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NITROGEN+SYNGAS
ISSUE 397
OCTOBER-SEPTEMBER 2025

CRU

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Cover: Casale

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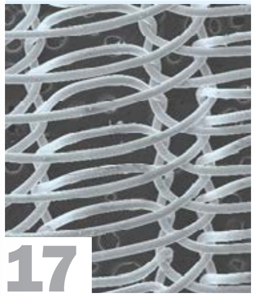

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Is the world ready for CBAM?

At the end of this year, the European Union's Carbon Border Adjustment Mechanism (CBAM) will move from its transitional phase into its 'definitive' phase, whereby the carbon costs of goods entering the EU will need to be priced in. CBAM requires suppliers to calculate the carbon emissions of their fertilizer (and other, e.g. steel) products, including indirect emissions, for example from electricity consumed in the process, and emissions of precursor or raw materials. They will then need to purchase CBAM certificates to cover embedded emissions above the established free allowance benchmark rates determined by the European Commission: 1.57 tonnes CO_2e/tonne ammonia and 0.23 tCO_2e/t nitric acid.

As CBAM is phased in, importers will be progressively required to cover the cost of a growing share of embedded emissions. In 2026, they will be responsible for any emissions above 97.5% of the free allowance rates, before the carbon price charge scales up to its full value under the EU Emissions Trading Scheme out to 2034, by which time it could be adding $140/t to 'grey' ammonia import prices. Major impacts will be felt in 2028-29, when the 'free allowance' will be cut by 10% and 22% respectively.

CBAM will have ripples far beyond the EU's borders, and reactions worldwide have been mixed. Some countries are trying to introduce their own similar schemes. The UK, for example, has agreed to continue with its own Emissions Trading Scheme (UK ETS), and is expected to continue to adopt a similarly priced carbon levy from 2027 to conform with EU regulations. India and China have indicated that they will be advancing their own emissions trading systems, although they have both criticised the CBAM itself, and Brazil, Japan and Turkey are also moving to an ETS-type system. In the United States there is a proposed "Foreign Pollution Fee" that would impose tariffs based on the carbon intensity of imported goods. Taiwan, Canada and Australia are in the early stages of their own CBAM development. Other countries such as Ukraine and South Korea are instead trying to negotiate deals or opt-outs.

> "Major producers... are in the process of setting up low-carbon ammonia production outside Europe..."

However, some nations have mounted legal challenges. The first came from Russia in May 2025, which claims that CBAM is not compliant with WTO rules, specifically the most-favoured-nation (MFN) and national treatment principles of the General Agreement on Tariffs and Trade (GATT). Russia claims CBAM discriminates by imposing different rules on imported goods based on the origin and carbon content, and by using non-compliant calculation methods. India and South Africa have also said they are considering a challenge under WTO rules – something that could take several years to resolve.

There are also still complications to be ironed out. The classification of 'blue' ammonia remains ambiguous, as no globally standardised threshold currently exists, although arguable from an economic point of view colour-based labels primarily serve to indicate production pathways rather than emissions performance, and the price of low-emissions ammonia will vary according to the level of carbon tax avoided. At the moment CRU is not forecasting any significant development of a separate market for low carbon ammonia until around 2030, unless there is a stronger pull from end use markets such as maritime fuels. However, it is coming and will need to be taken into account as a factor in the current generation of new plants being built.

In the meantime, major global producers such as Yara, OCI and CF Industries are in the process of setting up low-carbon ammonia production outside Europe, producing cheaper low carbon ammonia outside Europe and importing it at preferential cost to imported grey ammonia, or grey ammonia produced domestically in Europe. While some low carbon ammonia production will no doubt occur in Europe, many plants are now at risk of closure, and some downstream AN and particularly urea capacity may also not survive the coming transition. ■

Richard Hands, Editor

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Price Trends

Ammonia prices in both hemispheres had levelled out by the end of August, with the exception of a few marginal upticks in some regions on the basis of the latest supply-demand dynamics. All eyes are now on September's Tampa settlement, which should spell out the extent of the upside pressure set to emerge over the coming weeks.

Whilst no new spot business was reported out of Algeria, availability looks to be heavily constrained on reported outages at all three of Fertial's plants in the country, as well as uncertainty over the exact status of production at Sorfert. Delivered values into NW Europe have moved upwards towards the $600/t c.fr level. Regional imports continue, with Trammo discharging a spot consignment for CF in the UK, whilst Koch is shipping a Trinidadian cargo to Finland after agreeing a formula priced spot deal with Yara.

Across the Atlantic, market participants expect a moderate increase at Tampa for September, with Yara and Mosaic tapped to agree to at the very least a 5% premium on the $487/t c.fr fixed by the pair for August. The import line-up into Florida is strong at present, with phosphate major Mosaic increasingly active on the spot and contract market in recent weeks. Export wise, shipments out of the US Gulf are also robust, with a multitude of cargoes departing or set to load from Texas and Louisiana. However, despite assertions to the contrary, an August shipment from the Gulf Coast Ammonia (GCA) complex is unlikely to emerge before the end of the month.

In the Black Sea, contract cargoes from Trinidad and Algeria will soon arrive for Agropolychim. East of Suez, exports continue to flow out of the Middle East at a steady rate.

There was little change to normal proceedings in Southeast Asia, although prices in Indonesia have ticked up basis latest supplier targets and on ongoing turnaround at Parna Raya's 1,500 t/d KPI unit. In the Far East, both contract and notional prices edged up in Taiwan, China, although delivered values into South Korea, where imports have picked up of late, were unmoved.

Urea market sentiment has reversed on news trickling out of China, that there would be an additional export quota and shipments to India would be allowed. Confirmation is still awaited that India can receive the cargo but the prospect of this happening triggered a price correction. Looking forward to the next Indian tender with NFL scheduled to tender 2 September, talk amongst market players is of seeing prices slide below $500/t c.fr. Not all producers however are ready to accept that the market is moving down. Pupuk Indonesia offered 45,000 tonnes granular for September shipment and refused to accept that no-one could pay the owner's estimate of $503/t f.o.b., and the tender was scrapped. The highest bid came in at $475-479/t f.o.b. Bontang from Hexagon. There was talk of a $500/t f.o.b. price secured in Oman for October shipment but this could not be confirmed and seemed to make little sense as forward prices came under pressure on news that China would have additional quantities to place. ■

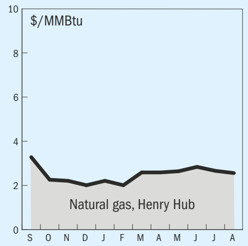
Table 1: Price indications

Cash equivalent	mid-Aug	mid-Jun	mid-Apr	mid-Feb
Ammonia ($/t)				
f.o.b. Black Sea	n.m.	n.m.	n.m.	n.m.
f.o.b. Caribbean	445-450	350-355	395	460
f.o.b. Arab Gulf	320-340	280-300	270-305	330-360
c.fr N.W. Europe	560-570	410-465	470-520	550-600
Urea ($/t)				
f.o.b. bulk Black Sea	460-470	355-365	350-355	385-395
f.o.b. bulk Arab Gulf*	386-515	300-390	345-389	402-445
f.o.b. NOLA barge ($/st)	420-445	343-355	300-315	402-418
f.o.b. bagged China	445-490	353-360	n.m.	n.m.
DAP ($/t)				
f.o.b. bulk US Gulf	787-805	713-715	628-640	588-595
UAN (€/tonne)				
f.o.t. ex-tank Rouen, 30%N	327-330	310-320	340-345	330

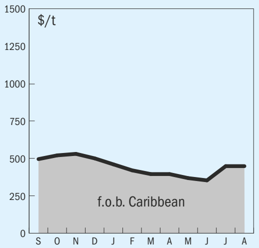
*Notes: n.a. price not available at time of going to press. n.m. no market. * high-end granular.*

END OF MONTH SPOT PRICES

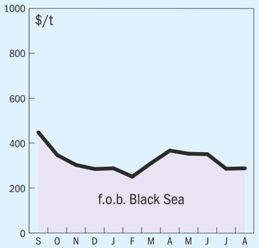
natural gas



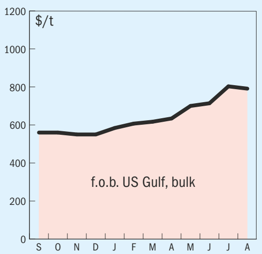
ammonia



urea

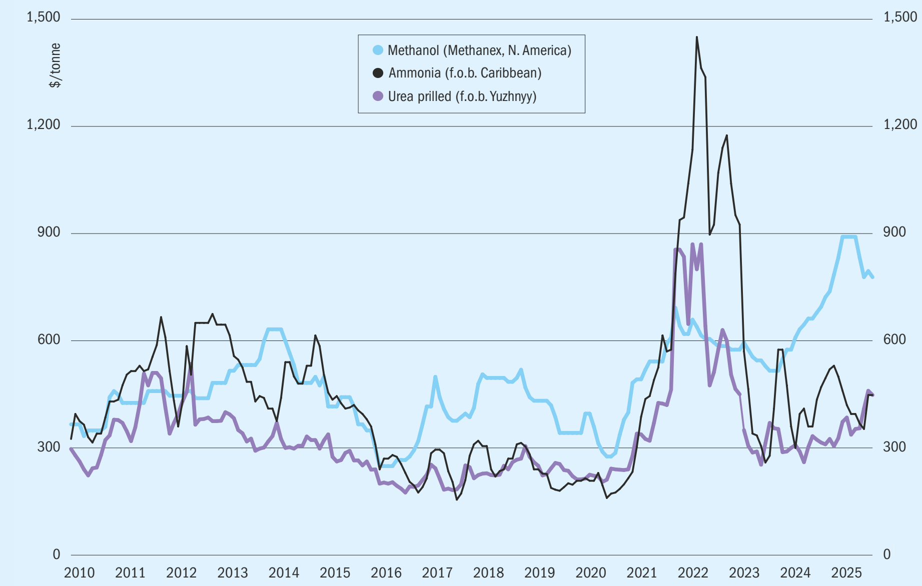


diammonium phosphate



Market Outlook

Historical price trends $/tonne



Source: BCInsight

AMMONIA

- Ammonia prices look well insulated against any declines over the immediate term, though the upside may be more limited in some regions than others.
- In Trinidad, market players are awaiting clarity from the island's Natural Gas Company (NGC) on when long-awaited feedstock constraints will come into effect. Trinidadian f.o.b. prices should gain ground in September, with the Tampa c.fr settlement expected to increase further on the $487/t cfr agreed for August.
- Ma'aden's 1.1 million t/a MPC unit has suffered an unplanned outage which could see the plant remain offline for up to two-three months. The outage could see around 150,000-200,000 tonnes worth of ammonia production lost. The company had been expecting to export 150,000 tonnes of ammonia in September.

UREA

- With China releasing additional quotas, global prices are expected to soften despite the huge volume India needs to secure. However, there is confusion over Chinese availability for India.
- China released the third round of urea export allocations on 20th August, at 700,000 tonnes, bringing the total export allocation figure to around 4.2 million tonnes, but it remains uncertain what volume, if any, from the allocation will be allowed to be exported to India. It appears that only a previously approved 300,000 t may be exported by nine distributors, while the export ban to India remains in place for all other suppliers.
- Indian demand is nevertheless still expected to bring prices higher in the longer term.
- There is growing concern that urea imports into Brazil will fall short of previous years as buyers focus on the cheaper priced AS from China.

METHANOL

- Methanol prices have spiked in India due to US sanctions being imposed against six Indian companies which are accused of buying Iranian methanol. The move has cut Indian buying of Iranian methanol and led to a sharp price increase domestically in India which is likely to continue for some months. Iranian exports continue to run at high levels, reaching 700,000 tonnes in August, in spite of the temporary shutdown of the Bushehr plant.
- Conversely, Chinese prices have fallen due to concerns about oversupply. Port stocks have reached 1 million t/a with storage space reported to be limited. MTO demand has been steady but economic news remains mixed and future demand uncertain. European methanol prices reached two year lows in early August before rebounding slightly. Lower demand has led to an excess of supply. ■

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Nitrogen Industry News

CHINA

Jilin Electric Power commissions green ammonia plant

Jilin Electric Power says that it has commissioned one of the world's largest green hydrogen and ammonia plants in Jilin Province. Jilin says that this is the world's largest operating green ammonia plant, with a capacity of up to 32,000 t/a of green hydrogen and 180,000 t/a of green ammonia; the largest combined PEM and alkaline electrolyser system, combining 196 MW of alkaline electrolysis and 52 MW of PEM electrolysis, respectively; and the world's largest block of solid-state hydrogen storage - 48,000 Nm3. The plant is fed by 800 MW of installed renewable power. The green ammonia is EU-certified under low-carbon fuel standards, and offtake agreements are in place with companies located in Europe, Japan and South Korea.

China is moving ahead rapidly with green ammonia capacity. In July Envision commissioned a similar sized green hydrogen and ammonia plant in Chifeng, capable of producing 320,000 t/a of green ammonia using 500MW of electrolysis capacity.

Zhongneng Chemical selects Eurotecnica technology for world-scale melamine plant

Eurotecnica says that Zhongneng Chemical Co., Ltd., a major player in China's nitrogen-based fertiliser sector, has selected Eurotecnica's proprietary Euromel® melamine technology for a new world-scale facility with a nameplate capacity of 120,000 t/a.

Zhongneng reportedly selected Euromel® technology for its outstanding performance, operational reliability, and hallmark total zero pollution feature. The multi-patented process which uses ammonia in the purification section, ensures that the ammonia, supplied by the upstream nitrogen fertiliser complex, is recycled without being consumed. This results in zero solid waste and liquid effluents and reduced operating costs.

Casale wins melamine contract

Casale has been awarded a contract to supply melamine technology by Anhui Haoyuan Chemical Group. The new melamine plant will feature Casale's uLEM-N technology, with a design capacity of 60,000 t/a, and will be fully integrated into an urea plant operated by Anhui Haoyuan. This is the third project that the two companies have developed together, following the successful implementation of two 1,500 t/a ammonia synthesis loop plants based on Casale's N-LOOP™ technology.

Casale says that its uLEM-N melamine process introduces a significant shift in sustainable design by eliminating caustic soda usage entirely thanks to ammonia-based purification, and features a highly efficient and proven high-pressure synthesis section using proven urea-based off-gas scrubbing. It operates with a zero liquid discharge approach, integrates simply with urea plants, reducing CAPEX.

Casale has also recently noted the successful conclusion of performance tests by the new 1,200 t/d coal-based ammonia plant owned and operated by Jiangsu Debang Xinghua Chemical Technology Co., Ltd., located in China's Jiangsu Province. Commissioned in June 2024, the plant features Casale's proprietary ammonia synthesis loop, which has reached 110% of capacity shortly after start-up and operated stably at 130% load for extended periods, with no bottlenecks encountered in the synthesis loop.

"We are extremely proud of the trust placed in us by Jiangsu Debang Xinghua Chemical Technology Co., Ltd. and pleased to see out technology making a real difference in performance. This achievement underscores our commitment to delivering cutting-edge solutions that help our customers meet and exceed their production targets" said Casale CEO, Federico Zardi.

Alliance for green energy projects

Clariant has signed a strategic cooperation agreement with Shanghai Boiler Works, a subsidiary of Shanghai Electric which specialises in energy conversion and the development of new energy applications, to jointly foster innovation in sustainable energy solutions. The partners say that they will combine their expertise to advance green energy projects in China.

Clairant says that the agreement is the result of close and successful cooperation in Shanghai Electric's new biomass-to-green methanol plant in Taonan, Jilin Province. In addition to supplying catalysts, Clariant provided technical on-site support during the successful startup of the 50,000 t/a plant. The second phase of the project, with a capacity of 200,000 t/a green methanol and 10,000 t/a sustainable aviation fuels (SAF), is expected to start production in 2027.

Georg Anfang, Vice President at Clariant, commented: "We are proud to add China's first biomass to green methanol plant in Taonan to a strong series of facilities that are already producing green methanol with our high-performance MegaMax catalysts. As China is becoming one of the frontrunners in the energy transition, our strategic alliance with Shanghai Electric will further strengthen Clariant´s footprint as a key enabler to produce clean energy, chemicals, and fuels."

PHOTO: CLARIANT

Shanghai Electric's biomass to methanol plant.

Qiu Jiayou, Vice President at Shanghai Electric, added, "We are proud of the successful launch of our new project and are equally delighted about our strategic agreement with Clariant, a company which understands and shares our vision for the future. Our teams look forward to joining forces to develop exceptional, sustainable energy solutions for customers around the globe."

The strategic cooperation agreement will combine Shanghai Electric's process competence and plant design capabilities with Clariant's catalyst expertise. The scope of the agreement includes collaborative research and development, engineering design services, supply of chemical equipment, and turnkey solutions. Clariant will share its extensive knowledge and advanced catalysts for producing green methanol, e-methanol, green ammonia, and sustainable aviation fuel, as well as for gas purification.

INDIA

Green ammonia plant for Andhra Pradesh

Polish company Hynfra PSA and the New & Renewable Energy Development Corporation of Andhra Pradesh have signed a memorandum of understanding to create the joint venture company JK Srivastava Hynfra (JKSH). The company plans invest $4 billion to build a new green ammonia plant powered by up to 3 GW of solar and wind energy supported by battery storage at Visakhapatnam in India's Andhra Pradesh province. The plant will initially produce 100,000 t/a of green ammonia, with the eventual goal of scaling up to 1 million t/a. The first phase is due to be completed in Q1 2029. Some of the green ammonia will be exported to Japan, South Korea and Taiwan, while the remainder will be used domestically in the fertiliser and power sectors, particularly to support the decarbonisation of coal-based power generation through ammonia co-firing.

Joint venture for green ammonia project

L&T Energy GreenTech Ltd (LTEG), a wholly-owned subsidiary of Larsen & Toubro (L&T), has entered into a joint development agreement with Japan's Itochu Corporation of Japan to develop and commercialise a 300,000 t/a green ammonia project at Kandla in Gujarat state. Under the agreement, LTEG and Itochu will collaborate on the development of the green ammonia facility, with Itochu planning to offtake the product for bunkering applications in Singapore.

Last year L&T acquired a sizeable land parcel at Kandla for the development of green hydrogen and green ammonia projects. This latest collaboration is p[art of the company's strategic vision to establish a presence across the green energy value chain and complements Itochu's initiatives to introduce low-carbon ammonia as a zero-emission marine fuel.

Commenting on the collaboration, Subramanian Sarma, Deputy Managing Director & President, L&T, said: "As the global energy landscape shifts decisively towards sustainability, L&T remains deeply committed to driving the clean energy transition through innovation, strategic partnerships, and engineering excellence. The partnership with Itochu reflects L&T's larger vision of enabling a cleaner, greener future through sustainable business focus".

Hiroyuki Tsubai, Executive Vice President, Itochu Corporation, said: "Through this joint development with one of the largest and most respected companies in India's private sector, L&T Group, our initiatives to introduce low-carbon ammonia to the maritime sector as an alternative zero-emission fuel will be reinforced. With this collaboration, Kandla, located on the west coast of India, will become the principal production centre of green ammonia for ITOCHU's bunkering operations in Singapore".

India's National Green Hydrogen Mission envisions a production capacity of at least 5 million t/a of green hydrogen by 2030, attracting investments exceeding $100 billion.

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BELGIUM

Yara seeking permit for rail transport of ammonia

Yara has applied for a new environmental permit in order to be able to import 275,000 t/a of ammonia by rail to its site at Tertre in the Saint-Ghislain municipality. The permit will cover ammonia to continue to operate downstream nitric acid and ammonium nitrate production at Tertre following the closure of the site's 400,000 t/a ammonia plant. A public inquiry into the permit is expected to be completed in early September 2025. Yara says that train traffic to the site will increase to around 5 trains per week if the permit is granted.

IRAQ

Design contract for new urea plant

KBR says that it has been awarded a front-end engineering design (FEED) contract for the development of an ammonia and urea production plant by KAR Electrical Power Production Trading FZE (KEPPT) in Basra, Iraq. Under the terms of the contract, KBR will provide FEED for a proposed 2,300 t/d ammonia production facility and 3,850 t/d urea unit. The design will be executed using KBR's proprietary ammonia technology.

"We are honoured to support this pivotal project, which monetises gas feedstock to boost the agricultural industry in Iraq," said Jay Ibrahim, President, KBR Sustainable Technology Solutions. "Underlined by KBR's expertise in market-leading ammonia solutions and proven FEED capability, this initiative should generate employment and reduce the dependency of fertilizer imports, while repositioning Iraq as a global ammonia producer."

RUSSIA

Ammonia-urea plan for Chechnya

The Chechen Republic's Ministry of Industry and Trade is reportedly in discussions with Chinese company Wuhuan over the construction of a mew nitrogen fertilizer plant in the region. Wuhuan is being considered as a potential EPC contractor, with technology and design coming from Russian design agency JSC GIAP. A site in the republic's Naursky district has been earmarked for the project, which aims to produce 1,700 t/dm of ammonia and 3,000 t/d of urea. Development and construction is expected to take five years, with plant startup currently scheduled for the first half of 2030. The total cost of the project is estimated at $2.4 billion.

NAMIBA

Green ammonia project proposal

The Namibian mining town of Arandis is reportedly in discussions with Cleanergy Solutions Namibia concerning a $2.85 billion investment to develop a large-scale green ammonia production site at Arandis, targeting production of 200,000 t/a of ammonia in the first phase based on abundant local solar energy. The Arandis Town Council approved the project in 2024 and is in the process of acquiring 2,400 hectares of land for the project, which is subject to the award of an Environmental Clearance Certificate, expected in the second quarter of 2026. The construction phase of the project will begin in 4Q 2026, with operations due to begin in 2030. Local infrastructure development will include pipelines and storage tanks for water, hydrogen and ammonia, as well as port, railway, road and power infrastructure, and may include handling and storage facilities. Cleanergy Solutions is a joint venture between Olthaver & List and Belgian company, CMB.TECH. It has operated a green hydrogen pilot project near Walvis Bay since 2024.

PARAGUAY

EIB loan agreed for Villeta project

ATOME says that the European Investment Bank (EIB), the lending arm of the European

Union, has approved financing in-principle of up to $135 million for the company's flagship Villeta Project. EIB is one of ATOME's senior debt providers for Villeta and the announcement follows the Green Climate Fund approval earlier this month. Details of the financing will be finalised in early course, following closing of the debt package with the consortium of leading international development

finance institutions. Based on the progress with financing, ATOME is projecting a final investment decision by the end of September 2025.

Olivier Mussat, ATOME CEO, commented: "The European Investment Bank board's in-principle approval of $135 million senior debt finance is another important milestone in the Villeta Project's maturity, credibility and genuine climate objectives. EIB is one of the largest providers of climate finance in the world and we are pleased to have EIB as one of the key supporters of this impactful, first-of-a-kind project."

ATOME has already secured a long-term supply of 145MW of low-cost hydroelectric power to feed green ammonia production, with 260,000 t/a of downstream green calcium ammonium nitrate production planned. A long term offtake agreement has been signed with Yara for the plant's entire output.

JAPAN

Study on ammonia fuel storage tanks and transportation equipment

Shipping classification society ClassNK has formed a consortium with IHI Corporation, JFE Steel, Tohoku University, and Institute of Science Tokyo to participate in Japan's Feasibility Study Program on Energy and New Environmental Technology. The consortium will promote the development of stress corrosion cracking (SCC) probability evaluation tools for fuel ammonia storage tanks and transportation equipment. Initially, the consortium will conduct a detailed study of the SCC mechanism involved in steel cracking due to the combined effects of mechanical stress and corrosion caused by liquid ammonia. Thereafter, the consortium plans to develop tools for easily and accurately assessing SCC probability. Finally, opinions will be solicited from stakeholders to formulate risk-based maintenance procedures for fuel ammonia storage and transportation facilities, and marine fuel tanks ultimately to promote the expanded use of fuel ammonia.

SOUTH AFRICA

Coal based fertilizer and methanol plant proposal

Suiso, a South African company specialising in blue ammonia production, is set to invest $1.7 billion in a coal-to-fertiliser facility in Kriel, Mpumalanga in the east of South Africa. The proposal is for a 1.5 million t/a 'blue' ammonia-urea plant which will replace South Africa's annual imports of 1.2 million t/a of urea, as well as producing 235,000 t/a of blue methanol for fuels, using advanced decarbonisation and carbon capture technologies. Suiso is partnering with Sinopec Ningbo Engineering, Stamicarbon, and ETG – the latter will distribute Suiso's fertilisers across Africa, supporting local agriculture and long-term food security.

"This is more than a fertiliser project," says Suiso founder Paul Erskine. "It's a commitment to South Africa's economic empowerment, food security, and sustainable development. With global partnerships, innovative technologies, and a focus on community upliftment, we are set to redefine the agricultural and economic landscape of the sub-continent."

SAUDI ARABIA

Contract awarded for large scale green ammonia plant

Saudi power group ACWA Power has awarded a front-end engineering design (FEED) contract to a consortium of Spanish engineering firm Tecnicas Reunidas and Sinopec Guangzhou Engineering for the development of a large green hydrogen and ammonia project in Yanbu. The project would include 4 GW of electrolysis capacity, enabling the production of 400,000 t/a of green hydrogen, which will then be converted into green ammonia for export. The plant's scope also includes water desalination infrastructure and an export terminal to support global distribution, though renewable generation assets are excluded from the current design phase.

Following the completion of the FEED contract, expected to take 10 months, the Técnicas Reunidas-Sinopec consortium is expected to present an engineering, procurement, and construction (EPC) proposal. Final commissioning is currently planned for 2030.

UNITED KINGDOM

Green ammonia plan for Scotland

Norwegian state-owned power group Statkraft says that it is moving ahead with plans for a 400 MW green hydrogen and ammonia production facility in the Shetland Islands, after securing a land lease near the disused Scatsta Airport. Known as the Shetland Hydrogen Project 2, the facility will use electrolytic hydrogen to produce green ammonia for a range of industrial applications, including use as a sustainable marine fuel and to help decarbonise fertiliser production.

Strategically located near the Sullom Voe oil terminal and the Shetland Gas Plant, the site will enable the conversion of excess renewable electricity into hydrogen during periods of grid constraint. Statkraft currently has three wind parks in pre-construction on Shetland, namely Mossy Hill near Lerwick, and Energy Isles and Beaw Field on the island of Yell. These projects are expected to play a key role in supplying renewable power to the hydrogen facility.

Scotland, which launched its Hydrogen Action Plan in 2022, aims to develop 5 GW of low-carbon hydrogen capacity by 2030 and 25 GW by 2045. In December 2024, the Scottish Government unveiled a hydrogen production and export strategy, targeting up to 3.3 Mt/year of green hydrogen by 2045.

NETHERLANDS

Nitrogen dioxide release caused by loading error

An explosion at the FrieslandCampina site in Borculo in July 2025 this year was reportedly caused by an error in the discharge of hydrochloric acid. The explosion released a mix of chlorine gas and nitrogen oxides. A truck driver reported to the wrong unloading point at the dairy company in Gelderland on 4th. Both the driver and a factory employee failed to properly check the cargo's paperwork, resulting in the hydrochloric acid being unloaded into a nitric acid tank. Furthermore, an incorrect coupling was used during the unloading process, the company reported after its own investigation. An orange cloud containing chlorine gas and nitrogen dioxide was released and spread throughout the surrounding area. Around 21:00, the site was evacuated and the fire department was alerted. At 22:13, the tank exploded. The tank lid was later found in a meadow near the factory.

UNITED STATES

BASF and Yara end low carbon ammonia project

BASF and Yara International ASA say that they have jointly decided to discontinue their project to develop a 1.4 million t/a low-carbon ammonia production facility with carbon capture and storage in the US Gulf Coast region. The companies say that this decision reflects their "commitment to focus on initiatives with the highest potential to achieve their respective value creation goals." Yara will continue its ammonia strategy as previously communicated, evaluating and maturing equity investment opportunities in US ammonia to determine the optimal project portfolio.

BASF and Yara continue to jointly operate a world-scale ammonia plant at BASF's site in Freeport, Texas. BASF also produces ammonia in Ludwigshafen, Germany, and Antwerp, Belgium, while Yara operates the world's largest ammonia system with production facilities in Europe, the Americas and Asia.

ETHIOPIA

Dangote to fund new urea plant

Aliko Dangote, self styled "Africa's richest man", has signed a $2.5 billion partnership with the Ethiopian Government to build one of the world's largest single-site fertiliser plants in Gode, Somali Regional State. The was signed on August 28th by Dangote Group and Ethiopian Investment Holdings, the government's strategic investment arm. Under the agreement, Dangote Group will hold a controlling 60% equity share, with EIH taking the remaining 40%. EIH says that the facility will be "among the top five largest urea production complexes globally… with production facilities boasting a combined capacity of up to three million metric tons per annum." The project will take gas feedstock via pipeline from the Calub and Hilala gas fields, with provisions for future expansions into ammonia-based fertilisers.

Chief Executive Officer of EIH, Dr Brook Taye, said: "This landmark agreement with Dangote Group marks a significant milestone in Ethiopia's journey toward industrial self-sufficiency and agricultural modernization. As the strategic investment arm of the Government of Ethiopia, EIH is proud to secure a 40% stake in what will be one of the world's largest urea production facilities." He added that the project would ensure energy security, boost productivity, and deliver "tremendous value to Ethiopian farmers."

Akilo Dangote said that the venture aligned with his vision to industrialise Africa. "This partnership with Ethiopian Investment Holdings represents a pivotal moment in our shared vision to industrialize Africa and achieve food security across the continent. We are committed to bringing our decades of experience in large-scale industrial projects to ensure this venture becomes a cornerstone of Ethiopia's industrial transformation and a catalyst for agricultural productivity throughout the region." he said.

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Syngas News

UNITED STATES

NextChem wins contract for blue hydrogen project

NextChem subsidiary KT Tech has been awarded a licensing, process design package and engineering services contract by a major international energy company for the application of its proprietary NX eBlue™ (electric steam methane reforming) technology for the production of low-carbon hydrogen in the Southwest of the United States. NX eBlue™ technology, part of NextChem's technological portfolio for syngas and hydrogen production, features an innovative electric steam methane reforming reactor along with a dedicated process scheme to produce low-carbon hydrogen. This technology significantly reduces CO_2 production and incorporates integrated carbon capture to further minimise CO_2 emissions, all allowing for operational flexibility and scalability.

NextChem says that the contract marks a key milestone in its strategy to accelerate the deployment of electrified hydrogen technologies combining renewable energy, carbon capture, and advanced reforming in a single, integrated technology solution. Fabio Fritelli, Managing Director of Nextchem, commented: "We are extremely proud of this achievement, which positions NextChem at the forefront of electrified hydrogen production, since it represents the first industrial application of our NX eBlue innovative technology".

CHINA

Start-up of world's largest methanol plant

Johnson Matthey (JM) says that the three methanol production trains of Inner Mongolia Baofeng Coal-based New Materials Co., Ltd., a wholly owned subsidiary of Ningxia Baofeng Energy Group, were successfully commissioned in November 2024, February 2025, and March 2025, respectively. Located in the Wushenqi Sulige Economic Development Zone of Ordos City, Inner Mongolia Autonomous Region, this plant employs Johnson Matthey's advanced methanol synthesis technology and catalysts, making it the largest single methanol plant in the world. Inner Mongolia Baofeng also stands as one of the largest chemical enterprises globally that produces polyethylene and polypropylene by using coal as a substitute for oil.

Ningxia Baofeng Energy Group is a key partner of Johnson Matthey in the fields of methanol process licensing and catalysts. The partnership between the two companies began in 2014 and has continued to deepen over the years. The successful start-up of this methanol plant marks another milestone in their long-standing collaboration. Johnson Matthey was awarded the contract for this project in 2020, which included process licensing for three methanol synthesis units, process design, technical review, commissioning support, and the supply of catalysts. To date, Johnson Matthey has licensed seven methanol synthesis units to Ningxia Baofeng Energy Group. This achievement underscores the company's sustained technology leadership in this critical and fast-growing market, as well as its commitment to delivering the highest standards of quality and performance.

This successful commissioning also represents JM's 14th methanol plant in China with a capacity exceeding 1.8 million t/a, further highlighting the proven success of using Chinese-fabricated radial steam-raising converters and compressors in large-scale projects.

Partnership for sustainable energy solutions

Clariant has signed a strategic cooperation agreement with Shanghai Boiler Works, a full subsidiary of Shanghai Electric specialising in energy conversion and the development of new energy applications, to jointly foster innovation in sustainable energy solutions. The partners will combine their expertise to advance green energy projects in China. The agreement is the result of close and successful cooperation in Shanghai Electric's new biomass-to-green methanol plant in Taonan, Jilin Province, China. In addition to supplying its MegaMax catalysts, Clariant provided technical on-site support during the successful startup of the 50,000 t/a plant. The second phase of the project, with a capacity of 200,000 t/a green methanol and 10,000 t/a of sustainable aviation fuels (SAF), is expected to start production in 2027. The ceremony for the official signing of the partnership contract took place last week at the Clariant Innovation Center in Frankfurt, Germany.

Georg Anfang, Vice President at Clariant, commented, "We are proud to add China's first biomass to green methanol plant in Taonan to a strong series of facilities that are already producing green methanol with our high-performance MegaMax catalysts. As China is becoming one of the frontrunners in the energy transition, our strategic alliance with Shanghai Electric will further strengthen Clariant´s footprint as a key enabler to produce clean energy, chemicals, and fuels."

Qiu Jiayou, Vice President at Shanghai Electric, added, "We are proud of the successful launch of our new project and are equally delighted about our strategic agreement with Clariant, a company which understands and shares our vision for the future. Our teams look forward to joining forces to develop exceptional, sustainable energy solutions for customers around the globe."

Methanol from biomass

Chinese electrolyser manufacturer LONGi Green Energy has begun construction on a $325 million green methanol project in Inner Mongolia that will combine biomass gasification with hydrogen from the company's electrolysers. The project, being developed at the Urad Rear Banner Industrial Park, will process 600,000 t/a of agricultural waste to produce 190,000 t/a of green methanol in the first phase. Phase 2 will expand ethanol capacity to 400,000 t/a, with hydrogen coming from new electrolysers powered by 850 MW of wind and 200 MW of solar power. LONGi says that the project will cut carbon dioxide emissions by 1.2 million t/a, while adding more than 1 GW of wind and solar capacity to the region's energy mix.

"Urad Rear Banner boasts abundant wind and solar resources, resulting in low-cost green electricity, enabling economical scale power generation," said Yu Litao, vice president of Xi'an LONGi Clean Energy Co, Ltd. "The abundant local agricultural biomass provides a low-cost source of carbon dioxide feedstock, laying the foundation for the subsequent development of a green methanol synthesis industry chain."

Ningxia Baofeng's site at Ordos, Mongolia.

MEXICO

Agreement for ancillary works on blue methanol plant

Transition Industries LLC has signed a heads of agreement with Italian contractor Bonatti SpA to deliver key infrastructure for the Pacifico Mexinol green methanol project in Sinaloa. Under the agreement, which includes a fixed lump-sum price, Bonatti will handle detailed engineering, procurement, construction, pre-commissioning, commissioning and startup for upgrades to the Terminal Transoceánica de Topolobampo port facilities. The work will cover methanol loading operations for export, underground transfer pipelines, vapor recovery systems, and dual fiber optic cables linking the main plant to the port. Bonatti may also build a closed-loop water pipeline to recycle municipal wastewater for plant operations, avoiding freshwater use and reducing environmental impact.

"We are proud to have Bonatti, a world-leader in pipeline EPCs, as part of our execution team," said Balmore Brito, Pacifico Mexinol Project Director at Transition Industries. "Bonatti shares our unwavering commitment to environmental and social sustainability."

Gustavo Blejer, Bonatti's Commercial Director for the Americas, called the project "an important step toward decarbonization" and said it would combine the company's global expertise with strong local experience in Sinaloa. The Pacifico Mexinol facility, being developed with the International Finance Corporation, is expected to begin operations in 2029, producing about 350,000 metric tons of green methanol and 1.8 million t/a of blue methanol from natural gas with carbon capture.

Siemens Energy and Techint Engineering & Construction have been selected to deliver the front-end engineering design (FEED) for the electrolysis as part of the green methanol project. Siemens Energy's Elyzer P-300 electrolyser has been confirmed as the backbone of the hydrogen production plant, featuring an estimated production capacity of approximately 4,000 kg/h of hydrogen. Cost certainty has been built into the FEED agreement, which sets an initial binding not-to-exceed lump sum firm price, followed by a final lump sum turnkey firm price for the full engineering, procurement and construction (EPC) contract – giving Transition Industries more predictable project costs and execution commitments.

AUSTRALIA

Uhde completes pre-FEED for major renewable fuels project

thyssenkrupp Uhde has completed the pre-FEED (Front-End Engineering Design) phase for the Portland Renewable Fuels Project in collaboration with HAMR Energy. The project, located in Victoria, Australia, will use biomass residues and renewable electricity to produce green methanol that can be used as a low carbon liquid fuel to power shipping and aviation.

In line with Australia's plans to become a global hydrogen leader according to the country's 2024 National Hydrogen Strategy, the project aims to contribute to one of its key objectives: the decarbonisation of long-haul transport. The green methanol that the plant will produce can be used to fuel ships, or be refined into sustainable aviation fuel (SAF), a direct substitute for fossil based jet fuel.

Nadja Håkansson, CEO, thyssenkrupp Uhde, said: "We are proud to support HAMR Energy in shaping the future of renewable fuels in Australia. Our proven capabilities in process engineering, technology integration and project execution are the cornerstones of this collaboration."

Richard Owen, Director and Chair, HAMR Energy added: "This milestone reflects both our ambition and our strategy: to work with global technology leaders to deliver Australia's next generation of clean fuels. The Pre-FEED phase marks an important step for a transformative project for our country's energy future."

thyssenkrupp Uhde will provide the biomass-to-methanol technology for the project. The company has over 100 years of experience in chemical process engineering, with a portfolio that includes proprietary technologies for gasification, methanol synthesis, and emissions reduction. Its Australian operations will

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Linde's hydrogen production plant at Leuna.

contribute local engineering expertise and project execution capabilities.INDIA

Biomethanol plant for Kandla

The Deendayal Port Authority (DPA), Kandla, has issued a tender for the engineering, procurement and construction (EPC) contract to build India's first port-based bio-methanol plant. The 3,500 t/a plant will use oxy-steam gasification technology to convert biomass into bio-methanol. The scope covers design, engineering, procurement, construction, commissioning, and product certification, with bidders required to outline plant life, warranties, capital expenditure, and operating costs. The move follows DPA's earlier call in May for turnkey proposals for a larger integrated plant of over 15,000 t/a, and its February 2025 agreement with Bapu's Shipping Jamnagar Pvt. Ltd. to develop India's first bio-methanol bunkering facility, including a dedicated bunker barge, at Kandla Port.

BELGIUM

Fossil fuel free plastics project

Lummus Technology says that its Novolen® polypropylene technology has been selected for a new grassroots plant in Antwerp. The plant will be part of a complex owned by Vioneo which will be the world's first industrial scale fossil-free plastics production complex. The complex, based on green methanol as feedstock, will also be highly electrified using renewable electricity and use renewable hydrogen as key components to its operations.

"Vioneo's goal of delivering the world's first fossil-free polypropylene plastics facility is bold, ambitious and one we are honored to support," said Leon de Bruyn, President and Chief Executive Officer, Lummus Technology. "Our proven polypropylene polymerization technology will allow Vioneo to produce high-performance, drop-in polypropylene grades through a low-emissions process without compromising quality or flexibility."

The first-of-its-kind plant will have a capacity of 200,000 and will use segregated green propylene and ethylene as feedstock to produce a wide range of polypropylene grades. With high-purity feedstock and proven technology, polypropylene will serve as a direct drop-in replacement for fossil-based alternatives. The plastics produced will be fully traceable and CO2 negative, allowing customers to reduce their Scope 3 emissions.

"Vioneo is driving the plastics industry's transition by proving that large-scale, cleaner production with green methanol-derived feedstocks is economically viable," said Alex Hogan, Chief Executive Officer, Vioneo. "Our collaboration with Lummus Technology… is fundamental to this vision. This world-first plant will use fully certified green propylene and ethylene from industrially proven methanol-to-olefins technology, to produce a broad range of high-quality, drop-in bio-polypropylene grades, significantly advancing a sustainable plastics economy."

Lummus' scope includes the technology license, process design package, support during the front-end engineering design phase and catalyst supply during ongoing operations.

GERMANY

Funding for green hydrogen plant

Linde has received a €4.3 million ($4.7 million) funding commitment to build a new 5MW alkaline electrolysis plant in Leuna, Saxony-Anhalt, adding to the region's growing hydrogen infrastructure. The project, which complements Linde's existing 24 MW facility, is scheduled for commissioning by the end of 2026 and is expected to produce 450 t/a of green hydrogen for local industrial customers via pipeline distribution. The funding was formally awarded on August 13 by Saxony-Anhalt's Economics Minister Prof. Dr. Armin Willingmann, backed by the state's "Future Energy" programme and the EU's European Regional Development Fund (ERDF).

DENMARK

thyssenkrupp completes acquisition of GHS technologies

thyssenkrupp nucera says that it has successfully completed the acquisition of key technology assets from Danish company Green Hydrogen Systems (GHS), as announced in June. The transaction was finalised following receipt of all necessary regulatory approvals and the consent of the court-appointed insolvency administrator. The asset deal includes intellectual property as well as a test facility with a full-size prototype in Skive, Denmark.

The company says that, via this acquisition, it has strategically strengthened its position in the field of alkaline water electrolysis (AWE), now additionally also focusing on pressurized solutions. The technology enables highly efficient hydrogen production at operating pressures of up to 35 bar, offering a key advantage for industrial applications that require compressed hydrogen. The acquisition is part of thyssenkrupp nucera's strategy to advance its development roadmap and foster innovation. The purchase price was said to be "in the high single-digit million euro range". ■

People

Alexander Döll.

The Methanol Institute (MI) has appointed **Alexander Döll** as its new Chief Executive Officer. He succeeds **Greg Dolan**, who is retiring after nearly 30 years of service and leadership. Döll brings more than 25 years of international experience across the energy, chemicals, and sustainability sectors. He has held senior positions at leading companies such as Dow and OCI Global, with a strong focus on public affairs, policy, and commercial strategy. His career spans Europe, the United States, the Middle East, Africa, and Southeast Asia; regions that are key to the future of the methanol industry. Before this appointment, he served as MI's Chief Operating Officer, helping to guide the organisation during a period of significant growth and momentum.

"I'm honoured to take on this role at such a dynamic time for our industry," said Döll. "Methanol has secured a clear role in the global energy transition - as both a low-carbon and clean fuel and a vital chemical building block found in thousands of products that touch everyday life. What sets this industry apart is the strength of its entire value chain - from production to technology to end use. MI has a unique role in bringing those voices together, and I'm excited to build on that foundation to help move the industry forward, with the support of our committed members and MI's incredible global team."

The Indian Farmers Fertiliser Cooperative Ltd (Iffco) has announced the appointment of **K J Patel** as its new Managing Director, succeeding **Dr Udai Shanker Awasthi**, who retired on July 31, 2025. Patel has a wealth of experience in the fertilizer and cooperative sectors and is expected to carry forward Iffco's legacy of innovation, farmer empowerment, and global excellence. Retiring MD Dr Awasthi, 80, had been the longest serving CEO of a major fertilizer company, with more than 30 years as MD of Iffco. In a tribute to Dr Awasthi, Iffco said that he had "shaped Iffco's trajectory, elevating it to unparalleled global prominence." A chemical engineer from Banaras Hindu University (BHU), Awasthi joined Iffco in Nov 1976, ascending through various pivotal roles before becoming its MD in 1993. He was instrumental in forging Iffco's global footprint, with strategic investments in ICS Senegal, Oman, Jordan, and the UAE.

Prior to working with Iffco, Dr Awasthi worked at Shriram Chemical Industries in Kota, and joined Zuari Agro-Chemical in Goa, in 1971. After joining Iffco in 1976, he worked on the projects that led to the construction of the plants at Aonla and Hazira from 1976-1986. In that latter year, he also became Managing Director and Chairman of Pyrites, Phosphates and Chemicals Ltd. (PPCL). From April 1991 to March 1992, he was appointed as the Chairman and Managing Director of Rashtriya Chemicals & Fertilizers Ltd. (RCF), before returning to Iffco in 1993 as the company's Managing Director, a position he held until this year.

Genesis Fertilizers says that **Derek Penner** has been appointed President and Chief Executive Officer of Genesis Fertilizers GP Inc., the general partner of Genesis Fertilizers Limited Partnership (Genesis Fertilizers). The other members of the Board are Ian Craven, Kathy Jordison and Garth Whyte, all of whom are independent directors, and Jason Mann. Mr. Whyte is currently the Interim Chair of the Board. Penner is a Chartered Professional Accountant (CPA, CA) and brings more than 20 years of senior financial, strategic and operational leadership experience in both Canada and international markets. ■

Calendar 2025/2026

SEPTEMBER

15-17

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

OCTOBER

12-15

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

13-17

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

14-16

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

20-22

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

JANUARY 2026

26-28

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

FEBRUARY

10-12

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

APRIL

23-26

Nitrogen+Syngas Expoconference USA 2026,
DALLAS, Texas, USA
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Plant Manager+

Incident No. 7 Nitric acid tank explosion – Part 1

The following case study describes a serious incident and the consequences of erroneously mixing nitric acid with hydrochloric acid. In Part 1 we report on the incident and the causes that led up to the event. In part 2 the impact, recommendations and lessons learned will be discussed.

The first news report

It was reported that an explosion and a large orange toxic cloud erupted on Friday 4 July 2025 at a factory (not related to fertilizers) after a chemical reaction between two hazardous substances inside a truck. No one was injured, but authorities evacuated the plant and closed roads as a precaution.

The incident began when nitric acid and hydrochloric acid – corrosive chemicals used to clean equipment – came into contact inside the vehicle. A spokesperson said the cloud contained dangerous substances that could irritate skin and airways. “Measurements by the fire service showed that the smoke contained toxic substances,” the spokesperson said. However, the chemicals quickly dispersed into the air without settling on the ground. Around 1 am, the cloud had evaporated and dissolved, according to the safety region. The mayor later announced that the situation was “fully under control.”

Authorities issued an alert advising residents nearby to close windows and doors and turn off ventilation systems. Several houses are located near the site. Emergency services closed access roads, urged people to stay away from the factory grounds, and evacuated the plant as a precaution.

The police cordoned off the area as a crime scene and launched an investigation to determine how the acids were able to mix. “The cause of the incident will be carefully investigated,” the mayor said. Officers are examining all possible scenarios, including deliberate tampering or an operational error.

Background information

The reaction between nitric acid (HNO_3) and hydrochloric acid (HCl) forms aqua regia, a highly corrosive mixture capable of dissolving noble metals like gold and platinum. This mixture is primarily composed of nitric acid, hydrochloric acid, nitrosyl chloride (NOCl), chlorine gas (Cl_2), and water.

Aqua regia is formed when concentrated nitric acid and hydrochloric acid are mixed (typically in a 1:3 ratio). The reaction is not a simple acid-base neutralisation. Instead, it involves oxidation and complex formation. Nitric acid acts as an oxidising agent, converting some chloride ions (from HCl) into chlorine gas. The chlorine gas then reacts with nitric acid to form nitrosyl chloride. The reaction can be represented as:

$$HNO_3 + 3HCl \rightarrow NOCl + Cl_2 + 2H_2O$$

Aqua regia is historically significant for its ability to dissolve gold, leading to its name meaning “royal water”. It’s used in various applications, including refining precious metals, cleaning glassware, and as a reagent in chemical synthesis. Due to its hazardous nature, it is crucial to follow strict safety protocols when handling aqua regia.

Properties of aqua regia are listed below:

- **Corrosive**: Aqua regia is highly corrosive due to its strong oxidising and acidic properties.
- **Fuming**: It produces irritating and toxic fumes, primarily chlorine and nitrosyl chloride.
- **Oxidising**: Aqua regia is capable of oxidising metals, including gold and platinum, which are normally resistant to individual acids.
- **Dissolves metals**: The reaction of aqua regia with gold (Au) and platinum (Pt) involves the formation of soluble chloroauric acid ($HAuCl_4$) and chloroplatinic acid (H_2PtCl_6) respectively.
- **Decomposition**: Nitrosyl chloride (NOCl) can further decompose into nitric oxide (NO) and chlorine gas.
- **Dangerous**: Aqua regia is extremely hazardous and should be handled with extreme caution in a fume hood, using appropriate personal protective equipment (PPE).

The following information was provided in the company’s preliminary investigation report dated 28 August 2025.

The incident

The incident began on 4 July 2025 at 12:58 pm when a tanker carrying hydrochloric acid (30% solution) from a third party supplier arrived at the wrong location. Drivers were allowed onto the scene due to poor communication and lack of verification. Without checking the bill of lading or the UN code, the hydrochloric acid was discharged into the tank containing the nitric acid solution (25% solution) at 1:20 pm. The error was discovered by the logistics department around 3:30 pm. The crisis group was activated and after consultation with a dedicated external company, it was decided to pour the contents of the tank into a specialty chemical container (IBC). Due to the rapidly changing situation, this ultimately didn’t continue. Around 7:14 pm the first sign of a chemical reaction appeared: orange smoke rising near the gas scrubber. Around 9:10 pm the scene was evacuated and the fire brigade was put into service. The situation escalated rapidly and at 10:13 pm the tank exploded.

Factory and environment overview

1. *Nitric acid tank (HNO_3)*
2. *Sodium hydroxide/caustic tank (NaOH)*
3. *Position where the lid of the exploded nitric acid tank dropped*
4. *Loading office operator’s workplace*
5. *Location of crisis team immediately after discovery of acid mixing event*
6. *Provincial highway*
7. *River*
8. *Entrance/gateway to premises*
9. *Storage of hydrochloric acid (HCl) and sodium chlorite ($NaClO_2$)*

A summary of the event:

- **Chemical reaction** – Hydrochloric acid was accidentally added to the nitric acid tank, resulting in a violent chemical reaction.
- **Gas formation and explosion** – reaction resulting in corrosion, pressure increase and orange smoke column; Later, the tank exploded and the lid was thrown hundreds of metres.
- **Smoke spread** – Smoke gradually spread with the wind causing visible disturbance to the surrounding area.
- **No casualties but damage** – No casualties but smoke and noise disturbance causing damage to the environment.
- **Stopped production** – factory closed.

Facility damage.

The causes

Due to a series of human errors, hydrochloric acid (30% solution) was accidentally discharged into a storage tank containing nitric acid (25% solution). Both of these substances are used in the plant for cleaning and water purification. The mixing of the two acids resulted in a drastic chemical reaction, and preliminary findings suggest that both human and technical and organisational factors played a role. The driver delivered his goods to the wrong production site and was allowed into the factory. The identity of chemicals was not verified by bills of lading or signs such as UN codes. The UN code refers to an orange sign with a black number that indicates which hazardous substances are being transported. The UN code identifies substances on tanker trucks and tank units. The scheduling was misinterpreted and the prescribed verification procedure was not applied. In addition, the driver used the connector he carries with him to adapt the hose of the hydrochloric acid tanker to the nitric acid tank, and connected it in front of the staff present. The highly reactive combination of hydrochloric acid and nitric acid led to rapid corrosion of the tank and ultimately explosion from heating the liquid in the sealed tank. So far, it has been found that with the training available, operators cannot easily cope with this situation, instructions are scattered across multiple systems, and the four-eyes principle is not applied when connecting and unloading chemicals.

While the crisis team acted quickly based on the local company’s contingency plan, the case of chemical mixing was not covered.

The causes are summarised as follows:

- **Wrong location and insufficient verification** – The driver delivered to the wrong factory and did not check the identity of the chemical via bill of lading and UN code.
- **Incorrect connection** – A hose was connected to the wrong tank using a carry-on connector in the presence of employees.
- **Organisational improvement points** – Operators have been found to be unable to handle the situation easily to date. Indications are fragmented and the four-eyes principle is not applied.

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South America's nitrogen industry

South America has become the largest importing region for nitrogen fertilizers, with Brazil overtaking India as the world's largest urea importer. While there have been attempts to use local gas to develop a domestic nitrogen industry, these have faced challenges on a number of fronts.

The Latin America and Caribbean region has become the world's largest net food-exporting region, according to the International Food Policy Research Institute. Its exports help to stabilise global food supplies and reduce food price volatility. Many countries of the region rely upon food exports, for up to 80% of their total export earnings in some cases, and agriculture is an important source of income and foreign exchange for many countries of the region. Fertilizer, particularly nitrogen fertilizer, plays a key part in sustaining this industry, and hence demand for fertilizer is strong across the region.

However, while there is plentiful oil and gas across the continent, attempts to develop this into a domestic nitrogen fertilizer industry have had mixed success at best. Brazil's fossil fuels industry has been mired in corruption and several forced closures; Venezuela's nitrogen industry - a flagship for the region in the 1990s - has contracted along with the rest of its economy under presidents Chavez and Maduro; Trinidad rapidly expanded ammonia production in the 1980s and 90s but more recently has faced gas shortages and production curtailments; and while Chile has a large domestic methanol industry at its southern tip, it has not managed similar for ammonia. One of the few success stories has been Argentina's Profertil urea plant at Bahia Blanca.

Brazil

Brazil has the largest economy in Latin America and is 10th among the world's top economies by nominal GDP, and 8th when measured by GDP purchasing power parity (PPP). It is a major global player in mining, agriculture, and manufacturing, with significant exports of iron ore, coffee, soybeans, and beef. The economy relies on both natural resources and a growing services sector. While recent growth has shown resilience, projections indicate a slowdown in 2025 due to higher interest rates and slowing household consumption.

In terms of fertilizer demand, Brazil's fertilizer use has been rapidly growing over the past decade, as agricultural land is expanded. Cultivated area in Brazil has risen by 50% in the past 40 years, albeit often at the expense of clearing of rainforest areas. Coupled with increasing intensification of agriculture, this has meant that demand for urea – far and away the most popular nitrogen fertilizer in Brazil – has risen from 5.4 million t/a in 2014 to 8.3 million t/a in 2024. Overall Brazilian nitrogen demand represents now about 60% of that for the whole of Latin America, making it one of the most important consumers worldwide.

Brazil is all the more important in the urea market because it imports more than 90% of its requirement 9see Table 1). There are three urea plants in Brazil. Camacari and Laranjeiras, with a combined capacity of 1.0 million t/a were originally owned by state oil and gas company Petrobras but both were closed down in 2018 due to poor production economics. After an abortive sale to Russia's Acron fell through, in 2019 the plants were leased to chemical company Unigel for 10 years, but Unigel in turn was forced to close the plants down again in 2023, citing high gas feedstock prices making them uncompetitive compared to imported urea. In May this year Petrobras began court proceedings to take the two sites back under its control under a plan by president Lula de Silva to restart them.

The other urea plant, a 720,000 t/a unit at Araucaria, was originally owned by Petrobras but was privatised in 1993 as Ultrafertil. Under this guise it passed through the hands of first Bunge, then mining giant Vale, and then back to Petrobras in 2017, before being idled in 2020 due to economic difficulties at Petrobras. Petrobras approved a restart for the plant last year as part of its 2024-2028 strategic plan. The site's automotive urea solutions plant began operations this August using imported urea from Yara, but the restart of the ammonia-urea plant is expected imminently, making it the only operational urea plant in Brazil. Aside from these, the only other nitrogen facility is an ammonia and industrial grade AN plant at Cubatao, with 600,000 t/a of capacity, operated by Yara.

In the 2010s, Petrobras tried to develop three new fertilizer complexes, at Linhares, Uberaba and Tres Lagoas, at a total cost of $6.5 billion, with the strategic goal of reducing or ending Brazil's dependence on nitrogen fertilizer imports. However, a lack of natural gas availability and a recession in the Brazilian economy led to Linhares and Uberaba being cancelled, and work at Tres Lagoas, where a 720,000 t/a ammonia plant and 1.2 million t/a urea were reportedly 80% complete, being halted in 2014. Last year Petrobras approved the revival of the Tres Lagoas project, with work scheduled to recommence this year, and a targeted completion date of 2028.

The push to restart shuttered plants and revive stalled construction projects has come from the Brazilian government's National Fertilizer Plan, which aims seeking to reduce the country's dependency on imported fertilizers. How successful this will be remains to be seen, but in theory it could result in 2.9 million t/a of operational urea capacity in Brazil by 2028. Even so, Brazil's demand for urea is projected by CRU to increase to 9.8 million t/a by 2029, meaning that it will remain the world's largest importer for the foreseeable future.

Another wrinkle for Brazil's nitrogen industry has come from the direction of those imports. Prior to the Russian invasion of Ukraine, Brazil imported much of its urea from Russia, but those volumes have fallen due to international sanctions on Russian banks, and more has been imported from the Middle East and Nigeria. A surprising increase has also come from imports of Chinese ammonium sulphate, which have risen rapidly from 2 million t/a in 2019 to 6.1 million t/a in 2024. Ammonium sulphate has increased its share of total Brazilian nitrogen demand from 14% in 2020 to 25% in 2024. Figures for 2025 show a continued increase, with May 2025 imports of AS from China up 47% year on year.

Table 1: **Urea production and consumption, Latin America and Caribbean, 2024 (million t/a)**

	Production	Consumption
Argentina	1.2	2.3
Bolivia	0.5	0.0
Brazil	0.1	8.3
Mexico	0.3	2.0
Trinidad	0.6	0.1
Venezuela	0.8	0.2
Others	0.0	2.9
Total	3.5	15.8

Source: CRU

Argentina

Argentina is Latin America's other major agricultural producer, and consumer of fertilizers. Argentina's agriculture is a pillar of its economy, making it a global power in the export of commodities like soy derivatives, corn, beef, and wheat. The fertile Pampas region is particularly important for large-scale production. Argentina is the world's third largest food exporter, with the agricultural sector accounting for 15.7% of gross domestic product (GDP), and around 25% of Argentina's net exports.

Urea consumption was 2.3 million t/a in 2024, and though this figure rose during the 2010s, it has been relatively stable since 2020. It is expected to grow modestly to around 2.5 million t/a in 2029. Domestic nitrogen production comes from a single 1.3 million t/a urea plant, Profertil at Bahia Blanca, co-owned by Argentinian oil and gas firm YPF and North American fertilizer producer Nutrien, which almost exclusively produces for the domestic market. This leaves a shortfall of around 1.1 million t/a (see Table 1) which is made up with imports from North Africa (mostly Algeria and Egypt) and Nigeria. Various plans for a second urea plant have circulated over the past decade, but there is as yet no firm commitment.

Bolivia

Bolivia is not a major consumer of fertilizer but has large natural gas reserves, discovered in the late 20th century, which attracted numerous ammonia/urea project ideas. Bolivia supplies natural gas via pipeline to Brazil, and a site on the pipeline at Bulo Bulo, in the centre of the country, was chosen to build an ammonia/urea plant, under the auspices of state oil and gas company YPFB. After a long and difficult development process, the 726,000 t/a urea plant finally became operational in 2017, but was forced to close in 2019 due to high production costs. After maintenance was carried out to replace damaged equipment items it restarted in September 2021, and has operated successfully since then, though it has struggled to reach capacity. Production was 350,000 t/a in 2023, but rose to 545,000 t/a in 2024, with exports going to Brazil and Argentina.

Chile

Chile has no nitrogen fertilizer company, but explosives producer Enaex operates 850,000 t/a of ammonium nitrate production at Mejillones for explosives production. The site began operating in 1983, and has grown to four AN trains over the succeeding decades, the most recent capacity increase being in 2010. Aside from a small (15,000 t/a) electrolysis based plant using hydroelectricity, there is no domestic ammonia production, however – 350,000 t/a of ammonia is bought in from Nutrien to feed the site's downstream nitric acid and ammonium nitrate production after the site's ageing ammonia plant was sold, dismantled and transported to be rebuilt in China in 2013.

Enaex has become interested in the possibility of using renewable energy in Chile to generate ammonia. An 18,000 t/a 'green' ammonia demonstrator plant is under development, licensed by KBR, with completion expected in 2025.

Spain's Ignis Energy has also been developing a large-scale green hydrogen and ammonia project in Chile's southern Magallanes region, with some of the strongest winds in the world. Ignis has been planning 2.25 GW of wind power network at Tierra del Fuego on Chile's southern tip, with associated electrolysers to facilitate the production of green hydrogen and ammonia. In 2023, the company signed lease agreements for around 50,000 hectares of land for the project. However, the company recently signalled that it is slowing development until a market for green hydrogen and ammonia emerges, and has ended several agreements with local land owners in the face of an increasingly slow development process.

"Even though we firmly believe that this industry will develop and mature, the company is considering a longer time frame than initially planned and a reduction in the project to adapt it to this new reality," Ignis said in a recent statement.

Mexico

Mexico is the third largest consumer of urea in Latin America, at 2.0 million t/a in 2024. As with many countries in the region, this runs far ahead of domestic production, which totalled 280,000 t/a in 2024. State-owned Petroleos Mexicanos (Pemex) operated several 1950s vintage ammonia and urea plants at Cosoleacaque, Chihuahua and Salamanca, and in 1996 Mexico produced 2.5 million t/a of ammonia and 1 million t/a of urea, but as with Brazil high gas prices led to the closure of much of the ammonia production by 2005. Attempts to refurbish plants and restart production at Cosoleacaque have been stymied by Mexico's gas pipeline network, which does not connect the ammonia production sites in southeastern Mexico to the more exten-

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sive pipeline network in the north of the country, which is able to import cheaper natural gas from the United States.

The solution was to build a new urea plant at Topolobampo in Sinaloa state, on Mexico's west coast, but the project, initiated back in 2014, has faced local environmental opposition and legal challenges, and was not given final approval until 2021. The site has been cleared and prepared and developer Proman achieved financial closure on the $1.5 billion project in 2023 and engaged thyssenkrupp Uhde to design and build the 2,200 t/d ammonia plant. However, the project remains controversial, and in June this year the Mexican government announced a review of the project's permits.

In the meantime, another $1.3 billion project in Mexico's northeastern Tamaulipas region appears to have begun construction earlier this year. The Oleum facility, situated close to the town of Reynosa near the Mexico-US border, will have capacity to produce around 330,000 t/a of ammonia and 700,000 t/a of urea. Operations are expected to begin in late 2027, according to the company.

Casale has also been awarded a licensing and engineering services contract by Pemex for a new fertilizer complex at Escolin, Veracruz, including a 1,200 t/d ammonia plant and 2,125 t/d urea plant. Detailed engineering studies were conducted at the end of 2024, with production scheduled for 2028.

Mexico also has a number of green ammonia project proposals circulating, including CIP's project Helax, Hy2gen, Asian Energy Capital and Tarafert. As yet there do not appear to be any final investment decisions, however.

Venezuela

Venezuela developed a gas-based urea industry at three complexes on its northern coast in the 1980s and 90s; Nitroven at El Tablazo in Zulia state in the west, Fertinitro at Jose in the east, and Pequiven's Puerto Moron in between the two. The country's total production capacity totalled 2 million t/a of urea in the early 2000s. Most of the plants were state-owned, but Fertinitro, completed in 2002, was a joint venture between state petrochemical major Pequiven (35%), Koch Nitrogen (35%), Snamprogetti (20%) and Empreseas Polar (10%). Koch became involved after PCS Nitrogen pulled out of the project in the late 1990s.

The Topolobampo site in Mexico, still awaiting new urea capacity.

However, the advent of president Hugo Chavez in 1999 and his 'Bolivarian revolution' saw Venezuela's economy slide. Much of the oil, gas and downstream industry was nationalised, including Fertinitro in 2010, and corruption and mismanagement left plants badly maintained. Pequiven did complete a replacement, 2,200 t/d ammonia-urea plant at Moron with financial support from China, which began production in 2014, but production at all of the sites continues to be dogged by interruptions in electricity and gas supplies. Venezuelan urea continues to be a valuable source of foreign earnings, but production was only around 800,000 t/a in 2024 out of a total capacity of 3.0 million t/a. President Maduro, successor to Chavez, announced a new 1.6 million t/a urea project last year, part funded with Turkish money, for the Fertinitro complex at Jose, but there is no sign of progress as yet.

Trinidad

Trinidad is an interesting adjunct to the Latin American nitrogen industry. Its boom years were in the 1980s and 1990s, when its relatively cheap natural gas prices made it attractive for suppliers to the United States, which was facing high gas prices. Ten ammonia plants with a combined capacity of 5.7 million t/a were developed on the island, as well as 1.3 million t/a of urea capacity and urea ammonium nitrate (UAN), most of these intended for export to the US.

However, Trinidad's fortunes took a turn with the US shale gas boom, which led to the restart of idled capacity in North America and the construction of new plants, while Trinidad's cheap gas prices had not been sufficient to develop new gas reserves at the pace that gas was being used for ammonia, methanol and LNG production, and consequently Trinidad's ammonia plants have faced production curtailments due to gas supply shortages.

The shift in US trade flows also forced Trinidadian exporters to seek alternative buyers, including Europe, Morocco, and markets east of Suez. While these markets absorbed some volumes, they typically offered lower netbacks due to longer shipping distances. Moreover, Europe-bound ammonia will soon face additional costs under the Carbon Border Adjustment Mechanism from 2026.

These challenges are reflected in Trinidad's declining exports. Between 2010 and 2024, ammonia exports fell from 5.2 million t/a to 3.2 million t/a, and its global exports share dropped from 27% to 19%. The forecast through 2029 points to stagnation, as growth in low-emissions capacity from the US and Middle East is expected to capture market share, particularly in Europe and Asia. Nonetheless, with Trinidad still supplying around one-fifth of the merchant market, its role remains significant.

Overall, Trinidad's ammonia production has fallen from 5.4 million t/a in 2016 to 4.1 million t/a in 2024, and this latter level of production is expected to be maintained out to 2029.

A major importer

Overall, in spite of some returning and new capacity in Brazil and Mexico, and the possibility of some low carbon based capacity in Mexico and Chile, the Latin American region is expected to continue to be a major importer of nitrogen over the next few years, particularly Brazil, as well as Argentina to a lesser extent. Mexico may achieve some measure of self sufficiency using US imported gas, while Trinidad and Venezuela will continue to be net exporters, albeit at relatively lower levels compared to historical rates. ■

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PHOTO: US NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Toxic algal blooms on Lake Erie, 2022, a by-product of eutrophication and nitrate pollution.

Nitrate wastes as a source of ammonia

The past few years have seen a rapid increase in attempts to generate ammonia from streams of nitrate polluted wastewater, but how practical are these methods?

Nitrogen is an essential element for life, and one of the key constraints on plant growth, particularly food grains such as wheat, corn, rice etc. And while it surrounds us in the atmosphere, converting this into a form usable by plants – generally as a nitrate – takes place at a slow pace in nature, either via atmospheric lightning discharges; the conversion of nitrogen to nitrates via rhizobia bacteria in the root nodules of legume plants; or the decomposition of plant or animal wastes or manures.

Converting nitrogen directly into ammonia via the Haber-Bosch process has allowed the rapid expansion of the mineral fertilizer industry and the consequent increase in farming yields achieved worldwide in the 20th century, and allowed the expansion of human population to 8.2 billion people. However, over-application of nitrogen in the environment has become a problem in many regions. Over-fertilization can lead to a lack of oxygen in lakes, rivers, or seas. This results in the mortality of fish, the loss of species, and a decline in bathing water quality. Sensitive plants that depend on nitrogen-poor soils disappear. Nitrogen oxides from traffic and industry produce ground-level ozone and particulate matter while the use of fertilizer releases nitrous oxide, a major greenhouse gas.

Excess nitrogen in the environment is reflected in the soil surplus, which is calculated as the difference between inputs (e.g. fertilizers, animal manure, or atmospheric deposition) and outputs (e.g. plant growth). This nitrogen surplus has increased rapidly in Europe as shown by data published by Germany's Helmholtz Centre for Environmental Research (UFZ) in 2022[1], reaching a peak in the mid-1908s because of the increased use of synthetic fertilizers. Since then the surplus has decreased to an extent as a result of the EU Nitrates Directive, reforms to the Common Agricultural Policy (CAP), and economic and political changes. There have also been technological advances such as more precise fertilization. However, the nitrogen surplus has remained at a high level since the 2010s.

Impetus for wastewater treatment

In an attempt to reduce this nitrogen surplus, in April 2024 the EU launched a public consultation on the Nitrates Directive to assess if it remains fit for purpose. EU member states are required to identify waters polluted by nitrates and waters that are eutrophic (i.e. polluted with algal blooms which feed on nitrates and which reduce oxygen content in the water), affecting the aquatic ecosystem's balance, and implement measures aimed at preventing and reducing water pollution caused by nutrients. Furthermore, the EU Water Framework Directive aims for all European surface waters to achieve "good status" by 2027, together with the Urban Wastewater Treatment Directive (UWWTD) and the Nitrates Directive.

While this provides additional impetus for water treatment and more targeted fertilizer application, with an increasing focus on the so-called 'circular economy', the past few years have also seen an increasing interest in potentially recovering nutrients from wastewater streams, with the potential for their reuse as a fertilizer.

Electrochemical conversion

The suggested method for this is the electrochemical conversion of nitrate to ammonia, ideally using electricity that is ideally produced from sustainable sources, like wind and solar energy, producing ammonia at room temperature. Large-scale application of electrocatalytic denitrification of water has previously been limited by the lack of catalysts with a high selectivity of nitrate reduction to N_2, but nitrate reduction to ammonia is much easier from a catalytic point of view as no N-N triple bond needs to be formed, and in recent years there has been considerable interest in the development of catalysts that actually aim at the selective electrocatalytic reduction of nitrate to ammonia. A number of promising candidate materials have been identified[2], including titanium dioxide with promoters, copper oxide nanowire arrays, electrochemically reduced to Cu/Cu_2O, copper-nickel alloys, titanium, and ruthenium nanoclusters.

Various types of wastewater have previously been used, or modelled, in studies on electrocatalytic denitrification, though nitrate concentration is a limiting factor. A high concentration of nitrate makes the production of ammonia easier and more cost efficient but limits the type of wastewater that can be utilised. The highest level of nitrate is found in low-level nuclear waste, a wastewater stream that has extensively been studied in electrocatalytic denitrification as biological treatment is not possible. Lower concentrations of nitrate are found in industrial runoff, for example from the textile industry.

While nitrate polluted groundwater from agricultural runoff is most widely available, nitrate concentrations have been found to be too low for an electrolysis process, with the electrical energy input leading to side reactions. A possible solution is to concentrate the nitrate prior to reduction, though of course this adds an extra step to the process and increases cost, although it also encourages decentralised ammonia production near point of need and provides clean water for aggregation of farmland at the same time. Some Chinese researchers have instead used a membrane structure in which iron was atomically dispersed within a dense woven carbon nanotube framework. An applied voltage draws the nitrate ions through the small pores, where they are reduced to ammonium[3]. The process claims four times greater efficiency than conventional electrochemical methods.

Cost

The Haber-Bosch process consumes approximately 4 kWh of energy per kg of ammonia produced. Comparable figures for some of the processes mentioned above report an electrocatalytic rate for ammonia production of e.g. 22 kWh for the RU nanocluster process, based on the cell voltage, partial current density, and production rate[2]. The price of electricity for electrocatalytic ammonia synthesis will represent the largest proportion of operating expenses, assuming that nitrate-rich wastewater is readily available and the reaction takes place at room temperature. The Ru nanocluster catalyst with an energy consumption of 22 kWh/kg ammonia would represent approximately 4.8 kWh for the production of 1 kg of NH_4NO_3. Based a Dutch electricity cost of €0.137/kWh, this results in production costs of approximately $776/tonne ammonium nitrate, excluding investment and maintenance costs. While high, this is not far distant from current delivered EU AN prices of around $500/t, and the production costs could be reduced by making use of locally produced electricity from renewable sources.

Early days

At the moment this is still a new and developing field of study, and so far still confined to laboratory scale processes, but results have shown some promise for the concept of selectively producing ammonia electrochemically from nitrate. Van Langevelde et al have noted that, even if the catalytic performance is good, large volumes of wastewater need to be dealt with, resulting in the need of a large reactor and long reaction times, and it is difficult to foresee if sufficient amounts of wastewater can be supplied. It is expected that concentration of nitrate prior to the reduction process will be necessary to avoid dealing with large volumes of wastewater, requiring further research. No studies on the large-scale treatment of real wastewater from different sources have yet been carried out. Even so, the fact that on a first analysis, the catalysts developed for the reduction of nitrate can compete with current technologies for ammonia production, and a rough estimation suggests that the fertilizer price can compete with fertilizer produced in the Haber-Bosch process[2].

However, Huang et al argue that the feasibility of large-scale ammonia production remains highly questionable due to the insufficient concentration and low capacity of nitrates feedstock in real wastewater. Taking the example of ammonium nitrate, they calculate that about 17% of nitrate ions would leach to the ground water as nitrate contaminants annually, which, even if those nitrate contaminants could be successfully converted to ammonia with 100% selectivity, would only represent a total of about 2 million t/a of recovered ammonia5. This, they argue, is "relatively insignificant" when compared to the nearly 200 million t/a of ammonia produced annualy via the conventional Haber–Bosch process, even without considering the energy needs for nitrate collection and reduction, ammonia separation, purification, and compression. Instead they advocate for nitrate conversion to N_2, which can be safely released to atmosphere or, in the case of wastewater containing nitrates at high concentrations, recycling and purifying nitrate salts to produce NO_3^- chemicals or fertilizers rather than converting them into ammonia. ■

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NITRIC ACID

PHOTO: THYSSENKRUPP UHDE

Demand for nitric acid

Covestro's Baytown nitric acid plant, Texas.

Nitric acid demand continues to be dominated by fertilizer uses via various nitrate and NPK fertilizers, but industrial chemical production, metallurgical uses and explosives production are continuing to contribute to growth, especially in Asia.

Nitric acid is the second most used industrial acid after sulphuric acid. Based on 100% nitric acid, total tonnage was about 80 million t/a in 2024. The route almost exclusively used for nitric acid production is the Ostwald process, developed early in the 20th century by German chemist Wilhelm Ostwald. Ammonia gas is mixed with air and passed over a platinum-rhodium catalyst gauze at high temperatures (around 850°C). This oxidises the ammonia into nitric oxide (NO). The nitric oxide gas is then cooled and further oxidised with excess air to form nitrogen dioxide (NO_2). The nitrogen dioxide gas is then passed through absorption towers where it reacts with water to form a solution of nitric acid.

Nitric acid production represents about 10% of all ammonia demand globally.

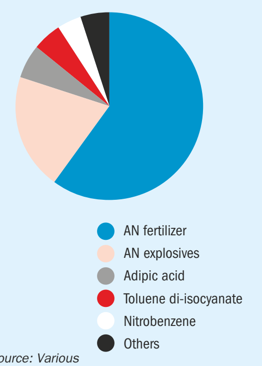
Uses

In terms of end uses, nitric acid is predominantly used for the production of ammonium nitrate and its various derivatives, including urea ammonium nitrate (UAN) and calcium ammonium nitrate (CAN), as well as other specialty fertilizers and mixtures such as NPK fertilizers (Figure 1). Outside of its fertilizer use, ammonium nitrate is also widely used in the explosives industry as a component of ammonium nitrate-fuel oil (ANFO), a mixture that is the most common industrial blasting explosive, used in mining and quarrying, and representing around 90% of the commercial explosives market. However, while around 80% of nitric acid is used in AN manufacture, the remainder mainly goes to a number of industrial processes, with the three largest by end use being:

- Nitrobenzene production, for use in dyestuffs;
- Toluene di-isocyanate (TDI), used in polyurethane manufacture, and;
- Adipic acid, used in nylon and other polyamide manufacture.

There is also a substantial quantity used in metal extraction and treatment, especially ferrous metal etching and cleaning and the passivation of steel, as well as the reprocessing of uranium.

Fig. 1: Nitric acid consumption, 2024



Source: Various

Various grades of nitric acid are produced. So-called "weak" nitric acid, which has a nitric acid concentration of around 45-65%, is mainly used for fertilizer and ammonium nitrate production. Concentrated (or "fuming") nitric acid, at around 96-98% HNO_3, is used for the chemical and metallurgical uses mentioned above. 'Highly pure' nitric acid with parts per billion concentrations of metals or other contaminants is used in the semiconductor industry for cleaning and etching of silicon wafers.

Because nitric acid production is almost always integrated into downstream production, on a geographical basis capacity tends to concentrated wherever AN is manufactured, primarily in Europe and Eurasia and North America, as well as, increasingly, in China. European/Eurasian capacity is mainly for AN and CAN fertilizer production, and around 85% of fertilizer grade AN capacity and 75% of CAN capacity is based in Europe and the CIS. North American is capacity mainly for UAN and AN explosives production, and about 55% of all UAN capacity is in North America and the Caribbean. Industrial/technical/explosive grade AN capacity is more widely spread, according to the requirements of domestic mining industries. About 25% is based in China. As well as this TAN capacity, Chinese nitric acid capacity is mainly focused towards chemical and metallurgical uses. Highly pure nitric acid capacity is concentrated in South Korea and Taiwan, China.

Demand projections

In terms of end-use markets, ammonium nitrate fertilizer use peaked in about 2012, at 22.8 million t/a, and saw a slow decline to 19.2 million t/a in 2021, then a fall to 16.9 million t/a in 2023. CAN use likewise dropped from 15.3 million t/a in 2021 to 13.0 million t/a in 2022. The invasion of Ukraine and consequent sanctions on Russia, one of the major exporters of AN and CAN fertilizers, has been the main reason for this, with European consumption falling particularly. However, these figures are seeing something of a turnaround as market conditions favour AN in Europe, and consumption of AN and CAN is expected to return to 2020 levels by 2028. Increased consumption in, e.g. Brazil is also boosting demand. Ammonium nitrate is preferred as a fertilizer in regions with short growing seasons, as the nitrate is present in a form readily available to the plant, unlike urea, which must hydrolyse to nitrate in the soil before it can be taken up. UAN consumption also took a dip in 2022, from 26.5 million t/a to 22.7 million t/a, but is expected to reach 27.7 million t/a by 2028, mainly due to increased consumption in Europe (especially France) and the US.

The commercial explosives market, meanwhile, is based mainly based around mining and quarrying. Three industries have traditionally dominated demand for mining explosives; coal mining, iron ore mining, and copper mining, collectively using more than two thirds of all explosives. Of these three, coal mining has remained essentially static over the past decade, and TAN use for coal mining is falling. However, this is more than offset by increased consumption for iron ore mining, with Australia, Brazil, China and India the leading producers, and copper mining, mainly in Chile, Peru, China and Congo. Overall, demand for TAN is expected to rise from 16.9 million t/a in 2024 to 17.6 million t/a in 2028.

Industrial chemical markets are a much faster growing segment for nitric acid, with average annual growth rates for TDI, nitrobenzene and adipic acid ranging from 3.5% to 4.9%, and it is a similar story for some of the metal treatment segments. However, collectively they only represent 20% of nitric demand, and so growth in these segments only brings the overall growth rate for nitric acid demand to just over 2% year on year.

Table 1: Fertilizer nitrates consumption by region, 2024, million t/a

Region	FGAN	CAN	UAN	Total
Europe	6.5	10.6	5.7	22.8
Russia	5.3	0.1	1.3	6.7
USA	0.2	0.1	14.8	15.1
Latin America	2.0	0.7	0.8	3.5
Australia	0.0	0.0	0.7	0.7
Others	3.9	2.6	2.3	8.8
Total	17.9	14.2	25.6	57.7

Source: KPI

Nitrous oxide

The nitric acid industry is under increasing pressure to reduce its emissions of nitrous oxide, N_2O. It is estimated that around 5 kg of nitrous oxide are produced for every tonne of nitric acid, which has turned nitric acid production into the single largest industrial process source of nitrous oxide. Because of N_2O's high global warming potential; around 270-300 times that of CO_2, even the emission of relatively lower quantities can have a significant impact on man-made climate change.

Because of this, installation of N_2O abatement technologies has been strongly encouraged via the Kyoto Protocol, and has become mandatory in some jurisdictions, including the European Union. So-called 'tertiary' NOx removal systems are increasingly popular, treating final 'end of pipe' emissions, as they are an easier retrofit to existing plants. Iron zeolite catalysts have proven effective at decomposing N_2O to N_2 and O_2, and form the basis of thyssenkrupp's EnviNOx® process, which has achieved N_2O removal rates of 98-99%, with overall NOx emissions being reduced to as low as 1 ppmv. BASF's DeNOx process uses a vanadium oxide catalyst instead for similar effect. In early September 2025, thyssenkrupp Uhde announced that it had just successfully delivered and commissioned an EnviNOx unit for Covestro's Baytown, Texas, facility as part of Covestro's Nitric Acid Unit Climate Initiative (NAUCI), equating to an annual abatement of approximately 154,000 t/a of CO_2 equivalent. Meanwhile the European Union is revising its 'best available techniques' (BAT) and lowering guidance figures for permissible N_2O emission levels as part of its Large Volume Inorganic Chemicals (LVIC) directive.

However, of the estimated 580 nitric acid plants operating globally, around half are believed to still have no N_2O abatement technology in place, mostly in countries without the appropriate emissions control legislation in place. To try and combat this, the German Environment Ministry's Nitric Acid Climate Action Group (NACAG) has been partnering with governments and nitric acid producers in these countries and providing financial support to install abatement technology. In its most recent report (2024) it cites having signed up 10 operating companies which are actively engaged in N_2O reduction strategies, with an impact of 2.6 million t/a of CO_2 equivalent reduction.

The US Environmental Protection Agency says that it believes that the nitric acid and adipic acid industries could remove 80% of their emissions of CO_2 equivalent gases by 2030, or around 116 million t/a of CO_2e, with a 65% reduction in emissions achievable at break-even prices below $20/t.

Low carbon nitric acid

As with all industries nitric acid is also facing pressure to lower the carbon intensity of its production as well as emissions. This is a particular focus for the European industry, which represents around one quarter of nitric acid production and use. Nitrogen fertilizer prices could rise over the next decade as a result of EU targets on ammonia producers, with significant implications for fertilizer affordability. The cost of fertilizer grade ammonium nitrate (FGAN), which is driven by the cost of ammonia, could rise to as much as ~$1,500/tonne N in real terms in 2030 if produced with green ammonia in line with EU policy obligations. The same product was selling for as low as ~$800/t N in 2020 when produced with conventional grey ammonia. If using the lowest cost form of imported green ammonia from the USA, the cost of FGAN would be roughly half, at ~$800 /t N in 2030. A similar cost would also be achieved using blue ammonia from the USA.

At the same time, high natural gas prices have impacted upon European producers, and the combined burden of tightening NOx standards, carbon pricing and offshore low carbon ammonia production will push marginal producers in Europe to refit their plants or face closure. ■

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Turnaround planning using risk management and cost control

Becht's Risk Based Work Selection (RBWS) process is a structured, data-driven method that uses risk and benefit-to-cost analysis to optimise turnaround and maintenance work in industrial facilities, resulting in significant cost savings and improved reliability. **Abby King**, **Clayton A. Smith** and **Frank Engli** demonstrate how, supported by proprietary software, the RBWS approach enhances decision-making, documentation, and cross-functional team alignment, while helping clients achieve substantial reductions in unnecessary work and overall turnaround expenses.

In today's petrochemical and power industries, sustained long term reliability of facilities is a key to profitability and competitiveness. The cost of unreliability, which includes health, safety and environmental (HSE) incidents, is difficult for even healthy companies to endure, and with investment in the right proactive measures, can be avoided. Risk based work selection (RBWS) is a work process that prioritises and optimises turnaround and maintenance work without sacrificing reliability. RBWS uses risk to screen individual worklist items to ensure they are justified by either HSE risk reduction or financial benefit to cost analysis. Significant reductions in turnaround work scope typically result from this structured work process. At the same time, the nature of the process is such that there are numerous additional benefits such as 'sleeper' risks not previously considered, minimising discovery work, and helping with alignment of the cross-functional teams.

Inconsistent methods for screening turnaround and maintenance work can lead to missed opportunities for risk reduction and a poor return on investment (ROI). Becht's RBWS method is a systematic and consistent approach to screen turnaround work lists using historical and industry performance data. Becht's reliability/maintenance and turnaround specialists have reviewed turnaround work scopes for over 20 years. Becht has deep experienced facilitators with strong risk-based inspection, maintenance, turnarounds and facilitation backgrounds.

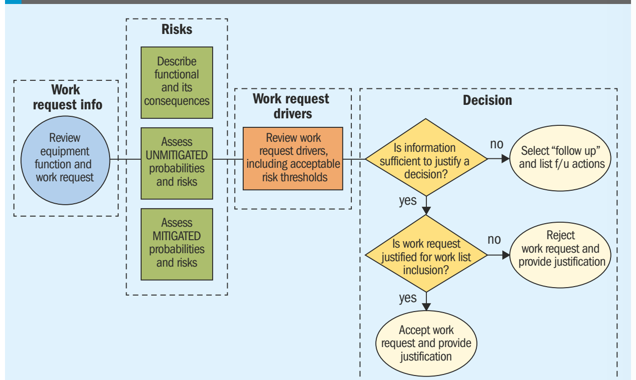
Becht's average work list optimisation is an average of \$7.2 million in reduced turnaround spending per review with a reduction of 26% of low ROI work list items.

Clients often get a ROI of greater than \$12K for every dollar they spend doing an RBWS review. Several of Becht's clients have saved over \$100 million in total turnaround costs over a two-year period, by using the Becht RBWS process.

The RBWS process is data driven, ensures consistency of decision making and results in a risk-optimised worklist. The process includes consideration of risk management, reliability and conservation of financial resources. The results are fully documented for leadership review and future turnaround planning. Fig. 1 shows the RBWS work process.

Questions that drive the RBWS justification process include (but are not limited to):

Fig. 1: BechtRBWS work process



Source: Becht

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- Can the work be done cost effectively on-stream rather than during the turnaround?
- Does the Risk of deferral meet the HSE threshold?
- Is there a clear justification for the work?
- Is the scope and cost well-defined?
- Is there a clear mitigation of consequences from doing the work?
- Is the cost for the doing the work meet the client's benefit-to-cost ratio threshold (this consideration only applies when HSE risk is below threshold)
- Will the work eliminate a bad actor?

RBWS is a process which is not limited to fixed equipment but covers all equipment classes (see Fig. 1).

Becht's approach to RBWS is to combine an SME knowledge based approach with the right tools for consistency, documentation, and ease of facilitation.

The software tool

Use of the right software tool saves time and improves the results of the RBWS review. Becht's RBWS process uses the proprietary web-based software tool, BechtRBWS, to achieve consistent and efficient facilitation of cross-functional meetings, store the worklist data, and document decision making and results. Documentation of the rationale allows the leadership team to understand the 'whys' of the outcome, develops consistency between disciplines and sites, and provides a roadmap for future turnaround planning.

The information necessary to conduct an RBWS should already exist. The challenge is digging the information out of desk drawers, databases, and Excel spreadsheets, and organising it for review during the RBWS. No other tool in the refinery has the structure and required fields to capture the specific subset of data needed for the RBWS. RBWS assessments are for a very specific timeframe; one turnaround cycle, usually 4-7 years.

The software will have this timeframe built into it. The BechtRBWS tool also has the ability to document the unit economics and turnaround premise guidelines into the tool for that can be referenced for future turnaround events or updated if the event timing has changed.

What characteristics should an RBWS tool have?

Documentation – An RBWS session is only as good as the documentation. Being transparent about the team's thought process and recommendations enables leadership to make informed decisions on what is "in" or "out" of a turnaround and why. Proper documentation helps eliminate recycling before and during the turnaround and can also be used as the starting point for future turnarounds. A dedicated tool preserves the data and results of the RBWS. This is commonly seen as an underlying benefit to clients as time between final scope approval and the RBWS Review increases.

Data gathering – A dedicated software tool should lessen the burden of data gathering for RBWS. Well defined data fields, along with examples, help guide teams during the data acquisition phase. Becht recommends that teams new to RBWS should have training on the process and the data that they are required to gather. Setting clear expectations for the data to include in work scope submittals will help minimise rework and help communicate the expectation that work items will be scrutinised and require justification.

Facilitation – RBWS requires input from a cross-functional refinery team with several members participating in a session at any given time. Therefore, being efficient is critical to a successful RBWS. The RBWS tool should ease the data entry, facilitation, and risk calculations done during a session, minimising the downtime. Toggling between screens and scrolling back and forth takes time and can be distracting and confusing. An ideal tool will have a single screen that is the focus during the session.

That screen will present the data that was pre-loaded along with fields that capture the discussion during the session and show the risk assessment results.

Accessibility – Sharing information across a site or from site to site can add a lot of value for improved workflow, "lessons learned", benchmarking, and to leverage work products from a past turnaround for a future turnaround. An RBWS tool should enable this by being accessible. Web-based tools that can be logged into from anywhere have a distinct advantage over tools that are loaded onto a single computer.

Reporting – A software tool should have reporting capability built-in so it can roll up results that show the items reviewed, deferred, or recommended to be in/out of the turnaround.

Most software have standard report templates but having the ability for customised reports is a beneficial feature. An example of a report that clients like to see is the benefit to cost graph, which plots each discretionary item in terms of cost versus financial risk mitigated (i.e. benefit), see Fig. 8.

Preparation

The cross-functional team consists of an expert facilitator leading a group of refinery operations, maintenance, technical supervisors, and subject matter experts. As a team of plant personnel participates in the review, developing an efficient process is critical, to minimise meeting time. There are preparation steps recommended so the team can hit the ground running upon starting the RBWS review.

Worklist data – During the review, the drivers (process or equipment integrity) for the turnaround work items are evaluated. The risk-based process is structured to challenge the work list items and determine whether the turnaround work is justifiable, or whether deferments are permissible. Effective evaluation of the drivers requires the right information. Thus, the data should support the evaluation of the benefits of performing the tasks versus deferring the item until the next turnaround. In addition to work scope item description, hours to complete, cost estimate (±30% is recommended), a description of "what will happen if this worklist item is not performed" is required. Also, for each common type of turnaround task, Becht provides specific direction on the information required. For example, in order to justify a heat exchanger cleaning the following information and data is requested:

- Past history
- Service (clean/dirty)
- Monitoring/data such as pressure drop over time
- Percent slowdown or shutdown and time to clean
- U-values or the ratio of ΔTemperature to ΔTemperature at design

The RBWS input workbook is reviewed by the Becht team and there is typically a back-and-forth finalisation of the data prior to the review session. For a site which doesn't have experience with the RBWS process, it typically takes two weeks after the first worklist is provided to fully prepare for the review. The worklist, when complete, is imported into the web-based application.

Training and preparation – For sites that have not been through the RBWS process, an on-site or webinar-based series of meetings is highly recommended prior to the review. The training should educate the participants, see Table 1 for typical participants for training, so that expectations for the meeting are understood. The site's goals for the turnaround and reliability considerations are reviewed with the leadership team.

Prescreening is also one of the preparatory steps where items that are deemed essential to the turnaround are taken out the review process and automatically accepted into the finalised turnaround worklist. Becht develops the list of prescreening criteria with the client and culls the list of items that will be covered during the review. Example criteria include: (1) Very low-cost items that don't warrant review and (2) Items required for regulatory compliance. This reduces the scope of the review and meeting time, while maintaining the full value of the RBWS review.

Risk basics

Risk is the fact that something bad can happen.

Risk concepts should be well understood by the cross functional team. It is formally defined as the probability times consequence, with respect to an adverse event (see Fig. 3).

Development of risks during a risk-based work process requires defining some of the following information:

- What can happen? Consider the initiating and cascading events, contributing factors and outcome.
- What are the consequences? Quantify the HSE and Economic Consequences.
- What is the likelihood, or probability of the failure scenario?

A risk matrix is required to provide structure to the evaluation. The BechtRBWS software dynamically imports any conventionally designed risk matrix such as the sample shown in Fig. 4.

Table 1: **Preparation and training meetings for new clients**

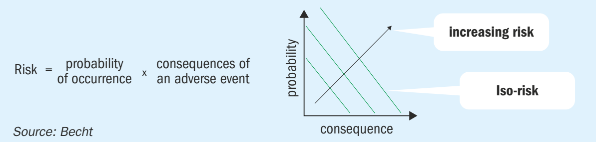
Topic	Personnel
Kickoff	Tunaround manager
Discussion of equipment worklists for equipment types with SMEs	Lead fixed equipment inspector Machinery supervisor Electrical supervisor Instrumentation supervisor
Discussion of reliability considerations	Reliability manager
Training on the RBWS work process and examples	Key stakeholders and contributors to worklist Complex managers, process people, operations, reliability, inspection, HSE specialist
Discussion of corrosion rate prediction and NDE inspections	Metallurgist
Prescreening work prior to turnaround manager meeting	N/A
Close out meeting to review follow up items	Turnaround manager

Source: Becht

BechtRBWS includes a risk calculator, which is based on the client's risk matrix and risk definitions, so that the cross-functional team can estimate business and HSE risk levels. In calculating risk, the probability and consequence categories are combined, and unmitigated and mitigated risk levels are displayed. Both economic and HSE risks are used.

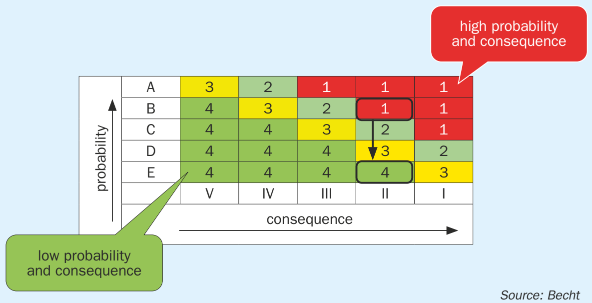
The benefit to cost ratio (BCR) is the benefit of mitigation (reduction in business risk) divided by the cost of the task. The cross-functional team uses the BCR along with other considerations (unmitigated HSE

Fig. 3: **Risk basics**



Source: Becht

Fig. 4: **Sample conventional risk matrix**



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risk, cost of action item, bad actor resolution, etc.) to make the determination whether the task is in-scope based on previously developed task acceptance criteria. The group should clearly document a justification for the decision. Ultimately the important considerations from a risk perspective is:

- HSE risks are mitigated to achieve acceptable risk levels.
- Business risks are mitigated based on ROI, or BCR.

Consequence evaluation

Becht has an in-house methodology to determine consequences for loss of containment incidences. An automated part of the BechtRBWS tool which considers fluid properties (flammability, toxicity and vapor cloud potential), pressure and size of expected leak are considered to determine the consequence category in accordance with the client's consequence category definitions.

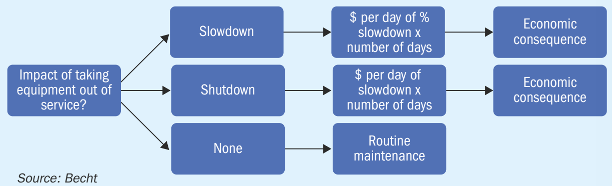
Economic consequences are used in calculating the Benefit to Cost Ratio (BCR) for discretionary work list items. The lost profit opportunity for a slowdown or shutdown is provided for this calculation and the steps in Fig. 6 are followed to calculate the potential economic consequences of failure.

When determining the number of days for the shutdown or slowdown it is important to consider how much time is needed for operations to isolate and decontaminate the equipment for maintenance, inspection to determine repair scope, days of maintenance to conduct repairs, any special considerations for the equipment such as post weld heat treatment of weld repairs, and the time it takes to return the equipment to service. As an example, depending on geographical location, complexity of the unit, and equipment considerations a typical outage duration for a drum is 7-10 days, whereas a tower could take 14-21 days depending on size.

Outcomes and case studies

An RBWS assessment for a major turnaround (> 500,000 MHrs) is likely to take as much as two weeks, provided the front-end planning and prescreening are effectively completed and the items on the worklist are of a requisite quality. Fig. 7 plots the task cost savings achieved as an outcome of a series of completed RBWS reviews by unit/turnaround block event. Table 2 shows sample results of a recent RBWS.

Fig. 6: **Economic consequence of failure**



Source: Becht

Table 2: **Sample RBWS results**

	No. of items	$ Value
In-scope	156	12,086,000
Out of scope	158	12,715,000
Pending	13	1,541,000
Total reviewed	327	26,342,000

Source: Becht

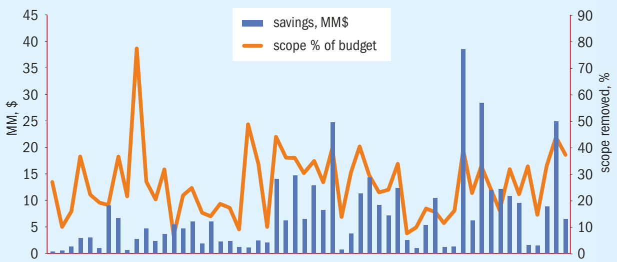
The results in Table 2 are from a one week RBWS where the list was prescreened by the site. The first step in RBWS is determining if the work can be executed on the run with little or no impact to production. Items that can be executed on the run can then be prioritised by routine maintenance for execution. One of the main drivers to execute work outside of the turnaround is a reduced cost. Experience in industry indicates that routine maintenance work is at least half the cost of turnaround work, and depending on sites region, turnarounds can be as high as four times the cost of doing the work compared to work done in routine maintenance.

At this particular site frequent inspections have been done in the past, providing the opportunity to reduce turnaround activities without accepting substantial risks. It was also identified that there was significant potential for discovery work in one of the units due to several process upsets over the last run.

Fig. 7: **Cost savings for completed RBWS reviews**

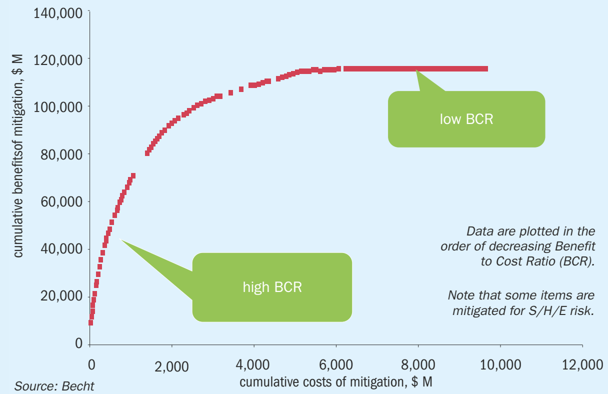
15 yrs of total RBWS reviews on average:
$7.2 MM cost savings
26% work scope removed
ROI = >12,000%

Large / mega RBWS reviews on average:
$16.8 MM cost savings
32% work scope removed
ROI = >13,500%



Source: Becht

Fig. 8: **Cumulative financial benefit-cost curve**



Source: Becht

At the same time, the RBWS process allows the team, guided by the facilitator, to consider lower cost actions if the proposed task is not justified but risk mitigation is warranted. Sleeper risks can be identified as an organic outcome of the discussion process.

Fig. 8 plots the work list tasks in the order of decreasing benefit-cost ratio (BCR) and illustrates the diminishing return nature of risk mitigation. This automated output from the RBWS work process allows plant managers to conserve maintenance resources and minimise risk by targeting the high return work list items (corresponding to the left side of the figure). Note: Fig. 8 does not consider HSE risk drivers, which are considered independently

Summary

Becht's data driven RBWS method is a systematic and consistent approach to screen turnaround work lists. The process is facilitated by Becht's reliability/maintenance and turnaround specialists, who have decades of experience in execution of RBWS and turnaround planning.

RBWS uses risk to screen individual worklist items to ensure they are justified by either HSE risk reduction or financial benefit to cost analysis. Significant reductions in turnaround work scope typically result from this structured work process. At the same time, additional benefits such as identification of 'sleeper' risks, minimisation of discovery work, and alignment of the cross-functional teams on a consistent approach for turnaround worklist development are realised through adoption of the Becht RBWS process. ■

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Increased efficiency through advanced gauze geometries

The development of ammonia oxidation catalysts is challenging due to the need for precise control over catalyst properties to achieve high efficiency and stable process operations. Additionally, the process requires extensive research and advanced characterisation techniques to understand and optimise the reaction mechanisms, making the development procedure complex and resource-intensive. **Dr. Florian Knaus** and **Dr. Christian Goerens** present Umicore's development and potential of a novel catalyst for the Ostwald process, aiming to enhance efficiency and sustainability in high-pressure nitric acid production.

The Ostwald process forms the basis for the production of around 80 million t/a of nitric acid (HNO_3), and is the primary industrial method for synthesising this compound[1].

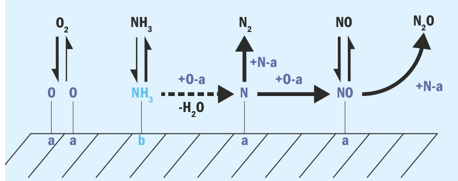
Nitric acid is a crucial nitrogen source, extensively used in the manufacture of fertilizers, explosives, and various chemicals. The Ostwald process involves three key stages: the catalytic oxidation of ammonia (NH_3) to nitric oxide (NO), the subsequent oxidation of NO to nitrogen dioxide (NO_2), and the absorption of NO_2 in water to form nitric acid. Catalysts, typically gauzes made from platinum group metals (PGMs) by various configurations, facilitate the oxidation of ammonia. This process also generates byproducts such as nitrogen (N_2) and nitrous oxide (N_2O), a significant greenhouse gas. The nitric acid industry, with an annual by-production of around 400,000 t N_2O, is the second-largest emitter of nitrous oxide, following the agricultural sector[2].

The development of novel catalysts for the Ostwald process is driven by the need to meet evolving industrial demands as well as increasing environmental standards. While significant progress has already been made over the past century, further advancements now require smaller, incremental improvements that demand substantial effort. By integrating advanced simulations, precise prototyping, and rigorous experimental validation, Umicore ensures that these high-effort steps lead to innovative and effective catalytic solutions.

Kinetics of the Ostwald process

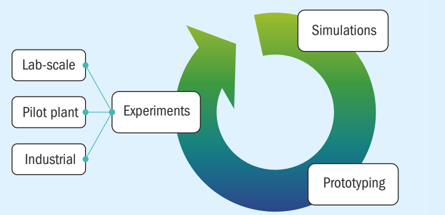
To investigate optimised catalysts for the Ostwald process, it is essential to first review the complexity of the process. In several studies a combination of flow characteristics and surface reaction mechanisms is used for simulation[3,4]. This approach is necessary since the design of the catalyst and the resulting mass transfer within the gauze package influences the concentrations on the catalyst surface and the kinetics of the ammonia oxidation.

Fig. 1: **Mechanistic scheme of reactions steps of ammonia oxidation provided by Kraehnert and Baerns. Solid lines show elementary reactions and dashed line shows a lumped reaction[5].**



Source: Umicore

Fig. 2: **Umicore's development routine**



Source: Umicore

A kinetic model used in current investigations is based on the mechanistic model developed by Kraehnert and Baerns. This was selected due to its superior agreement between experimentally observed and simulated product formation rates[5]. Fig. 1 summarises the mechanistic scheme and kinetic parameters employed for the ammonia oxidation reaction.

The model comprises ten elementary reactions involving six gas-phase species and six surface-bound intermediates. Adsorption steps for oxygen, ammonia, and nitrogen monoxide are treated as reversible, whereas adsorption of the by-products nitrogen and nitrous oxide is excluded.

Differentiation of plant types in the Ostwald process

The industrial production of nitric acid based on the Ostwald process, which involves the catalytic oxidation of ammonia, subsequent oxidation of nitrogen monoxide, and absorption of nitrogen oxides in water to form nitric acid. The implementation of these steps varies depending on the operating pressure, which defines the type of plant configuration. Three main categories of plant types are distinguished: low-pressure, medium-pressure and high-pressure plants[6].

Low-pressure plants operate at pressures between 1 and 2.2 bar and represent the earliest generation of nitric acid production facilities. These plants typically perform both ammonia combustion and NO_x absorption at atmospheric or near-atmospheric pressure. While simple in design, they suffer from low absorption efficiency and high NO_x emissions, making them largely obsolete under current environmental regulations.

Medium-pressure plants, operating between 2.3 and 6 bar, offer a balance between process efficiency and investment cost. They are widely used for small to medium production capacities and are particularly economical in regions with moderate energy and feedstock costs. Modern facilities employ dual-pressure configurations, which combine the medium-pressure ammonia oxidation with a high-pressure absorption (9 to 14 bar). This design optimises both (reaction kinetics and absorption efficiency), offering improved energy balance, lower NO_x emissions without extensive tail-gas treatment, and high product yields with reduced ammonia consumption. Dual-pressure plants are particularly favoured in Europe due to their superior performance in terms of energy efficiency and environmental compliance.

High-pressure plants, operating between 7 and 13 bar, are favoured in regions such as North America where energy and feedstock costs are relatively low. These plants compress both air and nitrous gases to high pressures, enabling enhanced absorption efficiency and reduced equipment size. The high-pressure operation allows for significant steam generation, which can be used for power recovery or exported. However, the increased pressure also leads to higher catalyst losses and requires robust materials and design to withstand the demanding operating conditions. High-pressure plants often incorporate interstage cooling in compressors and advanced heat recovery systems to optimise performance.

In summary, the choice of plant type is influenced by regional energy costs, environmental regulations, and desired production capacity, with dual-pressure plants representing the current state-of-the-art in nitric acid production technology.

Development of novel catalyst designs

At Umicore, the development of new catalysts involves a synergistic approach combining advanced simulations, prototyping, and experimental validation (Fig. 2). This methodology enables the design and optimisation of high-performance catalysts. Computational models predict catalyst behaviour, while prototyping and rigorous testing ensure theoretical predictions align with real-world applications. This integrated process accelerates development and ensures innovative catalytic solutions.

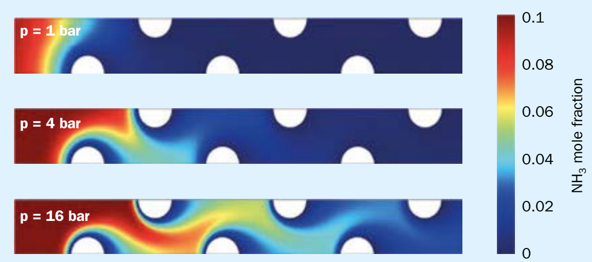
Simulation

Simulations are essential in the development of catalyst gauzes. They enable the prediction of material and design performance without the need for extensive and expensive experiments. This approach helps identify and optimise the most promising options, enhancing efficiency and durability. As a result, the development process is accelerated, leading to the creation of more effective and innovative catalyst gauzes.

The following investigations are made with the CFD model by Haas[3]. The model is based on a multi-wire catalyst geometry. The setup includes ten staggered rows of cylindrical wires. The main flow is in the x-direction. Due to symmetry, only half of the wires are modelled in an axial section. The simulations assess how radiation and pressure influence the catalyst performance. One outcome of simulations is that at higher pressures, the reaction tends to shift towards the lower gauzes. This behaviour is observed due to the increased density and reactivity of the gases, which enhances the interaction with the catalyst surfaces located at lower positions:

This shift in reaction towards the lower gauzes at higher pressures could be attributed to specific reaction parameters. These factors may lead to lower efficiency in the catalytic process, as the upper layers of the gauzes are not being fully utilised. Consequently, it might be important to increase the reaction surface on the top layers to enhance overall efficiency and ensure a more uniform distribution of the catalytic activity.

Fig. 3: **CFD simulation of ammonia conversion at three different pressures based on a model using cylindrical wires in a symmetrical order[4]**



Source: Haas[3]

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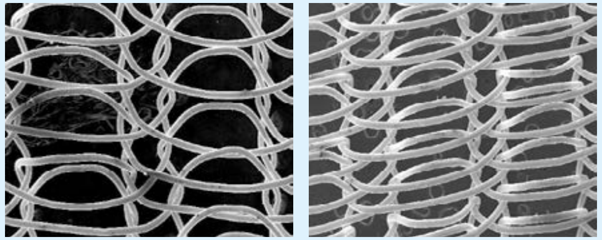
Fig. 4: **SEM-pictures of fresh catalyst gauzes:**
a) Standard gauze type **b) Xtranit-HDX gauze**



Source: Umicore

Table 1: **Parameters for pilot plant tests of Xtranit-HDX gauzes**

Test no.	1	2	3	4
Pressure, bar	9	8	8	9
Load, tN/m²/d	64	64	32	32

Source: Umicore

Prototyping

Prototyping plays a crucial role in the development of new catalysts at Umicore, and the use of flatbed knitting machines is an integral part of this process. These machines allow for the precise and efficient creation of catalyst gauzes, enabling a quick manufacturing and testing of various designs. By leveraging the capabilities of flatbed knitting machines, Umicore can optimise the structure and composition of catalyst gauzes, ensuring they meet the desired performance criteria. This approach not only accelerates the development cycle but also enhances the overall quality and effectiveness of the catalysts.

With simulations and Umicore's overall established development routine, a novel gauze type was developed which shows a higher wire density compared to a standard gauze geometry. It is expected that this increased surface leads to a higher conversion in the upper gauze layer, especially in high pressure plants.

In Fig. 4 a novel gauze type (4b) is shown in comparison to a standard gauze (4a), which has an increased surface to increase the conversion in the upper gauze layer, especially in high pressure plants.

Experiments

Besides simulations and developing prototypes, the final evaluation of novel catalysts can only be done in real experiments. For the following tests, the pilot plant at INS Puławy is used. The institute is equipped with state-of-the-art facilities and advanced analytical tools that enable comprehensive evaluation of catalyst prototypes. Additionally, it can run three reactors in parallel to get a direct comparison between different types of catalysts.

The results of pilot plant tests at high pressure conditions with varying plant load are shown in Fig. 5. The parameters used in the pilot plant to test the novel Xtranit-HDX gauzes are shown in Table 1.

As indicated in the graph, the novel Xtranit-HDX gauze type increases the catalyst performance towards higher conversion efficiencies of ammonia to NO_x significantly.

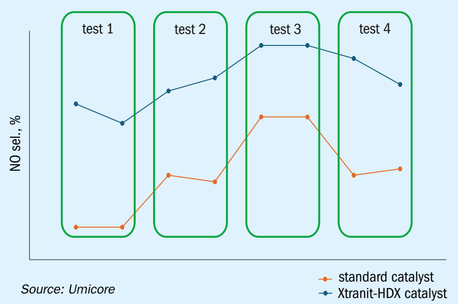
Besides pilot plant tests, first industrial tests were also carried out: For testing purposes, this novel type of catalyst design was installed in a high pressure plant with a load of 70 tN/m²/d and a pressure above 10 bar.

In Fig. 6 a comparison of two standard catalyst packages and two catalyst packages containing Umicore's Xtranit-HDX catalyst gauzes is shown.

By reviewing this comparison, two main observations are shown: First, the catalyst packages containing the novel Xtranit-HDX gauzes indicate an overall higher efficiency over the whole campaign. Besides that, an increase in long term stability can also be observed.

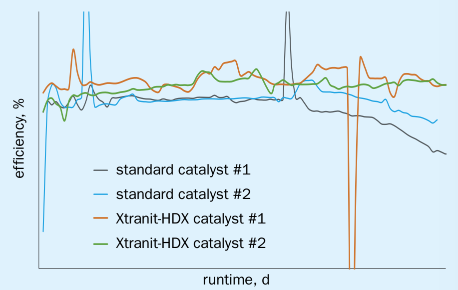
These first results from an industrial application show impressively how the adjustment of the knitting structure in the novel Xtranit-HDX gauzes can positively influence the performance of Umicore's catalyst especially in high pressure plants.

Fig. 5: **Pilot plant tests at high pressure conditions with varying plant load (32-64 tN/m²/d)**



Source: Umicore

Fig. 6: **Comparison of standard catalyst packages versus Umicore's Xtranit-HDX catalyst gauzes**



Source: Umicore

Summary

Umicore's development of a novel catalyst for the Ostwald process is driven by the need to meet evolving industrial demands and environmental standards. Significant progress has been made over the past century, but further advancements now require smaller, incremental improvements that demand substantial effort. To achieve these improvements, Umicore integrates advanced computational simulations, precise prototyping, and rigorous experimental validation.

Simulations provide a predictive framework for understanding how potential catalysts will behave under various conditions, streamlining the selection process by identifying the most promising candidates. Prototyping involves creating physical models of the selected catalysts, bridging theoretical predictions with real-world applications. Rigorous experimental validation assesses the performance, stability, and scalability of the prototypes, ensuring that the catalysts produced meet the highest standards of quality and efficiency.

The goal is to enhance efficiency and sustainability in high-pressure nitric acid production. By focusing on high-pressure plants, this catalyst aims to optimise the reaction conditions, reduce energy consumption, and minimise environmental impact, ultimately contributing to more sustainable industrial practices.

Outlook

Looking ahead, Umicore continues to focus on advancing catalyst technology to meet the evolving demands of the industry and environmental standards. By participating in the governmental funded project SuNiPro (**Su**stainable **Ni**trates **Pro**duction) Umicore aims to further enhance the sustainability and efficiency of nitric acid production. These initiatives reflect Umicore's commitment to continuous improvement and innovation in catalyst development for the Ostwald process.

Umicore will be sharing further insights at the upcoming Nitrogen + Syngas conference in Barcelona (10-12 February 2026) and the ANNA conference in Omaha (12-17 October 2025). ■

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Finishing technologies shaping tomorrow's fertilizers

Casale's high-performance finishing technologies combine flexibility and innovation with seamless integration and sustainability across the nitrogen fertilizer value chain. **Gabriele Marcon** and **Ken Monstrey** of Casale present the latest developments in Casale's comprehensive portfolio of fertilizer finishing technologies and highlight recent projects.

Casale offers a comprehensive suite of finishing technologies for nitrogen-based, complex and phosphate fertilizers. Over decades of active involvement in the fertilizer market, Casale has developed a complete portfolio of finishing technologies through both in-house technology development and strategic acquisitions. As a result, Casale can provide best available technologies for all production stages across the full range of fertilizers. As a licensor, Casale can offer clients a choice of different technologies from its portfolio at various stages of the production process. Additionally, Casale can manage all stages of a project in-house, from project development through engineering, procurement, construction, and both off-site and on-site services. Together, the client and Casale select the technology that best meets the client's needs, market requirements, and local regulations.

Casale holds a unique market position, offering technologies to produce ammonia, methanol, urea, melamine, nitrates, and phosphates. This unique feature allows for optimal integration among different processes and a tailored approach to any issue involving various areas of the client's complex. Casale provides a full line of technologies from ammonia to final products.

This article provides an overview of Casale's finishing technologies for various processes and grades. Granulation processes for urea, enhanced urea, nitrates, as well as granular ammonium sulphate fertilizer are highlighted.

Urea finishing applications

Fluidised bed granulation

With the acquisition of Green Granulation Technology (GGT), Casale's portfolio includes urea fluidised bed applications with over 20 references in a wide range of capacities. The optimised fluid bed dynamics (OFBD) have proven to be innovative and industry changing. The focus on energy efficiency, that has been directing the urea synthesis process developments during the last decades, was brought to the finishing process by the introduction of the OFBD. Casale's R&D capabilities have further refined the fluidised bed technology, resulting in a broader range of design options by adapting proven design features from other Casale technologies and introducing new, innovative developments. Therefore, depending on the client's requirements, the focus of a new fluidised bed process for urea fertilizer production can be based on capex or opex drivers or a perfect mix of features. These innovations have led to higher design flexibility and the ability to produce special grades such as automotive urea and cattle feed grade urea.

As an alternative, or as an additional feature, the fluidised bed process can be designed to produce DEF-grade urea. The granulation unit must operate without the addition of a granulation additive (zero formaldehyde or others), and the biuret content must be kept low enough to enable remelting without exceeding the maximum allowed biuret content of AdBlue. Therefore, the feed concentration to the granulator must be free of contaminants, such as formaldehyde, typically used as a granulation additive for fertilizer grade, and the urea feed concentration must be relatively low to guarantee low biuret content. These factors result in a feed composition likely to lead to poor spraying conditions in the granulation process, high dust production, and short run lengths. Casale's expertise in the urea field can provide solutions characterised by a urea feed concentration with very low biuret content that matches with the requirements for DEF-grade granulation, including a limited distance between the synthesis and the granulation buildings. Alternatively, a dedicated evaporation section within the granulation battery limits, operating under deep vacuum and low temperature conditions, can be foreseen. Both enable sending a feedstock to the granulator that falls within the parameters for water content, guaranteeing a high-quality final product.

In the absence of a granulation additive and at low biuret content, the granulation process depends entirely on optimised conditions in the subsequent spraying zones in the fluidised bed. Casale relies on the performance of specially designed hydraulic spray nozzles that are self-atomising without high atomisation air requirements. The Mark II and newly developed Mark III hydraulic spray nozzles produce a very homogeneous spray pattern with a narrow size distribution of droplets at low atomisation air pressure. The atomisation air merely blows the produced droplets deep into the fluidised bed layer, creating a maximum spray zone height, increasing efficiency, and ensuring a continuous flow of fresh particles towards the spray zones. The OFBD principles adopted in every Casale (and GGT) unit ensure smooth and predictable movement in the bed, providing an optimum alternation of accretion and drying phases during the granulation process. Unlike a bubbling bed granulator, the Casale OFBD operates at a low bed level, reducing the pressure drop over the system and thus reducing the unit's power consumption.

Recent technological innovations focusing on minimising the pressure drop over the product coolers and exhaust air scrubbers have further reduced the specific power consumption. Urea, as a commodity, still accounts for the largest market share of fertilizer applications worldwide. Therefore, Casale continues to focus on further development, deeper research, and finding marginal gains to keep the technology at the top of the innovation pyramid. In 2025, the first application of the new and improved Mark III liquid nozzle with higher operational reliability (fewer splits) and higher operational flexibility will be implemented.

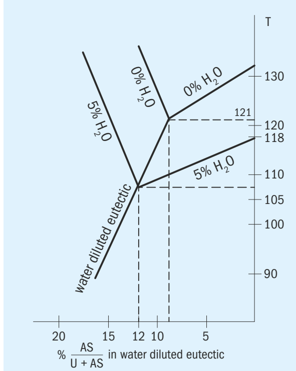
Enhanced urea finishing applications

Urea + AS in the double granulator

Meanwhile, the fertilizer market is shifting towards products that offer more than just a nitrogen source. Adding a sulphur source to urea is a straightforward step to increase efficiency and application field of general fertilizers. Ammonium sulphate (AS) is widely available, even as a by-product of other production processes, such as the ammonia abatement system in the scrubbing section, and it is a low-cost sulphur source. The main challenge when solidifying a mixture of urea and AS is the presence of a eutectic point, where the crystallisation temperature of the mixture drops by approximately 10°C (see Fig. 1). Under such conditions, the temperature in the fluidised bed must be reduced by 10°C to allow proper crystallisation. Lowering the bed temperature would normally lead to poor water evaporation inside the bed and poor drying of the granules, resulting in off-spec product.

Casale has therefore developed and patented the "double granulator" principle,

Fig. 1: **Urea – AS eutecticum graph**



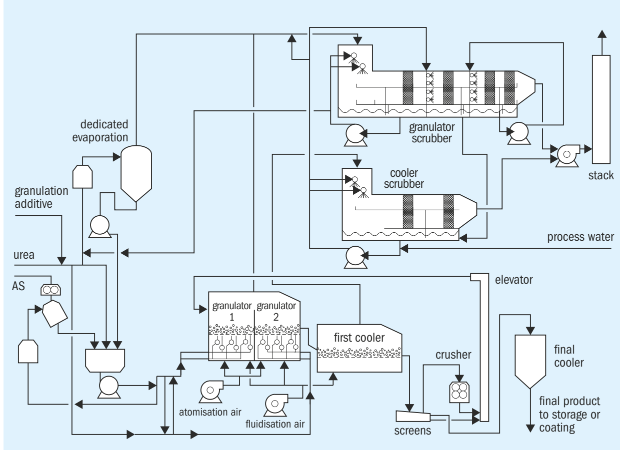
Source: Casale

a specific fluidised bed production process for UAS that offers the flexibility to produce standard urea granules or any grade of UAS from 0 to 25% ammonium sulphate content without any loss of quality features and without the need to reduce the bed temperature at any feed composition. The "double granulator" principle allows feeding different melt compositions to different granulator sections, avoiding the eutectic mixture of urea and AS and enabling the production of any UAS composition under optimal granulation conditions, ensuring top-quality product. This flexibility also allows clients to continue production even if the AS supply is compromised or reduced.

AS contents higher than 10 wt-% in the urea feed concentration (>96%) are no longer soluble and lead to slurry rather than solution spraying inside the granulator. Therefore, the liquid sprayers must be specially designed to handle the crystals. The scrubbing section can handle a large quantity of crystals and inerts in the airstream without upsetting the process. A dedicated evaporation section ensures that no AS is recycled to the upstream synthesis plant and is designed to prevent AS crystallisation in the evaporation heater. It also offers the advantage of adjusting the final water content in the UAS feed, influencing the crystallisation point and providing a second tool for fine-tuning the system to guarantee optimal conditions in the granulator (Fig. 2).

The first-of-a-kind double granulator plant for UAS production has been commissioned in the first quarter of 2025. The 1,200 t/d unit will be able to operate on both urea and UAS, with AS contents ranging from 0-20 wt-%. The commissioning on urea went smoothly. The AS storage and preparation section are being installed and AS addition is to be expected in Q3 of 2025.

Fig. 2: **UAS double granulator technology**



Source: Casale

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Enhanced urea application in the pre-granulator

Intense farming over long periods depletes the soil at high rates. Available farmlands are being stripped of valuable elements that crops need to grow sustainably. Standard general fertilizers add macronutrients such as nitrogen, phosphate, potassium, sulphur, etc., to the field, which plants need for growth. Growing crops also absorb micronutrients such as iron, boron, copper, zinc, etc. These elements are essential for vegetation, even in small amounts. Each harvest reduces the content of minerals in the soil. Casale offers technology to produce nitrogen-based fertilizers containing micronutrients in various doses for wide applications or tailor-made ends.

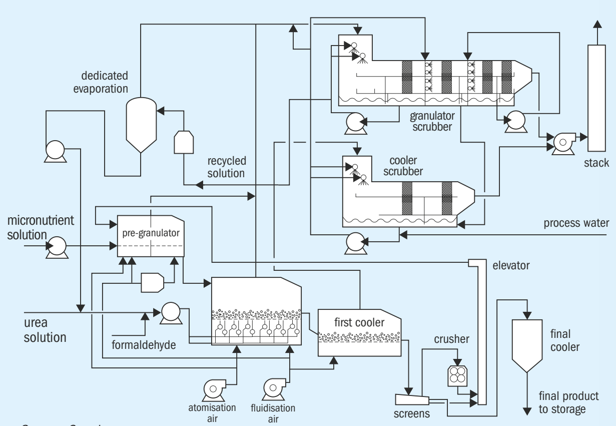
The pre-granulator technology (Fig. 3) adds micronutrients or other additives to the core of the granule rather than coating the granule. This is achieved by spraying small amounts of additive on the seeds produced by crushing oversize granules or adding specific seeds to the pre-granulator and covering them with a protective layer to shield them from heat impact in the further process. Adding specific elements to the granule's core greatly improves the additive's efficiency and eliminates premature wash-off in the field. The pre-granulator allows adding the additive under mild bed temperature conditions, preserving the additive's integrity.

Nitrates finishing applications

Fluidised bed granulation

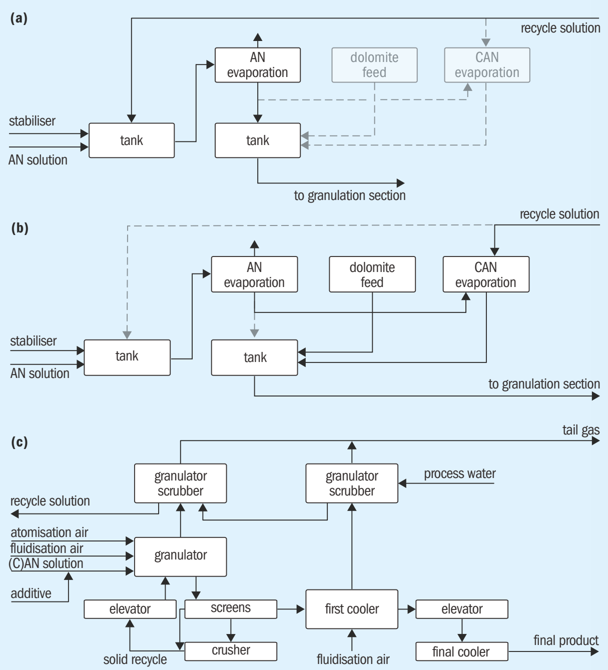
With the acquisition of Green Granulation Technology, Casale has also acquired a reference in AN/CAN fluidised bed granulation. The 1,015 t/d AN – 1,300 t/d CAN plant was constructed and commissioned during the COVID-19 pandemic and has been in operation since. This unit features the unique combination of AN and CAN in a fluid-bed-based plant and can be operated with different granulation additives and stabilisers. Hydraulic liquid spray nozzles ensure prime quality product features and low dust production during the granulation process. The step-by-step cooling is designed to preserve granule integrity throughout the process and prevent hazardous temperature cycling during production, which may compromise product density and eventually crumble

Fig. 3: **Pre-granulator technology**



Source: Casale

Fig. 4: **Fluidised bed granulation: (a) AN preparation loop, (b) CAN preparation loop, (c) AN/CAN granulation section**



Source: Casale

the granules, making them vulnerable to atmospheric pickup or organic contamination. The different crystal transition points of AN and the different influences of product stabilisers on these transition points are accounted for in the process design. Anti-backmixing features and flexible cooling ensure smooth crystallisation of the melt or slurry and controlled cooling to appropriate storage temperature.

The process consists of two melt preparation loops that may or may not be integrated depending on the end product. When producing AN grade, the AN loop provides the melt directly to the granulation section without passing through the CAN loop. When producing CAN grades, the AN melt prepared in the AN loop is sent through the CAN loop and brought to appropriate concentrations before being sent to the granulation section. Switching from AN to CAN can be done on the run. For a switch from CAN grades to AN, the system needs to be rinsed and cleaned, with the collected wash liquid stored in a shutdown tank for future CAN runs.

Temperatures in the preparation section are kept moderate to ensure safety while handling hot AN melt. The process stays safely away from the 180°C upper limit, with a safety trip initiation to ensure safe operation.

The fluid bed granulation plant (Fig. 4) is usually preferred when large capacity is required (usually above 1,500-2,000 t/d) and it can be designed for capacities up to 5,000 t/d in a single train configuration.

Drum granulation

In addition to fluidised bed technology, Casale also offers a flexible drum granulation loop technology for production of high-quality granules with uniform size and durability, well-suited for modern wide spreading on agricultural fields. The drum technology (Fig. 5) is used in over 50 plants worldwide and is very versatile, capable of producing a wide range of different AN-based fertilizers like ammonium nitrate fertilizer (HDAN), calcium ammonium nitrate (CAN), ammonium nitrate sulphate (ANS), etc., in the same plant. The resulting granules are well-suited for modern, wide spreading on agricultural fields. In view of the above characteristics, drum granulation is preferred when high product versatility and lower plant capacity are requested. Typically, drum granulation can achieve a capacity up to about 2,500 t/d in a single line.

Together with ammonium nitrate, various raw materials such as dolomite, limestone, calcium sulphate, ammonium sulphate, etc., can be added to obtain different types of AN-based fertilizers. This allows easy granulation of 33.5% N ammonium nitrate, 26-27% N ammonium nitrate (such as CAN), ammonium nitrate sulphate (ANS), and 34.7% ammonium nitrate for technical uses.

Additionally, nitric or sulphuric acid can be used in the acid scrubbing section to drastically reduce ammonia emissions to the atmosphere. Finally, a granulation agent and coating agent(s) can be used to improve granulation efficiency and guarantee optimal final product quality.

The plant is designed to achieve the lowest recycling ratio, depending on product grade, selected raw materials, and the ratio between solid and liquid phases.

The plant comprises the following major items:

- a rotary drum granulator, in which ANS is sprayed over a moving bed of recycled particles consisting of fines, dust, coarse ground grains, part of recycled final products, filler (e.g. limestone or dolomite) and solid raw material, if required (e.g. ammonium sulphate or calcium sulphate).
- a rotary dryer with hot air to decrease the residual moisture in the final product.
- a screen to separate the on-size product from the small and the oversize one. The latter are crushed, mixed with the former and fed back to the granulator together with a portion of the final product to keep a constant recycled flowrate.
- a fluidised bed cooler for the on-size product. A coating agent is added in a dedicated drum, to prevent caking. The product is then sent to storage.
- a dedusting and scrubbing system, which recovers ammonia and dust from all the gaseous effluents, to prevent pollution and minimise losses.

Villeta project

The Casale drum granulation technology has been recently selected and applied in the Villeta Green Fertilizer Project in Paraguay (Fig. 6).

Located 35 km from Asunción along the Paraguay River, the Villeta project utilises Paraguay's abundance of hydropower to establish a world-scale production facility for green fertilizers. This project aims to meet domestic and international fertilizer demands while significantly reducing greenhouse gas emissions, exemplifying a model for sustainable industrial development.

Key features include:

- a 145 MW power purchase agreement with ANDE;
- advanced production facilities capable of producing over 250,000 t/a of calcium ammonium nitrate (CAN);
- zero-carbon production processes are powered entirely by hydropower.

The Villeta project stands out for its reliance on advanced technologies, ensuring high efficiency and sustainability.

Fig. 5: **AN/CAN drum granulation plant**

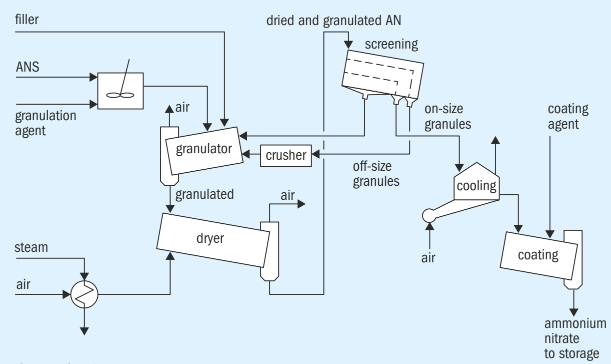


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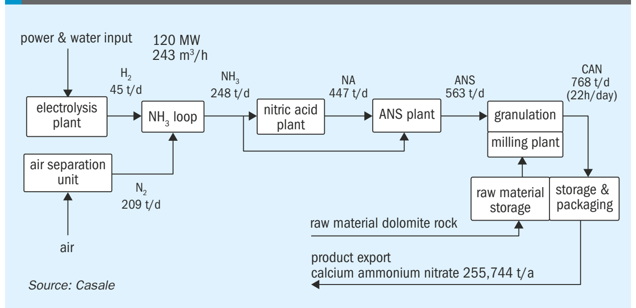
Fig.6: **Technology applied in the Villeta Green Fertilizer Project in Paraguay**



Source: Casale

Drum granulation technology further applications

In addition to AN-based fertilizers, the drum granulation loop technology is applied by Casale for both complex fertilizers (i.e. NPK) and the production of granular AS fertilizer. This concept allows the possibility to design a single granulation loop able to produce a very wide range of different fertilizers completing all the needs requested from the market.

The Casale multi-granulation plant is a single drum granulation plant equipped with all necessary equipment for AN-based fertilizers, NPK complex fertilizers and granular AS fertilizers. It includes dual pipe reactor technology (GPR+DPR), an AS pre-neutraliser, an ANS concentration section, and a common scrubbing system that can work with nitric acid, sulphuric acid or phosphoric acid.

Ammonium sulphate drum granulation

Casale's drum granulation technology suited for the direct production of fertilizer grade granular ammonium sulphate is illustrated in Fig. 7.

AS is produced by the direct reaction between sulphuric acid and ammonia that takes place in the pre-neutraliser and the granulator pipe reactor.

Sulphuric acid is also added in the acid scrubbing section to minimise ammonia emissions to the atmosphere. Finally, a granulation agent and coating agent(s) are used to improve granulation efficiency and guarantee optimal final product quality.

The plant configuration and H_2SO_4/ NH_3 split between the pre-neutraliser and the granulator pipe reactor is designed to achieve the lowest recycle ratio, minimising the equipment dimensions and therefore the plant investment cost.

The plant comprises the following major items:

- pre-neutraliser + pipe reactor installed in the granulator drum: ammonium sulphate is produced by the chemical reaction between ammonia and sulphuric acid. The reaction takes place in two different pieces of equipment. The first reactor is an agitated vessel, called the pre-neutraliser (PN), and the second reactor is the pipe reactor installed in the granulator drum (GPR).

  The PN is fed by a portion of ammonia and sulphuric acid; the product is fed to the GPR together with additional raw materials. Ammonia is, thus, split between the PN and GPR. The remaining stoichiometric amount of ammonia is injected directly into the drum granulator through the ammonia sparger.

  The water, mainly the recycled scrubbing liquor, is mostly fed to the PN to maintain good fluidity of the ammonium sulphate slurry. The balance of the water is fed to the GPR.
- rotary drum granulator, where AS slurry from the GPR is sprayed over a moving bed of recycled particles consisting of fines, dust, coarse ground grains, part of recycled final products.
- rotary dryer fed with hot air to decrease and control the residual moisture in the final product.
- screens to separate the on-size product from small and oversize product. The latter are crushed, mixed with the former and fed back to the granulator together with a portion of the final product to keep a constant recycled flowrate.
- fluidised bed cooler for the on-size product. A coating agent is added in a dedicated drum, to prevent caking. The product is then sent to storage.
- dedusting and scrubbing system, where ammonia and dust from all the gaseous effluents are recovered, to prevent pollution and minimise losses.

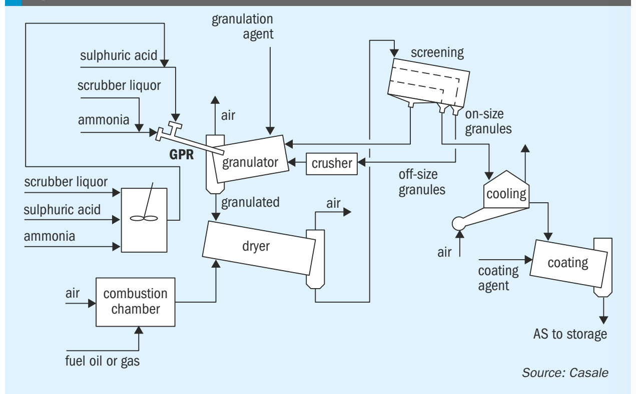
Turkmenistan project

Casale drum granulation technology for granular AS production has been recently selected and applied for Turkmenhimiya, the state-owned chemical company of Turkmenistan, and will be built in Turkmenabat.

Once completed, the new complex will produce:

- 100,000 t/a of ammonium sulphate (AS)
- 350,000 t/a of granular single superphosphate (SSP) ■

Fig. 7: **AS drum granulation plant**



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Benfield CO_2 revamp success: Strategic lessons and outcomes

VK Arora of Kinetics Process Improvements, Inc. (KPI, Houston) describes the systematic revamp of a Benfield CO_2 removal unit at a high-throughput ammonia plant, emphasising simulation-driven diagnostics and customised engineering solutions. The initiative was prompted by persistent operational challenges, including excessive steam consumption, elevated CO_2 slippage, and ongoing mechanical degradation.

The Benfield process remains widely used for CO_2 removal in ammonia, refining, and petrochemical plants. However, many of these legacy units now operate under significantly higher loads than originally designed for, resulting in chronic performance degradation. Common challenges include deteriorating hydraulics in absorbers and strippers, increased CO_2 breakthrough, solvent carryover, and rising steam consumption – all of which undermine plant efficiency, emissions compliance, and operational reliability.

This article discusses the systematic revamp of a Benfield unit (Act-1) at an ammonia facility operating at nearly 140% of its original design capacity due to multiple plant expansions. Previous incremental upgrades – such as packing replacements, higher circulation rates, and added ejectors – provided only temporary relief. Core issues persisted, including high CO_2 slippage (up to 4,200 ppmv), elevated inerts in the synthesis loop, high LP steam demand, and reduced ammonia conversion efficiency. These inefficiencies led to incremental losses in ammonia and urea production and accelerated mechanical deterioration in some critical equipment.

Original design and expansion

The ammonia plant was originally commissioned in 1992 with a nameplate capacity of 1,500 t/d. Subsequent capacity upgrades in 1997 and 2009 increased the plant's output to 2,125 t/d. However, the Benfield CO_2 removal system was not proportionally expanded during these debottlenecking efforts and underwent only limited modifications, as summarised below. The configuration of the Benfield system, as modified during the 1997 and 2009 expansions, is shown in Fig. 1.

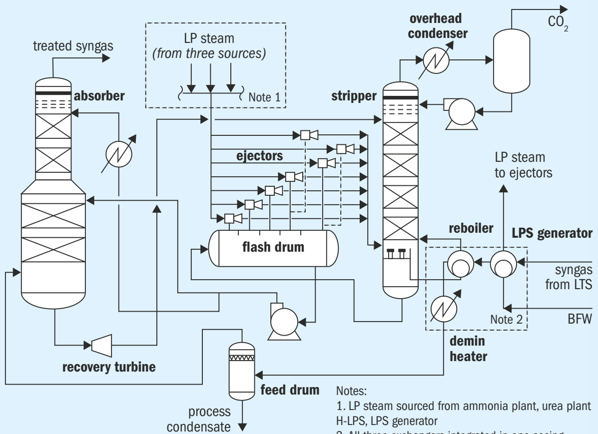
Prior modifications

To accommodate the increased load from the 1997 and 2009 capacity expansions, several incremental modifications were implemented on the Benfield CO_2 removal system:

- Replacement of random packing in the absorber with high-performance IMTP packing to mitigate flooding
- Addition of supplementary ejectors on the 4th and 5th compartments of the flash drum
- Installation of chevron trays in the stripper top section to reduce water and solvent carryover
- Upgrade of the overhead condenser and reflux drum system in the stripper
- Enhancements to the CO_2 overhead knockout vessel
- Increase in Benfield solution circulation rate by ~17%
- Increase in potassium carbonate (~7%) and activator (~50%) concentrations
- Increase in LP steam injection to the stripper and ejectors.

These incremental changes proved insufficient, as system performance continued to deteriorate under elevated throughput conditions.

Fig. 1: **Pre-revamp Benfield system**



Notes:
1. LP steam sourced from ammonia plant, urea plant H-LPS, LPS generator
2. All three exchangers integrated in one casing

Source: KPI

Pre-revamp operating challenges

Despite the incremental modifications introduced during the 1997 and 2009 capacity expansions, the Benfield CO_2 removal system continued to experience persistent and interlinked challenges that constrained plant throughput, energy efficiency, and overall reliability:

High CO_2 slippage (4200 ppmv, max), significantly above the original design limit of 1,000 ppmv. This elevated synthesis loop inerts, increases purge rates, and reduces ammonia conversion efficiency, ultimately impacting downstream urea production potential.

- Frequent pressure drop excursions and near-flooding in the absorber and stripper, reflecting severe hydraulic constraints and poor vapour-liquid distribution that undermined system stability.
- Excessive LP steam consumption, resulting in:
  - Overfiring of auxiliary boilers
  - Steam venting in the downstream urea unit
  - Elevated cooling water and demineralised water demand
  - Inefficient deaerator operation and increased operating costs
- Feed separator overload from elevated feed temperatures and rates, which led to solvent carryover and subsequent downstream fouling.
- Undersized flash drum and declining ejector efficiency, exacerbating hydraulic limitations and negatively impacting stripping performance.
- Restricted flow and thermal inefficiencies in the stripper reboiler circuit, worsened by degraded heat-transfer surfaces.
- Mechanical degradation of critical equipment – including flash drums, ejectors, reboilers, and associated internals – compromised system reliability and drove up maintenance frequency.

Collectively, these shortcomings resulted in unstable operation, elevated energy consumption, and reduced ammonia production efficiency, placing significant strain on downstream units and limiting the plant's ability to achieve production targets consistently.

Table 1: **Plant data versus simulation**

Parameters	Plant data	Simulation
Feed temperature, °C	119.3	119.3
Cold solvent temperature, °C	81.9	81.9
Warm solvent temperature, °C	118.4	118.4
Least flash pressure, kPa (abs)	143	143
Total circulation rate, %	100	100
Solvent flow to top bed, %	16.6	16.6
Solvent flow to third bed, %	83.4	83.4
Stripper bottoms vapour capacity factor	n.a.	0.461
Flash drum vapour capacity factor	0.368	0.361
Absorber bottoms vapour capacity factor	n.a.	0.789
Reboiler duty, %	100	100
CO_2 slippage, ppmv	4,200	4,200
Stripper bottom temperature, °C	127.3	127.4
Absorber bottoms temperature, °C*	128.8	125.7
Stripper top pressure, kPa (abs)	180	180
Absorber top pressure, kPa (abs)	3,175	3,175
Absorber ΔP	52	43.1**
Stripper ΔP	22.8	14.3**
Absorber percentage flood, %	n.a.	See profile
Stripper percentage flood, %	n.a.	See profile
Steam flow to ejectors, %	100	100

**The temperature difference is perhaps due to excessive carry over in the feed drum.*

***The calculation ΔP only for the packed beds while plant data ΔP is higher as it also includes pressure drop of trays, exit, inlet and across the distributors.*

Source: KPI

Revamp approach

To address persistent hydraulic, thermal, and reliability challenges, KPI executed a structured two-phase revamp methodology – developed in close collaboration with the end user – combining rigorous process modelling of the complete Benfield system with pragmatic, cost-effective engineering solutions. Phases 1 and 2 were completed by KPI in 2020, with full implementation and start-up successfully delivered by an EPC firm in mid-2022.

Phase 1

Phase 1 comprised simulation, performance modelling, and an integrated system assessment. KPI developed validated process simulation models that reasonably captured actual plant behaviour. These models enabled detailed scenario analysis, allowing precise bottleneck identification and quantification of operational limitations. A comprehensive assessment of column hydraulics, thermal performance, process integration, and mechanical adequacy was conducted for all major equipment: absorber, stripper, flash drum, ejectors, and reboiler, etc. Cost-benefit analyses were performed for multiple revamp options, incorporating vendor inputs for budgetary estimates and assessing implementation feasibility within plant layout constraints. Results were jointly reviewed with the end user, leading to the selection of the most technically and economically viable options and providing a robust, evidence-based foundation or Phase 2 PDP engineering.

Phase 2

Phase 2 comprised revamp engineering and the process design package (PDP). Based on Phase 1 outcomes, KPI prepared

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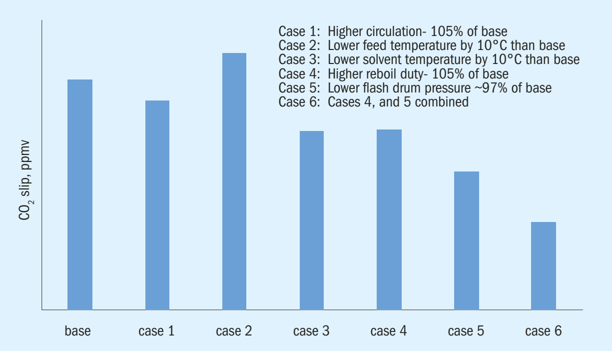
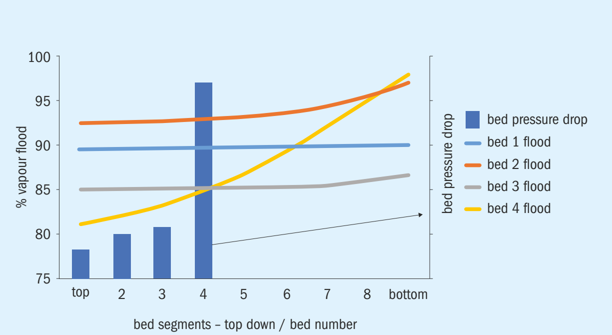
Fig. 2: CO_2 slippage – sensitivity of various parameters



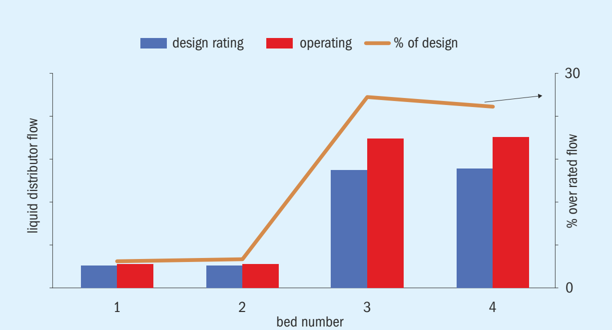
Source: KPI

Fig. 3: Absorber bed hydraulics



Source: KPI

Fig. 4: Absorber liquid distributors – rated vs actual flowrate



Source: KPI

a comprehensive PDP for modified and new components, including:

- Flash drum sizing and configuration
- Process specifications for ejectors, reboiler, and column internals
- Operational adjustments to ensure stable performance at the expanded load

Phase 1 findings directly guided the revamp scope, equipment selection, and budgetary estimate – ensuring well-informed, reliable and smooth execution. Following the PDP, the end user engaged an EPC contractor for detailed engineering, procurement, and installation, culminating in a successful system startup in mid-2022.

Plant data versus simulation

The entire Benfield system was rigorously simulated using actual plant data and furnished design inputs, including the specific packings installed in the absorber and stripper columns. The simulation demonstrated good alignment with plant performance, as summarised in Table 1.

The validated model was subsequently used to evaluate improvement options, including a parametric study, with key results summarised in Fig. 2

Key findings

Based on the Phase 1 study conducted under base (normal) operating conditions, the following items were identified:

Overall equipment loading

Nearly all major equipment in the Benfield CO_2 removal system had operated at or above original design limits. Hydraulic constraints had been especially pronounced in the absorber and stripper columns, adversely affecting vapour-liquid distribution, column efficiency, and overall system performance.

Absorber column

Flooding conditions: Fig. 3 indicates that Beds 2 and 4 were operating close to their hydraulic limits (at nearly 98% capacity) placing them at risk of incipient flooding.

Liquid distributors: The lower two bed distributors had been significantly under-rated and likely overflowing, reducing column efficiency. The upper two distributors, though closer to rated capacity, had poor designs with low drip density and inadequate liquid distribution. Fig. 4 indicates that the lower liquid distributors operated at over 125% of their rated capacity, while the upper distributors were nearing their maximum design limits).

Vapour distribution: Excessive vapour velocity through the feed nozzle into Bed 4 had caused vapour maldistribution. A vapour distributor had been required; two installation options had been evaluated:

- Hot-work installation inside the column wall during TAR – technically preferred but outage-dependent.
- External installation by shortening and raising Bed 4 by ~1 m – less desirable as it eliminated future lower manway access.

Stripper column

Flooding conditions: Bed 4 had operated at ~94% of flood capacity (Fig. 5).

Liquid distributors: As shown in Fig. 6, all four liquid distributors operated above 140% of their rated capacity, resulting in poor flow distribution and degraded performance.

Vapour distribution: As with the Absorber, two vapour distributors had been recommended; feasibility of turnaround hot-work installation needed review.

Reboiler circuit: Liquid head to the reboiler could have been increased by modifying the bottom chimney tray collector box – hot work required during turnaround.

Wash trays: Likely operated in the spray regime due to low liquid rates, risking carryover. Cold condensate makeup had been redirected from the reboiler vapour line to the wash trays to improve liquid loading.

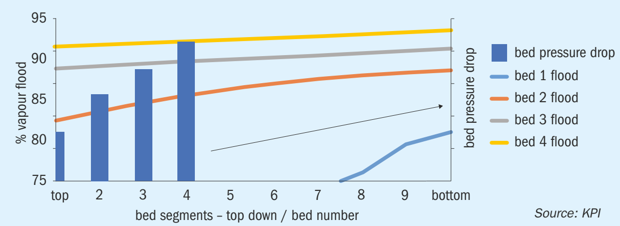
Packing evaluation

To address hydraulic limitations and reduce CO_2 slippage, KPI conducted an extensive, independent evaluation of multiple packing configurations (summarised in Tables 2 and 3) for both the absorber and stripper columns. These assessments were performed using KPI's validated Benfield simulation model.

Based on simulation results and performance trade-offs, the evaluation recommended retaining the existing packings and deferring any replacement decisions until after the installation and performance validation of upgraded vapour and liquid distributors in both columns.

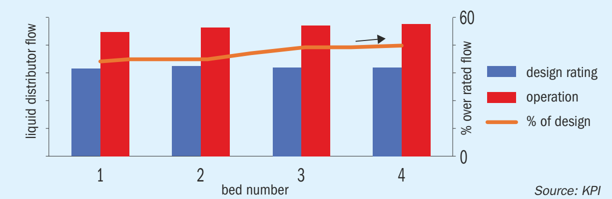
It was observed that the latest 4th-generation random packings demonstrated improved hydraulic characteristics but led to higher CO_2 slippage while structured packings offered potential enhancements in both hydraulic performance and CO_2 removal efficiency; however, their behaviour under high liquid load conditions remained uncertain, with limited full-scale commercial validation.

Fig. 5: Stripper bed hydraulics



Source: KPI

Fig. 6: Stripper liquid distributors – rated vs actual flowrate



Source: KPI

Table 2: Absorber packing combinations evaluated

Bed	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Bed 1 (top)	IMTP 60 random packing	MellapakCC™	RMP N 200X	SuperBlend 2-Pac # 5060
Bed 2	Top half: IMTP 60; Bottom half: IMTP 70	MellapakCC™	RMP N 200X	SuperBlend 2-Pac # 70
Bed 3	IMTP 60 random packing	No change	RMP N 200X	SuperBlend 2-Pac # 6070
Bed 4	Top half: IMTP 70; Bottom half: PROFLUX	No change	RMP N 125X	SuperBlend 2-Pac # 6070

Source: KPI

Table 3: Stripper packing combinations evaluated

Bed	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Bed 1 (top)	IMTP 60 random packing	MellapakCC™	RMP N 200X	SuperBlend 2-Pac # 6070
Bed 2	IMTP 70 random packing	MellapakCC™	RMP N 200X	SuperBlend 2-Pac # 6070
Bed 3	IMTP 70 random packing	Mellapak™ 125X	RMP N 200X	SuperBlend 2-Pac # 6070
Bed 4	PROFLUX severe service grid	Mellapak™ 125X	RMP N 125X	SuperBlend 2-Pac # 6070

Source: KPI

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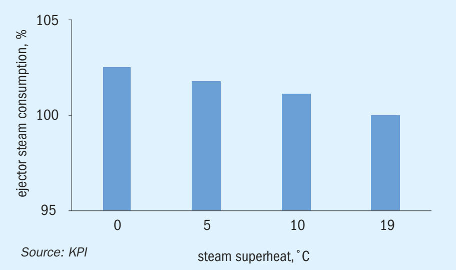
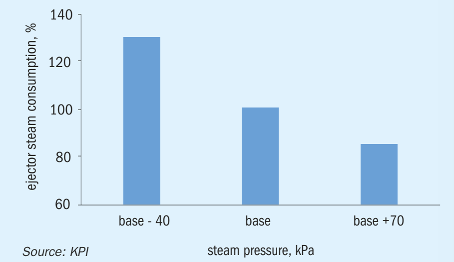
Fig. 7: **Ejector steam consumption – impact of steam superheat**



Source: KPI

Fig. 8: **Ejector steam consumption – impact of steam pressure**



Source: KPI

Flash drum and ejector system evaluation

Existing system: The flash drum had exhibited signs of aging (cracks in internals and welds) and several ejectors had shown wear and declining efficiency. Both had been scheduled for replacement during the next turnaround.

The existing drum was significantly undersized, offering insufficient vapour disengagement and inadequate residence time. A new drum, approximately 160% larger, was designed while retaining the original five-compartment layout to minimise piping modifications.

New ejector configuration: One ejector was designated per compartment, designed to operate under the existing low-pressure (LP) steam conditions. A detailed sensitivity analysis was performed to evaluate the influence of steam pressure and degree of superheat. The impact of these parameters on relative steam consumption by the ejectors was evaluated, as shown in Figs 7 and 8.

A slightly higher pressure greatly helps to reduce the steam consumption, whereas higher steam superheat is much less sensitive to the steam consumption.

Stripper reboiler replacement

Significant tube wall thinning in the existing reboiler had raised serious reliability and mechanical integrity concerns. A new design higher-duty replacement reboiler was engineered to increase the CO_2 stripping capacity and improve the thermosiphon circulation while remaining within the existing space and piping constraints. A longer tube bundle was selected to fit the existing footprint without requiring layout modifications.

The new design provided operational benefits including:

- The reduced steam consumption relieved the auxiliary boiler load and contributed to lower greenhouse gas (GHG) emissions.
- A lower heat load on the demineralised water heater improved deaerator stability and performance.

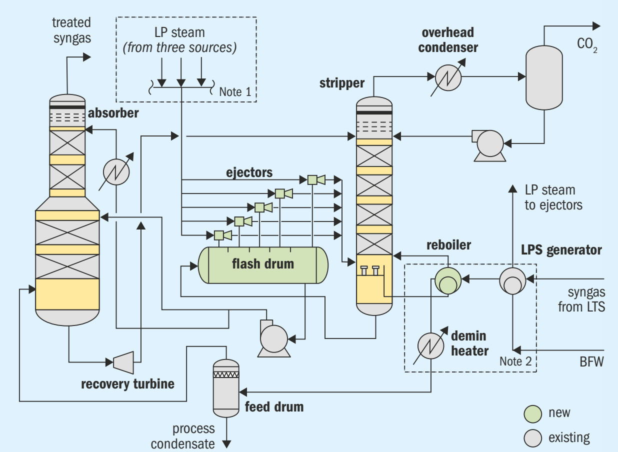
Recovery turbine

The existing turbine was already operating at full capacity with the largest impeller installed. While replacing it could have enabled recovery of approximately 225 kW of additional power, doing so would have required major hardware modifications, including pump relocation. An economic evaluation concluded that the upgrade was not justifiable based on cost-benefit considerations.

Separators

The absorber feed separator was significantly undersized, resulting in excessive vapour velocity and liquid carryover due to insufficient disengagement capacity. In contrast, the stripper overhead separator and treated syngas separator were found to be adequately sized for current operating conditions.

Fig. 9: **Post-revamp Benfield system**



Notes -
1. LP steam sourced from ammonia plant, & LPS generator, urea H-LPS eliminated
2. All three exchangers integrated in one casing
3. Sizing & specs of new modified items by KPI

Source: KPI

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Table 4: **Summary of major modifications/replacements**

Pre-revamp	Post revamp	Remarks
Underrated liquid distributors in absorber	All four liquid distributors replaced with high-efficiency units	Improved performance and stable operation
Maldistribution of inlet feed vapour to absorber	Installed an even-flow inlet vapour distributor	Welded option applied for durability
Incipient flooding in absorber beds	Issue resolved with items 1 and 2	Achieved stable hydraulic performance
Underrated liquid distributors in stripper	All four liquid distributors replaced	Enhanced separation reliability
Flash drum inadequate; affected ejector efficiency and integrity	Replaced with larger properly designed flash drum	Increased volume to ~160%
Inefficient ejectors; high steam demand and reliability issues	Replaced 7 ejectors with high-performance units	Improved steam efficiency and mechanical integrity
Reboiler mechanical integrity concerns and undersized	Replaced with a new one with a higher heat duty	Well supported enhanced stripping duty within the hydraulic and space constraints
Feed separator inadequate; caused carry-over	Replacement pending	Planned for future revamp phase
Power turbine recovery maxed out and bypassed	Upgrade deferred	Postponed due to economic constraints

Source: KPI

Key modifications and justifications

A comprehensive revamp was executed to address the hydraulic constraints, reliability risks, and energy inefficiencies identified during the Phase 1 assessment. The major upgrades introduced in the 2022 revamp are outlined in Table 4 and reflected in the post-revamp process flow diagram shown in Fig. 9.

Vapour inlet distributor in absorber

Problem: Maldistribution and high inlet velocity at the absorber feed nozzle led to poor vapour contact with the bottom bed and localised flooding.

Solution: Installed an even-flow vane-type vapour distributor to ensure uniform vapour flow and minimise localised velocity spikes.

Justification: Correcting vapour entry dynamics improved vapour-liquid contact, reduced CO_2 slippage, and enhanced overall absorption efficiency.

Liquid distributors in absorber

Problem: The four absorber liquid distributors were operating well above rated capacity, resulting in overflow, uneven liquid loading, and poor bed performance.

Solution: Replaced all four absorber distributors with high-efficiency orifice-deck types, designed for higher flow capacity and improved liquid distribution.

Justification: Proper liquid distribution is critical for maintaining mass transfer surface area across the packing. This upgrade resolved localised flooding, enhanced column efficiency, and ensured stable operation.

Liquid distributors in stripper

Problem: The stripper's four liquid distributors were severely under-rated, contributing to maldistribution and reduced column performance.

Solution: Replaced all four stripper distributors with high-efficiency designs capable of handling updated hydraulic loads.

Justification: Uniform liquid loading minimised hydraulic constraints, improved separation reliability, and enabled stable CO_2 stripping performance.

Flash drum replacement

Problem: The existing flash drum was undersized, limiting vapour disengagement and contributing to ejector instability.

Solution: Installed a new flash drum (~160% larger) while maintaining the five-compartment configuration to minimise site impact and piping modifications.

Justification: Resizing the flash drum restored vapour-liquid separation reliability, improved ejector suction performance, and reduced entrainment into downstream equipment.

Ejector system optimisation

Problem: Seven aging ejectors exhibited poor efficiency, high steam demand, and mechanical integrity issues.

Solution: Replaced the existing ejectors with five modern high-performance units, optimised for available LP steam pressure and temperature.

Justification: The new configuration improved motive steam economy, eliminated the need for higher-pressure LP steam, and minimised venting in the downstream urea plant.

Reboiler upgrade

Problem: The existing stripper reboiler suffered from tube thinning and reduced heat transfer, impacting reliability.

Solution: Installed a new reboiler (designed for higher heat duty) within the existing footprint and piping constraints.

Justification: Enhanced heat duty improved CO_2 stripping efficiency, reduced slippage, and stabilised thermal performance. It also reduced auxiliary boiler firing and steam consumption, lowering GHG emissions.

Feed separator (pending)

Problem: The absorber feed separator was undersized, causing excessive liquid carryover into the column.

Solution: Replacement is planned in a future revamp phase to align with current throughput.

Table 5: **Post revamp performance summary**

Parameter	Pre-revamp	Post revamp	Remark
CO_2 slip	~4,200 ppmv (max)	Reduced by ~1,500 ppmv (better than expected ~740 ppmv)	~50% contribution to incremental ammonia production
Absorber DP excursions	Frequent high DP excursions, unstable operation	No excursions, stable after revamp	Improved reliability
LP steam venting in urea plant	Ongoing LP steam venting	Full utilisation, no venting at all	Efficient steam usage
Auxiliary boiler firing (HP steam for ejectors)	Additional firing required	Much reduced firing and reduced GHG emissions	Sustainability gains
Max ammonia production	2,127 t/d	Record 2,149 t/d achieved consistently	~50% gain attributed to CO_2 slip reduction
Urea production	Baseline	Proportional increment	~90% of gain from improved CO_2 recovery
Overall energy consumption	Higher	Lower (despite ~3.5% rise in LPS flow to ejectors)	Net energy efficiency improvement
Plant reliability	Moderate	High	Enhanced operational stability
Environmental impact	Significant	Reduced	Positive sustainability outcomes

Source: KPI

Justification: Adequate feed separation is essential to protect column hydraulics and reduce solvent carryover.

Power recovery turbine (deferred)

Problem: The existing turbine was fully loaded and bypassed, with the largest impeller already installed.

Solution: Upgrade deferred due to economic constraints, as replacing the turbine would require major pump relocations and hardware changes.

Justification: Economic evaluation determined that the additional 225 kW power recovery did not justify the capital expenditure

Fig. 10: **CO_2 slippage – pre and post revamp**

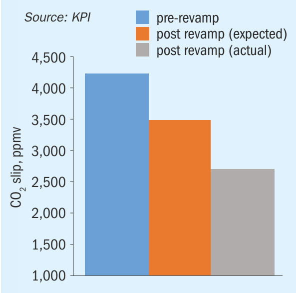

Table 4 presents a consolidated summary of key modifications and replacements, linking each pre-revamp issue to the corresponding solution and its realised benefits.

Post revamp performance

A comprehensive, simulation-driven approach was employed to revamp the Benfield CO_2 removal system, enabling quantifiable performance gains and streamlined evaluation of improvement options via cost-benefit analysis. Table 5 summarises the sustained performance metrics achieved following the mid-2022 revamp.

Key improvements achieved

Significant reduction in CO_2 slippage and capacity gain: CO_2 slippage was reduced by approximately 1,500 ppmv (refer to Fig. 10), directly improving synthesis loop composition, ammonia conversion efficiency. This supported incremental gains in ammonia and urea production. The revamped system achieved record ammonia production of 2,149 t/d, operating reliably at maximum load.

Hydraulic stability and operational reliability restored: Flooding and pressure-drop excursions in both the absorber and stripper were fully mitigated through upgraded vapour and liquid distributors, resizing of the flash drum, and replacement of ejectors. Uniform vapour-liquid distribution and restored hydraulic stability now enable predictable, high-capacity operation.

Enhanced energy efficiency and environmental benefits: LP steam consumption was significantly reduced, lowering auxiliary boiler firing and improving overall energy intensity. Steam venting to the urea plant was eliminated, improving water and energy utilisation across the integrated complex. Reduced auxiliary firing led to lower GHG emissions, supporting plant-wide sustainability and decarbonisation objectives.

Mechanical integrity and enhanced reliability: Replacement of aging equipment (including the flash drum, ejectors, and reboiler) addressed structural degradation and tube thinning, significantly improving long-term operability. The system now supports extended service life, lower maintenance requirements, and reduced unplanned downtime.

Conclusion

The comprehensive revamp of the Benfield CO_2 removal system at this 2,125 t/d ammonia facility delivered transformative improvements in performance, energy efficiency, and long-term reliability. It underscores the value of a simulation-driven, systematically engineered approach to upgrading aging CO_2 removal systems under increased throughput demands.

A systematic upgrade strategy was applied, combining validated process simulation with detailed hydraulic and mechanical assessments to diagnose performance bottlenecks. Improvement options were ranked using a cost-benefit framework to ensure impactful and economically viable implementation.

The revamp yielded significant benefits: restored hydraulic stability, reduced CO_2 slippage, lower steam usage, and improved energy efficiency – all contributing to maximising ammonia and urea production and enhanced long-term reliability.

Although implemented in an ammonia facility, the systematic methodology and solutions are broadly applicable to aging Benfield units in refineries and petrochemical complexes facing similar operational constraints. ■

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Optimising the finishing strategy for urea products

Stamicarbon has optimised urea granulation to meet rising global fertilizer demands by improving product robustness, reducing capital and operating costs through a simplified design, enhancing environmental performance with acidic scrubbing and UAS recycling, and scaling single-line plants up to 5,000 t/d while maintaining reliability and uptime.

Barbara Cucchiella, Ahmed Shams, Branislav Manic, Stamicarbon (NEXTCHEM)

As global agricultural production keeps growing to feed a rising population, expectations on urea producers are intensifying in parallel. Today's nitrogen fertilizer industry operates in a highly interconnected, capacity-sensitive market, where fluctuations in production and logistics challenges increasingly influence operational strategy.

Producers are under pressure not only to deliver larger volumes but to ensure their product maintains its physical integrity throughout global distribution. The need for urea granules with higher crushing strength, low caking tendency, and lower dust formation has become essential, driven by the global nature of fertilizer trade. The ability of urea granules to withstand shipping and storage conditions is now a requirement for market access.

At the same time, sustained demand from key importing regions, combined with continued stress on global logistics infrastructure, is encouraging many producers to prioritise large, single-train urea projects. These high-capacity facilities depend on granulation systems that can deliver consistent performance, high uptime, and comply with increasingly stringent environmental standards.

Moreover, technologies that offer added flexibility and access to new applications can be transformational. For urea plant operators, solutions that enable diversification, such as the integration of diesel exhaust fluid (DEF) production, can unlock additional revenue streams and improve competitiveness in an increasingly challenging market.

This article explores how advancements in granulation technology, and its integration with complementary solutions, are enabling producers to respond to these evolving demands and position themselves for long-term resilience and growth.

The granulation process

Stamicarbon, the nitrogen technology licensor of NEXTCHEM, has extensive experience licensing urea granulation plants

Fig.1: Pardis III granulation plant.

in various markets. Stamicarbon began developing its granulation technology through test facilities and smaller-scale units, before launching its first large-scale grass-roots plant in Egypt in 2006, which was later successfully revamped to operate at an even higher capacity.

Contracted in 2011, the Pardis III plant in Iran (Fig. 1) was the largest operational granulation facility based on the Stamicarbon granulation design at the time of its start-up in 2018, with a nameplate capacity of 3,250 t/d. The plant can operate at 110% capacity with a turndown ratio of 60% of the nameplate capacity. It is connected to a fertilizer-grade urea plant based on Stamicarbon's pool condenser design. Despite challenging weather conditions, the plant proves the reliable performance of the design, achieving an on-stream time of more than two months during extreme heat in summer.

In the original Stamicarbon urea fluid bed granulation process, urea melt with a concentration of about 98.5 wt-% is distributed by film spraying nozzles of proprietary design (Fig. 2). Granule seeds are coated with thin layers of urea melt film until they reach the required product diameter. This process stands out as highly cost-effective in terms of operational costs due to reduced formaldehyde content in the final product and low dust formation. In practice, this design has proven to operate for up to three months straight without the need for cleaning.

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

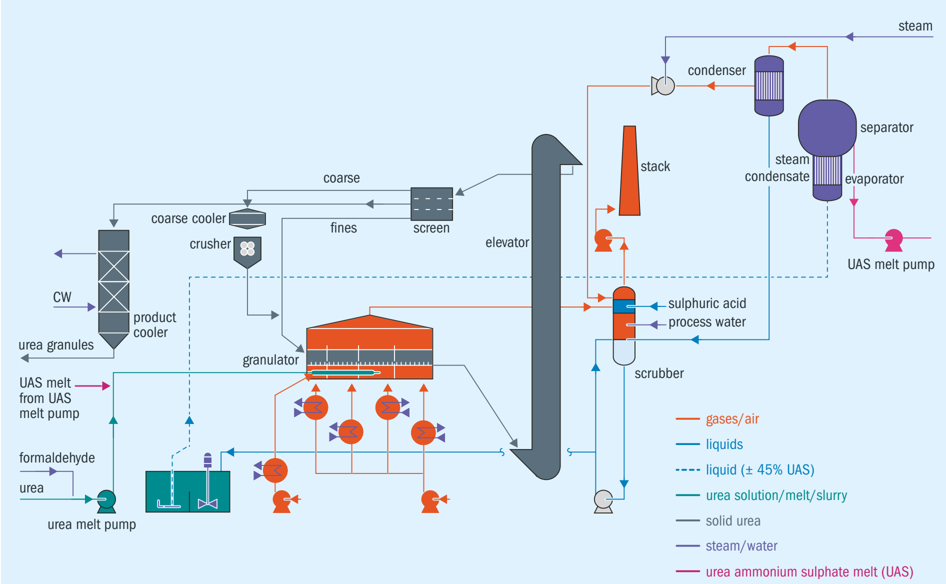
Further optimisation

In 2008, Stamicarbon introduced its optimised granulation design. It is distinct for its simplified layout (Fig. 3) with fewer equipment items, enabling a significant reduction in capital expenditure and operational costs while keeping its original performance and high on-stream times. In this improved design, the urea melt is fed to the granulator the same way as in the standard Stamicarbon design. The key difference is in the last compartment, where the granulated product is cooled down to a lower temperature. After passing the lump screen, the product is directly lifted with a bucket elevator to the classification equipment. Further, the complete solid product flows, using gravity force, through the main screens. The coarse product is fed to the crusher after cooling to temperatures below 70°C. The crushed product and the fines recycle flow are combined and recycled into the first compartment of the granulator as so-called seeds. The on-specification end-product in the outlet of the main screens is cooled to a storage temperature in a solid flow cooler that makes use of cooling water instead of cooling air. The dust-loaded air from the granulator, coarse cooler, and all the de-dusting points are collected and fed to a single granulator scrubber.

Eliminating two main fluidisation fans leads to significant cost savings in power consumption. The fluid-bed granulator cooler was omitted by increasing the length of the cooling zone in the original granulator, and the fluid-bed product cooler was replaced by a solids flow cooler. Furthermore, the respective granulator cooler scrubber with all necessary pumps and a fan were also omitted.

Fig. 2: Granulator film spraying nozzles.

Fig. 3: **Process flow diagram of Stamicarbon's optimised granulation design with an optional recycle evaporator section**



Source: Stamicarbon

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A water injection system was installed in the discharge of the fluidisation air fan to decrease the amount of fluidisation cooling air. This water injection system produces very fine droplets that evaporate along the air path to the granulator, cooling the fluidisation air. This feature is particularly efficient on exceptionally hot days or when the plant operates at production rates above its nameplate capacity. During such times, higher amounts of fluidisation air are expected, and using this system can significantly reduce those amounts.

Reducing equipment items significantly decreased the granulation plant's footprint and capital cost. The total capital expenditure reduction is not only achieved by eliminating equipment, but there are also savings in shipping cost, cost of insurance, construction, and the effect of reduced land use. Less operational equipment will also result in a reduction in maintenance costs and further operational savings.

> **"Complementing large-scale granulation can be done by adding DEF (also known as AdBlue®) production to a urea facility.**

Reducing emissions

During the crystallisation process of the urea melt in a granulator, the ammonia present in the urea melt is released and, in most cases, emitted into the air. Stamicarbon's granulation process, designed for efficient and environmentally friendly production, incorporates acidic scrubbing for effective ammonia capture. After the dust scrubbing stage, sulphuric or nitric acid is injected into a circulating aqueous solution brought into contact with the ammonia-laden air. The acid reacts with ammonia, effectively reducing its concentration in the exhaust air. The ammonium salt generated in this reaction can be sent outside battery limits or, if sulphuric acid is applied, incorporated into the end product. In this way, no disposal streams are sent to the atmosphere.

To develop this design, several obstacles needed to be addressed. The salt produced by the scrubbing system is about 55% water by weight and cannot be directly mixed with the main urea melt, which only contains 1.5% water and is fed into the granulator through nozzles. Therefore, to manage the water content in the recycled liquid urea ammonium sulphate (UAS) sent back to the granulator, a specific evaporation process is required (as illustrated in Fig. 3). This recycled UAS solution is then combined with the urea melt inside the granulator. The sulphur content in the end product is minimal, roughly 0.05-0.1% S, allowing the granules to be marketed as standard urea.

In response to increasing demand for sulphur as an essential plant nutrient, Stamicarbon has developed an innovative and adaptable modular process for manufacturing granulated urea enriched with higher levels of ammonium sulphate. A common approach involves recycling and concentrating liquid urea ammonium sulphate (UAS), allowing the salt to exit the granulation plant in solid form after being combined with molten urea. In Stamicarbon's design, solid ammonium sulphate is added to molten urea. Existing granulation plants can be retrofitted to use this innovative design with some modifications, installation of additional equipment, and potential upgrades to construction materials.

Scaling up to 5,000 t/d

Recent decades have seen a rapid rise in projects featuring higher plant capacity. Urea granulation plants with capacities over 3,000 t/d have proved to meet the growing performance and on-stream requirements.

Stamicarbon explored designing larger-capacity plants while maintaining its proven design philosophy and product quality. This led to the conclusion that a single-line configuration is more advantageous than a double-line configuration (two lines of 2,500 t/d each), as it could offer approximately 30% in capex savings on total investments.

In 2019, Stamicarbon licensed its first single-line 4,000 t/d urea granulation plant. The plant is equipped with the MMV scrubber to comply with environmental regulations. In 2022 and 2023, Stamicarbon secured contracts for licensing two more plants with a capacity of 4,000 t/d each for a customer in Africa.

Based on the experience with scaling up the conventional design, certain operational and manufactural challenges and supporting measures have been solved to scale up the optimised granulation design, making it possible to design a single-line 5,000 t/d granulation plant.

Diversifying product portfolio

Complementing large-scale granulation can be done by adding DEF (also known as AdBlue®) production to a urea facility. This offers a practical and effective way to diversify output and enhance the overall resilience of the plant. As market conditions fluctuate and product demands shift across regions, the ability to serve both fertilizer and fuels segments strengthens a producer's commercial position.

Stamicarbon's DEF production technology stands out from conventional methods by enabling producers to generate ISO 22241-compliant, high-purity urea solution directly from the urea melt without intermediate dilution, blending, or secondary finishing steps. This direct-from-melt approach overcomes a key challenge: standard urea streams often contain impurities such as residual ammonia, biuret, and formaldehyde that jeopardise DEF quality and can damage NO_x reduction catalysts. Stamicarbon's design ensures the urea solution meets purity standards, reducing investment in downstream treatment and minimising operational complexity.

In regions where emissions compliance or commercial demand for DEF is growing, this integration provides urea producers with greater flexibility and profitability, granting access to value-added markets.

Strategic importance of urea finishing technology

As market pressure continues to grow driven by demand dynamics, environmental expectations, and global logistics, Stamicarbon's integrated approach to urea finishing offers a solid foundation for long-term competitiveness and strategic adaptability.

Stamicarbon's granulation technology, together with its seamless integration with upstream and downstream solutions, provides a strategic toolkit for fertilizer producers. These technology choices enable operational flexibility, premium product capability, and efficient asset utilisation. ■

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