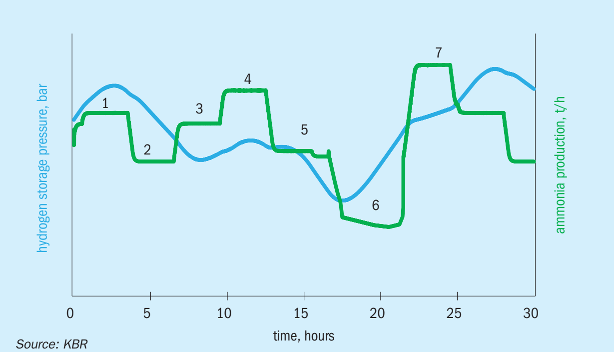
Compared to Fig. 6, Fig. 7 shows how the APC made more proactive moves to the plant operation over the first 15 hour period, resulting in higher average ammonia production. At around 17 hours (point 6) the hydrogen storage pressure is below the requirements for the forecasted period, here the APC reacts by directing hydrogen to the storage to fulfill that foreseen consumption. In total, during the 30 hours of operation under APC, ammonia production is about 4% higher than what was achieved by the operator intervention alone, as seen in Fig. 6.

Fig 6: **Projected ammonia production based on operator actions**



Source: KBR

Fig 7: **Projected ammonia production based on advanced process control**



Source: KBR

Conclusion

In this article KBR describes its end-to-end integrated digitalisation solution developed to overcome the challenges in green ammonia operation and achieve best in class, safe and reliable plant operation.

Adaptability and predictability are key features to successfully design, build, commission and operate green ammonia facilities. KBR's end-to-end digitalisation solution considers key issues such as capex and opex optimisation, increased reliability during operations, maintaining well trained, fully skilled operators, optimising the maintenance function and costs and proactively monitor and adjust plant performance based on expert advisory. KBR's solution covers the entire lifecycle of the plant, from the feasibility study stage to conceptual and detailed design, EPC, commissioning and handover, operations and maintenance up to the end of the plant's lifecycle. The aim is to balance the available renewable resources and to consistently deliver the lowest LCOA. ■

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Digitalised data to revolutionise catalyst operations

Data has always been crucial for successful operations in the chemical industry, but the growing volume of data is only as good as our ability to analyse it. Now, the market is about to experience a step change in data assessment, and Clariant is fully on track, thanks to cutting-edge technologies for real-time data monitoring, visualisation, and information exchange.

M. Aigner, C. Basilides-Schwarz, S. Gebert, A. Kariagin and S. Osborne (Clariant)

Operation of chemical plants has long relied on control systems and thousands of sensors, amassing vast amounts of process and performance data over decades. However, drawing meaningful conclusions from this wealth of data to improve catalyst operations typically requires collaborating with catalyst providers who are well-versed in both the data and the catalyst. Additionally, plant operators depend on the technical expertise of the catalyst provider especially when troubleshooting issues or evaluating remaining catalyst lifetime. The relevant process data is usually not accessible to all stakeholders, so it gets shared through manual data workflows using spreadsheets and email. Manual data workflows are time-consuming, resource-intensive, and prone to human error. Deriving value from the extensive plant data is a major issue with these old-fashioned analysis and communication techniques.

Because data analysis occurs sporadically and retrospectively, rather than being continuously conducted proactively on an accessible shared platform, there are many instances where valuable insights from catalyst providers are missed. Implementing proper data visualisations and a collaborative approach could help reveal hidden opportunities to optimise plant operations that are currently being overlooked.

Chemical plants collect massive amounts of data to enable problem identification and reveal actionable patterns to prevent issues. At times however, the analysis itself may lead to faulty conclusions. Significant deviations in expected and measured catalyst performance can stem from offsets in analysers, especially after shutdowns. Evaluating catalyst performance is typically needed to pinpoint those measurement offsets. A collaborative data platform granting catalyst providers access to process data allows plant teams to rapidly catch such faulty readings.

Planning for catalyst replacements is also crucial for plant operations but is often constrained by budget and logistics limitations. Plant operators would benefit from more advanced evaluation of remaining catalyst lifetime to optimise their own replacement strategy. Rather than just identifying the right changeout timing, the ideal loading scheme and potential implementation of more suitable products can also be assessed based on prior catalyst cycle learnings. Then again, proper data visualisation can strongly contribute to identifying these key considerations for enhancement.

CLARITY™: Bringing data to life

Clariant's cloud-based service portal – CLARITY – is the solution for overcoming the limitations of current methods for managing catalyst operational data. The platform provides plant operators real-time access to catalyst performance data and advanced analytics tools via secure dashboards. By automating data sharing and visualisation, the service portal eliminates the need for cumbersome spreadsheet-based data handling.

CLARITY's user-friendly interface connects plant operators directly to Clariant's technical experts for optimisation guidance. Over 80 plants worldwide have already adopted the platform, with more than 380 active users in 28 countries. The platform features customisable, well-organised dashboards that present performance insights in an accessible manner. This enables users to easily monitor all critical parameters and extract key information to guide data-driven decision making for process enhancement.

The platform's rapidly growing customer adoption is a testament to the substantial value it delivers. By pioneering innovative solutions that extract value from digitised data, CLARITY is establishing a competitive advantage in helping companies optimise catalyst performance.

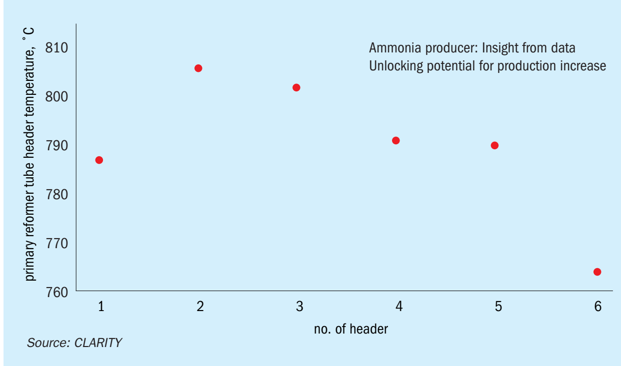
As Lorena Oviol, Head of Applied Catalyst Technology at Clariant, stated, "CLARITY, together with Clariant's catalysts experts, bring customer experience to a brand-new level. As competition continues to grow across industries, our state-of-the-art tools and data-driven insights will help our customers to stay ahead in their fields."

Optimising plant performance

Turning complex data into impactful visualisations provides critical insights and uncovers hidden opportunities. Well-designed graphics and interactive visual analytics enhance decision making by highlighting key information and relationships. By bringing data to life, effective visualisation unlocks the full potential of digitised data, enabling better business decisions that drive success.

In ammonia plants, CLARITY allows for monitoring of critical data such as reformer tube wall and exit temperatures. Maintaining tube wall temperatures (TWT) within safe design limits is vital for ensuring long-term, reliable operation of the primary steam methane reformer (SMR). However, being too conservative risks missing opportunities for higher yields and profits. Uneven firing patterns in the SMR can cause damage to the tubes or reduce hydrogen output. Optimising performance requires operating closer to the limits while retaining a safety margin. CLARITY makes it easier for plant operators to maintain the right balance by providing an easy-to-understand visualisation of tube temperature data needed to optimise reformer output while remaining within safe parameters.

Fig 1: Redistribution of firing can provide additional space for temperature increase, enabling up to 10% higher production



Source: CLARITY

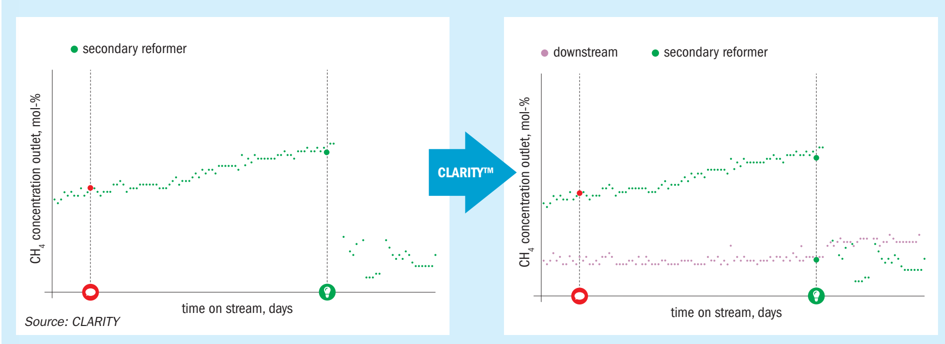
Case study A:

An ammonia plant customer experienced temperature deviations in the SMR outlet headers, signalling suboptimal operations. By using Clariant's CLARITY portal, the customer gained insight into these deviations, uncovering hidden optimisation potential within the reformer. Leveraging CLARITY's communication tools, the customer consulted Clariant experts on improving performance. Collaboratively, they adjusted burner firing to achieve more uniform operation and boost output: the customer implemented site changes while Clariant experts monitored performance until optimal conditions were achieved (Fig. 1). Reducing temperature variation widened the safety margin, enabling higher throughput and ammonia production. Ongoing monitoring allows continually optimised firing to capitalise on full capacity within safe parameters. The cooperative functionality of CLARITY streamlined joint efforts to fully optimise the SMR. This level of data-enabled collaboration positions the customer and Clariant to unlock the unit's complete potential through partnership.

Accelerating repairs and reducing risks

Real-time data analytics and monitoring enabled by the CLARITY platform allows rapid identification, diagnosis, and resolution of plant issues. By providing data-driven insights, corrective actions can be taken immediately, and problems may be quickly resolved. This minimises costly downtime from disruptions and optimises the speed and efficiency of problem resolution. With the ability to detect and address risks in real-time, plant processes that previously required several days to fix can now be resolved much faster. The platform's capabilities enable substantial time and cost savings.

Fig 2: Observing the mixing point (where flow from the secondary reformer is mixed with the flow from parallel reformer) shows that methane slip remained stable after mixing



Source: CLARITY

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Case Study B:

A syngas plant customer noticed a steady increase in methane leakage from a reactor after partial replacement of the catalyst in the secondary reformer. As they believed it limited their performance, the plant operators approached Clariant to determine the cause and find the optimal solution.

Through CLARITY's dynamic visualisation tools, Clariant experts rapidly reviewed relevant plant data – temperatures, flows, analysers – to troubleshoot and check for root causes beyond the perceived poor catalyst performance. Simultaneously, CLARITY also enabled direct communication between the customer and dedicated Clariant experts for real-time collaboration. The portal automatically notified users of new advice and questions.

The Clariant expert quickly conducted correlation analyses in the tool by evaluating the values of different measurement points in the flow scheme (Fig. 2). This revealed that the measurement was incorrect since related trends diverged. A calibration check was recommended, which verified the Clariant expert's conclusion: there was no issue with catalyst performance.

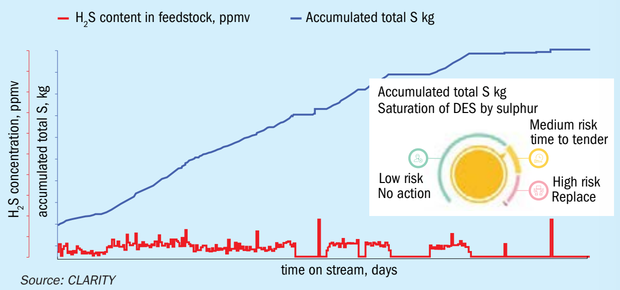
CLARITY's integrated visualisation, seamless interaction capabilities, and instant expert access enabled and accelerated remote troubleshooting. This rapidly fixed an issue that would have previously taken much longer to identify, and could have resulted in an extended, unplanned, and unnecessary downtime.

Preventing costly shutdowns

In the case of ammonia, hydrogen, and methanol plants, zinc oxide (ZnO) sorbent is used to remove sulphur, which enters these plants with the natural gas feedstock. If sulphur passes through to the downstream catalyst reactors, it can poison the catalysts, dramatically reducing yields and catalyst life. Such catalyst poisoning often requires costly, unexpected shutdowns and early catalyst replacement. Therefore, close monitoring of the actual performance and loaded capacity of the ZnO sulphur sorbent is critical to preventing sulphur leakage and damage to the vulnerable downstream catalysts.

Among a multitude of data collected, CLARITY continuously monitors incoming sulphur levels and process gas flow rates to calculate total incoming sulphur. The cumulative sulphur value in an ammonia plant is compared to the expected saturation capacity of the loaded desulphurisation vessel sorbent (Fig. 3). The graphical display shows proximity to potential sulphur breakthrough and indicates whether sorbent replacement should be considered at the next available maintenance window.

Fig 3: **Continuous incoming sulphur readings are combined with process gas flow rates to calculate the total amount of incoming sulphur**



Source: CLARITY

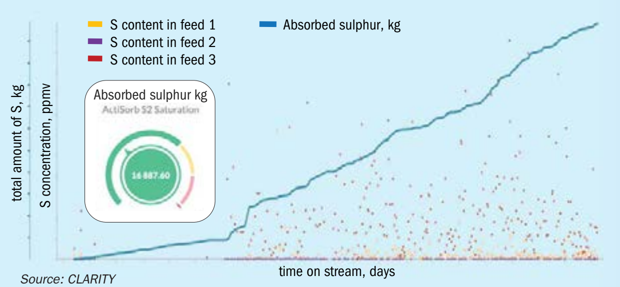
Case study C:

For a hydrogen plant with a two-bed desulphurisation system, the calculated, cumulative, sulphur pick-up capacity was 16,888 kg over approximately five years of operation. The CLARITY platform showed that given the loaded sorbent volumes and types, the estimated remaining sulphur capacity was enough to operate until at least the next turnaround for this plant at current inlet sulphur levels (Fig. 4). The continuous updates, based on actual incoming sulphur, provide increased accuracy in determining the remaining sorbent capacity.

Case study D:

Sulphur peaks can contain organic or inorganic sulphur species. With certain sorbent systems, organic sulphur may slip through during high inlet sulphur events. In such cases, an improved sorbent load capable of both sulphur hydrodesulphurisation and absorption is needed to minimise breakthrough. Without continuous monitoring via CLARITY, identifying peaks of organic sulphur as the root cause would be extremely difficult. The trending and visualisation features allow Clariant experts to review the situation before planned shutdowns and to recommend more suitable loading schemes or product combinations. This was implemented for an ammonia customer in February 2023 and despite similar high spikes in the incoming sulphur levels, the exit sulphur leakage was kept below detection limits – thereby better protecting the downstream catalysts and improving overall life and yields (Fig. 5).

Fig 4: **Cumulative absorption capacity for a hydrogen plant with a 2-bed desulphurisation system over ~5 years**



Source: CLARITY

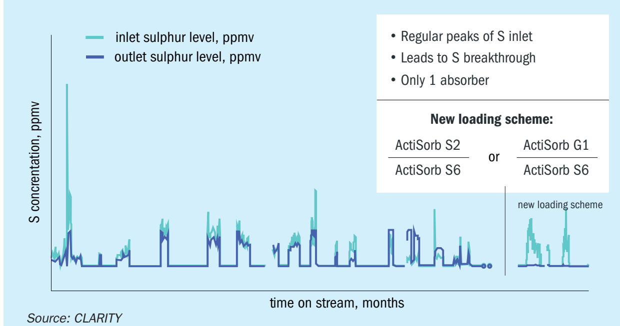
Driving continuous innovation

Clariant's innovative CLARITY platform is transforming data utilisation in the chemical industry. By providing real-time analytics, visualisation, and collaboration tools, CLARITY not only facilitates efficient handling of process data but also enables plant operators to optimise catalyst performance, rapidly resolve issues, and prevent costly unplanned shutdowns. Numerous examples highlight the advantages of CLARITY for unlocking valuable insights from operational data. The platform's ability to detect early signs of problems allows immediate implementation of corrective actions.

Overall, the digitalisation and automation of data analysis through CLARITY helps plant operators to achieve the best possible performance of Clariant's catalysts, thus enhancing efficiency, productivity, and profitability of the plant. The rapidly growing adoption of CLARITY confirms that plant operators recognise the benefits of transitioning from conventional methods to leveraging advanced analytics and visualisation. As the article demonstrates, CLARITY can improve catalyst operations by facilitating communication between catalyst provider and plant operator.

Going forward, Clariant is further advancing CLARITY's capabilities by incorporating catalyst specific features like smart alerting and performance predictions that are supported by data science, artificial intelligence, and machine-learning tools. This next level of Clariant's digital service will enable customers to optimise catalyst performance, both now and in the future, to support achieving the best possible lifetime efficiency. With this dedication to digital solutions, Clariant aims to directly contribute to increasing efficiency, sustainability and optimising its customers' catalyst operations. ■

Fig 5: **Sulphur detection data showing sulphur peaks in an ammonia plant**



Source: CLARITY

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Process optimisation with AI – hype or reality?

Lisa Krumpholz, Managing Director of Navigance, delves into the world of artificial intelligence (AI) and discusses its potential to enhance process optimisation in syngas plants.

Syngas plants are vital for the synthesis of crucial industrial products like ammonia, methanol and hydrogen. Engineers working in these plants need to take decisions and have to provide answers to many different kinds of questions in their day-to-day operations: How can the plant meet its production target while optimising the energy usage within the plant to reduce costs and environmental impact? Does the heat distribution in the primary reformer need adjustments to ensure a low methane slip and good reforming efficiency? Is the methanol synloop operated optimally to maximise production? Is there any room to improve the CO_2 removal capacity? Is the syngas compressor operating well or are there any signs of anomalies? And engineers need to answer questions for taking a decision about the timing of the turnaround window and catalyst replacement: How will the performance of the low temperature shift catalyst develop until the next turnaround? Is it possible to delay the turnaround by a few months and what is the economic impact?

To make the right judgements, experienced engineers today already rely on analysis of their plant's operating data using specific models and tools. Will and can artificial intelligence (AI) be a game changer?

The rise of generative artificial intelligence (GenAI)

It's a little more than a year ago that a technology based on large-language-models (LLMs) created a massive hype about the opportunities of generative AI in our working lives. On 30th November 2022, OpenAI launched their chatbot ChatGPT. It is a tool that enables every user to steer a humanlike chat conversation with a very simple user interface, while the underlying model responds to questions and can create many types of written content, including explanations, articles, emails or software code, based on the user's input.

Since then, numerous GenAI models and tools have been developed and launched by various companies. No matter whether it is LLM-based GenAI or Text-to-Picture AI or others, they all have in common that their foundation are powerful machine learning models that are running in the background. These models are enabled by two essential factors: Firstly, they are based on a vast amount of data from many sources. That includes everything that is generally available on the internet, but also specifically developed databases for research like ImageNet, a database of labelled and sorted images. Secondly, what may seem to the users now as magic-like output, required countless iterations of model training and model refinement.

The GPT in ChatGPT stands for 'Generative Pre-trained Transformer' – describing the architecture of OpenAI's groundbreaking chatbot and it includes 'training' as an essential element it its name. A fundamental component of GPT, the transformer architecture was published in a paper in June 2017, while OpenAI released GPT-1 in June 2018. This initial model contained 117 million parameters. In only two years, OpenAI released the third iteration of its model, GPT-3, further improving its performance with a thousand-fold increase of parameters to 175 billion. This reflects the tremendous investments in its development and the speed at which it advances.

Challenges ahead for (Gen) AI applications in chemical processes

This leads to the question which role will GenAI play in the operation and optimisation of chemicals plants? When and how will GenAI help operators for example to fine tune process parameters to run an ammonia plant in the most energy efficient state for a desired production rate?

First some good news: There is lots of literature and information available on the internet related to chemical engineering and for syngas plants more specifically. For well-known problems GenAI tools like ChatGPT may therefore provide useful, generic answers, which help the user to get a better understanding of their problem. It does not necessarily tell how to solve it exactly (Fig. 1) and the user needs to verify the correctness of the information.

Yet, when it comes to analysing and making use of operating data from syngas plants – or any chemical plant for that matter – in an easy-to-use interface for an operator, there are several challenges to be solved that go far beyond the processing of language-based information from the public domain. Here are three significant areas that are a requirement to develop GenAI applications:

Data availability: One may think the chemical sector is in a good position to utilise its data for decision making. The use of

control systems has been widespread since the 1960s, and a typical ammonia, methanol or hydrogen plant now has hundreds to thousands of sensors collecting huge volumes of process and performance data. Today, this data is used to help control the plant, generate reporting and – increasingly common in recent years – may also be stored long term to support troubleshooting and analytics.

However, compared to information needed to develop and train ChatGPT to its current capabilities, the availability of chemical process data is sparse, virtually nothing is generally available on the internet. The data is in the hands of the chemical producers, while even the largest companies in the industry operate only a few ammonia, methanol or hydrogen plants when looking at it in the context of real big data needed for the development of GenAI.

Modelling technology: The underlying models of GenAI are very complex and need to be developed for syngas applications. The complexity and high number of influencing process parameters in any ammonia, methanol or hydrogen plant requires highly specialised models.

For use in dynamic, real-time optimisation of chemical plants, **hybrid process models** are known to overcome limitations and disadvantages of both individual model types: a) traditional first-principles models and b) purely data-driven black-box models. As the name suggests, they are a middle ground between the other two modelling technologies. Conceptually, a data-driven model, such as a neural network, is used as a basis and extended with expert knowledge of physical/chemical principles through e.g. 'feature engineering'. In essence, hybrid models combine flexibility and adaptability of data-driven models with the process specific fundamentals.

With sufficient data, hybrid process models can accurately describe the plant operation. Compared to first-principles models, they do not require that all the physical principles in measured data are ideally fulfilled but learn to describe the actual behaviour of the real plant, which may encounter heat loss in a pipe, an unevenly fired reformer or heterogenous catalyst activity in a reactor bed, to name a few examples. And this is a major point: each plant is different and has its own specifics. From the underlying process technology to details of the equipment

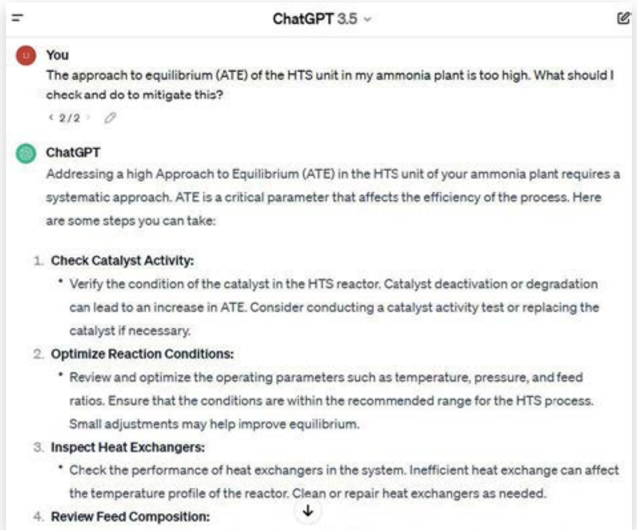

Fig. 1: An example of ChatGPT providing an answer to a question on high ATE in the HTS unit of an ammonia plant.

and available sensor data – no two plants are the same. It means that any AI-based application for syngas plants needs to understand and capture these specifics to provide detailed information and guidance to the operator in any particular situation.

Accuracy and reliability: Hallucinations of large language model based GenAI – meaning responses presenting false or misleading information as facts – are a known problem, which developing companies are still tackling. The safety standards and zero-accident goal of the entire chemical industry, require high accuracy and reliability of information, especially when it comes to information that is used to conduct changes in operating conditions for optimising a plant or monitoring its performance. Therefore, there is no allowance for such 'AI hallucinations' in the context of steering an ammonia, methanol or hydrogen plant.

Real-time optimisation or monitoring of ongoing operations, in which current data is continuously fed to a model, calls for robust dynamic models that must cope reliably with changing operational reality. It requires that models are running 'operationally' and quickly 'learn' with the changing conditions. Therefore, any model for continuous monitoring and optimisation of an ammonia, methanol or hydrogen plant must be monitored for performance and quality, which is part of a process called machine learning operations (MLOps). It's a discipline where the chemical industry can build on the progress and experience that has already been established over years in other industries.

In summary:

- Data availability is a challenge and making data available relies on the chemical producers operating ammonia, methanol and hydrogen plants. The first companies that will succeed in delivering a syngas process GenAI, will be companies that have access to sufficient process data from many different plants of a similar type.
- A pure data-driven approach to machine learning models for syngas plants is not proven successfully and on a large scale to date, limiting the advancements of any GenAI development. Hybrid models are capable to tackle this challenge and they will also become part of GenAI-like tools for process optimisation in the future.
- The reliability of models is essential. And well-proven approaches to run them on a large scale can be adopted from other industries.

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Paving the way for AI and eventually GenAI in the syngas industry

A few years ago, Navigance started to invest in developing a capable and scalable technology to build and operate plant specific process models for ammonia, methanol and hydrogen plants. Navigance's powerful, cloud-based platform today is operational for 100+ chemical plants. And it is suited to process data on a scale that will be sufficient to enable the development of GenAI in the future.

The other area of development is tailoring machine learning technologies to solve or support specific use cases and problems found in syngas plants. All solutions are built on hybrid base models which are specific to the ammonia, methanol or hydrogen process and then tailored with expert domain knowledge to the details of each plant and the desired optimisation goal or monitoring requirement. Here are some examples of currently implemented AI-based solutions in syngas plants:

Reformer optimisation

A common challenge for plant operators is to fine tune the reformer operation to minimise the methane (CH_4) slip from the primary and secondary reformer, while keeping the hydrogen to nitrogen ratio at the reformer outlet at the desired ratio of the ammonia synthesis loop. These key performance indicators (KPIs) of the reformer section are influenced by multiple process variables such as the primary reformer outlet temperature, steam to carbon ratio, process gas, steam and air flows as well as temperature distribution in the reformer. Usually, the operator is guided to keep these process variables within a defined operating window. However, further finetuning of the setpoints for the variables within this operating window is left to the experience of the individual operator.

Navigance has developed an AI-based Interactive Reformer Optimisation tool for the reformer section, which is provided as software-as-a-service (SaaS) in a web-based interface. This tool comprises a hybrid process model tailored to the primary and secondary reformer of the specific plant. It utilises plant specific, machine-learning based data analytics for predicting the impact of changes to defined process variables on selected KPIs of the reformer section.

The Interactive Reformer Optimisation tool visualises the current operating conditions in context to the defined operating limits together with the KPIs of the reformer section. The operator can simulate "what-if" operational scenarios to determine the impact of changes to the process variables on selected KPIs of the primary and secondary reformer compared to the current operation of the process. Thereby the interactive tool enables the operators to define and evaluate options to improve process performance with a reliable prediction of the impact of operational changes to the reformer section KPIs. The underlying machine-learning based, hybrid process models are continuously processing the plant data and allow the plant team to learn from the plant's behavior and to take informed decisions how to fine tune the reformer operation.

Catalyst performance prediction

A plant process engineer is often tasked to evaluate options and scenarios for determining the timing of economically attractive turnaround windows and take decisions on which catalysts to replace. Or when unforeseen issues such as catalyst poisoning or other incidents occur, to determine the impact and risk on meeting the next scheduled turnaround window for the catalyst replacement. This requires not only analysis of the current operating data but also a deep knowledge of the catalysts as well as specialised modelling tools to carry out projections. Mostly the engineer depends on the support of technical experts from the company providing the current catalyst in use.

Navigance has designed a solution with cutting-edge machine-learning based models for engineers to project the lifetime performance of specific catalyst types for different operational scenarios. Models for high-temperature or low-temperature shift catalysts are integrated into a web-based tool. It enables self-service catalyst performance projections of the catalyst in a hydrogen or ammonia plant based on current and historical operational performance of this plant. The development of these highly specialised hybrid models was made possible by using many data sets from more than 20 different plants and numerous catalyst loads totalling decades of operating data. Once tailored and trained with data from a specific plant, it allows the engineer to create multiple operational scenarios for projection of the HTS or LTS catalyst performance for time horizons from weeks, months to years. This supports informed decision-making for catalyst operation to meet planned turnaround windows based on economic considerations.

Outlook for the use of GenAI

At some point in time the currently already used hybrid models and the generated data and results will feed into Gen-AI-supporting models (based on Generative Adversial Networks (GANs)). It will still take a long time until GenAI models will be able to answer complex optimisation tasks, e.g. total energy consumption optimisation in an ammonia plant or even a CO slip optimisation.

On the other hand, the currently available AI-tools based on hybrid models can already perform these tasks when tailored to a specific plant. And they are also capable of reliably predicting or simulating the process behaviour in different operating scenarios.

The hype around GenAI tools, such as ChatGPT, lies in their ability to facilitate user interactions with underlying complex models through human-like communication. This has significantly contributed to a user-friendly experience, eliminating the need for specialised expertise. The first step towards a GenAI-like feeling for currently available AI-tools in the syngas industry will therefore be switching to an interaction with hybrid models in a chat-bot style rather than providing a user interface that demands lengthy data input and multiple clicks. Simplifying the interaction process can help to positively contribute to a wider adoption and acceptance of available AI tools in daily operation of ammonia, methanol and hydrogen plants and pave the way for even more powerful GenAI tools in the future. ■

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An ideal reactor for green methanol

As the production of renewable methanol continues to scale up, it will provide a long term, carbon-neutral energy solution to different transport sectors. However, the optimum design parameters for green methanol plants are substantially different to natural gas-based methanol plants and pose new challenges to the methanol loop designer. **Connor Longland** of Johnson Matthey (JM) discusses the challenges and presents the benefits of the tube cooled converter for e-methanol production.

Today, methanol is mainly produced from synthesis gas obtained from fossil fuels, but it can also be manufactured from sustainable sources. As the production of renewable methanol continues to scale up, it will provide a long term, carbon-neutral energy solution to different transport sectors. Methanol can be made by direct hydrogenation of carbon dioxide (CO_2) with renewable hydrogen (H_2). This production route mitigates the amount of CO_2 released into the atmosphere and offers a low-carbon alternative to conventional transportation fuels if it is produced by sustainable feedstocks, such as electrolytic hydrogen and carbon dioxide from waste streams of biological origin.

Hydrogen and carbon dioxide as feedstocks for green methanol production place different optimisation demands on designers compared to traditional plants based on syngas.

Natural gas-based methanol plants are based on the production of syngas by steam methane reforming in an endothermic process. The syngas produced is then fed into the methanol synthesis loop. Historically, refined methanol has benefitted from low natural gas prices that have allowed methanol synthesis loops on natural gas-based plants to run at syngas efficiencies in the range of 85-90%, with the unconverted purge gas being used as fuel in the steam methane reformer (SMR). Based on a typical natural gas consumption of 34GJ/t methanol and natural gas prices in the range of $3 per GJ, traditional merchant grade methanol historically trades in the range $300-400 per tonne[1].

The optimum design parameters for green methanol are substantially different because feedstock costs are much higher. To illustrate this, the typical energy consumption of a highly efficient green methanol process, including the expected energy demand to generate the electrolytic hydrogen, is around 11.5MWh/t methanol. Assuming a renewable electricity price of $30 per MWh[2], this brings the cost of methanol production based on electricity alone to $375/t. Furthermore, the fact that there is no natural home for the purge gas stream from the methanol synthesis loop means it is desirable for purge flows to be minimised as much as practicably possible.

This poses new challenges to the methanol loop designer and critically shifts the optimisation focus on to maximising the hydrogen and carbon dioxide conversion into product methanol.

Fundamentals of the CO_2 to methanol reaction

Methanol synthesis from carbon oxides (COx) and hydrogen is an equilibrium reaction favoured by low temperatures and high pressures. A typical methanol process is operated at 80 bara pressure with peak reaction temperatures of 280°C. At these conditions, the maximum methanol concentration at the outlet of the converter is around 14 mol-%. Therefore, as the per pass conversion of synthesis gas to methanol is limited by equilibrium, in order to achieve high conversion, the methanol synthesis section is arranged as a loop, recycling unreacted syngas, as in the example shown in Fig. 1.

In the CO_2 to methanol process, the carbon dioxide and hydrogen feed gas are mixed to achieve the desired stoichiometric ratio and compressed up to the pressures

Table 1: **Comparison of syngas feeds to the methanol synthesis loop from various sources**

	$CO_2 + H_2$	Steam reforming	Combined reforming	Coal gasification
Hydrogen, mol-%	74.0	70.3	67.5	67.6
CO, mol-%	-	14.4	22.6	28.6
CO_2, mol- %	24.5	10.4	7.6	3.0
Methane, mol-%	-	3.5	2.2	0.1
Nitrogen, mol-%	1.5	1.4	0.02	0.5
Argon, mol-%	-	0.0	0.1	0.2
$CO:CO_2$	<0.1	1.4	3.0	10
R ratio	2.0	2.9	2.1	2.05

necessary for methanol synthesis. Unconverted syngas is separated from the methanol product by condensation and the unconverted syngas is recompressed and sent back to the methanol reactor for another pass. A purge is taken to control the build-up of inerts and fresh syngas feed is added in to achieve the required methanol production.

As Table 1 illustrates, the syngas feed into the methanol synthesis loop is significantly different in a CO_2 to methanol plant compared to a conventional natural gas or coal based methanol plants. Most notable is the difference in the $CO:CO_2$ ratio, which can be very low depending on the composition of the CO_2 waste stream.

The heat of reaction for conversion of carbon dioxide to methanol is approximately half of that of carbon monoxide as shown in the enthalpies for the two reactions below:

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O \quad -49.5 \text{ kJ/mol}$$

$$CO + 2H_2 \rightarrow CH_3OH \quad -90.6 \text{ kJ/mol}$$

As a result, the heat released in the methanol converter with pure carbon dioxide and hydrogen feeds is lower compared to the traditional synthesis feed gas compositions.

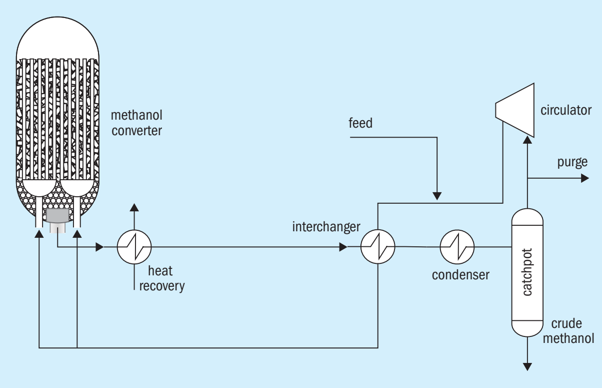
For syngas-based plants with high $CO:CO_2$ ratios, the heat of reaction needs to be managed by either a high heat removal efficiency or by limiting the per pass conversion and increasing the circulation ratio. The low $CO:CO_2$ ratios mean that the converter heat removal duty is lower, thus rendering the selection of converter type to be disconnected from the requirement for a high heat removal efficiency.

Moreover, the catalyst volumes required to achieve the same methanol production rate are greater for a CO_2 to methanol duty than for traditional syngas feeds. This is because the CO_2 has a slower rate of reaction and requires larger catalyst volumes than the CO reaction to methanol. An additional parameter leading to increased catalyst volumes is the potential for higher catalyst sintering rates in a CO_2 to methanol duty, due to the higher level of water formation in the reaction products.

The most critical parameter in the design of an e-methanol synthesis loop, however, is the recycle ratio (RR). This is the ratio between the flow of circulating gas at the outlet of the circulator and the flow of fresh make-up gas (MUG):

RR = (total gas to converter - MUG)/MUG

Fig. 1: **Schematic of methanol synthesis loop**



Source: Johnson Matthey

The higher the circulation ratio, the higher the feedstock efficiency and therefore the lower the variable production costs associated with generating the feedstock. With the price of renewable power dominating the methanol production cost, the circulation ratio becomes one of the most crucial factors affecting the levelised cost of methanol production.

Based on Fig. 2, the selection of the ideal converter type for CO_2 to methanol duty should take into account the requirement for higher circulation ratios, as well as for accommodating more catalyst volume per reactor. On the other hand, the reactor used does not necessarily have be as efficient in heat removal as would be required for a traditional syngas-based methanol synthesis loop.

Methanol reactor design

There is a new set of demands for reactors employed in CO_2-to-methanol duty for the production of e-methanol: the need to maximise feedstock efficiencies on one hand, and the absence of a suitable process option to make use of the purge gas fuel on the other.

Based on the above requirements, operating plants at high circulation ratios is preferred. To better illustrate this, a comparative study was carried out to determine the optimum circulation ratio for synthesis loops based on a tube cooled converter (TCC) and the most commonly used axial steam raising converter (ASRC), shown in Figs 3 and 4 respectively.

Fig. 2: **Hydrogen efficiency versus circulation ratio for a typical CO_2 to methanol loop**

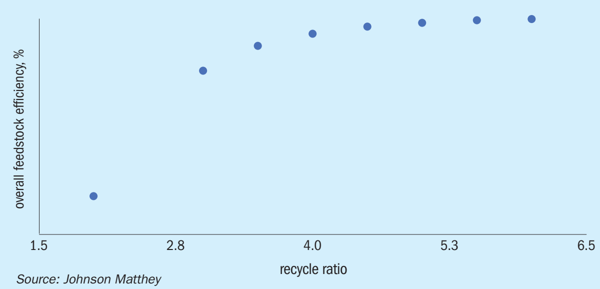


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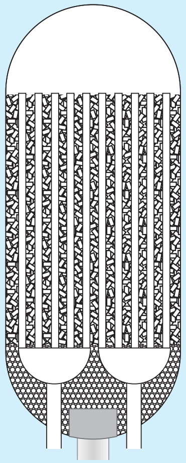
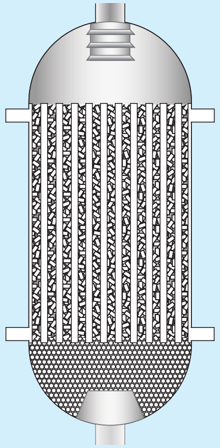
Fig. 3: **Tube-cooled converter**



Source: Johnson Matthey

Fig. 4: **Axial steam raising converter**



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What is the optimum circulation ratio?

This study considers a typical CO_2 to methanol plant with a capacity of 300 t/d.

Carbon dioxide and hydrogen are fed to the plant at 10 bar a, where they are mixed and compressed (as shown in Fig. 5). The syngas then passes to the methanol synthesis loop where it is reacted to form methanol. The crude methanol exits the loop and enters a three-column distillation train which refines the methanol to product grade. To control the build-up of inerts, a small purge is taken from the synthesis loop and passed through a hydrogen recovery unit (typically a membrane unit) which recovers 85% of the hydrogen and recycles it back to the front end. The remaining purge gas is exported OSBL.

In order to better illustrate the impact of feedstock efficiency on operating cost, hydrogen consumption has been translated to an electrolyser power demand.

Although the level of inerts in the feed and H_2/CO_2 ratio of the make-up gas also influence loop efficiency, these two parameters are assumed to be constant.

In carrying out the study the following assumptions were used:

- 300 t/d production
- hydrogen and carbon dioxide feed pressure at 10 bar a;
- 85% H_2 recovery in the hydrogen recovery unit (HRU);
- 98.5% distillation efficiency;
- hydrogen produced by electrolysis with an energy input requirement of 5 kWh/kNm³/hr;
- carbon dioxide feed conditions and composition assumed as typical from a carbon capture source.

Firstly, the effect of recycle ratio on the overall energy consumption for the TCC and ASRC-based loops was calculated and is shown in Fig. 6. The overall energy consumption is calculated as the total plant energy demand, including pumping/compression duties and electric process heating, plus the energy requirement for the generation of the hydrogen feed.

The results show that at low recycle ratios, which are typical for ASRC loops, the total power demand for the e-methanol plant is around 0.6 to 0.7 MWh/tonne larger than the high circulation cases that are characteristic of TCC-based synthesis loops. This is because, despite the low circulator power at low recycle ratios, the lower loop efficiencies mean that more power is required to both generate and compress the feed gases into the loop.

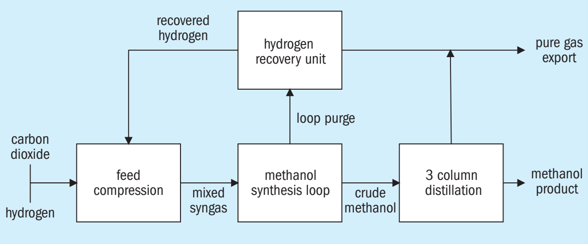
Depending on the performance of the HRU membrane, the minimum power consumption is achieved for circulation ratios in the range of 4-5, that translates to a methanol concentration at the exit of the converter of between 4.5-5%. These parameters are within the typical operating range for a TCC.

The TCC reactor can therefore easily adjust to the demands of the new CO_2-based process because the optimum circulation ratio for CO_2 duty is closely aligned with the TCC's optimum operating parameters from natural gas operation.

Conversely, this is not the case for the ASRC. The penalty for operating at the traditional circulation ratio of 2 for an ASRC-based loop is 6% higher energy consumption when compared with the high circulation (<4 RR) alternative, equating to an energy consumption of 12.2 MW/t methanol.

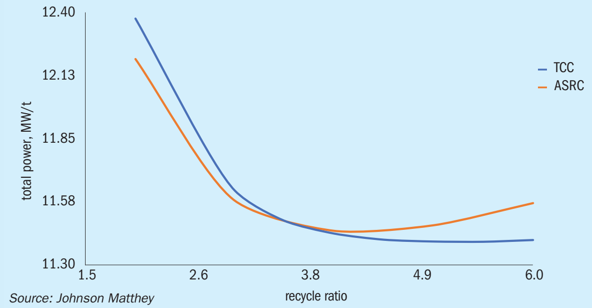
As shown in Fig. 6, in order to improve the process economics, the ASRC loop needs to operate at the same high circulation ratios that the TCC has traditionally operated at. However, as you operate at higher circulation ratios the per-pass conversion drops, meaning less reaction heat is generated in the converter and the advantages of having good heat transfer properties and raising steam become diminished.

Fig. 5 **Block flow diagram of the typical CO_2 to methanol plant used in the study**



Source: Johnson Matthey

Fig. 6: **Total plant energy requirement per tonne of methanol product for a TCC and ASRC loop based plant at a range of recycle ratios**



Source: Johnson Matthey

Additionally, because of pressure drop limitations, the way to facilitate an increase in the circulation ratio is to increase the diameter of the ASRC. This increases the size of an already relatively heavy converter, from the point of view of reactor weight per tonne of methanol production. An increase in the diameter of an ASRC converter would also entail an increase in the thickness and diameter of the tube sheet resulting in additional fabrication costs and complexity.

As plants become larger and the diameter increases, the thickness of tube sheets means that the overall weight of the ASRC makes it impractical to achieve the required duty in a single ARSC reactor. Due to the limitations in the diameter of an ASRC tube sheet design, it is not possible to design a single axial loop to function at capacities larger than 1,000 t/d whilst operating at high circulation ratios (see Fig.7). A second converter would be therefore required to achieve efficient operation at high capacities, increasing the capital cost requirements of the plant when compared with a single TCC loop, which has high circulation operating references up to ~2,500 t/d.

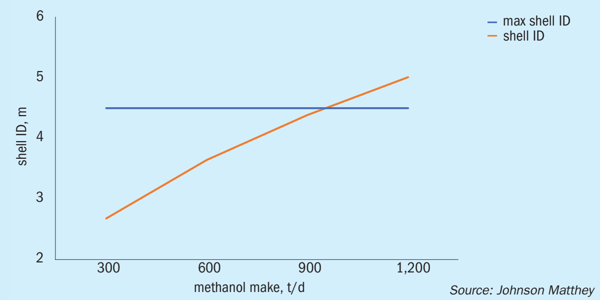
Operational flexibility

JM believes the tube cooled converter and the high circulation loop is well placed to cope with fluctuating feed rates and the potential increase in the frequency of start-ups/shutdowns predicted for a plant based on renewable power.

The catalyst kinetics and heat removal calculations for these reactors have been developed by JM over the last 40 years, with excellent correlations between modelled and real plant data. The only adjustment the operator needs to make is to adjust the inlet temperature to maximise methanol production as the catalyst ages. Turndown can be managed through adjusting the circulation rate and inlet temperature, which can be automated through a capacity management system.

The TCC is resilient to changes in operating conditions characteristic of high rates of turndown, as the tops of the tubes are open and not constrained by a tube sheet, removing any concerns about differential thermal expansion of the tubes relative to the shell. Having catalyst on the shell side also reduces the risk of damaging the catalyst through radial tube expansion.

Fig. 7: **ASRC shell internal diameters (ID) whilst operating with a high circulation ratio at a number of methanol production capacities**



Source: Johnson Matthey

Conclusions

The optimum design parameters for a CO_2 to methanol plant are significantly different to those considered when designing a conventional syngas-based methanol loop. Consequently, the advantages that an axial steam raising converter can offer for syngas-based designs are not applicable for CO_2-to-methanol duties. At small capacities the benefits from the generation of steam are diminished and the presence of a steam system can be capex intensive, whilst at large capacities, the ASRC-based loops either suffer from inefficiencies due to operating at low circulation ratios or induce higher capital investment, as the mechanical design necessitates the specification of multiple converters at higher circulation rates.

The TCC reactor is considered to be the ideal choice for e-methanol plants, as it avoids the requirement for a high-pressure steam system, especially attractive for low capacity plants. In addition, the mechanical design of the TCC is well suited to high circulation ratios and the operational flexibility requirements of a green methanol plant dependant on renewable energy sources for feedstock generation. Finally, the TCC has a long history of efficient operation at high circulation ratios, meaning established optimum operating parameters can be utilised to maximise feedstock efficiencies and minimise operating costs. ■

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