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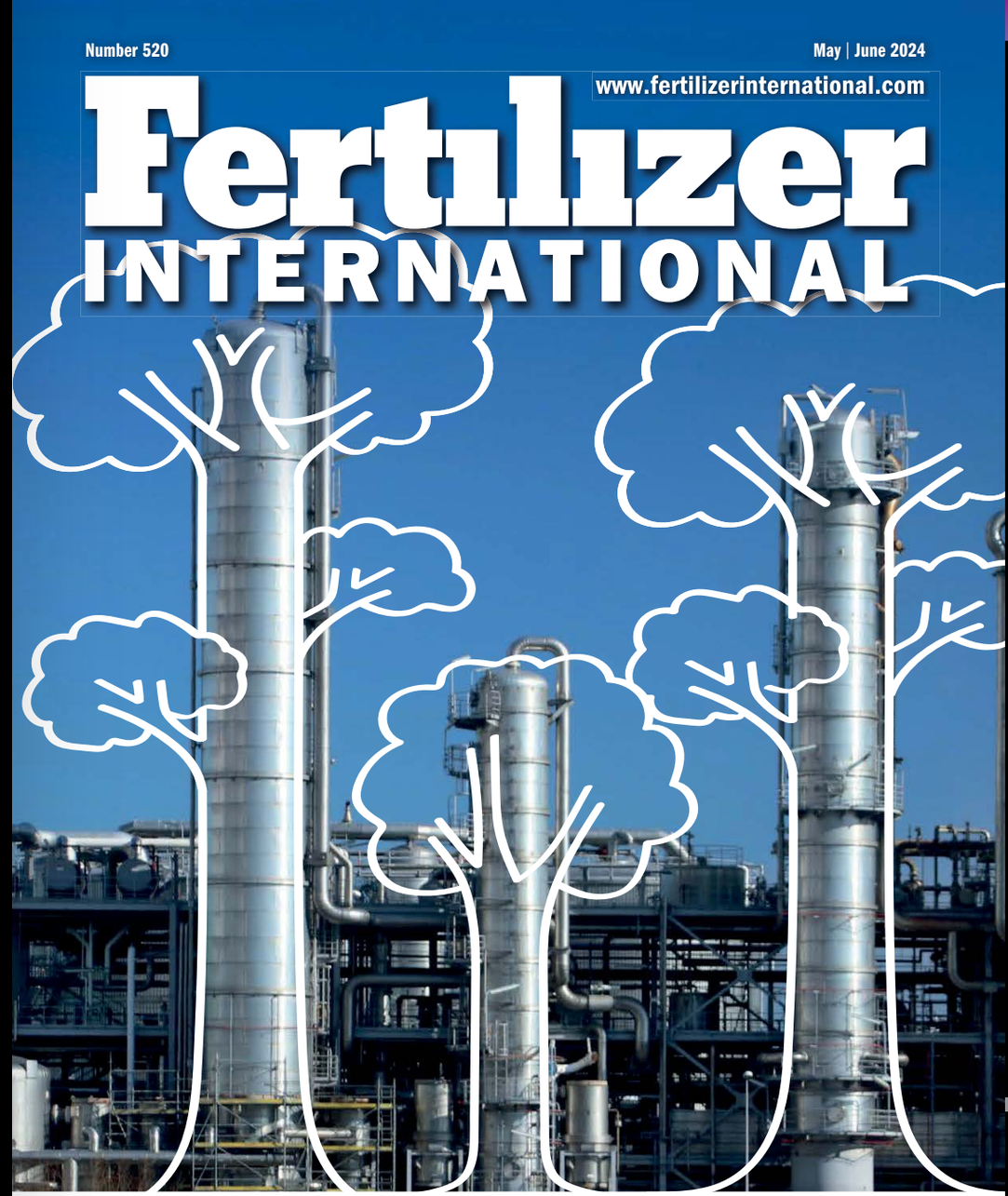

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Cover: Casale

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Chilling headwinds

> **"There are calls for the fertilizer industry and food manufacturers and retailers to link up and share the costs and risks of ammonia decarbonisation – and, importantly, shield the agricultural sector from the cost burden this could impose."**

A lot of low-carbon ammonia projects have been announced in recent years – so many, in fact, you've probably lost count.

Not my words but those of the Ammonia Energy Association (AEA), the trade body for the emerging low-carbon ammonia industry. The AEA, in a landmark report published in May last year, compiled a complete list of all low-carbon ammonia projects for the first time (*Fertilizer International*, 514 p24).

The report revealed that the 100+ projects announced so far have a combined low-carbon ammonia capacity of 172 million tonnes. That's equal to 75 percent of today's global installed ammonia capacity (228 million t/a) or 95 percent of current world demand for ammonia (180 million t/a).

While some of these plants are already operational or under construction, most are still at the feasibility or design concept stages. Consequently, many developers have yet to make final investment decisions or specify a start-up date.

However, a sizeable cluster of projects *have* announced they will commission by 2030.

These pioneering near-term projects could together provide 68 million t/a of low-carbon ammonia capacity by the end of the decade, if they were all to enter production, calculates the AEA. They roughly divide between 47 million tonnes of green ammonia capacity and 21 million tonnes of blue ammonia capacity.

Collectively, these projects are more than sufficient to meet market demand for low-carbon ammonia out to 2030, suggests the AEA. That includes established end-uses such as fertilizer manufacture and industrial feedstocks – as well as emerging but potentially massive new markets like shipping fuel and power generation.

None of this is certain, though, with increasing signs over the last 1-2 years that the decarbonisation of ammonia is facing strengthening headwinds. The deteriorating macroeconomic climate has had a chilling effect, as Laura Cross, IFA's director of market intelligence, explained to delegates at Argus Fertilizer Europe in Lisbon last October (*Fertilizer International* 518, p18):

"It's easy to underestimate how much capex inflation – and a change in the lending environment – we've seen in the last two years. There was a period when we were tracking green and blue ammonia project announcements almost daily. [Now,] with these announcements slowing down and projects being indefinitely delayed, the two main drivers being cited are, one, it's now much more expensive to build these projects – because there's increased demand for capex – and, two, it's become much more expensive to borrow the money to invest."

Having bankable demand from the market is a decisive factor in securing finance and getting low-carbon ammonia projects over the line, says the AEA (*Fertilizer International*, 514 p24):

"One simple, key factor will determine how many of these projects succeed: demand. To de-risk project financing and support offtake agreements, clear demand signals are required from both regulators and customers alike."

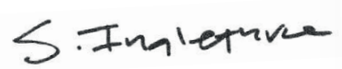
The recent Global Project Tracker update from Mission Possible Partnership (MPP) provides an illuminating snapshot of the ammonia industry's decarbonisation efforts. MPP says a goal of 60 operational green and blue ammonia plants by 2030 is needed to keep chemical industry decarbonisation on track.

To date, however, only 20 percent progress has been made towards this 2030 goal with around 12 low carbon ammonia projects either operational (three projects) or having reached a final investment decision (a further nine).

More positively, MPP is reporting a marked increase in the green ammonia investment pipeline, with a focus on production for export. This includes a ramp-up of government-supported announcements in India, both for domestic fertilizer production and offtake agreements with Japan.

In a call to action, MPP wants fertilizer producers/suppliers, farmers and consumer goods companies to link up and share the costs and risks of ammonia decarbonisation – and, importantly, shield the agricultural sector from the cost burden this could impose.

The main barriers facing low-carbon ammonia projects, according to MPP, are the market's sensitivity to green premiums and difficulties in securing offtakes because of the long, complex and fragmented value chains for green ammonia. Partnerships across the value chain are therefore looking increasingly crucial to prevent projects stalling. ■



Simon Inglethorpe, Editor

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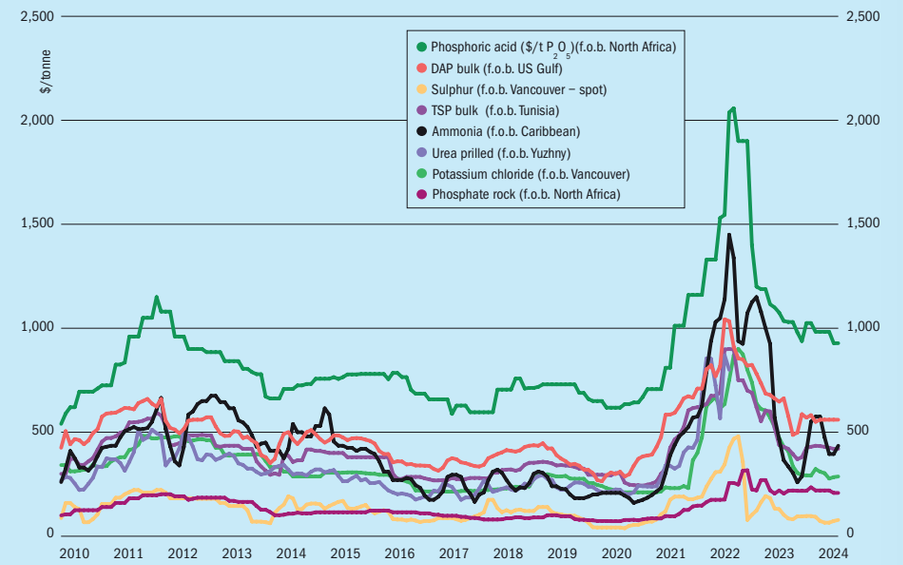
Historical price trends $/tonne



Source: CRU

PRICE TRENDS

Urea: Prices continued their global decline in mid-April, including at New Orleans. The notable exception was Brazil where prices firmed due to buyer interest in the market for May and beyond.

Elsewhere, prices took another turn for the worse. A cargo for May loading out of Oman was reported at $280/t f.o.b., while Egypt also drifted downwards with tonnes sold at $300-305/t f.o.b. Europe, meanwhile, was largely quiet with only Italy showing any real interest, and prices there slipping back to $320/t cfr. This was still higher than values in Turkey, where a sale was reported at $305/t cfr.

Unfounded rumours created another wave of uncertainty about Chinese urea exports. These wrongly suggested that export inspection certificates had been pulled because of escalating domestic prices.

Ammonia: There were hints in mid-April that the previously stable-to-soft outlook for ammonia prices East of Suez could firm, with signs of upwards pressure on some benchmarks due to supply issues. Full details of reported sales into the Far East at $375-400/t cfr are, however, still awaited. Domestic Chinese prices, meanwhile, declined once again.

Bullish Asian sentiment is supported by the impending shutdown at Ma'aden's 1.1 million t/a capacity MWSPC ammonia unit. This is likely to tighten the market further, with mixed reports about whether the curtailment will extend beyond the planned one-month period.

West of Suez, firming natural-gas prices in NW Europe reached $10/MMBtu in mid-April, equating to regional ammonia production costs in the low-$400s/t. This remains below the cost of imported ammonia, however, with a spot sale into the region reported at $490/t cfr.

Phosphates: DAP prices east of Suez extended their declines in mid-April. MAP prices in Brazil held firm – contrary to price deterioration elsewhere – helped by dwindling MAP stocks following low first quarter imports.

> **"The second quarter India phosphoric acid contract settled at $948/t cfr, down just $20/t on the first quarter price. This settlement could counteract some of the bearish sentiment that has gripped the phosphates market east of Suez, as many participants were expecting a lower price."**

Market sentiment is largely bearish due to increased DAP export availability from China. The country's exports quota has reportedly been set at 5.6 million tonnes of DAP/MAP for May-September. This is significantly up on China's first quarter exports of just 240,000 tonnes DAP/MAP shown in preliminary customs statistics.

The second quarter India phosphoric acid contract settled at $948/t cfr (100% P_2O_5), down just $20/t on the first quarter price. This settlement could

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Market price summary $/tonne – mid-April 2024

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	435	-	f.o.b. E. Europe 238	f.o.b. US Gulf	560	-	-
f.o.b. New Orleans	-	325	-	-	-	-	-
f.o.b. Yuzhny	Port closed	Port closed	-	f.o.b. N. Africa	570	420	928
f.o.b. Middle East	285	283	-	cfr India	546	-	968
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	287	-	cfr US Gulf	100	f.o.b. Vancouver	78	-
cfr India	319	-	-	-	f.o.b. Arab Gulf	88	-
f.o.b. Western Europe	-	629	-	-	cfr China	105	-
f.o.b. Baltic	225	-	-	-	cfr India	107	-

Prices are on a bulk, spot basis, unless otherwise stated. Phosphoric acid is in terms of $/t P_2O_5 for merchant-grade (54% P_2O_5) product. Sulphur prices are for dry material. n.a. = not available.

counteract some of the bearish sentiment that has gripped the market east of Suez, as many participants were expecting a lower price.

Potash: Downward price pressure affected potash markets across the globe in mid-April, as slow demand in many regions persisted longer than expected. While potash spot prices advanced in Brazil and China, they slid in southeast Asia and northwest Europe.

In southeast Asia, standard MOP spot prices were assessed at $280-315/t cfr, while Brazilian potash prices remained at $305-315/t cfr amid slowing demand. US potash continue to decline but remains at a premium, despite the $35/st fall in the average US Midwest price since the start of the year.

Many potash market participants are worried about the impact of tensions between Israel and Iran. 2023 MOP exports from the Middle East totalled 11 percent of global trade, highlighting the region's importance for the market.

Sulphur: Sulphur spot prices were trending stable to higher in mid-April amid limited spot market activity. The Middle East spot price was up at $85-90/t f.o.b. with some recent sales entering the $90s/t f.o.b. range. The Middle East price has gained 30 percent since mid-February this year.

While activity in key market China remains subdued, with cfr prices unchanged for eight weeks, appetite from Indonesia, Brazil and southern Africa has added some price support. Continuing good availability, including high stocks at Chinese ports, is expected to limit the upwards price momentum.

OUTLOOK

Urea: Prices are now expected to have peaked with demand proving less robust than previously anticipated. Consequently, the market remains largely pessimistic about the price trajectory in coming weeks, amid confusion over exports from China and concerns over the Iran's attack on Israel. In the Middle East, prices are forecast to bottom out in June at $290-300/t f.o.b., before buying returns and tender activity in India picks up. The US and Latin America have been the most bullish regions for urea in recent weeks. Prices at New Orleans are expected to average $365/st in April before dropping to $300/st f.o.b. in June.

Ammonia: prices look set to trend downwards with the April uptick at Tampa likely to be the last show of price support until the back end of the third quarter. Delays commissioning new assets and unscheduled plant curtailments could, however, add a degree of tightness to an otherwise lengthy market. In the Middle East, spot averages of $280-290/t f.o.b. are unlikely to improve in the near-term. In Europe, as elsewhere, the cfr benchmark should bottom out mid-year. This regional market could lengthen further if Uralchem's Black Sea transshipment terminal at Taman starts to export in June.

Phosphates: DAP/MAP prices are forecast to drift gradually lower over the next six months due to higher exports from China, with some key global benchmarks dipping below $500/t by the end of the third quarter The extent of Chinese DAP/MAP export availability will be key in determining short-term market direction, although some markets like Brazil may remain immune for now. Buying interest for DAP/MAP has dropped seasonally in the US and Europe but should pick up in Brazil soon.

> **"Potash prices are expected to trend downwards in coming months. MOP demand is weak across the globe, while key markets have ample supply. CRU has also revised its 2024 Russian and Belarusian export projections upwards."**

Potash: Prices are expected to trend downwards in coming months. MOP demand is weak across the globe, while key markets have ample supply. CRU has also revised its 2024 Russian and Belarusian export projections upwards. This supply growth could dampen any price increases that arise from improved demand. The India contract is expected to be settled at $290/t cfr in April, down $29/t from the current contract; China is expected to settle at the same price of $290/t cfr in May.

Sulphur: While future months are likely to see firmer sulphur prices, on the back of good affordability and improving demand, availability will cap price appreciation. Rises in downstream phosphate production are expected to spur this price recovery. However, the recent growth in sulphur production, together with stock drawdown and high Chinese inventory levels, is expected to limit upwards price potential in the short term. ■

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MOROCCO

OCP and Fortescue announce ambitious partnership

OCP Group and Fortescue subsidiary Fortescue Energy have announced a 50:50 joint venture (JV) to supply green hydrogen, ammonia and fertilizers to Morocco, Europe and international markets.

The two companies are planning to rapidly grow Morocco's renewable energy industry and downstream sectors via four cornerstone projects:

- Establishing large-scale integrated green ammonia and green fertilizer production capacity, based on renewable energy, electrolysis, ammonia generation and fertilizer production.
- Manufacturing green technology and equipment.
- An R&D and Technology Hub, located alongside the Mohammed VI Polytechnic University (UM6P) near Marrakech.
- Capturing corporate venture capital to drive investment in key green technologies.

The overall objective is to generate green hydrogen and ammonia for two main end-uses: firstly, supplying the green energy market and, secondly, manufacturing accessible and affordable carbon-neutral, customised fertilizers for farmers around the world.

Mostafa Terrab, OCP Group's chairman and CEO, said: "Our strategic partnership with Fortescue is a testimony to our joint commitment to decarbonisation, driving the development of cutting-edge facilities and delivering competitive renewable energy, products and technology. This is a key step towards fulfilling our vision of simultaneously ensuring global food security and combating climate change."

Dr Andrew Forrest, Fortescue's executive chair and founder, said: "Together, Fortescue and OCP will build a world-leading and globally competitive platform to accompany Morocco's journey into a green energy production, manufacturing, and industrial powerhouse. Together, we will be a key originator and green corridor into Europe and to and from the Atlantic basin."

He added: "Morocco will be a major player in the global energy transition given it is home to some of the world's most prospective wind and solar resources, two large coastlines, and is in close proximity to Europe and the Americas."

Mark Hutchinson, Fortescue Energy's CEO, said: "OCP and Fortescue are fully aligned on their ambitions. We intend to create in Morocco one of the world's leading integrated renewable energy, manufacturing, and technology enterprises, supplying not only a large and growing domestic market for green products, but also with the potential to supply other countries and continents."

The venture is subject to customary closing conditions and regulatory approval.

Mostafa Terrab, OCP Group's chairman and CEO, shakes hands with Dr Andrew Forrest, Fortescue's executive chair and founder, at a joint venture signing ceremony in Marrakesh in April.

PHOTO: FORTESCUE.

OCP launches sustainable crop inputs subsidiary

OCP Group has set up a new subsidiary company, OCP Nutricrops, to manufacture carbon-free, customised fertilizers.

The new venture, launched in April, will accelerate OCP's ability to deliver customised crop nutrient products globally and help bring about the transition to more sustainable agricultural systems.

By capitalising on OCP's leading production and distribution capabilities for phosphate fertilizers, OCP Nutricrops plans to offer products and solutions that:

- Preserve soil health
- Increase crop yields sustainably
- Combat climate change
- Protect the natural environment.

"OCP Nutricrops' primary mission is to help farmers access the most efficient and sustainable soil health and plant nutrition solutions and the latest application expertise, wherever they are in the world," OCP said in a statement.

Flexible production systems will be used to manufacture nutrient formulations tailored to the crop, climate and soil. These products will be designed to boost farm productivity and incomes by helping farmers preserve and enhance their soils.

The business will also provide training in precision nutrient management techniques. These will follow '4Rs' principles, ensuring that crops get the right nutrients, at the right rate, in the right place, at the right time, while also minimising costs to the farmer.

Central to OCP Nutricrops and its mission is an environmental commitment to make climate positive agriculture a reality. The company has set itself the goal of delivering 100 percent customised, carbon-free products – this being based on a target to reach carbon neutrality for Scope 3 emissions by 2040. OCP says it will build on its existing international partnerships with governments, researchers, agronomists and distributors to deliver this net zero goal.

Soufiyane El Kassi, the chairman & CEO of OCP Nutricrops, said: "OCP Nutricrops will spearhead a new direction for effective soil health and plant nutrition solutions. Only by using customized soil and plant nutrition solutions can we improve global food security while combatting climate change and protecting the natural environment. OCP Nutricrops is committed to working collaboratively with farmers and all our stakeholders to accelerate the journey towards the fully customized and farmer-centric solutions required to drive a just agricultural transition."

OCP Nutricrops, as well as having its own in-house team of dedicated agronomists, will draw on the expertise of Morocco's Mohammed VI Polytechnic University (UM6P) and its international partners to access the latest technological advances and the most accurate agricultural data.

The company is aiming to optimise soil health and help farmers maximise their productivity via advanced soil mapping and by creating customised products, while also protecting the environment and combatting climate change. ■

UNITED STATES

CF Industries and JERA partner on low-carbon ammonia

CF Industries, the world's largest ammonia producer, and JERA, Japan's largest energy company, have signed a joint development agreement (JDA) for a greenfield low-carbon ammonia production plant at CF Industries' Blue Point Complex in Louisiana.

Under this agreement, the two companies will evaluate a joint venture agreement to build a 1.4 million t/a capacity low-carbon ammonia plant.

JERA is considering a 48 percent ownership stake in the project, as well as an agreement to procure more than 500,000 tonnes of low-carbon ammonia annually. This will be used to meet low-carbon fuel demand in Japan.

JERA and CF Industries previously signed a memorandum of understanding to explore the potential for jointly developing the project. The two partners are now aiming to move to a final investment decision (FID) within the next 12 months with the potential to commence production in 2028.

"We are pleased to expand our relationship with JERA as our companies advance leading-edge decarbonization initiatives that will help JERA and Japan achieve their decarbonization goals," said Tony Will, the president and CEO of CF Industries Holdings, Inc. "We believe that JERA's projects, which represent the first meaningful volume of what we believe will be substantial global demand for low-carbon ammonia as an energy source, will demonstrate the significant contribution ammonia can make to meet the decarbonization goals of hard-to-abate industries. We look forward to continuing to work closely with JERA and other stakeholders in Japan as regulatory requirements and government incentives regarding low-carbon ammonia are finalized."

JERA plans to reduce power plant CO_2 emissions by replacing thermal coal at its existing power stations with low-carbon ammonia. The power generator is currently conducting the world's first commercial-scale demonstration test of ammonia fuel substitution at its Hekinan thermal power station in Japan.

"We are pleased to further advance our partnership with CF Industries," said Yukio Kani, JERA's global CEO & chair. "With JERA's dedication to low carbon fuel development and CF Industries' expertise as one of the leading ammonia producers, we are confident in making tangible progress towards realizing a low-carbon ammonia value chain, and ultimately ensuring a decarbonized energy supply that is sustainable, affordable, and stable."

GERMANY

OCI supplies COMPO EXPERT with lower carbon ammonia

Netherlands-headquartered OCI Global has made its first delivery of lower carbon ammonia to COMPO EXPERT for use in NPK production in Germany.

OCI, a leading nitrogen, methanol, and hydrogen producer, has been supplying COMPO EXPERT, a German producer of high-quality specialty fertilizers and biostimulants, with ammonia for more than a decade.

Under a new supply agreement, COMPO EXPERT will initially replace 25 percent of the 'grey' ammonia it uses at its Krefeld production plant in Germany this year with

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lower carbon 'blue' ammonia. The company then plans to raise the percentage of OCI-supplied lower carbon ammonia used at Krefeld over the next two years.

The lower carbon ammonia is sourced from OCI's ammonia production facilities in Texas in the United States and is imported via the company's ammonia terminal and distribution hub at the Port Of Rotterdam. It is guaranteed to have a carbon footprint 60 percent lower than the industry standard (2.6 $kgCO_2e/kgNH_3$).

OCI's Texan plant has been certified for lower carbon ammonia production and the carbon footprint calculation used has been verified by third party auditors SCS global.

OCI and COMPO EXPERT say that the switch to lower carbon supply sources is a testament to their joint commitment to sustainability and the decarbonisation of ammonia and fertilizer production.

Aviv Bar Tal, Global VP Commercial Nitrogen at OCI Global, said: 'We're delighted to be supplying COMPO EXPERT with our lower carbon ammonia and supporting them in their ambitions to lower the carbon footprint of their fertilizers. We have enjoyed a long-term partnership with COMPO EXPERT, further cemented by this agreement, which will see them start to use lower carbon ammonia in their production at Krefeld from this year."

He added: "OCI's goal is to increase the volume of lower carbon products we supply to our distribution customers in Europe, gradually replacing conventional products with more sustainable ones. We are significantly increasing our production of lower carbon ammonia, including at our Texas Blue Clean Ammonia facility currently under construction, which has capacity for an additional 1.1 million tonnes per year, and via our terminal in Rotterdam we will support the European decarbonization of existing industries and future energy and bunkering customers."

Dr Ingo Müller, COMPO EXPERT's CEO, said: "At COMPO EXPERT, we are dedicated to minimizing the negative impact on the environment. We do not only consider our own production, but also our raw materials. As ammonia is our most important raw material, and has the largest contribution to our carbon footprint, replacing 25% of our demand in 2024 with a lower carbon variety is an important step with a major contribution to our goal. For us, ammonia with a lower carbon footprint is not just a technological advancement; it is a pivotal step towards a more sustainable agriculture."

CANADA

thyssenkrupp Uhde and Genesis Fertilizers sign pre-FEED contract

PHOTO: THYSSENKRUPP

Signing ceremony between Germany's thyssenkrupp Uhde and Canada's Genesis Fertilizers.

thyssenkrupp Uhde has been commissioned to carry a conceptual design study for a reduced-emissions fertilizer plant on behalf of Genesis Fertilizers. The two companies signed a pre-FEED (front-end engineering and design) contract in April.

The study covers the conceptual design for an integrated fertilizer complex at Belle Plaine, Saskatchewan, Canada. The proposed complex will incorporate units designed to produce 1,500 t/d of ammonia, 2,600 t/d of granulated urea/urea ammonium sulphate (UAS), nitric acid and liquid urea ammonium nitrate (UAN), and will also have the ability to produce diesel exhaust fluid (DEF).

thyssenkrupp Uhde will provide the engineering know-how for the integration of these units within the production complex. A key focus of the study will be low-carbon production and the minimisation of emissions. The engineering design will therefore consider the potential for using renewable electricity to generate green hydrogen feedstock. The incorporation of thyssenkrupp Uhde's proven EnviNOx® technology would also eliminate nitrous oxide emission from nitric acid production.

Jason Mann, president and CEO of Genesis Fertilizers, said: "Our primary goal is to ensure the supply of fertilizers to the farmers in Western Canada based on the most advanced technologies available with the lowest possible carbon footprint. We are pleased to be working with a strong industry partner that offers expertise in all the processes and technologies involved from a single source."

Lucretia Löscher, COO, thyssenkrupp Uhde, said: "This project is a further proof that the transition of the fertilizer industry towards more sustainability has started. Our expertise in clean fertilizer technologies and their integration is essential to support our customers on their journey to protect the climate."

IVORY COAST

Canada provides $7.3 million of fertilizer finance

Global Affairs Canada has provided a CAD 10 million ($7.3 million) funding boost for the Africa Fertilizer Financing Mechanism (AFFM). The funding is aimed at improving food production and incomes for 800,000 African smallholder farmers.

The extra finance will provide credit guarantees for the fertilizer supply chain in eight African countries It will also be used to provide technical assistance to farmers and encourage sustainable agricultural practices that improve soil health.

The AFFM is administered by the African Development Bank Group (AfDB). It is designed to increase fertilizer use and improve agricultural productivity across the Bank's member countries by providing innovative kinds of financing.

Global Affairs Canada (GAC) is the Canadian government department responsible for international development. The CAD 10 million in AFFM funding provided by GAC has been specifically earmarked for the 'Fostering Africa's agricultural productivity through fertilizer value chain financing' (FOSTER) programme.

This programme provides access to 80,000 tonnes of organic and inorganic fertilizer, as well as encouraging efficient fertilizer use, and is expected to increase crop yields by 30 percent. It assists 800,000 smallholder farmers in total. Around 40 percent of its beneficiaries are expected to be women while 10 percent are young farmers.

"We thank Global Affairs Canada for its support to advance the Africa Fertilizer Financing Mechanism's implementation of its Strategic Plan 2022-2028, which focuses on broadening access to finance through capital investments and policy reforms, among other priorities that benefit Africa's smallholder farmers," said Dr Beth Dunford, the AfDB's Vice President for Agriculture, Human and Social Development.

Ahmed Hussen, Canada's Minister of International Development, said: "Canada is proud to support resilient, climate-smart agriculture and adaptable food production systems in Africa. We remain committed to promoting inclusive, green growth in partnership with the African Development Bank, including through our contribution to the Africa Fertilizer Financing Mechanism."

BRAZIL

Brazil Potash granted mine installation license

Brazil Potash has received the mine installation license for its Autazes potash project from the Amazon State Environmental Protection Institute (IPAAM).

The granting of the license is a major milestone for the company as it will allow the construction of the project to go ahead, finance permitting. The clearing of this final regulatory hurdle follows several years of environmental, social and technical studies, as well as consultations with local indigenous people.

The Autazes potash project is located in Brazil's Amazonas state near the town of Autazes, 120 kilometres from the city of Manaus. The 2.2 million t/a capacity project, although located deep in the country's interior, is situated just eight kilometres from the Madeira River, the Amazon's biggest tributary (*Fertilizer International* 517, p51).

If it proceeds, output from the Autazes mine could eventually supply 20 percent of Brazil annual potash consumption of around 12.6 million tonnes. Importantly, the project's 'in-market' position, close to Brazil's major farming regions, and the potential for river barge transportation, should provide Brazil Potash with a cost and transit time advantage over international suppliers.

The company is forecasting a delivered MOP cost of $166/t (cfr Mato Grosso) for the project with product transit times to domestic farming regions of just 2-3 days.

FINLAND

UPM launches biostimulant product range

UPM Biochemicals entered the crop inputs market in March by launching the UPM Solargo™ range of biostimulants. These are bio-based and offer a sustainable alternative to chemical fertilizers, according to the company.

After successful test marketing in Europe, UPM has begun expanding production of UPM Solargo™ products, which are derived from lignin, at full industrial scale. These are suitable for a broad range of field- and greenhouse-cultivated crops, and boost plant growth by improving the health of the soil microbiome and by increasing water retention.

UPM's new biostimulant range, while not directly providing plants with nutrients, do increase nutrient absorption, nutrient use efficiency and the stress tolerance of crops. In long term testing, they have been shown to increase crop yield and crop quality, with the potential to significantly reduce demand for traditional NPK fertilizers, according to UPM.

"The launch of UPM Solargo™ marks the successful end of many years of research and development. By bringing this family of novel, bio-based plant stimulants to market, we establish yet another, entirely new category of high value sustainable chemicals and live up to our commitment to pioneer sustainable chemistry" says Christian Hübsch, Director Sales & Marketing Biochemicals at UPM. ■

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People


PHOTO: YARA

Hans Olav Raen, CEO, Yara Clean Energy.


PHOTO: AMEROPA

Josh Zacharias, the recently appointed new CEO of Ameropa.

Nadja Håkansson became thyssenkrupp Uhde's new CEO on 1st May.

"We are delighted to welcome Nadja Håkansson to thyssenkrupp Uhde as the new CEO," said Miguel López, CEO of thyssenkrupp AG. "With an extensive background in the energy technology industry, Nadja brings a wealth of experience and leadership to thyssenkrupp Uhde to position the company as an enabler of the industry's transformation towards further CO_2 emissions reduction."

"thyssenkrupp Uhde has significant potential for shaping the green transformation in our industry, and I am honored to lead this prestigious company as we embark on this exciting journey together," said Nadja Håkansson. "I am looking forward to being part of thyssenkrupp Uhde's engineering competence, to fostering a culture of innovation and to delivering sustainable value to our customers & stakeholders."

During her career, Ms Håkansson has held various management positions at Siemens and Siemens Energy. This includes more than 18 years of experience working both nationally and internationally in supply chain management, operations, sales and corporate management.

Most recently, as SVP for Africa at Siemens Energy, Nadja was responsible for overall portfolio development in the African market. She holds an MSc in Industrial Engineering and Management from Linköping University's Institute of Technology.

Hans Olav Raen is the new CEO of Yara Clean Ammonia (YCA), having assumed the role at the start of May. Mr Raen was previously OCI's business director for fertilizers in Europe. Hans Olav has more than 25 years of experience in the fertilizer industry. This includes a twelve-year stint with Norsk Hydro and Yara International, between 1997 and 2009, during which Mr Raen held commercial and managerial roles in Europe and Africa. He holds a master's degree from the College of Europe as well as a degree in digital leadership from the ESSEC Business School in Paris.

"We are pleased to announce that Hans Olav will be heading Yara Clean Ammonia. Together with the strong YCA-team, I am confident that Hans Olav will support and lead the company to the next level, spearheading the rapidly growing clean ammonia business," said Magnus Krogh Ankarstrand, Yara International's EVP for corporate development.

Josh Zacharias became the new group CEO of Ameropa on 15th April. Mr Zacharias, 44, was born in Washington DC and is a dual US and Swiss national. He graduated from Carleton College with a BA in Mathematics and then received an MBA from New York University. He has held a variety of junior and senior management positions in the US, Australia, Romania and Switzerland since joining Ameropa in 2009.

Mr Zacharias is currently CEO of Ameropa subsidiary Azomures, the Romanian nitrogen fertilizer producer. He started his career at Ameropa in finance, first as a financial analyst for M&A at the company's Binningen headquarters, then as risk manager and controller at Ameropa North America, and finally as CFO at Ameropa Australia.

In 2013, he moved into the commercial side of Ameropa's business as head of trading at Ameropa Australia and also headed the Browns retail business selling directly to farmers in Australia. In 2018, he returned to Binningen and assumed the role of Group chief risk officer for almost two years.

Andreas Zivy, chairman of Ameropa Holding AG, said: "The Board and shareholders are delighted to appoint Josh to his new position. Due to the variety of roles he held, Josh is very familiar with all of our businesses both in trading and management functions. Also, he has intimate knowledge of three of our most important markets, the US, Romania and Australia. At age 44, he offers a long-term perspective to our company, and as a member of the fourth generation of shareholders, he will continue the culture of a family company."

Josh Zacharias commented: "I am excited and honoured to be appointed as CEO of our more than 75-year-old family-owned business with a long history of success in grains and fertilizers. During more than 15 years, I had the privilege to get to know all parts of the organization and I truly look forward to working with the many dedicated people that Ameropa has around the world." ■

Calendar 2024

MAY

20-22
IFA Annual Conference, SINGAPORE
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

JUNE

6-7
NH3 Event, ROTTERDAM, Netherlands
Contact: NH3 event Europe
Tel: +31 10 4267275
Email: info@nh3event.com

7-8
47th Annual International Phosphate Fertilizer & Sulfuric Acid Technology Conference, CLEARWATER, Florida, USA
Contact: Edin Veladic, convention chair
Email: vicechair@aiche-cf.org

JULY

98th Annual Southwestern Fertilizer Conference, NASHVILLE, Tennessee, USA
Contact: Pat Miller
Tel: (512) 259-2118
Email: SWFC@SWFertilizer.org

SEPTEMBER

16-18
TFI World Fertilizer Conference, WASHINGTON DC, USA
Contact: Valerie Sutton
Tel: +1 202 962 0490
Email: vsutton@tfi.org

NOVEMBER

4-6
CRU Sulphur & Sulphuric Acid Conference 2024, BARCELONA, Spain
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

12-15
Biostimulants World Congress, MIAMI, Florida, USA
Contact: New Ag International
Tel: +44 (0)20 8052 2011
Email: info@newaginternational.com

Fertilizer financial scorecard – earnings decline as market normalises

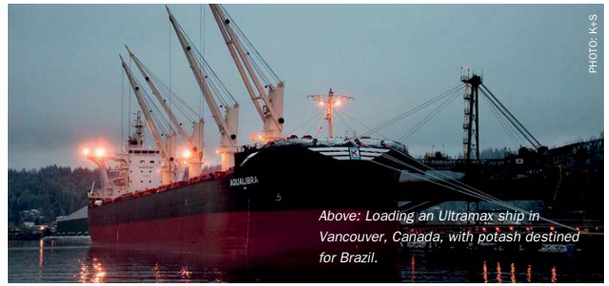
PHOTO: K+S

Above: Loading an Ultramax ship in Vancouver, Canada, with potash destined for Brazil.

We compare and contrast the 2023 financial performance of selected major fertilizer producers following the publication of fourth quarter results.

2023 was a year in which the fertilizer market once again readjusted.

It is perhaps an irony that the same factor that helped create record industry earnings levels in 2022 – unprecedented fertilizer prices – cast a shadow over 2023 by leading to postponed purchases, creating supply overhangs that prompted price declines and lower market activity. Yet there were upsides too as 2023 progressed, including greater market stability, improving fertilizer affordability and demand recovery.

During the preceding two years, 2021 and 2022, the fertilizer industry's financial performance reflected convulsions and volatility in the global market as the world economy cranked up after the Covid-19 pandemic and its associated lockdowns. Supply-side factors – notably the shockwaves in commodity and energy markets created by Russia's invasion of Ukraine and the impact of sanctions on Belarusian potash supply – conspired to create a market defined by high and record fertilizer prices in 2022. While high prices create excellent margins for fertilizer producers, they were accompanied by deep concerns over both fertilizer availability and affordability (*Fertilizer International* 512, p13).

As a consequence, all of the six major listed fertilizer producers highlighted here – Nutrien, Yara, Mosaic, CF Industries, K+S and ICL – reported unprecedented results in 2022. These six companies experienced annual earnings growth in the range 71-186 percent that year. These double- or triple-digit earnings increases came on top of what was, for many, already a record-breaking set of results in 2021 (*Fertilizer International* 508, p13).

Nutrien, for example, saw its full-year earnings more than triple – from $3.7 billion in 2020 and $7.1 billion in 2021 to reach $12.2 billion in 2022. Almost inevitably, that earnings rollercoaster, having reached its zenith in 2022, fell back in 2023, albeit to a highly respectable $6.1 billion for the full year.

"In 2022, Nutrien generated record earnings and operating cash flows as prices for agriculture and crop input products rose in response to supply-side shocks," said Ken Seitz, Nutrien's president and CEO. "Crop input market fundamentals shifted in 2023 as supply chains adapted and higher cost inventory worked its way through the channel, resulting in lower fertilizer selling prices and retail gross margins compared to the record prior year."

Potential upsides also emerged as 2023 progressed, noted Seitz, with market stability, improving fertilizer affordability and demand recovery being foremost.

"As the year progressed, we saw increased market stability and stronger fertilizer demand in North America, supported by improved grower affordability and lower channel inventories. Fertilizer demand in key offshore markets also increased in the second half of 2023, however the level of market stabilization varied by product and geography," Seitz said.

Nutrien, due its scale, manufacturing might and retail reach, tends to act as fertilizer industry bellwether. It's therefore unsurprising that its industry peers, the other listed major companies, also experienced substantial earnings falls in 2023. The silver lining being that 2023 earnings were generally healthy and – for many companies – matched or exceeded pre-pandemic levels.

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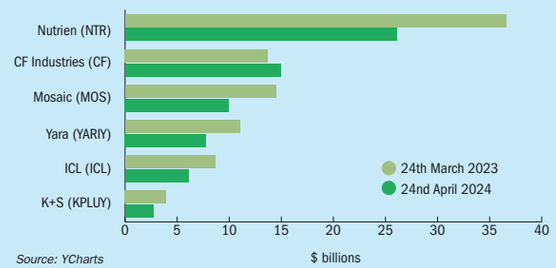
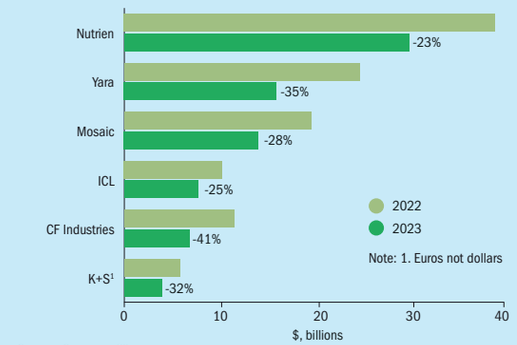
Fig. 1: **Market capitalisation snapshots, 2024 vs 2023**



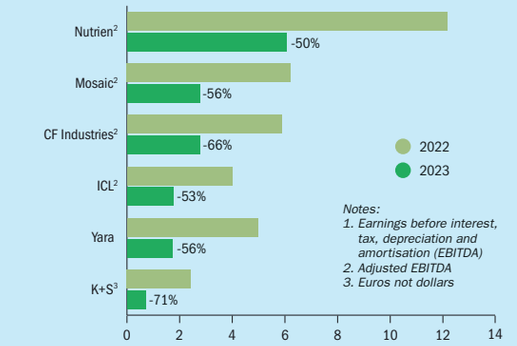
Source: YCharts

Fig. 2: **Revenues, 2023 vs 2022**



Source: Company filings

Fig. 3: **Earnings[1], 2023 versus 2022**



Source: Company filings

Nutrien eyes improving market stability and demand

Nutrien's market capitalisation, at more than $26 billion, is unrivalled in the fertilizer sector (Figure 1). The world's largest crop nutrient company produces around 25 million tonnes of potash, nitrogen and phosphate products annually from operations and investments in 13 countries, distributing these to agricultural, industrial and feed customers across the globe. Its agriculture retail business serves more than 500,000 farmers worldwide through 2,000 plus retail outlets across the Americas and Australia.

Nutrien's revenues declined by 23 percent year-on-year (y-o-y) in 2023 to $29.1 billion (Figure 2). Earnings (adjusted EBITDA) for the year also fell back by 50 percent to $6.1 billion (Figure 3). Free cash flow – a measure of profitability – ended 2023 at $5.1 billion (Figure 4), versus $8.1 billion for the preceding year. The company's long-term debt stood at $8.9 billion at the end of 2023 (Figure 5).

Nutrien attributed its earnings decline in 2023 to two main factors: lower realised selling prices across all segments and lower earnings from its Nutrien Ag Solutions retail business – the latter being linked to lower gross margins for both crop nutrient and crop protection products.

Nutrien is the world's largest potash producer. The company achieved potash sales of 13.2 million tonnes from its Canadian mines in 2023. Of this volume, 8.4 million tonnes were destined for overseas markets with the remaining 4.8 million tonnes being sold within North America.

Potash contributed 40 percent to Nutrien's full-year earnings. Potash earnings at $2.4 billion (adjusted EBITDA) in 2023 were 58 percent down y-o-y, with lower realised selling prices overshadowing higher North American sales volumes and lower mining taxes and royalties. Overseas potash sales volumes were lower, versus the record levels of 2022, primarily due to logistical snags at Canpotex's West Coast port and lower shipments to India and Southeast Asia. The costs of goods sold (COGS) for potash fell to $105/t last year, down by $7/t on 2022, mainly due to lower royalties.

Similarly, Nutrien's nitrogen earnings fell by 53 percent in 2023 to $1.9 billion, again due to lower realised selling prices.

These more than offset a one percent y-o-y rise in nitrogen sales volumes to 10.4 million tonnes and lower natural gas costs. The average COGS for nitrogen products declined to$233/t in 2023, a 29 percent fall y-o-y, mainly because of cheaper natural gas.

Earnings at Nutrien's retail business, Nutrien Ag Solutions, fell by 36 percent from their record levels of the previous year to $1.5 billion in 2023, these declines being mostly driven by lower gross margins. Crop nutrients sales were down 17 percent y-o-y at $8.4 billion – despite higher sales volumes in 2023 – due to lower prices across all regions.

Nutrien's phosphate earnings also declined by 21 percent y-o-y to $470 million in 2023. Once again, this was mainly attributed to lower realised selling prices, this time for phosphate fertilizer products, albeit partially offset by lower ammonia and sulphur raw material costs. Nutrien's phosphate sales volumes did, however, grow by seven percent y-o-y to 2.6 million tonnes. Lower sulphur and ammonia costs also helped to push down the average COGS for phosphate products by 11 percent to $583/t in 2023.

Nutrien is bullish about 2024 market prospects. "We saw a continuation of strong fertilizer market fundamentals in North America during the fourth quarter [of 2023] driven by improved affordability, an extended fall application season and low channel inventories. As we look ahead to 2024, we expect to deliver higher fertilizer sales volumes and retail earnings, supported by increased crop input market stability and demand," commented Ken Seitz, Nutrien's president and CEO.

Yara – creating value in turbulent times

With a market capitalisation of $7.8 billion (Figure 1), Norway's Yara International is one of world's largest crop nutrient providers based on total product deliveries.

The Oslo-headquartered company produced 18.4 million tonnes of finished fertilizers and 6.4 million tonnes of ammonia from its global assets in 2023. Finished fertilizer production included:

- 5.9 million tonnes of compound NPKs
- 5.5 million tonnes of nitrates
- 4.3 million tonnes of urea
- 1.6 million tonnes of calcium nitrate (CN)
- 0.9 million tonnes of urea ammonium nitrate (UAN)
- 0.3 million tonnes of single superphosphate (SSP).

Yara calculated that its premium product sales in 2023 generated $1.9 billion in added-value, compared to the commodity fertilizer alternatives.

Yara's annual product deliveries fell by five percent y-o-y to 30.1 million last year. These were divided between:

- 22.3 million tonnes of fertilizers
- 6.4 million tonnes of industrial products
- 1.5 million tonnes of traded ammonia.

2023 was a year of high volatility and operational challenges, according to Svein Tore Holsether, Yara's president and CEO:

"The results in 2023 were significantly down from the record results in 2022, as lower selling prices more than offset lower production costs leading to lower margins. Despite the challenging operating environment, we delivered a strong free cash flow of $1 billion [see Figure 4] showcasing the robustness of our business model.

"The resilience of our organization has been impressive – first during the pandemic, and then amid the repercussions of Russia's invasion of Ukraine. Value chain disruptions have become the new normal, and in this situation we have demonstrated to the fullest how we can utilize our global presence and reach, within both production and deliveries, to create value also in times of turmoil."

Yara's annual revenues fell back on 2022's record levels, down by 35 percent y-o-y, to $15.5 billion in 2023 (Figure 2). Earnings (EBITDA) also declined by almost two-thirds to $1.7 billion (Figure 3). This fall mainly reflected lower margins from lower selling prices, with these more than offsetting lower production costs.

Yara's global product deliveries decreased by five percent y-o-y in 2023, although the regional pattern was mixed:

- European deliveries increased by three percent versus 2022.
- In the Americas, 2023 deliveries fell by eight percent compared to the previous year, mainly due to lower third-party product availability.
- Deliveries to Africa and Asia were five percent higher in 2023, partly driven by a rebound in farm economics.

Yara's energy prices declined by more than 50 percent last year:

- Its global weighted average gas cost averaged $10.9/MMBtu in 2023 versus $21.8/MMBtu in 2022.
- Its European weighted average gas cost averaged $14.9/MMBtu in 2023 versus $31.8/MMBtu in 2022.

Yara also reported the following price developments) for two of its key premium products (fourth quarter 2023 basis):

- 54 percent y-o-y fall in the average realised price of calcium ammonium nitrate (CAN 27) to $334/t
- 27 percent y-o-y fall in the average realised global compound NPK price to $629/t (average grade).

Yara commented that higher fertilizer prices in 2022 saw farmers and distributors in some regions postpone purchases – a market environment that created supply overhangs and prompted price declines and low market activity as 2022 ended and 2023 began. These fertilizer price declines do have an upside, in Yara's view, as they have improved affordability and therefore provided scope for a potential catch-up in fertilizer demand in most regions.

Yara has also seen increased buying activity and higher prices since the start of 2024, signalling a potential volume catch-up into the main application season in the Northern hemisphere, in its view.

"As we now embark on a new year, Yara is well positioned with a strong track record also in more volatile markets. I am confident in our strategic progress, with a focus on optimizing and decarbonising our asset footprint, and contributing to decarbonizing shipping fuel, the food value chain and other energy-intensive industries," said Svein Tore Holsether.

Mosaic navigates a dynamic market

Florida-headquartered The Mosaic Company is the world's leading combined phosphate and potash producer with a market capitalisation of $10.0 billion (Figure 1). The company sold around 25.6 million tonnes of products in 2023, with sales volumes split between three business segments:

- Potash segment: 8.9 million tonnes
- Phosphates segment: 7.0 million tonnes
- Mosaic Fertilizantes: 9.7 million tonnes.

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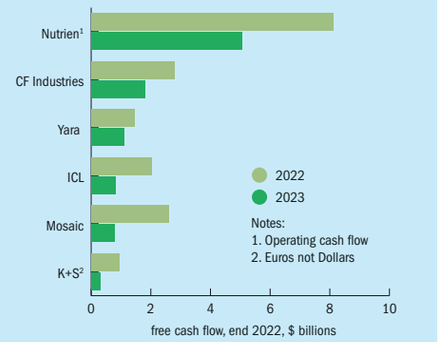
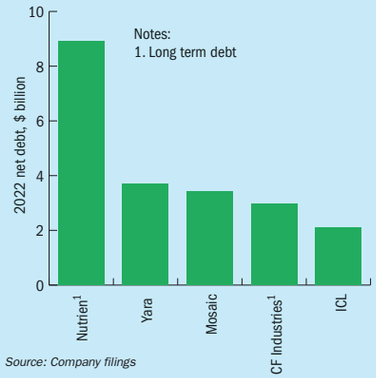
Fig. 4: **Free cash flow, end 2023 vs end 2022**



Source: Company filings

Fig. 5: **Net debt, end 2023**



Source: Company filings

Mosaic's earnings fell back by 56 percent y-o-y to $2.8 billion (adjusted EBITDA) in 2023 (Figure 3). This was achieved from full year revenues of $13.7 billion (Figure 2).

Phosphate earnings (adjusted EBITDA) totalled $1.2 billion in 2023, down from $2.2 billion in 2022. This largely reflected lower selling prices such as the fall in the average diammonium phosphate (DAP) selling price from $913/t in 2022 to $646/t last year.

The company's potash earnings (adjusted EBITDA) totalled $1.5 billion, down from $3.1 billion in 2022, this major fall, again, largely reflecting lower prices. Consequently, Mosaic's average gross margin for potash declined to $137/t in 2023, down from its more lucrative $351/t average for the previous year.

In a further sign of lower realised prices, full year earnings (adjusted EBITDA) at Mosaic's Brazilian subsidiary Mosaic Fertilizantes declined to $327 million in 2023, having topped $1.0 billion the previous year. The subsidiary's average gross margin of $22/t last year, versus $111/t in 2022, was negatively affected by lower prices, inflationary cost pressures and higher priced inventory.

"Mosaic successfully navigated a highly dynamic market in 2023. We delivered strong free cash flow and returned significant capital to shareholders while reinvesting in the business," said Bruce Bodine, Mosaic's president and CEO. "Looking into 2024, Mosaic expects to continue to benefit from a strong phosphates market, and is well positioned to deliver solid results as we optimize our low cost potash operations. In addition, we are focused on improving our phosphates production level, expanding our portfolio of value-added products, growing our leading presence in Brazil, and enhancing the overall efficiency of our operations".

CF Industries adds capacity and advances on clean energy

Leading North American and UK nitrogen producer CF industries was yet another major fertilizer producer reporting a decline in revenues and earnings in 2023 after filing record figures in 2022. Full-year revenues ($6.6 billion) and earnings ($2.8 billion adjusted EBITDA) fell y-o-y by 41 percent and 53 percent, respectively (Figures 2 and 3). Despite this fallback, CF's 2023 earnings matched the company's 2021 performance and were around 70 percent higher than annual levels pre-pandemic. Full year net cash from operating activities ($2.8 billion) and free cash flow ($1.8 billion, Figure 4) for 2023 also remain healthy.

CF highlighted the following in its 2023 results:

- Closing the acquisition of the Waggaman ammonia production plant from Incitec Pivot in December 2023.
- The mechanical completion of the electrolyser installation at CF's Donaldsonville, Louisiana, complex during last year and the start of commissioning activities for this green ammonia project.
- The expectation that the final investment decision (FID) on the proposed greenfield low-carbon ammonia plant in Louisiana would be announced by CF and its partner in the second half this year.

"CF Industries' 2023 results demonstrate the strength of our business and our team," said Tony Will, the company's president and CEO. "We ran our plants well, added the Waggaman ammonia production facility to our network, and advanced our clean energy strategy.

The Illinois-headquartered company has a market capitalisation of $15.0 billion (Figure 1). Echoing its industry peers, it attributed the 2023 decline in earnings to lower average selling prices, commenting that "lower global energy costs reduced the global market clearing price required to meet global demand".

Average selling prices, representing all of CF's nitrogen product segments, fell by 88 percent y-o-y to $473/t in 2023. This price level compares to average selling prices for the company of $936/t in 2022, $498/t in 2021 and $271/t in 2020.

The company did, however, benefit from lower cost of sales in 2023, versus 2022, his being linked to much lower natural gas costs. The company's average natural gas cost last year was $3.67/MMBtu, compared to $7.18/MMBtu for the preceding year.

CF's production volumes last year were relatively stable, as follows:

- 9.5 million tonnes of ammonia
- 4.5 million tonnes of granular urea
- 6.8 million tonnes of UAN (32%)
- 1.5 million tonnes of AN.

Total products sold in 2023 were up at 19.1 million tonnes versus 18.3 million tonnes for 2022.

Looking ahead, CF Industries foresees positive fundamentals for the global nitrogen industry, with a favourable short-term global nitrogen supply-demand balance tightening in the medium-term. The company expects resilient near-term global nitrogen demand driven by strong agriculture applications and recovering industrial demand. Nitrogen supply, meanwhile, will be affected by challenging production economics in key producing regions due to the cost and availability of natural gas, in CF's view.

"We believe that the global energy cost structure presents attractive margin opportunities for our North American-based production network in the near-term and that the global nitrogen supply-demand balance will tighten considerably in the medium-term," said Tony Will. "As a result, we expect to continue to drive strong cash generation, underpinning our ability to create significant shareholder value from disciplined investments."

'Solid' results for K+S

After a record 2022, revenues at K+S declined by 32 percent y-o-y to €3.9 billion (Figure 2), while earnings (EBITDA) for the year fell by 71 percent to €712 million (Figure 3). Despite these declines, financials from the German potash and salt producer were broadly comparable with pre-pandemic levels. The company generated free cash flow of €311 million in 2023 (Figure 4) and, unusually for the sector, has been without net debt since the end of 2022.

With a market capitalisation of $2.7 billion, K+S is western Europe's largest potash producer, having a global market share of around nine percent. The company is also growing its portfolio of specialty fertilizers. These products are chloride-free and/or supplement potassium with other elements such as magnesium, sulphur, sodium and micronutrients.

"Despite the upheavals in the market and challenges on the cost side, we achieved solid results in 2023," says Dr Burkhard Lohr, the chairman of K+S. "Our committed teams have once again proven their capabilities."

Lower realised prices for potassium chloride (€359/t) and fertilizer specialities (€394/t) were a feature of 2023 market conditions. The company's agricultural segment sold 7.3 million tonnes of fertilizer products in 2023 (up slightly from 7.1 million tonnes in 2022). This sales volume was divided between 4.6 million tonnes of potash and 2.7 million tonnes of specialty fertilizers. K+S fertilizer products sold at an average price of €372/t in 2023, versus €628/t in 2022 and €298/t in 2021.

K+S cited price volatility in its commentary on 2023 agricultural market developments: "In the first few months of the financial year, customers initially remained reluctant to buy. Following the conclusion of a contract by a competitor in China, which was significantly lower than expected at $307/t, price pressure intensified and spread into other sales regions. The subsequent price recovery later in the year could not offset this development."

The company expects to see increasing normalisation and a return to more balanced market conditions in its outlook for 2024:

"Following the upheavals in the market over the past two years, K+S is optimistic that the balance between supply and demand on the potash market can return this year. The observable return of supply from Russia and Belarus outside Europe and North America should be accompanied by a further normalisation on the demand side worldwide. An oversupply on the potash market is, therefore, not to be expected for the year as a whole."

ICL emphasises value and cash generation

Israel's ICL Group is a leading producer of potash, phosphates and specialty fertilizers with a market capitalisation of around $6.1 billion (Figure 1). The company delivered annual sales of $7.5 billion, earnings (adjusted EBITDA) of $1.8 billion and free cash flow of $818 million in 2023 (Figures 2, 3 and 5).

While sales and earnings for last year fell back from the record levels seen in 2022 – by 25 percent and 56 percent, respectively – both were still higher than reported in 2021. ICL also emphasised the significant value delivered to shareholders in 2023, via more than $350 million in dividend payments, and the continuing strong cash generation by the business.

"ICL delivered adjusted EBITDA of $1.8 billion and operating cash flow of $1.6 billion, on the backdrop of a record 2022. During 2023, we expanded into additional new end-markets, with the groundbreaking of new advanced facilities and the launch of new innovative products, which will have a long-term impact on growth. We executed against our cost reduction plan and launched further efficiency measures in the fourth quarter, as we continued to respond to challenging market conditions and remained resilient in the face of war," said Raviv Zoller, ICL's president and CEO.

The Potash ($843 million) and Phosphate Solutions ($550 million) business segments contributed 48 percent and 31 percent, respectively, to overall company earnings in 2023. ICL's specialty fertilizer business, Growing Solutions, also generated seven percent of earnings ($119 million), while the Industrial Products segment ($277 million) delivered the final 16 percent share of earnings.

ICL operates potash production assets in Israel (Dead Sea works) and Spain (Cabanasses mine). Total potash output in 2023 (4.4 million tonnes) was down 271,000 tonnes y-o-y, mainly due to weather conditions and war-related issues in the Dead Sea as well as on-going geological constraints in Spain.

Overall, ICL's Potash business generated revenues of $2.2 billion in 2023, versus $3.3 billion in 2022. These were affected by a fall in the average realised potash price (CIF) to $393/t last year, down from an average of $682/t in 2022.

Polysulphate production at ICL's Boulby mine in the UK, meanwhile, also continues to rise. Production of this polyhalite product reached one million tonnes in 2023, a new annual record.

Total revenues accrued by ICL's Growing Solutions business segment were $2.1 billion in 2023. The segment markets and sells the company's controlled-release fertilizers (CRF), water-soluble fertilizers (WSF), liquid fertilizers and straights (MKP/MAP/PeKacid), polyhalite products (FertilizerpluS), soil and foliar micronutrients, secondary nutrients, biostimulants, soil conditioners, seed treatment products and adjuvants. Sales of these specialties fell slightly y-o-y, with lower prices only partially offset by higher volumes, mainly in micronutrients, CRFs and straight fertilizers.

Looking ahead, ICL is expecting its specialty business segments (Industrial Products, Phosphate Solutions and Growing Solutions) to deliver earnings (adjusted EBITDA) of around $0.7-0.9 billion in 2024. Potash sales for 2024 of 4.6-4.9 million tonnes are also forecast. ■

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Is sulphur nutrient supply meeting crop demand?

Sulphur plays an important role in crop nutrition. Indeed, sulphur is increasingly being recognised as the fourth major crop nutrient alongside N, P and K. However, a combination of intensive agricultural practices, increasing application of high-analysis fertilizers and tighter air quality regulations has led to increasing sulphur deficiency in soils. In this insight article, CRU's **Peter Harrisson** looks at what's driving sulphur deficiency and whether there's a gap in the market for sulphur fertilizers.

The sulphur cycle

Plants are able to take up sulphur as a soil nutrient in sulphate form. This can be supplied directly through atmospheric deposition and sulphate fertilizers, or via the oxidation of organic sulphur or elemental sulphur fertilizers. Organic sulphur accounts for around 95 percent of the sulphur found in soils and, when converted into sulphate, is either taken up by plants or lost from the system by leaching. The major factors influencing the levels of available sulphur in soil are the rate of plant uptake versus replenishment by atmospheric deposition, animal/crop wastes and fertilizer applications (Figure 1).

In the past, little attention was paid to artificially applying sulphur as a nutrient because soils had abundant natural supply. Yet increasing issues with crop quality and yields in recent years are being attributed to soil sulphur deficiency. The reasons behind growing global soil deficiency include:

- Falling atmospheric SO_2 emissions
- Rising crop areas and yields
- Increasing consumption of high-analysis fertilizers.

Falling atmospheric emissions

Tight emissions controls have reduced the amount of SO_2 entering the atmosphere and being deposited as acid rain. Emissions in Europe and North America have been in decline since the 1980s, with the rest of the world now implementing similar policies.

While the introduction of sulphur limits in liquid fuels has been the main policy driving down sulphur emissions, increased SO_2 capture from power generation and industrial processes (including base metals smelting) has also led to SO_2 emissions falls. Sulphur emissions from industry

Fig 1: **The sulphur cycle**

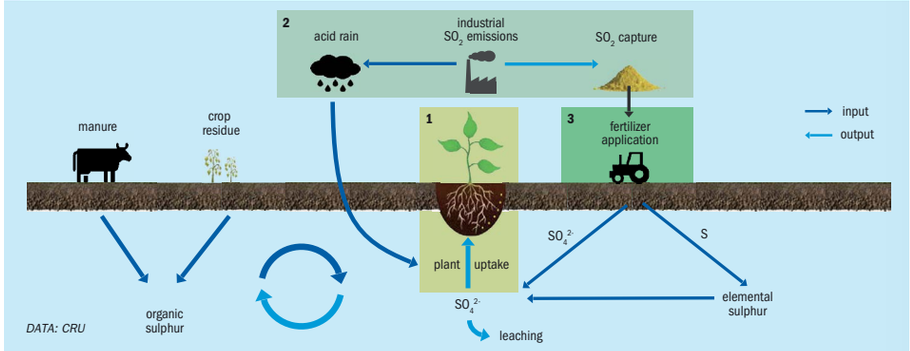
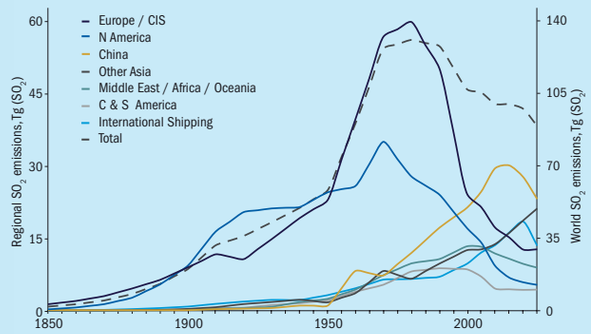


Fig 2: **The decline in global anthropogenic sulphur emissions has reduced sulphur deposition to soils. Emissions have fallen furthest and fastest in North America and Europe.**



Source: CRU, European Geosciences Union, IEA

in North America and Europe have fallen furthest and fastest, with emissions in China and other Asian countries only beginning to decline from the mid-2010s (Figure 2).

Rising crop areas and yields

Modern agriculture is removing more nutrients from the soil as it become more intensive, with higher yielding crops, shorter growing seasons and more frequent crop rotations (Figure 3). Agricultural expansion has accentuated this issue, as increased N, P, K and S nutrient applications are typically required on previously unproductive (and often low quality) land. The planting of crops with a fundamentally higher sulphur nutrient requirement, such as sugar, canola and soybeans, has been another factor behind the increasing agricultural need for sulphur.

Increasing consumption of high-analysis fertilizers

The relative and/or absolute decline in the consumption of traditional sulphate-containing fertilizers, including ammonium sulphate (AS), single superphosphate (SSP) and sulphate of potash (SOP), and their increasing replacement with high-analysis fertilizers, such as urea, diammonium phosphate (DAP) and muriate of potash (MOP), has been a long term trend (Figure 4). Consequently, the dominant fertilizers across N, P and K products all have low or no sulphur content, as sulphate-containing fertilizers now supply only a minor share of primary nutrient demand.

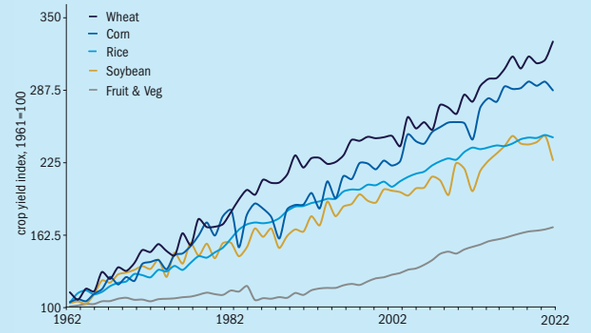
Current market for sulphur fertilizers

Sulphur nutrient supply to agriculture has been calculated from consumption data for sulphur fertilizers. This includes large-scale sulphate-containing products such as AS, SSP, SOP, ammonium thiosulphate (ATS) and gypsum, alongside NP+S and sulphur-bentonite, together with the residual sulphur content found in DAP, monoammonium phosphate (MAP) and triple superphosphate (TSP). The nutrient contents of these major sulphur-containing fertilizers are shown in Table 1.

In 2022, global sulphur nutrient supply is estimated at 13.8 million tonnes, with sulphate-containing fertilizers such as AS and SSP accounting for 68 percent of this total (Figure 5).

The AS market has grown in recent years because of increasing involuntary production in China (as a by-product of caprolactam production), while at the same time the country's SSP demand has halved. In contrast, SSP demand remains strong in Brazil, India and Australia (Figure 5),

Fig 3: **More sulphur is being removed from soils due to growing crop yields. The global crop yield index, 1961-2022**



Source: CRU, FAO

Table 1: **Nutrient content of major sulphur-containing fertilizers**

	N	P	K	S
AS	21			24
SSP		18		10
SOP			50	18
NPS	10-12	40-46		7-15
ATS	12			26
DAP+MAP	10-18	46-50		1.5
TSP		46		1
Sulphur-bentonite				90

Source: CRU

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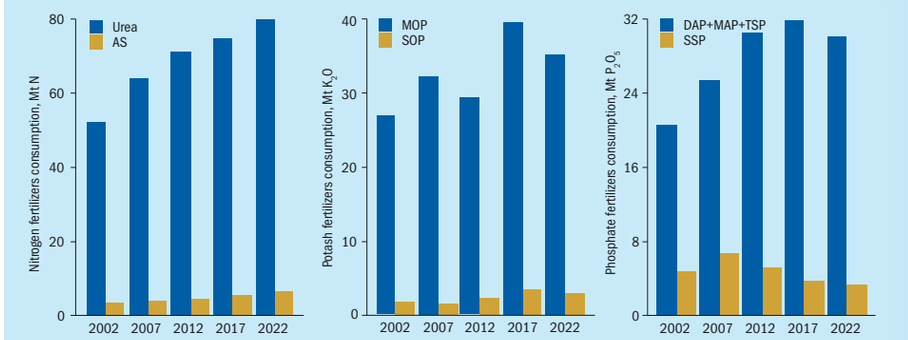
Fig 4: **N, P and K fertilizer consumption. This is increasingly being met by high-analysis products (urea, DAP/MAP, MOP) with relative or absolute declines in the consumption of traditional sulphate-containing fertilizers (AS, SSP, SOP).**



Source: CRU

although total global consumption has still declined over the last decade.

SOP commands a small market relative to MOP, which is 10 times larger, despite being highly prized as a chloride-free potassium and sulphur source for high-value crops. Chinese SOP demand has grown considerably since 2000, outpacing more modest demand growth across other regions.

The NP+S product group has been responsible for the greatest change in sulphur nutrient consumption globally. At the start of the decade, NP+S emerged as a new sulphur fertilizer with strong demand in India, Brazil and the United States, with new demand having been developed in Ethiopia and Australia.

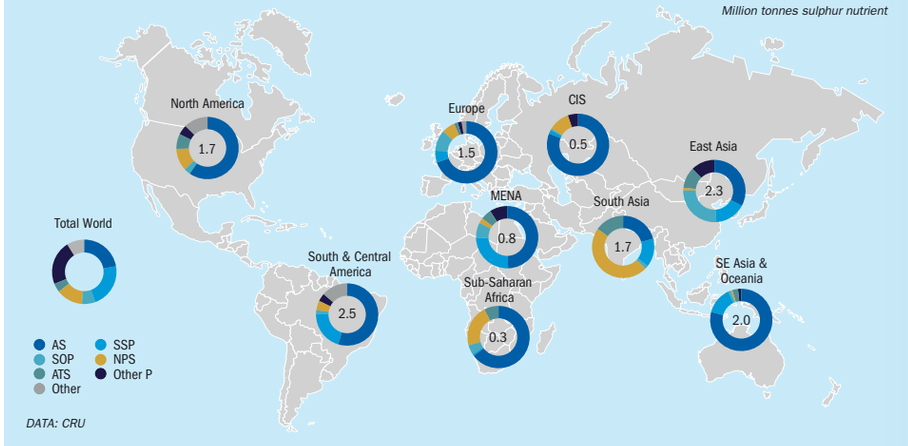
The types of NP+S consumed vary between regions with the Americas and Africa focussed on DAP/MAP-like products with only 5-10 percent sulphur content, whereas India and Southeast Asia have a preference for products such as 20-20-0-13.

Other notable sulphur fertilizers include: gypsum, the calcium sulphate by-product of phosphate fertilizer production which has traditionally been soil-applied in Brazil; sulphur bentonite, a product specifically designed to help combat sulphur deficiency in North America, India and other countries and regions.

How does sulphur nutrient supply compare to crop demand?

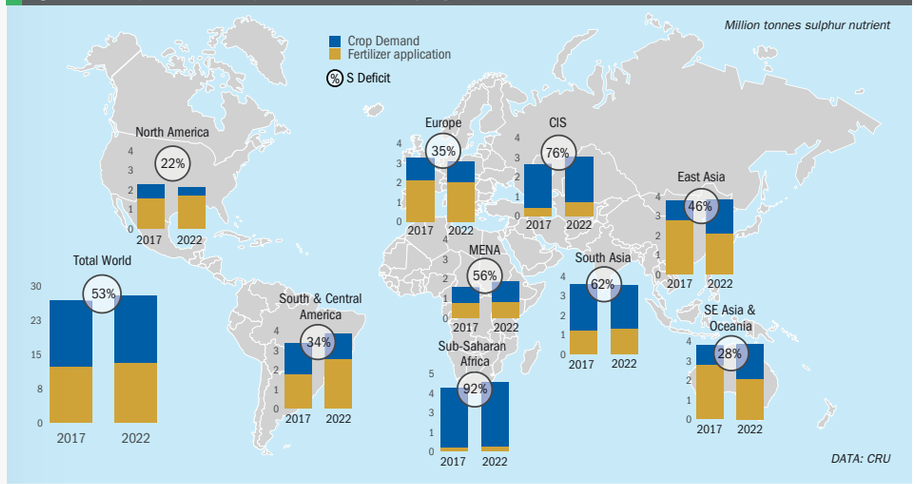
Crops use sulphur to produce essential amino acids, proteins, oils and other organic compounds – and is especially important in initial plant growth stages.

Fig 5: **Global sulphur nutrient supply by product**



DATA: CRU

Fig 6: **Global sulphur nutrient crop demand and deficit, by region, 2017 versus 2022**



Sulphur demand varies with agricultural practice. Pasture for a low intensity grazing operation, for example, will typically require an S application of only 5-10 kg/ha, whereas sulphur hungry crops, such as canola, may require up to 5-10 times this application rate.

Globally, it is possible to estimate crop nutrient demand for sulphur by multiplying different crop growing areas by their region-specific sulphur requirements. Regional sulphur deficits can then be calculated by comparing sulphur nutrient demand with actual sulphur product applications.

Only around half of the global sulphur requirement from crops is being met by fertilizer applications currently, based on CRU estimates for 2022. All global regions are calculated to be operating with a sulphur nutrient deficit, this being most pronounced in India, Africa and the CIS region. Despite high levels of sulphur nutrient application in East Asia and South Asia, sulphur nutrient deficits are calculated at 46 percent and 62 percent, respectively (Figure 6).

In parts of Asia, the atmospheric deposition to soils from high sulphur emissions will help to 'naturally' fill some of these nutrient gaps – although deficits will still occur in agricultural areas located far from industry. Unmet crop demand will also be affected by extreme climate conditions in some regions where high sulphur losses from the soil are often sustained due to high rainfall events.

Agricultural use and crop nutrient demand for sulphur have both steadily risen in the Americas, driven by crop choice on the demand side and high volume AS and NP+S applications (e.g., from Mosaic's sulphur- and zinc-enhanced MicroEssentials MAP product) increasing nutrient supply.

Prospects for sulphur demand

The fundamental demand for sulphur in agriculture will only keep growing in CRU's view. The mainly sulphate-containing fertilizers currently produced have – to date – been unable to fully fill the widening demand gap in recent years, as the world continues to reduce atmospheric sulphur emissions. Consequently, the contribution from sulphur-enhanced fertilizers, which either coat or incorporate sulphur into the matrix of high-analysis fertilizers, is expected to grow as they become more popular and their industrial production increases.

Therefore, although increasing incidences of sulphur deficiency are being recognised across the world, the global sulphur deficit is expected to narrow marginally over the coming five years. Increases in sulphur nutrient consumption are mostly expected to take place in regions where there is already a major focus on sulphur crop nutrition, such as the Americas, Southeast Asia and Oceania.

Sulphur nutrient supply expected to close the gap to crop demand

Sulphur is one of the key nutrients required in crop production. Changing agricultural practices and new environmental regulations have caused sulphur levels in soils to fall quite significantly. Cases of sulphur deficiency are becoming more widespread and have affected the quality and yield of certain crops more than others.

Despite growing sulphur nutrient demand over the near term, the gap between supply and demand is projected to narrow. CRU expects the demonstrated success of NP+S, alongside other sulphur-containing products, to continue to incentivise investment in sulphur-enhanced fertilizer technology to meet projected strong future demand. ■

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The recovery of valuable sulphur fertilizers from wastewater and biogas

PHOTO: FERTIPAQ

One 10 litre container of S-600 liquid fertilizer contains six kilograms of finely dispersed elemental sulphur particles (5-20 microns).

Sulphur is a necessary nutrient for strong and healthy plant-growth and disease resistance. Fertipaq manufactures the liquid suspension fertilizer S-600 using sulphur recovered wastewater and biogas streams. This organic product is an ideal nutrient source for crops with a high sulphur requirement.

Introduction

Sulphur is an element consumed at a large scale by many different sectors, including agriculture, the chemical industry, and cosmetics and pharmaceuticals manufacturers. Currently, more than 80 percent of the world's sulphur supply comes from the desulphurisation of crude oil and natural gas. Yet some studies are predicting a shortage of sulphur as soon as 2040, as the world moves away from fossil fuels as part of the energy transition. Because of this, recovering elemental sulphur from sources that are not reliant on fossil fuels – such as wastewater and biogas streams – looks set to become an increasingly important and more sustainable source of sulphur in future.

From wastewater to organic fertilizer

Fertipaq recovers, stabilises and reuses the organic sulphur generated by THIOPAQ® biogas desulphurisation units installed at industrial sites. THIOPAQ® technology was developed by Paques – the parent company of Fertipaq – in collaboration with universities, research institutes and several industry customers. It can be used to remove hydrogen sulphide gas (H_2S) from a wide range of biogas streams and is compatible with all biological anaerobic systems installed by Paques.

Biogas is an important renewable energy source. However, the H_2S present in the biogas generated by anaerobic digestion plants, anaerobic wastewater treatment plants and landfill sites needs to be removed. This is due to health, safety and environmental reasons – and because of the corrosion of equipment such as gas engines, boilers and piping.

The Fertipaq story begin in 2014 with an in-house innovation competition from Paques, a Netherlands-based company specialising in wastewater treatment. Employees were invited to submit novel commercial ideas for a business start-up.

Fertipaq turned from an idea into a fact when employee Leo Habets won this competition. His innovative proposal was for a new business, Fertipaq, to start where Paques stops – and close the recovery cycle by turning previously wasted sulphur into a high-value fertilizer.

How THIOPAQ® works

THIOPAQ® scrubbers remove hydrogen sulphide using a continuously biologically regenerated caustic solution. Within the scrubber, a biogas stream containing H_2S is brought into contact with a wash solution flowing in counter-current. This enables the absorption of H_2S under slightly alkaline conditions (pH 8-9) via a biochemical reaction with hydroxide ions. The captured sulphide is then oxidised into elemental sulphur by autotrophic sulfidogenic bacteria using a bioreactor.

Previously, H_2S-rich biogas was burnt off resulting in acid rain. While this can be partly beneficial from an agriculture point of view – due to the soil deposition of sulphur (see article on p20) – combustion was banned because of human respiratory problems and the large-scale forest die-off associated with acid rain.

Avoiding atmospheric pollution, by installing desulphurisation units worldwide to remove H_2S from biogas, is now also good news for farmers. Recovering sulphur in this way and turning it into a liquid fertilizer allows much more precise sulphur fertilization of crops – without the damaging environmental and health impacts caused by acid rain. Applying sulphur fertilizers to crops also has dual benefits by promoting the nitrogen uptake necessary for strong crop growth and high yields.

Practical crop benefits of Fertipaq S-600 fertilizer

The thinness of the crop, poor nitrogen availability and wet weather were all major concerns for wheat growers in the Netherlands during spring 2023. Fertipaq's distributors responded by advising the spraying of Fertipaq S-600 – both as a sulphur fertilizer and to boost nitrogen availability.

The subsequent application of Fertipaq S-600 to the wheat crop started to deliver satisfactory results for growers in the Netherlands as the 2023 season progressed.

"The plant was really not thriving. Furthermore, the levels of nutrients from the cattle manure were disappointing – so, we had to look at an alternative to make the nitrogen available," a Dutch farmer told Fertipaq. "We started spraying Fertipaq S-600 in April, it would have been the second node, applying three litres per hectare. Faced by both wet and cold conditions at tillering, you know sulphur helps with these problems."

QUICK FACTS ABOUT THIOPAQ®

- More than 30 years of operational experience
- More than 300 THIOPAQ® references worldwide
- Developed via continuous innovation
- In-house manufacturing and quality control
- Thorough hydrogen sulphide (H_2S) removal
- Production of high-quality elemental sulphur suitable for fertilizer use.

Fertipaq S-600 can be easily blended with other nutrients in the spray tank, although Fertipaq does recommend adding the product last. Fertipaq can be mixed at a ratio of between 1:50 and 1:100, depending on the sulphur needs of the crop.

As is usual with other products, farmers will need to inspect and maintain the spray tank and spray nozzles after field spraying to prevent residue build up and clogging.

Making Fertipaq S-600 part of the fertilizer plan

Fertipaq S-600 is not a replacement for the granular sulphate-enriched calcium ammonium nitrate (CAN) commonly applied on grassland and arable crops in northern Europe. Instead, it offers supplementary additional sulphur during the growing season. Depending on the crop, S-600 can be sprayed up to 4-5 times at 3 l/ha concentration during the season (Table 1). For wheat, this fits in well with the usual spray regime, with growers typically spraying the crop once in the fall, once in the spring, twice during the growth regulation stage, and possibly one final time at the flag leaf stage.

There are indirect benefits too. Although Fertipaq is not a fungicide, and is not certified as such, there is evidence that adding it to a fertilizer plan helps plants flourish and creates a more robust and resistant crop.

Table 1: **Recommended number of applications of Fertipaq S-600 for different crop types.**

Crop type	Recommended spray applications
Grains	4-5
Rape seed	3-5
Beans, peas, lupin, and sunflowers	2-3
Corn	2-3
Potatoes	2-3
Sugar beets	2-3
Grapes	2-3
Fruit (such as berries)	3-4
Vegetables	3-4
Hops	1-2
Grassland	1-3

**Recommended rate of three litres per hectare*
Source: Fertipaq

PHOTO: FERTIPAQ

Fertipaq's liquid S-600 sulphur fertilizer can be added to the spray tank for field application.

Biologically-recovered vs chemically-derived sulphur

Fertipaq S-600 has a number of advantages compared to chemically-derived sulphur. The form of elemental sulphur present is naturally hydrophilic, for example, and therefore easy to disperse in water. Chemically-derived sulphur, in contrast, is hydrophobic, this making extra steps necessary to turn it into a hydrophilic liquid product. The naturally small particle size of the biologically-recovered sulphur in S-600 (5-20 microns) is another advantage – compared to the larger particle size of chemical sulphur (typically >50 microns) – as these are more easily dispersed in soil and therefore more uniformly available for uptake by the crop. ■

COMPANY PROFILE

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PHOTO: RNZ

Raza Soomar, the MD of RNZ Group.

RNZ – Innovations for sustainable agriculture

RNZ Group is positioning itself as the most innovative and sustainable fertilizer producer in the UAE. In partnership with Shell, the company has been manufacturing sulphur-enhanced fertilizers using Thiogro technology since the end of 2022. **Raza Soomar**, RNZ's managing director, provides an overview of the company and highlights recent business successes.

Introduction

Dubai-headquartered RNZ Group is a leading supplier of water-soluble fertilizers, granular NPK grades and organic fertilizers to the Middle East, Africa and Southern Asia (MEASA) region. The company's fully automatic NPK blending and granulation plant, set up in the United Arab Emirates (UAE) in 2011, has a combined production capacity of 105,000 t/a.

Notable RNZ product lines include:

- **Granular NPK fertilizers**: 60,000 t/a production capacity, 200 formulations
- **Water-soluble fertilizers**: 40,000 t/a production capacity, 400 formulation
- **Suspension fertilizers**: special formulations for precision agriculture
- **Straight fertilizers**: international supply partnerships with leading producers.

These operational capabilities for customised and crop-specific fertilizer grades are supported in-house by state-of-the-art R&D facilities.

RNZ is also the region's first producer of sulphur-enhanced urea products which are marketed under the Purti NS Plus brand name. These are manufactured using patented Thiogro technology in partnership with Shell. The production plant for these products was successfully commissioned in Kizad, UAE, in December 2022.

The Purti NS Plus range is manufactured with 100 percent local input materials and includes NS10+ (10-0-0+75S) and NS20+ (20-0-0+50S) formulations. NS20+ is produced for the local market and tailored for specific soil issues and crop nutrition needs in the UAE.

PHOTO: EMIRATES

RNZ is the exclusive fertilizer supplier to Bustanica, the world's largest vertical farm in Dubai. Leafy greens from the farm, which is wholly owned by Emirates Flight Catering, are served on Emirates flights and sold in 160 retail stores across the UAE. They are grown using RNZ's HydroMaster specialty fertilizer range.

The beneficial effects of these sulphur-enhanced fertilizers include:

- **Reducing pH**. The sulphur oxidation process helps reduce pH in the active root zone.
- **Releasing nutrients**. More nutrients (calcium, iron manganese and zinc) are available for uptake in treated soils.
- **Sulphate availability**. Pre-harvest sulphate levels are higher in treated soils.
- **High bioactivity**. Beneficial microbes are more active in treated soils thanks to the sulphur oxidation process.

RNZ has also successfully developed the HydroMaster specialty fertilizer range. These are specifically formulated for hydroponics and vertical farms. The company is the exclusive supplier to Bustanica, the world' largest vertical farm located at Dubai in the UAE.

The food security challenge

Subsidiary company RNZ Agrotech Limited was established in 2020 to contribute to the objectives of the UAE's National Food Security Strategy. This is aiming to achieve zero hunger by 2050 by ensuring the whole population has access to safe and nutritious food. Achieving this goal will require the widespread adoption of sustainable agricultural practices that increase crop productivity while protecting ecosystems.

The UAE has major food security challenges being an arid country with water scarcity and limited arable land that faces extreme weather conditions throughout the year. RNZ is helping address these challenges by championing innovation and collaboration in the MEASA region. The company is working with multidisciplinary teams from internationally-renowned organisations to develop innovative low-carbon and sustainable fertilizer manufacturing technologies.

Centre of Excellence

RNZ Group set up the Centre of Excellence for Fertilizer Technology Research (COE-FTR) in Kizad, Abu Dhabi, in 2020. This state-of-the-art centre is the first of its kind for fertilizer science and technology research in the UAE.

PURTI NS PLUS – RNZ'S FLAGSHIP FERTILIZER RANGE

RNZ, in collaboration with Shell, has introduced patented Thiogro technology to the region via the innovative Purti NS Plus range, including the highly concentrated NS10+ (10-0-0+75S) sulphur fertilizer. The composition of this sulphur-enhanced urea product is as follows:

- Total urea content: 10.0 percent minimum by weight
- Total elemental sulphur (ES) content: 75.0 percent minimum by weight
- Moisture content: 0.5 percent maximum by weight.

Detailed product characteristics are set out in Table 1.

Table 1: **The main characteristics of RNZ's NS10+ sulphur-enhanced fertilizer.**

Characteristics	Value
Active ingredients	Urea and elemental sulphur
Minimum nitrogen content as urea	10.0 percent (w/w)
Minimum sulphur content	75.0 percent (w/w)
Elemental sulphur (ES), average particle size	40 microns
Granules dispersion time (aqueous system, gentle shaking)	<2 minutes
ES oxidation rate (time period for 50 percent oxidation)	6-9 days
Yield increase for cereals, millet, oilseed and legume crops	21-33 percent approx.
Reduction in ammonia losses	13-22 percent
Net return on investment	8-20 percent

Source: RNZ

Features and benefits

RNZ's NS10+ product is a sulphur-enhanced nitrogen fertilizer that combines micronised elemental sulphur with urea using patented Thiogro technology. It is designed to increase crop yields, improve farm productivity and reduce input costs. Benefits include:

- Providing critical nitrogen (N) and sulphur (S) crop nutrients in one application
- Enhanced nitrogen and sulphur use efficiency
- Prevents nutrient overapplication and reduces nutrient losses
- Increased soil microbial biomass and activity
- Higher crop yields and better quality produce.

RNZ NS10+ is designed to meet the early nitrogen and sulphur requirements of crops before and after their planting or emergence. This allows the crop's remaining nitrogen requirements to be applied as a top-dressing during vegetative growth stages at 'the right time' – as recommended by the 4Rs. This avoids excessive nitrogen fertilization, leaching, or volatilization, and enhances the use efficiency of both nutrients. Higher nitrogen use efficiency – by lowering the loss of applied nitrogen – reduces both input costs and environmental impacts.

Sulphur is known to act in synergy with nitrogen, with poor sulphur availability affecting nitrogen use efficiency. Conversely, when applied together, nitrogen and sulphur can improve their combined agronomic efficiency compared to individual applications. ▶

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PHOTO: RNZ

PHOTO: RNZ

RNZ is developing value-added nitrogen-sulphur (NS) and sulphur bentonite (SB) fertilizers enriched with micronutrients.

Crop trial results

A series of field trials were carried out using treatments with Purti NS Plus fertilizers. In all crops, these treatments significantly increased yields and improved crop quality as follows:

- **Wheat**. Significant increases in effective tillers, spike length, number of grains per spike, and 1,000 seed weight. These improvements generated an increase in net return of up to 22 percent.
- **Maize**. Significant increases in plant height, cob length, cob girth, number of rows per cobs, number of grains per cob and 1,000 grain weight.
- **Mustard**. Significant increases in primary and secondary branches per plant, silique length, total number of siliques per plant, grain numbers per silique, 1,000 seed weight, and seed, stover and biological yield. There was also an increase in electrical conductivity and available soil N and S.
- **Potato**. Significant increases in number of stems per plant, number of tubers per plant, weight of tubers per stem and tuber yield.

Value-added elemental sulphur fertilizers

RNZ's Centre of Excellence is also developing new value-added sulphur fertilizer formulations to meet the nutrient needs of growers worldwide. These include NS+ and sulphur-bentonite products enriched with micronutrients such as zinc, boron and selenium.

(continued from p29)

The COE-FTR is dedicated to research, development and the commercialisation of innovative and climate-smart fertilizers. The centre's advanced laboratories are well equipped with instruments for the characterisation and analysis of fertilizer materials and offers:

- Chemical analysis of more than 30 major elements and microelements
- Full soil testing including pH, EC, C/N, organic matter, microbial counts and soil chemistry
- Full water testing including water hardness, pH, EC, nitrates and other chemical elements
- Full plant tissue analysis for major and micronutrients, nutrient ratios, biomass and crop health indicators.

COE-FTR also includes an incubation centre and pilot-scale product testing and production facilities. The centre works in collaborations with prestigious partners such as UAE University, Shell and Bustanica.

Research and development at the COE-FTR focuses on six priority areas.

- **Value-added and climate-smart fertilizers**. This includes the commercialisation of advanced inorganic, organic, hybrid, nano and smart fertilizers that incorporate stabilisers, inhibitors, and coatings. These innovative products are designed for controlled nutrient release, better nutrient use efficiency and lower environmental footprints.
- **Customised fertilizer technologies and guidance to growers**. The centre develops and validates customised fertilizer products, based on soil health data, and provides guidance on balanced fertilization. Field tests are conducted to confirm on-farm performance prior to commercialisation. A complete fertilizer range for hydroponics has been developed and commercialised using RNZ's in-house R&D capabilities.
- **Recycling biowastes and managing soil health**. Using a circular economy approach, soil carbon stocks can be improved using tailor-made organic fertilizers based on locally available biowastes. Increasing the organic carbon content of soil also enhances the nutrient use efficiency of inorganic fertilizers. Efforts are also being made to recycle urban municipal waste and convert it into compost with a carbon content of more than 10 percent.
- **Pilot plant tests**. An in-house pilot plant facility enables RNZ to validate new fertilizer manufacturing technologies prior to scale-up, commercial production and marketing. RNZ has a dedicated technology scale-up team that works with internal and external experts to assess the technical and commercial feasibility of manufacturing value-added and new fertilizers.
- **Setting up an Agri-Tech incubator**. This provides the resources and an environment where fresh ideas and innovation can succeed, with a special focus on encouraging and supporting young people and women. The incubator enables RNZ's team to test and validate new product formulations and services.
- **Strengthening dialogues, policies and regulations**. The centre encourages growth and investment in the fertilizer sector by providing a forum for dialogue and brainstorming with external stakeholders. Technical guidance and support can also help assess current fertilizer practices and their impacts, and provide evidence for policy, regulation and environmental protection. Proactive engagement with government over mandatory compliance issues is also valuable. Overall, the task of policy advocacy becomes much simpler and more effective by engaging with all stakeholders in society.

> **"RNZ is the region's first producer of sulphur-enhanced urea products which are marketed under the Purti NS Plus brand name."**

Sustainability commitments

RNZ Group is implementing a new manufacturing model for value-added and hybrid inorganic-organic fertilizers based on circular economy principles, renewable energy and the recycling of materials. The company's processes are being optimised to support the UAE's sustainability ambitions and meet the goals of the United Nations Global Compact (UNGC) and UAE Alliance for Climate Action (UACA).

RNZ is planning to move beyond net zero and become carbon positive by:

- Moving to a circular production model with zero waste
- Adopting renewable power sources for its energy needs – including solar power installations at its Jebel Ali and Kizad sites
- Running vehicles on biofuels and using electric forklifts.

Conclusion

Fertilizers are crucial inputs that will undoubtedly play an important role in the future of food security. Their production and costs are largely dependent on the availability of feedstock materials. Recent geopolitical risks have led to serious increases in fertilizer costs and subsequently higher food prices. This has led RNZ to create an international centre for advanced research on fertilizer technologies. This centre can help to tackle the geopolitical pressures placed on farmers and consumers by developing sustainable, efficient and innovative agricultural inputs.

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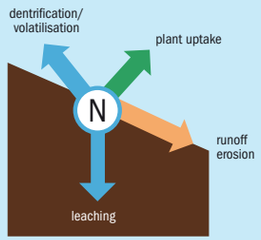
Enhanced efficiency fertilizers for advanced nitrogen management

Addressing the 'leaky' nature of nitrogen fertilizers is a longstanding priority for growers, fertilizer producers and retailers alike. **Dr Karl Wyant**, Nutrien's Director of Agronomy, examines the valuable role enhanced efficiency fertilizers (EEFs) can play in improving nitrogen use efficiency.

Introduction

Growers continue to face the task of improving nutrient use efficiency. For nitrogen fertilizers (urea, ammonium sulphate, liquid urea ammonium nitrate, etc.), this is a dual challenge requiring higher crop uptake of nitrogen, relative to the amount applied, and reducing environmental impacts by closing off the multiple pathways for nitrogen loss in the field[1] (Figure 1).

Fig 1: **In a perfect world, 100 percent of applied nitrogen fertilizer (N, centre) would be taken up by the crop during the growing season (green arrow). However, the multiple pathways for field losses reduce nitrogen use efficiency.**



Source: University of Delaware

Traditional nitrogen applications, even with careful management, can still result in significant field losses which reduce the overall nitrogen use efficiency of the crop (Table 1). The main loss pathways for specific forms of nitrogen in the fertilizer and the soil (NO_3^- nitrate, NH_4^+ ammonium, NH_3 ammonia and N_2 nitrogen gas) are as follows:

- **Leaching** of nitrates occurs when water passing through the soil beyond the root zone transports nitrate with it. Nitrate easily leaches through sandy and other permeable soils. Leaching also occurs when nitrate fertilizers or pre-existing nitrates in the soil are exposed to strong rainfall events or irrigation. Nitrogen leaching losses can reach up to 50 percent of total applied N.
- **Volatilisation** is the loss of nitrogen as ammonia gas (NH_3). It commonly occurs when urea or urea ammonium nitrate (UAN) liquid fertilizers (e.g., UAN 32) are on or near the soil surface. Nitrogen volatilisation losses can be as high as 40 percent of total applied N.
- **Denitrification** occurs when oxygen is deficient in the soil and anaerobic bacteria convert nitrate to various nitrogen gases (N_2 etc.) which then escape resulting in nitrogen loss. Denitrification often occurs after rain events when soils are waterlogged. Denitrification can result in nitrogen losses of up to 50 percent of total applied N.
- **Soil erosion** can cause nitrogen losses (NH_4^+) of up to 20 percent of total applied N.

Losing nitrogen fertilizers to leaching, volatilisation, erosion, or denitrification means they are unable to drive crop growth and yield and has the potential to pollute the environment.

Table 1: **Estimates of crop uptake versus potential loss pathways (immobilisation erosion, denitrification, volatilisation, leaching) as a percentage of the total nitrogen applied as fertilizer. The higher the crop uptake percentage, the higher the overall efficiency of the application.**

Mechanism	Form of N	Potential range
Crop uptake	NH_4, NO_3	50-80%
Immobilization	NH_4, NO_3	10-40%
Erosion	NH_4	0-20%
Dentrification	NO_3	0-50%
Volatilisation	NH_3	0-40%
Leaching	NO_3	0-50%

Source: Nutrien (2024)

Improving nitrogen use efficiency – fertilizer formulations

To drive up nitrogen use efficiency (e.g., delivering more harvested crop per unit of applied nitrogen), the fertilizer industry has created various formulations designed to help increase nitrogen uptake by the crop – by retaining the applied nitrogen in the soil and reducing the risk of potential nitrogen losses[1]. Broadly, this category of fertilizers is known as **enhanced efficiency fertilizers (EEFs)** with several options to choose from (Figure 2).

EEFs are defined by the Association of American Plant Food Control Officials (AAPFCO) as:

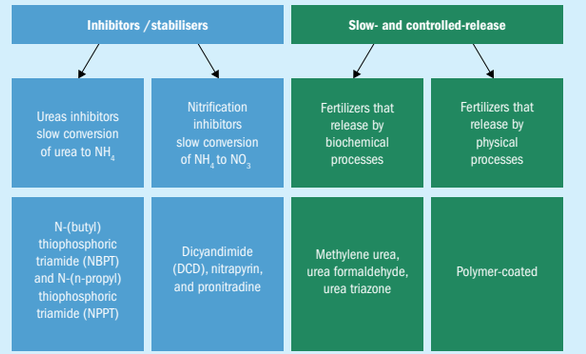
"Any fertilizer product that reduces nutrient losses to the environment while increasing nutrient availability for the crop."

These products generally function by either controlling/slowing the release of nutrients or by helping prevent the soil reactions that lead to nutrient losses.

Categories of EEFs include slow-release fertilizers (SRFs), controlled-release fertilizers (CRFs), and stabilised fertilizers (SFs):

- **Stabilised fertilizers (SFs)**. These incorporate a stabiliser or chemical inhibitor to slow biological (microbial) transformations of nitrogen in the soil (e.g., urea to ammonia, ammonia to nitrate, etc.). The duration of the inhibition or stabilisation effect is determined by the active ingredient used and its concentration. Inhibiting or slowing the biological processes reduces the risk of nitrogen loss by preventing excess accumulation of either ammonia or nitrate.
- **Slow-release fertilizers (SRFs)**. These products release nitrogen by biochemical breakdown. Release time is determined by the nature and/or chain length of the nitrogen compound present and the biological activity of the soil.
- **Controlled-release fertilizers (CRFs)**. These coated granular products release nitrogen by diffusion through the coating when in contact with soil moisture and temperature. Release rate is controlled by coating thickness, coating type and soil temperature.

Fig 2: **Enhanced efficiency fertilizers (EEFs). A summary of various technologies available on the market to help reduce fertilizer nitrogen losses. The main categories are shown on the top row, the mode of action in the middle row, with examples of active ingredients on the bottom row.**



Source: Trenkel (2010)

Choosing the right EEF

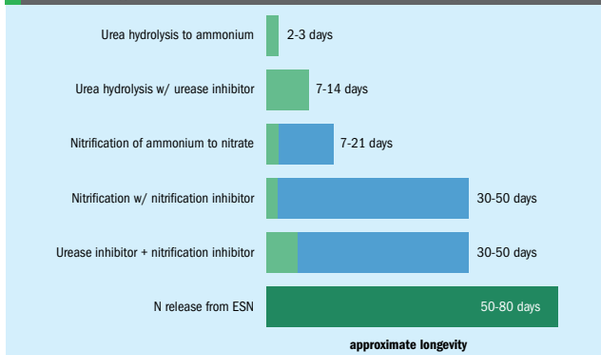
The obvious dilemma for growers, when trying to improve the overall nitrogen use efficiency of their crop growing programme, is which EEF to select – especially given the many options and brand names on the market. In making the right decision, it is helpful to ask two essential questions:

1. How long do I need to protect my nitrogen?
2. Which loss pathway(s) do I need to protect against?

Answering these questions will help growers to select the product with, firstly, the right mode of action and, secondly, the most suitable duration of protection. Products can then be categorised on this basis, as shown in Figure 3.

Stabilised fertilisers that incorporate inhibitors (e.g., urease and nitrification inhibitors) tend to protect against a specific pathway and offer a comparatively short duration of protection. Slow- and controlled-release fertilizers that function via biochemical or physical protection, meanwhile, tend to guard against a wider spectrum of losses over a longer period (Figure 3).

Fig 3: **Time period for urea hydrolysis and nitrification in soils versus the duration of nitrogen protection afforded by various EEF technologies* (%)**



Source: Nutrien (2024) **The bottom bar is for Nutrien's ESN® (0-0-44) polymer-coated urea product.*

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Beyond EEFs and the role of the 4Rs

A quick review of the basics of nitrogen fertilizer application can help improve uptake efficiency when used in conjunction with an EEF. The four main management factors that help improve the efficiency of applied nitrogen fertilizers are commonly known as the 4R's:

- Right application rate – how much nitrogen do you need?
- Right formulation – nitrogen fertilizer type and EEF selection
- Right timing of application – match nitrogen application to crop uptake rates
- Right placement – place the nitrogen where the crop can access it.

Along with the 4R guidelines, holistic crop and nutrient management should focus on the following to help promote the proper use of fertilizers[1]:

- Promoting root growth by improving soil structure (good soil aeration, storage, and supply of water), soil pH management (liming), the creation of soil organic matter, and promoting soil health. Strong, vigorous crops will make good use of applied fertilizers.
- Using soil and plant analyses for nutrient planning and to constantly monitor crop growth and development.
- Applying amounts of nutrients that correspond as precisely as possible to crop needs, growing conditions, and realistic yield performance.

Concluding comments

Fertilizers plays a critical role in meeting the increased global demand for food, fibre, and fuel. They must, however, be applied safely, effectively, and efficiently to prevent wasted input dollars and reduce risks to the environment. Using an enhanced efficiency fertilizer (EEF), alongside proper 4R nutrient stewardship guidelines, has the potential to greatly increase nutrient use efficiency across the globe.

As covered here, growers face many challenges when making effective crop fertilization management decisions. Selecting the right nitrogen source, rate, time, and application method (4Rs) is critical – as is choosing the right EEF based on local conditions. Matching the EEF with the specific nitrogen loss pathway and the duration of protection required will help ensure a good return on investment and less errant fertilizer behaviour in the environment. ■

SPOTLIGHT ON ESN®

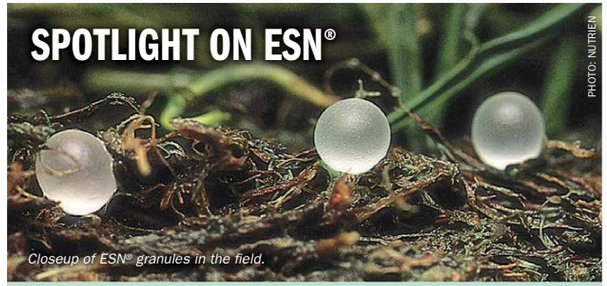


PHOTO: NUTRIEN

Closeup of ESN® granules in the field.

Controlled-release fertilizers (CRFs) are a popular type of EEF defined by the AAPFCO as follows:

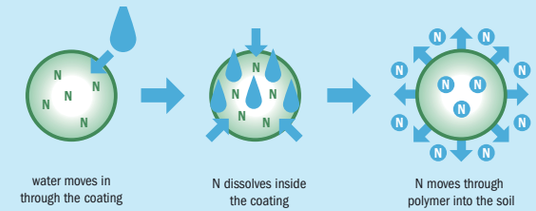
"A CRF has been engineered to provide nutrients over time at a very predictable rate under specific conditions (e.g., 3 month release at 21°C)."

CRFs are typically coated with polymer membranes to help control the release of nutrients to the soil (Fig. 4). Nutrien's ESN® (44-0-0) is a successful CRF product that has been on the market for many years – and provides a good example of how polymer-coated urea (PCU) formulations work.

ESN® technology encapsulate urea granules within a flexible polymer coating which protects against the nitrogen loss pathways discussed previously. This protection is especially valuable when high nitrogen rates are applied at times when crop demand is low.

The unique polymer coating releases nitrogen based on the two requirements for crop growth: soil moisture and temperature (Fig. 4). Moisture creates a nitrogen solution inside the coating. This then moves through the coating at a rate based on soil temperature. The release of nitrogen increases as soil temperatures rises and, conversely, the rate of nitrogen release slows when the soil cools or is cold. The positive correlation between soil temperature and nitrogen release from ESN® also matches rising crop demand for nitrogen as, similarly, plant growth also increases as soils become warmer. ■

Fig 4: **Schematic showing how polymer-coated urea functions in the field[4]. Nitrogen release rate (far right) is dictated by soil temperature. The warmer the soil, the faster the release rate.**



Source: Nutrien (2024)

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Boosting UAN efficiency with inhibitors

Urease and nitrification inhibitors are cost efficient and easy to implement solutions for improving the nitrogen use efficiency (NUE) of urea ammonium nitrate (UAN). The use of inhibitors enables farmers to substantially reduce nitrogen losses and achieve their environmental targets, explains **Thomas Profitt**, Syensqo's Global Enhanced Efficiency Fertilizer Manager, while improving crop yields and generating a positive return on investment.

UAN – a major US and European nitrogen fertilizer

Urea ammonium nitrate (UAN) is a 20 million tonne global market (UAN 30 basis), representing 5.5 percent of total agricultural nitrogen use (Figure 1). Due to regional buying preferences, consumption is concentrated in North America and Europe, where UAN accounts for around 24 percent and 13 percent of agricultural nitrogen use, respectively.

UAN contains three different types of nitrogen with:

- 50 percent in ureic form
- 25 percent in nitrate form
- 25 percent in ammonium form.

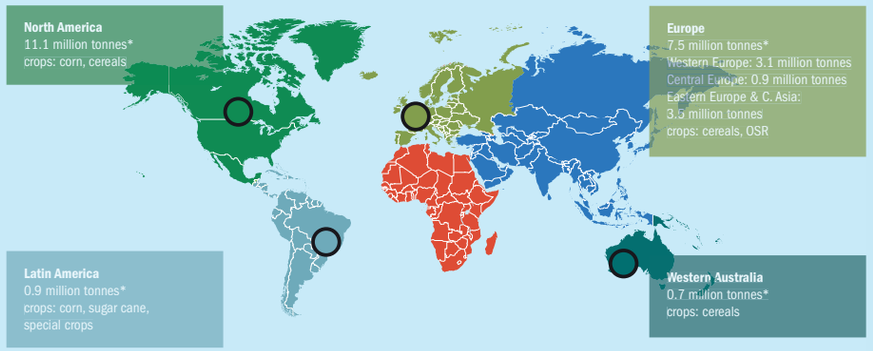
Three main UAN grades are produced – UAN 32, UAN 30 and UAN 28 – reflecting their nitrogen content of 32 percent, 30 percent and 28 percent, respectively (Table 1). UAN is generally traded and shipped as the more highly concentrated UAN 32 and then diluted at the destination port to generate UAN 30 or UAN 28, the exact choice of product being determined by the severity of winter conditions and the need to prevent freezing during farm storage.

Table 1: **Properties of the three main UAN grades**

	Nitrogen content (% w/w)	Density at 16°C (g/cm³)	Freezing point (°C)
UAN 28	28	1.28	-18
UAN 30	30	1.30	-9
UAN 32	32	1.33	0

Source: Syensqo

Fig 1: **Global UAN consumption* by region and crop**



Source: IFA (2021) **UAN 30 equivalent*

UAN is often blended with ammonium thiosulphate (ATS) or ammonium sulphate (AS) to create the popular liquid NS blends that are typically applied to cereals and oilseed rape.

UAN production is mainly located in the United States, Russia, Trinidad, Egypt and eastern Europe. The price of UAN 30 has varied widely over the past four years, rising from €160/t in 2020 to €700/t in 2022 before falling back to around €220/t at port currently.

Why do farmers prefer UAN?

UAN is often one of the first input purchases made by farmers during the growing season, typically costing over €150/ha for a nitrogen application rate of 200 kg/ha. For farmers, the main perceived benefits of UAN – thanks to its liquid form – are its simplicity in storage, handling and application.

The ability to use the same sprayer as other agrochemical applications along the same field track is also an advantage. Having a spray width of up to 48 metres with automatic GPS control gives farmers the necessary precision and enables night-time applications.

As farm sizes have expanded, with less labour and the narrowing of the ideal application window, farmers are increasingly forced to apply their fertilizer products in unfavourable weather conditions. This carries a significant risk of crop yield loss, wasted input costs and a poor return on investment.

Nitrogen use efficiency well below 100 percent

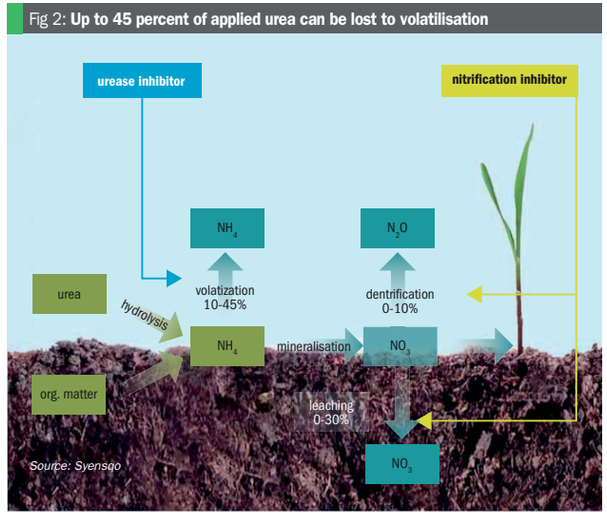
The urea content of UAN (50%) can be volatilised as ammonia and lost to the atmosphere (Figure 2). In dry conditions, with wind and a high pH, up to 45 percent of applied urea can be lost to the crop.

These volatilisation losses can, however, be drastically cut using urease inhibitors. In 2021, the addition of an NBPT urease inhibitor in four field trials in France, for example, reduced average nitrogen volatilisation from 10 percent to 2.5 percent, reducing nitrogen losses by a factor of four[1].

NBPT helps to slow the urease reaction in soils by acting as a competitive enzymatic inhibitor that delays the conversion of urea into ammonia (NH_3). This provides time for the urea to migrate from the surface and penetrate deeper into the soil profile, where NH_3 cannot volatilise when the conversion occurs.

Since 2023, the use of urease inhibitors with both UAN and urea has been compulsory in the UK for applications later than the 31st March[2].

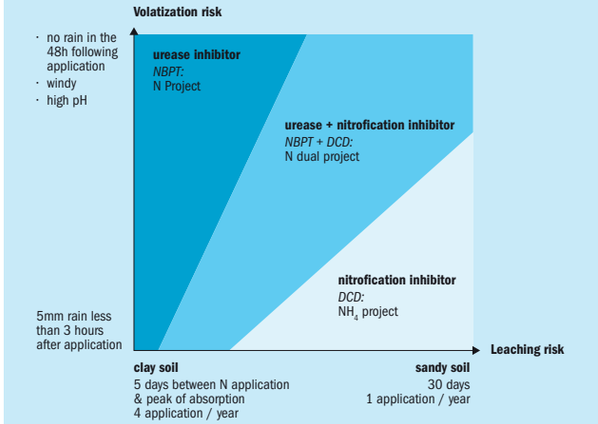
Fig 2: **Up to 45 percent of applied urea can be lost to volatilisation**



Up to 30 percent of nitrogen leached

Both the urea and nitrate forms of nitrogen are prone to leaching if significant rainfall occurs following application. Factors such as high application rates, the presence of sandy soils and infrequent fertilizer

Fig 3: **The AgRHO® N Protect range of urease and nitrification inhibitors can be customised for a wide range of soil and weather conditions**



Source: Syensqo

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Table 2: **Sensor tube volatilisation test results after six days: saturation times for different use rates of AgRHO® N Protect B with UAN (tubes 2-5) versus the control (UAN only, tube 1).**

Tube	1	2	3	4	5
Use rate	UAN only	AgRHO® N Protect B + UAN (0.7 l/m³)	AgRHO® N Protect B + UAN (1.0 l/m³)	AgRHO® N Protect B + UAN (1.35 l/m³)	AgRHO® N Protect B + UAN (1.7 l/m³)
NBPT (ppm)	0	202	289	390	491
Tube saturation (hours)	37	116	146	159	155

Source: Syensqo

applications – which result in a longer time interval between application and crop uptake – all increase the risk of leaching.

Soil bacteria convert the ammonium (NH_4) present in nitrogen fertilizers into the soluble nitrate (NO_3) form that is more prone to leaching – a process known as nitrification. The use effective nitrification inhibitor, such as Syensqo's AgRHO® NH_4 Protect, can therefore help prevent leaching.

AgRHO® NH_4 Protect is unique to the market as it contains the active ingredient DCD in a fully solubilised form. It has a 'bacteriostatic' action and functions by temporarily preventing nitrosomonas bacteria from multiplying on contact with nitrogen fertilizers. This reduces susceptibility to leaching by preserving NH_4 for longer and providing the plant with more gradual NO_3 nutrition. A reduction in nitrous oxide (N_2O) emissions is another benefit reported in the literature.

AgRHO® N Protect is part of range of urease and nitrification inhibitors from Syensqo that can be customised for a wide range of soil and weather conditions (Figure 3).

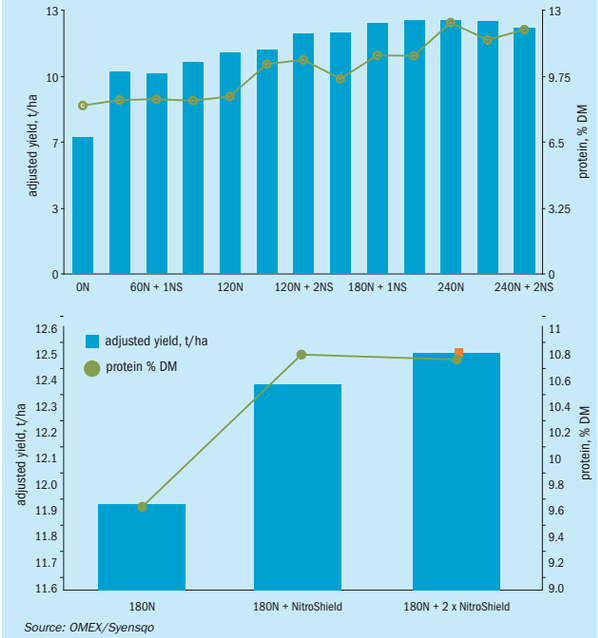
Using the AgRHO® N Protect urease inhibitor with UAN

AgRHO® N Protect is certified for the European market under regulation EU 2019/1009. Because its active NBPT ingredient is only stable for a few days when mixed with UAN, this inhibitor product is most commonly added by the farmer just before application from a canister. Advantageously, AgRHO® N Protect gives growers the flexibility in terms of when to select and where to use a urease inhibitor. Its use rate can also be adjusted for the volatilisation intensity.

For volatilisation, the degree of mitigation offered by AgRHO® N Protect is directly proportional to the concentration of active NBPT ingredient. A recommended use rate of 1.35 l/m³ for UAN 30 (equivalent to 390 ppm of NBPT per m³ of UAN 30) generally provides growers with the optimum cost/efficiency ratio.

The effects of NBPT dosage on volatilisation can be measured using sensor tubes, as shown by Table 2. Tube saturation is reached after 116 hours at half the recommended dose of NBPT (200 ppm), with this increasing to 156 hours at the full recommended dose (390 ppm). The full NBPT dosage therefore results in much greater inhibition of volatilisation versus the half use rate – the result being that more nitrogen will end up in the crop with less ending up in the environment.

Fig 4: **OMEX winter wheat trial Cambridgeshire, UK. The effects of AgRHO® N Protect® on yield and grain protein content (top). Improvements in wheat yield and grain protein content at the optimum nitrogen application rate of 180 kg/ha are also shown (bottom).**



Source: OMEX/Syensqo

Syensqo's partner OMEX, in association with Velcourt, carried out an AgRHO® N Protect® trial on winter wheat in Cambridgeshire in the UK. This demonstrated the field benefits and agronomic value of AgRHO® N Protect® by assessing the reduction in volatilisation losses from UAN applications at different times. Spring soil analysis indicated 50 kg N in the soil down to 60 centimetres.

The UK trial examined the yield response of winter wheat to UAN for two surface nitrogen applications. The protein content of the wheat, a quality parameter, was also measured. The effects of adding AgRHO® N Protect® to just one application (1N) or both applications (2N) were studied.

The optimum N application rate for the wheat crop at this UK field location was 180-200 kg/ha, based on the yield response curve (Figure 4). The addition of AgRHO® N Protect® at this optimum application rate (180kg N/ha) delivered significant yield benefits (+500 kg grain). Overall. incorporation of AgRHO® N Protect® as part of the full fertilization programme achieved +200 kg of additional grain yield.

UAN plus AgRHO® NH_4 Protect

Soil nitrification incubation tests were used to measure the effects of the nitrification inhibitor AgRHO® NH_4 Protect on the conversion of NH_4^+ into NO_3^- in a standard soil at 28°C. Results show that adding AgRHO® NH_4 Protect (5 l/m³) to UAN 30 doubled the time taken for nitrate conversion (200 kg N/ha threshold) to 28 days, versus 14 days for the untreated UAN 30 control (Figure 5).

To ensure its safety and efficiency, AgRHO® NH_4 Protect is registered in France under ANSES No 1170075 and No 021-1081 and in the wider EU market under regulation EU 2019/1009.

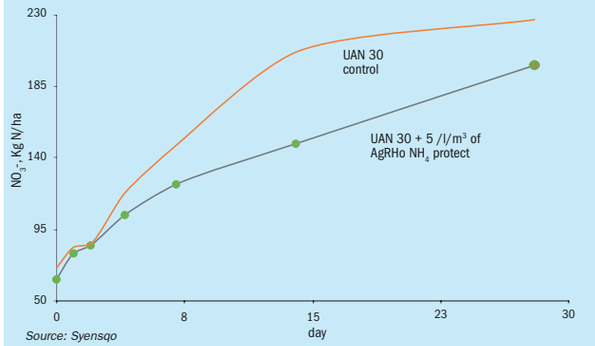
The additional benefits of adding AgRHO® NH_4 Protect to UAN were confirmed in five corn crop trials in the United States. In trials carried out at four sites in Illinois and one site in Indiana, the addition of this nitrification inhibitor delivered an average corn yield improvement of 0.7 t/ha versus the untreated UAN control (Figure 6).

Conclusions

Urease and nitrification inhibitors are effective technologies with a proven ability to increase nitrogen use efficiency (NUE), as shown by this article and demonstrated in numerous laboratory and field trials. The cost efficiency of these inhibitors offers farmers an unbeatable approach to reducing nitrogen losses (NH_3, NH_4 and N_2O) that typically generates a return on investment (ROI) of around 300 percent.

Syensqo's Dual Protect technology, by combining highly effective urease and nitrification inhibitors, is fast becoming the market reference product. ■

Fig 5: **Incubation test results showing the effects of the nitrification inhibitor AgRHO® NH_4 Protect on the nitrate conversion of UAN 30 in a standard soil at 28°C.**



Source: Syensqo

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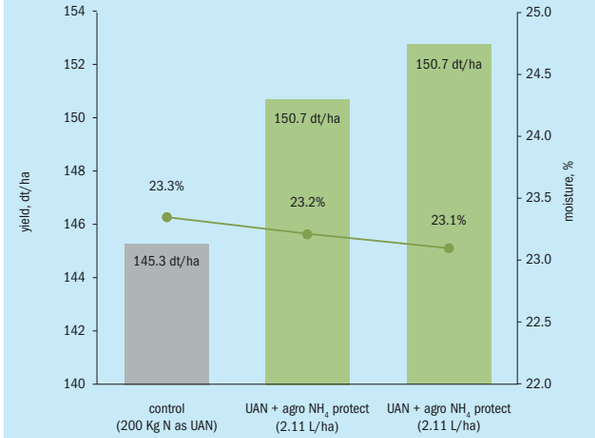
Fig 6: **The effects of adding the nitrification inhibitor AgRHO® NH_4 Protect to UAN on US corn yields. Average of four trials in Illinois and one trial in Indiana.**



Source: Syensqo *Note: dt/ha = decitonnes (0.1 tonnes) per hectare*

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One-stop shop for green fertilizer technologies

The need for immediate climate action and cuts in carbon emissions has never been more urgent, especially in a world where ecosystems are increasingly under threat. The production of green fertilizers offers a clear route to achieving these goals by decreasing the chemical industry's reliance on fossil fuels. Stamicarbon's **Carmen Perez**, **Rolf Postma** and **Nikolay Ketov** outline the company's innovative and integrated approach to green fertilizer technology.

Introduction

Combining ammonia production using renewable power with the most efficient fertilizer technology is a promising green production pathway. Indeed, Stamicarbon, the nitrogen technology licensor of MAIRE engineering group, believes this approach can improve agricultural sustainability and deliver humanity's food needs while preserving the planet for future generations. The company is actively contributing to the transition to green fertilizers by advancing a suite of technologies that can be integrated and customised to design energy-efficient, carbon-free production plants.

In this article, we will explore the innovative world of green fertilizer technology and examine its potential to revolutionise fertilizer production. We also highlight the synergies made possible when adopting a unified approach from a single technology licensor.

Green ammonia to fertilizers

Ammonia is produced on an enormous scale globally and plays a crucial role in fertilizer production. Achieving fertilizer industry climate goals will therefore depend on the sustainable synthesis of this fundamental basic chemical in future.

Currently, the reliance of ammonia production on fossil fuel feedstocks leads to large-scale greenhouse gas (GHG) emissions. Nonetheless, there is a viable route to a more sustainable ammonia industry.

The most promising pathway, in the view of many industry leaders and regulators globally, is the shift to green hydrogen and green ammonia production. The starting point for both these products is water electrolysis powered by renewable energy generated by wind, solar, geothermal or hydroelectric sources.

The electrolysis process, by splitting water into hydrogen and oxygen, provides a carbon-free feedstock for ammonia production. This production pathway, because it uses proven and readily-available technology, is increasingly being seen as one of the most practical routes for transitioning to carbon-free ammonia production.

Despite this, an immediate green ammonia transition on a global scale is not yet possible. This is primarily due to the limited availability and high cost of renewable electricity and other challenges such as a shortage of suitable electrolysers.

These factors have acted as a roadblock to change and have left pioneering green ammonia companies with many unanswered questions. This is especially true of market entrants wishing to develop 'power-to-X' plants – where the X refers to a range of potential final products. These can include fertilizers, fuels or an intermediate energy carrier used in transport and trading.

There are also additional technological challenges when adapting conventional ammonia production plants – originally designed to consume fossil fuels – to accommodate renewable feedstocks. Successful modification of these existing production assets will be crucial for the efficient and economically viable shift to green ammonia production. Managing the intermittent nature of renewable energy supply is another challenge, as the storage options for green electricity and green hydrogen are generally expensive.

Despite these hurdles, green ammonia technology can be a viable and practical option in certain markets and regions globally. In Stamicarbon's view, a shift to medium-scale sustainable fertilizer production, tailored to local needs, can be a practical first step toward a carbon-free future, especially in areas rich in renewable energy resources and with a high demand for fertilizer. This strategy promotes the sustainable agricultural use of fertilizers, supports global environmental goals by eliminating fossil fuel reliance, and can reduce a country's dependency on fertilizer imports.

Stamicarbon has introduced Stami Green Ammonia technology to address and overcome the technical challenges associated with carbon-free production. Green ammonia plants designed using this innovative technology can effectively handle the fluctuating nature of renewable energy sources while also offering lower capital expenditure (capex) and operational costs (opex).

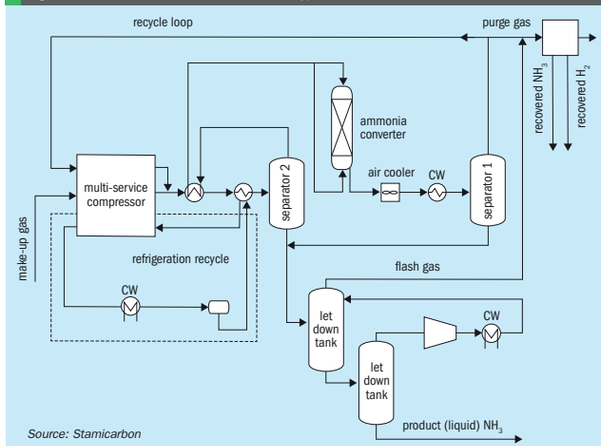
Features of Stami Green Ammonia design

Stamicarbon has developed a new market standard – focused on medium-scale production plants – to address the growing demand for sustainable ammonia. Stami Green Ammonia is based on a modified high-pressure ammonia synthesis loop operating at approximately 300 bar (Figure 1). This optimised layout is ideal for plants that rely on green feedstocks and have capacities ranging from 50-500 t/d.

Hydrogen and nitrogen make-up gas for the ammonia synthesis unit is generated from the upstream electrolysers and nitrogen generation unit. This is then compressed to a pressure of over 300 bar by an electrically-driven, multi-service reciprocating compressor. The same compressor is also responsible for recompressing the recycle stream containing unconverted gas and managing the refrigeration loop.

The high-pressure synthesis loop enables single-stage condensation of ammonia using cooling water. Eliminating the need for a dedicated refrigerating compressor, by minimising equipment requirements, delivers a 25-30 percent capex saving – an essential cost reduction given the absence of economies of scale for a plant of this size.

Fig. 1: **Stami Green Ammonia technology**



Source: Stamicarbon

More than 70 percent of ammonia is recovered in separator 1 with the remaining 30 percent condensed in separator 2. The second separator is placed upstream of the converter to protect the catalyst by condensing out contaminants (mainly water) from the make-up gas.

High-pressure conditions within the synthesis loop enable the use of a smaller reactor and a lower catalyst volume. A single-bed axial-flow ammonia converter with a tubular design is used. The feed is pre-heated to the temperature necessary for catalytic

Fig. 2: Computer generated 3D model of a Stamicarbon Green Ammonia plant

PHOTO: STAMICARBON

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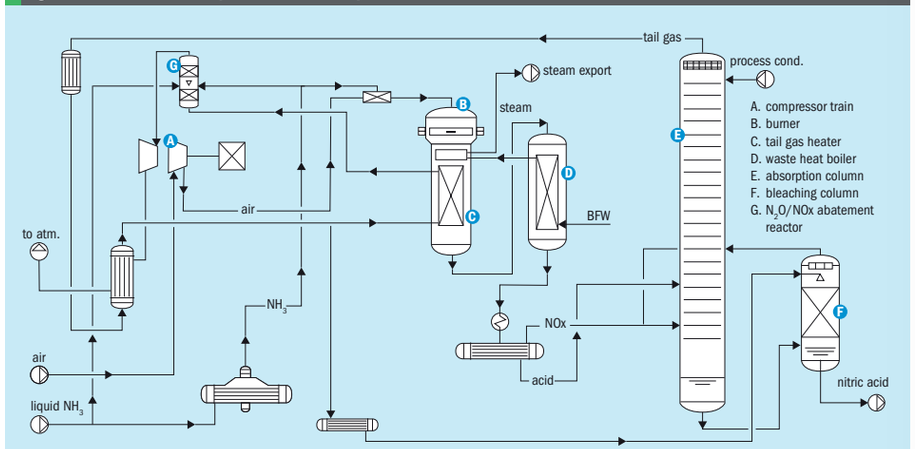
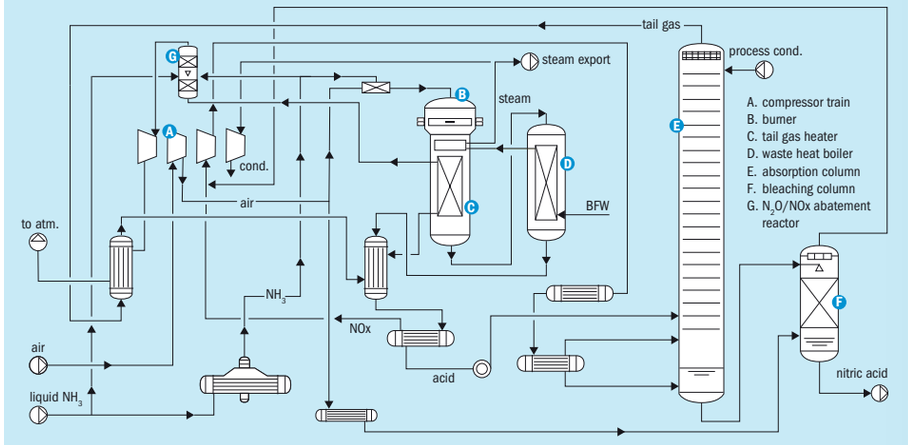
Fig. 3: **Stamicarbon's mono-pressure nitric acid process**



Source: Stamicarbon

Fig. 4: **Stamicarbon's dual-pressure nitric acid process**



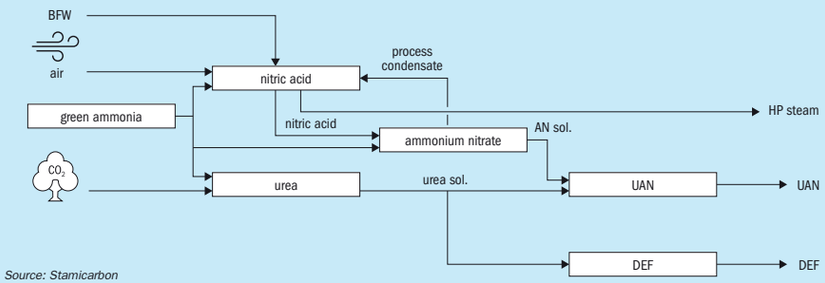
Source: Stamicarbon

activity by capturing heat from the exothermic ammonia synthesis reaction. A heater integrated within the ammonia converter is also used during start-up.

The green ammonia plant (Figure 2) uses between 25-250 MW of power, depending on its capacity. Plant footprint varies, being about 15x30 metres for smaller scale units with this increasing to 50x50 metres for larger scale units.

The plant can generate green ammonia for atmospheric storage at ambient pressure and a temperature of -33°C. Alternatively, ammonia can be produced under pressurised conditions (16–18 bar) at ambient temperature for storage or direct use in a downstream production plant.

Fig. 5: **Integration of green ammonia and nitric acid technologies**



Source: Stamicarbon

Stamicarbon's nitic acid process

When setting up a fertilizer plant, the goal is to optimise energy recovery while keeping investment costs low.

Stamicarbon's nitric acid technology offers high energy efficiency and reliable operation, being designed to minimise heat losses and maximise the recovery of heat from process streams. Greenhouse gas emissions are also minimal due to its tail gas treatment system.

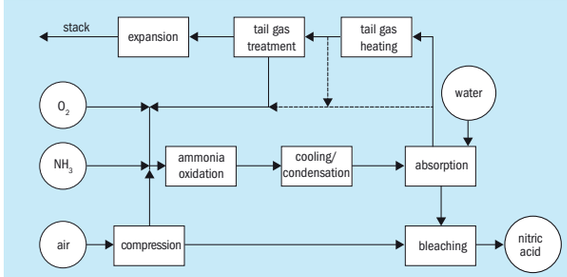
The technology, which has either a mono- or dual-pressure design, uses the Ostwald production process to convert ammonia to nitric acid in two steps:

- Step 1: The oxidation of ammonia (NH_3) to form nitric oxide (NO), which is further oxidized to nitrogen dioxide (NO_2)
- Step 2: The absorption of the nitrogen dioxide (NO_2) in water (H_2O) to form nitric acid (HNO_3).

In the mono-pressure process, oxidation and absorption sections operate at the same pressure level (Figure 3). The dual-pressure process, in contrast, by using different pressure levels in the oxidation (4-6 bar) and absorption sections (8-12 bar), combines the advantages of medium-pressure combustion with the efficiency of high-pressure absorption (Figure 4).

The standout feature of Stamicarbon's nitric acid technology is its exceptional steam generation capabilities. This adds significant value particularly under favourable pressure and temperature conditions. Overall, Stamicarbon's nitric acid plant design provides guarantees on: steam export, N_2O/NOx emissions, cooling water consumption, acid quality, and ammonia consumption.

Fig. 6: **Oxygen integration in nitric acid technology**



Source: Stamicarbon

Integration of technologies in a green fertilizer complex

A mono- or dual-pressure nitric acid plant can be integrated efficiently within a larger urea ammonium nitrate (UAN) production complex (Figure 5). The resulting green fertilizer complex can include a green ammonia plant, a nitric acid plant and other units such as a urea solution plant, an ammonium nitrate solution plant, and a UAN mixing plant.

Having a portfolio of technologies for green ammonia, urea, nitric acid and ammonium nitrate allows Stamicarbon to improve the integration of individual plants and make the complex more economically attractive.

Stamicarbon is continuously evaluating options for improving the integration of green ammonia and nitric acid technologies. One promising option involves integrating oxygen generated by water electrolysis and the nitrogen generation unit (Figure 1) into the nitric acid plant.

This can be accomplished in several ways. When the ammonia feed for the nitric acid plant is sourced from a green ammonia plant, for example, oxygen from the electrolysers could replace a portion of the air-supplied oxygen in the nitric acid process. The addition of air sourced from recirculated tail gas (Figure 6) would also be necessary to ensure that the ammonia and oxygen mixture upstream of the burner remains below the explosive limit.

Integration offers the following key advantages versus the standard nitric acid process:

- Recirculating a portion of the tail gas reduces emissions, with the total flow of NOx and N_2O released into the environment cut by about 40 percent.
- Catalyst demand is reduced due to the lower flow rate of the abatement system.
- A smaller cross-section reduces the total catalyst volume by up to 40 percent.

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- Use of a lower power compressor increases steam export by more than 30 percent.
- Capex is reduced thanks to the use of a smaller compressor unit and expander and the lower amount of catalyst used in abatement.
- The potential for increased conversion efficiency by looping NOx gases back into the reaction, via the burner, the bleacher, or both.

Capitalising on process integration

Integrating the oxygen stream into standard mono- or dual-pressure nitric acid technology can deliver capex and opex savings.

Opex benefits include the increase in steam export and lower N_2O emissions. N_2O reductions, when converted into their CO_2 equivalent, can deliver operational cost savings.

Overall, process integration, based on local prices and considering only the increase in steam export, can yield a cost reduction of more than $5/t of nitric acid, compared to the standard mono-pressure nitric acid concept. This is equivalent to an annual saving of more than one million US dollars for a 450 t/d nitric acid plant.

Additionally, carbon taxes are being introduced and carbon capture is being monetised in an increasing number of countries and regions. Because of this, the integrated process – by converting cuts to atmospheric N_2O emissions into CO_2 equivalents – could potentially deliver cost reductions for a 450 t/d nitric acid plant of more than one percent of total operational costs. The application of carbon taxes in more locations and at higher rates suggest operational costs could be reduced even further in future.

Overall, Stamicarbon's complete technology package for a green fertilizer complex is a competitive option for the local production of a high-value products and has significant potential in a carbon-free economy. Having a single licensor provide all of the technology for a green fertilizer complex can also streamline process integration, reduce emissions, simplify maintenance and – ultimately – maximise operational efficiency.

Conclusion

Supplying crop nutrients to meet rising global food demand, while simultaneously reducing the environmental impacts of fertilizer production, is a critical challenge. In response, the nitrogen fertilizer industry is developing and introducing new green technologies based on fossil-free feedstocks as part of the shift to towards more productive and sustainable agricultural systems.

Globally, major fertilizer industry players are already taking significant steps towards achieving this goal. The fertilizer industry's adoption of green technologies and practices is a strategic response to both the changing demands of global agriculture and rising environmental concerns.

Stamicarbon, as a single licensor for a green fertilizer complex integrating ammonia, urea, nitric acid, and ammonium nitrate production, is able to maximise process synergies by reducing capex, opex and the environmental footprint of plant operations.

Stamicarbon offers a combination of proven technologies with decades of experience in engineering and delivering integrated fertilizer units worldwide. As highlighted in this article, in sustainable fertilizer production, having one technology licensor covering the whole value chain offers multiple advantages. These include better process integration between different production units and improved energy efficiency. Having a single company responsible for a green fertilizer project is also simpler and can reduce project timescales.

Overall, this integrated approach will be an essential part of the industry's successful shift to sustainable fertilizer production and meeting the dual demands of higher agricultural productivity and environmental stewardship. ■

Case study: grassroots green fertilizer complex in Nebraska

In 2023, a prominent North American fertilizer producer awarded MAIRE group, through Stamicarbon, licensing and basic engineering design contracts for a 450 t/d capacity green ammonia plant in Gothenburg, Nebraska.

This milestone contract was secured thanks to the capabilities of two MAIRE business units: Sustainable Technology Solutions led by NEXTCHEM and Integrated Engineering & Construction Solutions through KT-Kinetics Technology. Tecnimont USA's knowledge of the local supply chain and construction market was also a key factor that helped secure this award.

The Gothenburg fertilizer complex will be the first to use Stami Green Ammonia technology for nitrogen fertilizer production from renewable feedstocks. It is expected to start up in 2026. Additionally, the complex will be the first to integrate Stamicarbon's technologies for urea, nitric acid and ammonium nitrate.

The design package for the fertilizer complex includes a 450 t/d capacity green ammonia plant and a 330 t/d capacity nitric acid plant. This will be integrated with a urea section, neutralisation section and UAN mixing section. The nitric acid plant will operate at a constant pressure of eight bar, combining the absorption and bleaching operations in a single piece of equipment. In addition, all the high-pressure steam generated by the nitric acid plant will be exported and used in other sections of the fertilizer complex due to the absence of a steam turbine.

Once operational, the Gothenburg complex will diversify fertilizer production in the Western Corn Belt while having a negative carbon footprint. The plant will consume CO_2 waste from other production facilities in the region, combine wastewater with groundwater, and use electricity from renewable sources to produce cleaner fertilizers and chemical products.

The facility, by leveraging locally produced renewable energy, has impressive projected annual production outputs. These include 365,000 tons of urea ammonium nitrate (UAN) and 146,000 tons of ammonium thiosulphate (ATS). Additionally, the plant will produce 20 million gallons of diesel exhaust fluid (DEF) annually to supply heavy-trucks in the region.

This project case study is a practical example of how an integrated production complex can incorporate key units based on Stamicarbon technology – for green ammonia, urea, nitric acid, ammonium nitrate and DEF. This one-stop shop approach optimises plant operations and achieves the lowest possible emissions, along with a high level of integration for utilities. ■

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phosphates & potash INSIGHT

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Polyhalite: a future facing fertilizer for a changing world

PHOTO: ANGLO AMERICAN

After more than three years in the role, Dr Alexander Schmitt, Chief Marketing Officer, Anglo American Crop Nutrients, says he has never met an agronomist who is not excited by polyhalite – or met a farmer who is not intrigued by its potential

Fertilizers will always be fundamental to food production, but they will also have to be low emissions, environmentally friendly and support healthy soils. In this article, **Dr Alexander Schmitt**, Chief Marketing Officer, Anglo American Crop Nutrients, explains how polyhalite meets all three of these criteria – while also helping to increase the quantity and quality of food a farmer can produce.

Introduction

Agriculture is facing a significant challenge: how to grow more food to feed more people, while combatting climate change, and healing the world's largely damaged soils. The agricultural practices of the past are not sustainable solutions for the future.

This is why Anglo American is investing in the Woodsmith Project, which has the potential to redefine perceptions of mining in the 21st century, thanks to its minimal surface imprint and low environmental impact design.

Woodsmith will be nearly invisible from the surface with all ore mined and conveyed underground to the port via a 37 kilometre tunnel, the longest tunnel on mainland UK. What will be the deepest mine in Europe – at 1,600 metres – will blend into the landscape, while protecting and enhancing the surrounding biodiversity, and helping support and develop a thriving local community.

The changing face of farming

In order to fully understand the size of the market for polyhalite – and our cornerstone granular product POLY4 – it is important to understand the changes facing agriculture, the nature of the mineral, and the commitment, planning and experience that Anglo American is applying to the development of our Crop Nutrients business.

The first reason that we have confidence in polyhalite is that farming is changing: Sustainable farming practices are increasing; food companies are adopting ambitious environmental performance targets; emissions and nutrient pollution restrictions are tightening; and governments are incentivising more sustainable practices. Soil health is being discussed in Brussels, Washington, Beijing and beyond – evidence that the ground is shifting for agriculture and a sign that the way fertilizers were used in the past will not be the same in the future.

By one estimate, the world has lost a third of its arable land due to erosion or pollution in the past 40 years, in part due to fertilizer misuse. Fertilizers will always be fundamental to food production, but they will also have to be low emissions, environmentally friendly and support healthy soils.

Unlike many legacy products, polyhalite meets all three of these criteria while also helping to increase the quantity and quality of food a farmer can produce.

Improving farming practices in this way will be crucial if we are to succeed in meeting an expected 50 percent increase in demand for food by 2050 without harming the planet.

Polyhalite is not potash

This means that new solutions and products must be brought to market – we cannot keep relying on the very tools that have helped to cause the problem. One of the common misconceptions encountered around polyhalite is that it must be akin to potash. This is far from true. The nutrient with the highest content in polyhalite is sulphur, followed by calcium, potassium and magnesium.

Historically, sulphur has been undersupplied and underappreciated compared to nitrogen, phosphorus and potassium (see page 20), but it is now recognised as an essential component of the biological processes involved in crop growth, such as the metabolism of nitrogen (increasing nutrient efficiency) and protein production. Previously deposited on soils from the atmosphere due to acid rain, successful air pollution controls have had the unintended effect of reducing farmers' access to this vital nutrient.

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However, the key difference between polyhalite, versus potash and other legacy mass market mineral fertilizers, is its naturally-occurring multi-nutrient make up. By providing multiple nutrients in one efficient natural product at a global scale, POLY4 will enable more farmers to supply their crops with a more balanced and nutritious diet. This leads to stronger, healthier and more productive crops, thus delivering tangible positive impacts for farmers.

Doing our research

The final reason we remain confident in polyhalite is the huge amount of research, trials, customer engagement and commercial development we have been undertaking. We have conducted over 1,900 commercial demonstrations in over 40 countries across over 90 crops, expanded the marketing team significantly, and built on the existing five major distribution partner contracts with numerous market development agreements, and devised a comprehensive downstream engagement strategy to prepare the agricultural world for polyhalite.

To date, we have engaged with over 350 distributors, retailers, co-operatives, blenders and manufacturers, and conducted over 500 engagements with universities, NGOs, global research institutions, media, and membership associations.

Preparing the market

In the three and a half years in my role, I have never met an agronomist who is not excited by polyhalite, nor a farmer who is not intrigued by its potential. There is no denying we have a lot of work ahead of us in convincing farmers to use polyhalite. But we are already well underway and our confidence in our ability to carve out a market for the first new globally scalable mineral fertilizer in 75 years has only increased.

As a natural, low-carbon product, POLY4 will help enable a transition to the soil-nourishing and environmentally-friendly fertilizer practices that are required at scale.

Farming is changing and farmers need new solutions; with POLY4, Anglo American is well positioned to help address that need. ■

PHOTO: ANGLO AMERICAN

The under-construction Woodsmith polyhalite mine in the UK.

PHOTO: ANGLO AMERICAN

Soybean sprout.

ORGANIC CERTIFICATION

Anglo American's multi-nutrient polyhalite fertilizer POLY4 is now organically certified in more than 30 regions globally. The most recent certification from the California Department of Food and Agriculture (CDFA), announced in April, is another important step in the development of a global premium market for polyhalite, according to the company.

POLY4 has already been recognised by eight organic certification bodies around the world. These include the international Ecocert scheme, as well as similar schemes in the US, Canada, the UK, Germany, Netherlands and other parts of Europe.

POLY4 is suitable for both traditional and organic farming systems. Globally, Anglo American has completed almost 1,900 commercial field trials with the product in 43 countries across 90 crops.

Tom McCulley, CEO of Anglo American Crop Nutrients, said: "Farming is changing for the better. The agricultural practices of the past need to evolve urgently towards sustainable solutions for the future. Polyhalite ticks a lot of boxes for the future of food production, being well suited to more balanced crop nutrition solutions that can help to improve yields while supporting soil health and reducing harm to the environment. California is a state that is supporting this critical transition by expanding climate smart agriculture through regenerative farming.

"The organic certification in California is particularly important given the state is the largest producer and consumer of organic products in the USA and grows over a third of the country's vegetables and nearly three-quarters of the country's fruits and nuts. Our POLY4 product is particularly well suited to such high value crops, enhancing both yield and quality, so representing significant additional value to farmers." ■

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PHOTO: CRU

CRU Phosphates 2024

More than 370 delegates from over 150 companies and 40 countries gathered at the Hilton Warsaw City Hotel, Warsaw, Poland, 26-28 February, for CRU's Phosphates 2024 conference.

This year's presentation programme proved highly popular with some sessions standing room only.

We report on selected keynote and commercial presentations given at CRU's 16th Phosphates International Conference and Exhibition held in Warsaw in February.

Additions to the team

Nicola Coslett, the CEO of CRU Events, opened the event by welcoming delegates to Warsaw for the first time:

"Welcome to the 16th edition of CRU's Phosphate Conference. For those of you who are new to the event, welcome to the phosphates community, and we are happy you have joined us this year in the beautiful city of Warsaw. It's the first time in my 15 years at CRU we've run the event in Poland.

"We're delighted to announce we have over 370 people in attendance, including 70 speakers, 50 exhibitors, and 100 operators joining us this year. And with an excellent programme planned over the next few days, with both commercial and technical presentations, many thanks to all our speakers for their contributions.

"CRU is excited to announce the recent acquisition of *Fertilizer International* and its two sister publications – adding **Simon Inglethorpe** and colleagues – with this expanding our technical expertise alongside our unrivalled team of 30 dedicated and highly experienced fertilizer analysts.

"This will enhance CRU's ability to deliver more comprehensive and insightful information to you, our clients. And with so many new entrants into ammonia, phosphate, and the fertilizer industries, the need for technical knowledge and insights has never been more important."

Prices at the crossroads

"We find [phosphate] prices at something of a crossroads, currently, with supply and demand factors ultimately cancelling each other out." That was the opening message from CRU's **Humphrey Knight** in the conference's keynote market outlook presentation.

"What we've seen over the last six months is this unusual situation where many prices have essentially flatlined … [with] some major phosphate import and export benchmarks essentially running at more or less the same level, around $600 per tonne. That's really unusual behaviour.

"So, what's going on in phosphate prices – they are behaving very differently to other parts of the fertilizer sector. Nitrogen and potash prices have, broadly speaking, faced downwards pressure over the past six months. Consequently, DAP and MAP prices find themselves significant outliers in the global fertilizer market."

On the demand side, crop prices are key, said Knight. While these have been elevated for much of the last four years, due to tight supply, decline has now set in.

"When we talk about fertilizer demand, we have to consider crop prices first and foremost – particularly the prices of key fertilizer consuming products such as corn, soybean and wheat. Many crop prices are now getting close to levels we haven't seen since early 2020.

"Essentially, crop prices are coming down because there is a consensus that the tight supply situation is going to change and come to an end this year. Consequently, there is a relatively muted and bearish overall outlook for crop prices over the rest of 2024."

Yet, against this weakening demand backdrop, phosphate prices remained stubbornly high in early 2024 – resulting in deteriorating affordability. This has affected the US in particular and has also seen Brazil's barter ratio (i.e., the number of 60 kg soy/corn bags needed to purchase one tonne of fertilizer) slide into unfavourable territory.

While affordability is likely to remain a headwind in the year's first half, CRU believes global phosphate fertilizer demand will rise in 2024 by around two percent year-on-year, driven by Brazil and the US, with the weakness in Asian demand set to continue.

"Yes, affordability is very challenging, but there is one caveat – inventories in key consuming markets such as India and Brazil are pretty low," said Knight. "This implies that replenishment is required and demand is coming down the road over the next few months."

But it is the supply side of the market that really explains anomalously high DAP and MAP prices, suggested Knight:

"If we really want to understand why phosphate prices find themselves at these elevated levels, very different to those of nitrogen and potash, we have to look at the supply side of the equation, and particularly China and Morocco, the world's two largest DAP and MAP exporters. Supply from both has become limited, albeit for very different reasons."

Morocco's DAP and MAP exports, for example, having peaked at 8.0 million tonnes in 2020, declined over the next two years to a low of 6.3 million tonnes in 2022. Subsequently, an upturn in volumes last year saw Moroccan exports partially recover to 7.0 million tonnes in 2023 – with volumes potentially reaching 8.2 million tonnes this year.

China's government, meanwhile, has become increasingly interventionist, implementing periodic export restrictions on DAP and MAP since late 2021. These restrictions were initially put in place response to very high international prices – and resulted in a halving of DAP/MAP exports from China in 2022. The subsequent easing of restrictions last year saw exports of these recover by 25 percent year-on-year.

"I think if you are looking for one single event behind what has happened in phosphate pricing, and why it's so different to nitrogen and potash, it is this situation in China, ultimately," said Knight. "That's the main thing to take away."

On balance, CRU expects DAP and MAP prices to gradually fall over the next six months [March-August 2024].

"CRU's view is that challenging affordability, the weak demand situation we find ourselves in, and unsupportive raw materials, will finally begin to bite and outweigh those supply issues," said Knight. "Admittedly, we also take a view that supply limitations will ease through 2024 – but I accept there is significant risk attached to that."

In terms of what to watch for in 2024, Knight highlighted the shipping disruption from Houthi attacks – with phosphate rock and phosphoric acid exports from Red Sea ports (c.11.0 million tonnes combined) being particularly vulnerable. A deepening Middle East conflict could create more serious fertilizer market risks, suggested Knight, given the region's status as a major global supplier.

Another development to watch out for this year is a US court ruling on the future of countervailing duties (CVDs). These duties have drastically cut Moroccan and Russian phosphate fertilizer imports into the United States since 2021. Current US price premiums (e.g., MAP f.o.b. NOLA) could end if CVDs were slashed or ended, a development that could also herald the large-scale return of Russian and Moroccan product to the US market.

"This one single issue alone [CVDs] could result in significant disruptions or changes to trade flows and major changes to phosphate pricing dynamics," said Knight. "So potentially really worth keeping an eye on."

Overall, Knight's key takeaways were:

- **In the short-term, prices to fall as poor affordability finally bites.** Supply limitations set to ease in 2024 with demand returning due to stock replenishment.
- **Over the medium-term, an elevated cost floor and high capacity utilisation to support prices out to 2028.** Phosphate fertilizer pricing will also be increasingly driven by national policies and corporate strategies.
- **Lithium iron phosphate (LFP) demand is set to inject growth into the still niche specialty phosphate sector.**
- **The phosphate rock market is vulnerable to near-term disruption to dry bulk freight.** A quarter to one-third of global merchant rock trade comes out of Red Sea ports.

Phosphorus and the future of farming

In this well received presentation, Nutrien's **Karl Wyant** placed phosphorus – and phosphate fertilizers – at the centre of faming and the food system.

Improving phosphorus use efficiency was highlighted as a major challenge.

In a perfect world, 100 percent of phosphorus applied via fertilizers will go into the crop to drive yields. But, in practice, the efficiency of phosphorus fertilizers is typically between 5-30 percent, noted Wyant:

"Phosphorus is plagued because it's so reactive in the soil. On the low side, it can be five percent efficient on high-pH, high-calcium soils. We can push efficiency to about 30 percent with some formulations pushing this higher to 40-50 percent."

Innovation in fertilizer formulations and precision technology were part of the answer, in Wyant's view:

"What we can do is take the familiar and take the new to drive a new version of fertilizer. And those new versions of fertilizers, their promise is improved efficiency.

"Nutrient has worked on this in our innovation pipeline. We took our MAP and added micronised sulphur. Now we have a specialised phosphorus product [Smart Nutrition MAP+MST] that contains sulphur – and we can drive efficiency with it."

PHOTO: CRU

The informative and witty talk by Karl Wyant, Nutrien's Director of Agronomy, on the future of farming was a Warsaw conference highlight.

Precision technology is also driving more efficient phosphorus use.

"In the last 15 years, the world has come a long way with affordable and accessible technology becoming available to help growers make decisions," said Wyant. "We can choose the right formulation and actually drive our application rates, our recommendations, off real-world data."

The adoption of variable rate application technology (VRT) has been one notable trend, said Wyant:

"In the United States, we started to see an upward trend in adoption of variable rate technology in about 2003, with corn leading the way. What I mean by variable rate is having a full map of the soil nutrient conditions on the field – so you can actually put more fertilizer where you need it and less fertilizer where you don't."

Much greater adoption of VRT, in turn, has spurred demand for soil analysis. Indeed, soil sampling and analysis in the United States has grown exponentially, during the last 15-20 years, increasing from around three million samples tested in 2003 to more than 10 million samples each year currently.

"Cheaper soil samples, faster throughput, means you can do a lot more with the data. So soil sampling just keeps growing," observed Wyant.

Regenerative agriculture is also becoming a more central focus for growers, in Wyant's view:

"If you haven't heard of regenerative ag, it's a movement that's focusing on improving soil health and soil carbon

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sequestration. That's something that, as an industry, we're going to have to understand – how does phosphate drive carbon sequestration, how does phosphate drive soil health outcomes, and how does phosphate relate to what's left over: crop residues."

Wyant described these leftover farm residues as 'crop trash':

"We're seeing more crop trash left over, and cover crop trash, so there's a value there for phosphate – we published an article on this with *Fertilizer International* [516, p30]. There's about 50 kilograms per hectare of phosphate just left in corn residue, just sitting on the field."

Such residues have both nutrient and monetary value that, ideally, should be captured instead of being neglected.

"If we're going down this regenerative pathway, the nice chunk of money in the phosphate is an incentive to figure out how we make sure that's accounted for across our financial budgets and nutrient budgets in the field," said Wyant.

Wyant closed by saying a bond of trust was necessary between all those with a stake in food production, especially from the industry's ultimate customers – food consumers:

"Remember, here at the top of this food system, we're all consumers. Having trust across the different players and partners is important in making sure that our future as an industry – not just the farming side but also industrial and feed markets – is secure and we have that social license to operate."

Biological demand for phosphorus, and its necessary presence in the diet of animals and humans, also needs to be more widely known, Wyant suggested. That includes the role of phosphorus in bones, in the phospholipids that encloses all plant and animal cell membranes, in the ATP that powers biological work, as well as the phosphorus that binds DNA.

This requirement for phosphorus, from plants, animals and humans, is fundamental and ever present.

"My final closing point is, wherever you need phosphorus, in bones, DNA and ATP, biological demand remains the same," summed up Wyant.

The specialty phosphate outlook

CRU's **Mauricio Fortuna** unveiled the exciting new findings from the recently published specialty phosphates market report. This covers:

- **Core specialty phosphates:** purified wet-process phosphoric acid (PPA) / thermal process acid (TPA), technical monoammonium phosphate (tMAP), and lithium iron phosphate (LFP) and lithium manganese iron phosphate (LMFP) collectively categorised as LxFP.
- **Niche specialty phosphates:** sodium tripolyphosphate (STPP), elemental phosphorus (P_4) and superphosphoric acid (SPA).
- **Animal-feed phosphates:** dicalcium phosphate (DCP) and monocalcium phosphate (MCP) / monodicalcium phosphate (MDCP).

The report's outcome, particularly for the LxFP segment – where CRU's view of demand has tripled since its previous estimate – were extraordinary, as Fortuna explained:

"Over the past few months, I've been working on our specialty phosphates report, which covers not just LFP, but other phosphate niches like elemental phosphorous, STPP and animal feed. And I'm quite excited to share some of the conclusions I've come to. Some of the numbers are truly remarkable. Extraordinary amounts of growth fuelled by this new and exciting industry."

Less spectacularly, the outlook for niche specialty phosphates and animal feed phosphates was characterised by a mix of decline, stagnation or stable recovery, Fortuna said:

"The story for niche specialty products is important, but perhaps less exciting. In animal feed phosphate, we do see a recovery following a falloff in 2022. But it is going to be a stable and steady recovery, not a story of dramatic growth in the foreseeable future.

"In other niche specialty markets, STPP most notably, we're seeing a decline. And in niche markets like P_4 and SPA, we foresee either a stagnant or a gently rising market."

While rapid LxFP demand growth was attracting a lot of interest, there was a need to keep this in perspective, Fortuna cautioned.

"The most interesting part of this story is the extraordinary growth in the LFP demand over the next few years in our forecast just out for 2028. If we consider it out to 2035, that growth keeps going.

"With that said, it's important to note that, even with this extraordinary amount of [LxFP demand] growth, that's only going to be a few percent of demand compared to fertilizer products. It's worth keeping in mind that fertilizer is still going to be the most important market for this industry."

The projected rise in the use of LxFPs in the cathodes of electric batteries was driving this grow, explained Fortuna:

"Our batteries team sees quite an aggressive growth in cathode active material [CAM] demand with total growth multiplying by seven or eight times by 2035. Although LFPs are somewhat new to the market, we do expect them to be the dominant cathodic material during this growth, accounting for about half of the total demand in the next decade."

China's continuing dominance of CAMs, and therefore PWA/TPA and tMAP production for the LxFP market, was Fortuna's key message: "My one takeaway from this entire presentation is that China is going to absolutely dominate this market in the medium-term," he said.

Almost all LxFP growth in the next 5-7 years is going to be focused on China, in CRU's view.

"On capacity, I have to emphasise how much this is a China-centred growth story – at least in the medium term," said Fortuna. "Although we do know of a few [LxFP CAM] projects in the United States, in Morocco, in Chile, they completely shrink in comparison to the projects in China."

The other key takeaways from the presentation were:

- The use of PWA and tMAP inputs in LxFP cathodes is strengthening.
- The production of cathode materials far outpaces downstream demand.
- Cost is the main determinant for phosphate rock selection and deciding whether to consume high grade rock with low impurities or to spend more on the beneficiation of lower grade rock instead.

LFP battery value chain – unlocking growth

In a companion presentation, CRU's **Sam Adham** discussed how the phosphates industry could unlock growth from the strongly growing LFP battery market and its value chain.

Echoing Mauricio Fortuna in the previous presentation, Adham said China is massively over producing LxFP cathode active materials (CAMs) – 1.6 million tonnes in 2023 versus demand of 0.8 million tonnes

PHOTO: CRU

Panel discussion on phosphorus recovery moderated by Robert Van Spingelen, President, ESSP (far left) with (from left to right) Laia Llenas Argelaguet, Deputy Director, BETA Technological Center, Marzena Smol, Head of Division, Mineral & Energy Economy Research Institute, Sara Stiernstrom, Product Manager, EasyMining, Marc Sonveaux, Head of Industrialization, Prayon Technologies, Lucas van der Saag, Process Engineer, ICL Fertilizers.

– and LFP battery cells. The country has also drastically cut production costs.

"Chinese companies have got LFP battery costs down to an art," said Adham. "They've already minimised processing and labour costs – so now the cost of LFP is really down to the price of lithium."

Insufficient CAM supply outside of China, said Adham, is acting as a barrier to LxFP uptake and cost reduction elsewhere. Also, until recently, LxFP CAM investments outside of China were mostly limited to small start-ups, with these lacking know-how and therefore having little chance of securing large supply contracts with major automakers.

This situation is now changing, however, thanks to the US Inflation Reduction Act (IRA).

"The Act offers very generous tax credits for companies producing critical minerals, battery components and EVs sold in the US, as long as the sourcing requirements for these critical minerals and battery components are being met," said Adham. "It's the latter requirement that has spurred a wave of [LxFP CAM] investments outside of China."

South Korea – which has the second largest industrial base for electric batteries after China – in collaboration with the US is spearheading the move into LFP/LMFP, said Adham:

"Most of these [investments] are linked to the US supply chain, most of them are in countries that have free trade agreements with the US, and most of them involve South Korean and Chinese companies. The upshot is that there's now a viable path outside of China for LFP cathode battery supply to develop sufficiently, to meet international demand."

Summing up, Adham said: "The takeaway is that LFP has and will continue to be a major chunk of demand for batteries, and it is the scale-up of that supply chain outside of China that will continue to unlock further growth, with much of that depending on favourable policies."

Specialty market – challenges and opportunities

ICL's **Juan von Gernet** took a deep dive into the broader specialty fertilizer market – illuminating what he described as an opaque industry where good data is hard to come by.

Even coming up with an agreed definition for specialties is problematic, as von Gernet explained:

"Defining what are specialty fertilizers, ironically, is a really difficult question to answer. Everybody has their own opinion of what the definition should be, so you get lots of contrasting opinions.

"Different companies and marketers also offer different products within their specialty baskets. What I've done is come up with my own definition – which is our product portfolio."

ICL's portfolio includes straights, micronutrients, semi-specialty products, blends, biostimulants and controlled-release fertilizers (CRFs). Based on that mixed basket, specialty products collectively provide a global market with a volume of between 20-25 million t/a and a value of $18-24 billion, said von Gernet, depending on the year.

Although slippery to define, specialty products are functionally similar.

"[They're] fertilizers formulated to address the specific needs of the plant, the soil, the prevailing application conditions," said von Gernet. "While also allowing for increased nutrient uptake and reduced losses to the environment."

One of ICL's prized semi-specialty products is potassium magnesium sulphate (SOPM), or rather the mineral polyhalite, a calcium-rich variant marketed by ICL under the Polysulphate brand.

"Global [SOPM] demand is around three million tonnes annually. Production is concentrated in the US, Germany, the UK. I was actually down the [UK] Boulby mine, 1.4 kilometres underground in the North Sea, just a couple of weeks ago.

"Boulby is where ICL produces and markets Polysulphate – potassium magnesium sulphate with a fair amount of calcium in it – a product close to our hearts. What's cool about Polysulphate is that it has a very low carbon footprint in comparison to other fertilizers and can also be used in organic farming."

Juan ended his presentation by highlighting underlying drivers (regulations, energy pricing, the battery boom, climate, soil, land and water availability, value, margins, competition etc.) and assessing the mix of market opportunities versus challenges/risks for these. He concluded that:

- **Trade restrictions, Covid-19, energy prices, sustainability and margin potential** have all affected the specialty market in recent years.
- **Consumer pressures and the regulatory drive for better sustainability** will act to spur demand growth in future.
- Looking ahead, **ICL expects specialty market growth above five percent p.a.** – which will attract further interest in the segment and ultimately lead to more intense competition.

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- Importantly, while many players are broadening their specialty portfolios, **no single company can offer a complete basket of 'core' products** – suggesting that a fair amount of **industry consolidation** is likely in coming years.

An integrated phosphate ecosystem

Marc Sonveaux of Prayon Technologies set out the company's vision of a sustainable phosphates industry. At the heart of this was an integrated 'ecosystem' based on four Prayon processes:

- GetMoreP
- Ecophos
- Prayon Ecophos Loop Process (PELP)
- Mg Leaching.

Collectively, these processes can take currently unusable low grade phosphate rock (including tailings) and secondary phosphate sources (sewage sludge ash, bone ash, spent acids, solid residues) and transform these into a range of valuable phosphate products (DCP animal feed, DCP super rock, phosphoric acid) and co-products ('eco' gypsum, pure calcium chloride, Al/Fe chlorides).

"We have the GetMoreP process based on sulphuric acid and the EcoPhos process using hydrochloric acid," said Sonveaux. "We also have the PELP technology for fly ash and the brand new Mg leaching process presented at this conference."

The PELP process can produce purified technical phosphoric acid, while dicalcium phosphate (DCP) – so-called 'super rock' – is generated by other process routes.

"This DCP, what we call super rock, can be used to replace very high-quality phosphate rock [as a feedstock]," said Sonveaux. "In the phosphate industry, if you replace natural rock phosphate with DCP super rock, you generate more concentrated phosphoric acid and less but cleaner gypsum that can be valorised in the plaster or cement industry."

Prayon describes PELP as an "outstanding technology for phosphate recycling" from sewage sludge ash (SSA). The technology, which has been validated at pilot-scale, recovers 96-98 percent of phosphorus from SSA while removing up to 99 percent of the impurities present.

"With PELP technology, sewage sludge ash is dissolved in phosphoric acid and then filtered to remove the impurities and insoluble part of the ash, explained Sonveaux. "Then we have three specific stages of ion exchange, to remove calcium/magnesium, iron, and aluminium, and [finally] we have phosphoric acid concentration."

Sonveaux summed up Prayon's three overall aims on sustainability:

"Firstly, as a producer, we try to use secondary phosphate sources in our production plants as much as possible. Secondly, as a technology supplier, we are developing processes that optimise phosphorus use and bring high value to secondary phosphates. Thirdly, as a commercial partner, we hep generate value from the selling of products derived from secondary sources."

The PuraLoop recycling process

Lucas van der Saag explained how ICL is delivering on its objective to develop a portfolio of fertilizers based on recycled sources of phosphorus. The company has developed an innovative process known as PuraLoop to transform sewage sludge ash (SSA) into an efficient fertilizer and effective plant nutrient source.

"The idea at ICL, with our current process, is to use this sewage sludge ash as basis for the production of fertilizer," said van der Saag. "We believe that sewage sludge ash, as a raw material, has a huge potential for phosphate recovery."

About 31 percent of sewage sludge from Europe's wastewater treatment plants ends up being incinerated to create SSA currently. This one source alone could provide around six percent of Europe's phosphate fertilizer demand, according to some estimates.

"If we look towards the future, if all of Europe's sewage sludge was incinerated and reused, we could go up to around 20 percent [of demand]," said van der Saag. "So there is great potential in using sewage sludge ash to replace phosphate ore in Europe."

In the PuraLoop process, SSA is firstly mixed with sulphuric acid or phosphoric acid in an acidulation step. The run-of-pile (ROP) material obtained is then granulated. Last year, ICL met all the necessary EU regulatory requirements to produce single superphosphate (SSP) and triple superphosphate (TSP) from SSA, including a fertilising products regulation (FPR) audit and full REACH registration.

The advantages of using SSA as a fertilizer production raw material, said van der Saag, was that it eliminated odour and was essentially cadmium- and fluorine-free. Agronomic trials have also shown very good results, he added.

A full-scale industrial PuraLoop installation is now up and running at ICL's Amfert production site at the port of Amsterdam. This is capable of producing two products: PuraLoop 0-38-0 and PuraLoop 5-5-22. The company manufactured 1,000 tonnes of PuraLoop 0-38-0 during successful production runs at the end of last year.

van der Saag highlighted the many benefits for the EU from 'closing the loop' on phosphorus:

"One is that we can turn waste into a product of agronomic and economic value. We can also reduce our dependency for critical raw materials on outside sources and, finally, we can have a leadership role in environmental and technological innovations for food and fertilizer production."

Technical presentations

Summaries of key presentations from this year's excellent technical programme can be found in the CRU Phosphates 2024 preview in our January/February magazine (*Fertilizer International* 518, p36).

Importantly, two key industry players, JESA Technologies and Prayon Technologies, chose CRU Phosphates 2024 to launch newly patented processes on the market. JESA's James Byrd presented the SWIFT process for valorising fluorine, turning this from a nuisance pollutant into a valuable co-product. We will report fully on SWIFT in the July/August issue of *Fertilizer International*.

Kevin De Bois of Prayon, meanwhile, gave delegates an overview of Prayon's new magnesium removal process for phosphate rock, as highlighted in our January/February magazine (*Fertilizer International* 518, p38). This new approach has real potential to transform both phosphate resource efficiency and resource availability.

Market information

Please note that market information and commentaries reported here date from the time of the event in late February 2024. These should therefore be interpreted with caution. Although reasonable care and diligence has been taken, CRU does not guarantee the accuracy of any data, assumptions or forecasts. ■

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Phosphoric acid plants – engineering by experience

How does an engineering company complete the basic and detailed engineering for a phosphoric acid plant – and provide the full design for the off-site sections and utilities? **Jan Tytgat**, De Smet Agro's Process Engineering Manager, explains an approach based on partnership with the technology licensor and client that combines engineering expertise with experience.

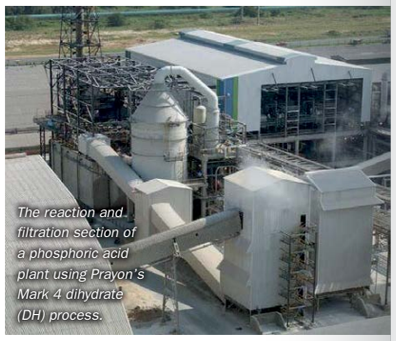


PHOTO: DE SMET AGRO

The reaction and filtration section of a phosphoric acid plant using Prayon's Mark 4 dihydrate (DH) process.

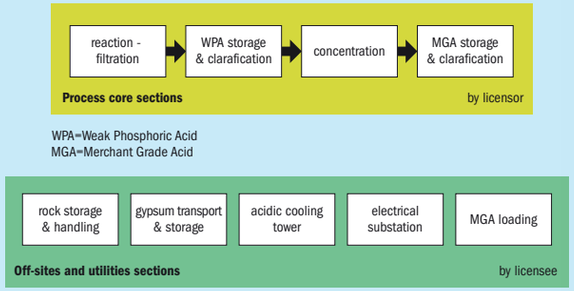
Successfully designing a new phosphoric acid plant requires a combination of experience and know-how. De Smet Agro is Prayon's most experienced engineering partner with an unparalleled track record, having completed the design of numerous phosphoric acid projects globally during the last 60 years.

Each new phosphoric acid plant (PAP) project begins with a process design package (PDP) from Prayon, the technology licensor. This is usually prepared from pilot phosphoric acid production tests on a phosphate rock concentrate. The engineering company (technology licensee) then proceeds with the following project phases:

- Basic and detailed engineering to complete the phosphoric acid plant process design.
- Provision of full and detailed mechanical, piping, civil & structural, electrical & instrumentation design and a 3D-model of the PAP.
- Complete engineering for off-site sections and utilities.
- Preparation of the capex estimate and a preliminary financial model, if required.
- Construction supervision and participation in plant commissioning, training and start-up activities.

The overall design concept for a phosphoric acid plant and the respective engineering activities of the licensor (Prayon) and the licensee (De Smet Agro) are summarised in Figure 1. Essentially, the licensor is responsible for core phosphoric acid process activities, while the licensee handles off-site sections and utilities.

Fig 1: **Overall design concept for a phosphoric acid plant showing the division of responsibilities between the technology licensor (top) and the licensee (bottom)**



Source: De Smet Agro

The off-site section design includes complete engineering for:

- Storage, handling and loading/unloading of the phosphate rock raw material
- By-product removal/storage – phosphogypsum and fluosilicic acid
- The acidic cooling tower
- The electrical substation
- Final product loading – concentrated phosphoric acid or merchant grade acid (MGA).

Phosphate rock

Phosphate rock handling, storage and dosing – for both dry solids and slurries – are summarised in Figure 2.

Phosphate rock concentrate is often imported by ship or brought directly from the mine to the plant by rail or truck. It is then unloaded and carried to an open storage area, a silo or a warehouse. Even solid phosphate rock can still contain up to 12 percent moisture, depending on the upstream beneficiation and drying process. Open storage is not generally recommended when other facilities and plants are located nearby. Phosphate rock, if fine and dry (less than two percent moisture), can be carried by the wind and form unwanted piles within the plant's boundary.

If desired, phosphate rock blends can be prepared on site from different quality rock sources using payloaders and belt conveyors.

The installation of a rock grinding unit may be necessary, depending on the final particle size requirements of the selected phosphoric acid production process. A ball mill, a roller mill or a pendulum mill can be used. The grinding assembly typically consists of:

- A dosing hopper and weighing belt conveyor
- A set of conveyors and elevators
- Hot air injection
- The grinding mill fitted with a fan and ducts for ground rock
- A ground rock silo, separator and a dedusting system.

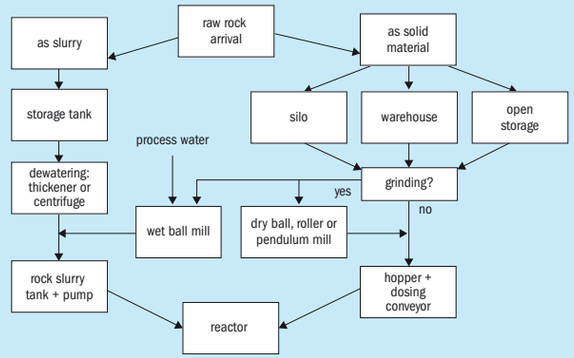
Conditioned phosphate rock is conveyed to a buffer hopper (see photo) – usually sized for a few hours production capacity – and then dosed on a weighing belt conveyor for onward transport to the phosphoric acid reaction tank via a belt or chain conveyor.

For some projects, raw rock is mixed with process water and sent to a wet ball mill, an option that is almost dust free and does not require hot air transport. The resulting ground phosphate rock slurry is sent for storage in a slurry tank.

PHOTO: DE SMET AGRO

Phosphate rock dosing hoppers and weighing belt conveyors

Fig 2: **Overview of phosphate rock storage, handling & dosing**



Source: De Smet Agro

Table 1: **Summary H_2SO_4 based Prayon processes**

Prayon processes (H_2SO_4 based)	Dry rock feed	Rock slurry feed	Crystalisation	Filtration	P_2O_5 acid strength	Yield efficiency	P_2O_5 in gypsum
Di-Hydrate (DH)	Yes	Yes	single	single	25-29%	94-95%	low
Hemi-Hydrate (HH)	Yes	No	single	single	40-42%	92-94%	very low & self-drying
Di-Attach Hemi-Filtration (DAHF)	Yes	No	double	single	32-35%	97-98%	high & self-drying
Hemi Di-Hydrate (HDH)	Yes	No	double	double	40-45%	98-99%	very hgh
Di Hemi-Hydrate or Central Prayon (CPP)	Yes	Case-by-case	double	double	32-35%	98-99%	very high & self-drying

Source: Prayon

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Phosphate rock storage capacity will mainly depend on the frequency of raw material deliveries. If the rock is brought in by ship once monthly, for example, storage must be sufficient to receive this shipload and ensure a minimum of one month's production. The capacity of ship unloading equipment and conveyors must also enable transfer of the cargo from ship to storage in the shortest possible time.

The rock handling capacity between the storage and the reactor, on the other hand, will depend on factors such as plant capacity, the P_2O_5 and water content of the rock, and expected plant yield. Typically, imported phosphate rock contains 30-38 percent P_2O_5 and 1-3 percent moisture.

A dry rock feed to the phosphoric acid reactor is usually preferred, as slurry feed is not suitable for all types of phosphoric acid process (Table 1). Use of a dry feed also prevents the (sometimes accidental) overdosing of process water to the reactor that can occur with slurries.

Water balance – an important consideration

The viability of using a slurry feed requires a closer look at the water balance of a phosphoric acid plant. Process water mainly enters the phosphoric acid production process via the filter as gypsum cake washing water and is then recycled back to the reactor (see Figure 3 for a typical DH process). Water also leaves the reaction-filtration section:

- With the filtrate as weak phosphoric acid
- With the phosphogypsum as crystalline and free water
- As water vapour to the stack via the scrubber
- As water vapour via the flash cooler condenser to the cooling tower.

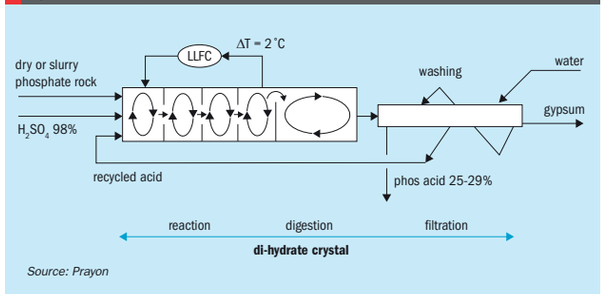
Phosphoric acid production processes (see Table 1) that generate hemihydrate gypsum ($CaSO_4.^1/_2\ H_2O$) produce filtered acid with a higher P_2O_5 content compared to the DH process that generate standard gypsum ($CaSO_4.2H_2O$). The P_2O_5 content of filtered or weak acid of the HH process, for example, is around 40-42 percent versus 25-29 percent for the single DH process (Table 1). This is important for the water balance as stronger 42 percent P_2O_5 HH acid obviously contains less water than weaker 29 percent P_2O_5 DH acid.

In addition, since hemihydrate contains 1.5 molecules less crystalline water than gypsum, less water will leave the HH process in the form of phosphogypsum waste. Overall, therefore, more water will exit a DH process plant via both the weaker acid and the phosphogypsum waste generated. These higher water losses allow the DH process – the most commonly used phosphoric acid production process globally – to easily accept rock slurry feed as well as dry rock feed.

Phosphate rock that arrives from the mine and beneficiation plant as a slurry is stored in agitated buffer tanks. The agitators maintain a homogeneous suspension to allow upstream pumping of the slurry to the reactor.

The solids concentration of the rock slurry arriving on site can be as low as 45-55 percent. This could be pumped directly to the phosphoric acid reactor but is usually partially dewatered to about 63-65 percent solids by using thickeners or centrifuges or a combination of both.

Fig 3: **Typical dihydrate (DH) phosphoric acid production process**



Source: Prayon

Reducing the quantity of water entering the reactor via the rock slurry is beneficial as its improves subsequent filtration efficiency by allowing greater washing of gypsum on the filter.

The materials used in rotary and static dewatering equipment and piping need to be carefully selected, as these are in contact with high concentrations of abrasive solids. The piping systems also need to be equipped with suitable abrasion resistant valves and flushing lines.

Phosphogypsum

In the reaction section – the heart of the phosphoric pant – sulphuric acid and phosphate rock are reacted together to produce phosphoric acid and phosphogypsum (PG). The PG is separated from the phosphoric acid via filtration using a table filter, belt filter or tilting pan filter.

The PG generated by most plants using a DH or HH single crystal process generally contains too many impurities and needs to be disposed of. Double crystal processes, in contrast, deliver much better quality PG.

PG leaving the filter typically contains 20-25 percent free moisture and can be transported via belt conveyors to a dry PG stack. Alternatively, PG can be mixed with water and pumped to wet PG stack or PG pond to settle, allowing water to be returned and recycled.

Marine outfalls are also permitted in some projects. This involves flushing the PG with seawater into homogenisation tanks for subsequent pumping out to sea. Lime water can also be added to these tanks to neutralise the PG slurry, if specified by local regulations or necessary for downstream applications.

Double-crystal phosphoric acid processes that generate hemihydrate instead of gypsum during the second crystallisation stage, such as the DA-HF or CPP process (Table 1), provide an extra advantage: they generate a self-drying, high quality phosphogypsum by-product. The natural rehydration of hemihydrate (plaster of Paris) into gypsum reduces free moisture from about 20-25 percent to 10 percent over a curing period of 3-4 weeks (Figure 4). After curing and crushing, this self-drying gypsum product can potentially be used in the plasterboard industry or as a cement retardant, depending on the quality of the original phosphate rock.

Acidic cooling tower

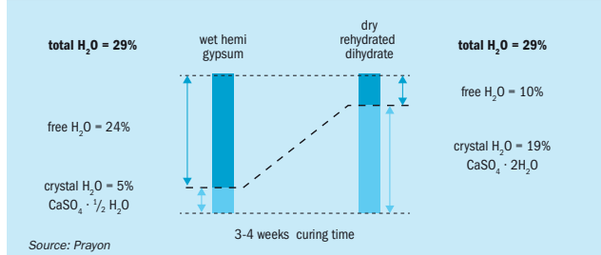
Cooling water is needed throughout the phosphoric acid plant at the following sections:

- **Reaction flash cooler**: Large amounts of heat are generated in reaction tanks by the dilution of sulphuric acid and the exothermic reaction of sulphuric acid and phosphate rock. This is generally removed by either air cooling or evaporative cooling. In the second option, cooling water is used to condense evaporated water in a condenser downstream of the flash cooler.
- **Vacuum filter**: Gypsum generated in the reaction tanks is separated from weak phosphoric acid on a vacuum filter. Cooling water is used by a condenser downstream of the filter to reduce the amount of water vapour entering the vacuum pump.
- **Concentration evaporators**: Filtered acid is typically generated at either 25-29 percent P_2O_5 (dihydrate process) or 40-42 percent P_2O_5 (hemihydrate process) concentration. This needs to be further concentrated to the required fertilizer-grade or merchant-grade acid (MGA), usually up to 52-54 percent P_2O_5. This is achieved by combining a heat exchanger and an evaporator under vacuum in a forced circulation loop. Cooling water is used by a condenser downstream of the loop to condense the evaporated water generated.

Direct contact condensers are widely used downstream of the reaction flash cooler, vacuum filter and concentration evaporators. Cooling water in these condensers is typically acidic (pH <2) as it adsorbs the fluorine present in phosphoric acid when this is released as vapour under vacuum. Consequently, special acid resistant materials are used when designing cooling towers for phosphoric acid plants – and the associated cooling water piping, hot water channels and cold and hot cooling water circulation pumps. Forced draft concrete cooling towers fitted with anti-acid protection are recommended and commonly used.

There are several installation options for cooling water networks at phosphoric acid plants based on channels and/or piping plus vertical or horizontal cold and hot cooling water pumps, as described fully in a previous De Smet Agro article (*Fertilizer International* 509, p61). The engineering company will always select the cooling water design option that delivers the operational flexibility required by the client while taking account of any layout constraints.

Fig 4: **The hemihydrate form of gypsum is self-drying as it rehydrates to the dihydrate form over several weeks**



Source: Prayon

Electrical substation

Electrical power is an important and essential utility at a phosphoric acid plant. The engineering company therefore needs to provide a complete design for an electrical substation that includes:

- High voltage (HV) feeders from the grid
- Medium voltage (MV) and low voltage (LV) transformers
- The MV and LV panels and motor starters.

Heavy oil-type transformers are usually placed on the ground floor of the substation along with the HV switchgears. Bus ducts and LV motor control centre (MCC) panels, in contrast, can be located on a higher floor. A separate room is usually provided at the substation for the battery charger and batteries.

The safety of the substation design is assessed by performing proper short circuit analysis, voltage drop and harmonics calculations and ensuring these meet local regulations. All electrical equipment generates heat and therefore requires cooling. Transformers located outdoors can be cooled by natural ventilation while air conditioning is provided in hot climates for electrical gear installed inside the substation.

The installation of additional emergency power units is included in the substation design if these are required and have been requested by the client.

PHOTO: DE SMET AGRO

Electrical Substation at a phosphoric acid plant.

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Merchant grade acid and fluosilicic acid

In plants producing for export, the concentrated phosphoric acid needs to be conditioned to merchant grade acid (MGA), typically at 52-54 percent P_2O_5. In many cases, the MGA is cooled down to about 45°C in maturation tanks. Solids content is also reduced – typically from 2-3 percent solids to a maximum of 0.5 percent solids – using clarifiers equipped with a rake and flocculants. The clarified MGA can then be sent to the export storage tanks. The trouble-free and efficient removal of sludges at the bottom of the clarifiers requires special attention.

Storage and loading facilities are also designed for fluosilicic acid (FSA), a by-product of fluorine recovery at phosphoric acid plants. Dedicated loading pumps are designed to safely transfer the MGA or the FSA from their respective export storage tanks to rail or road tankers.

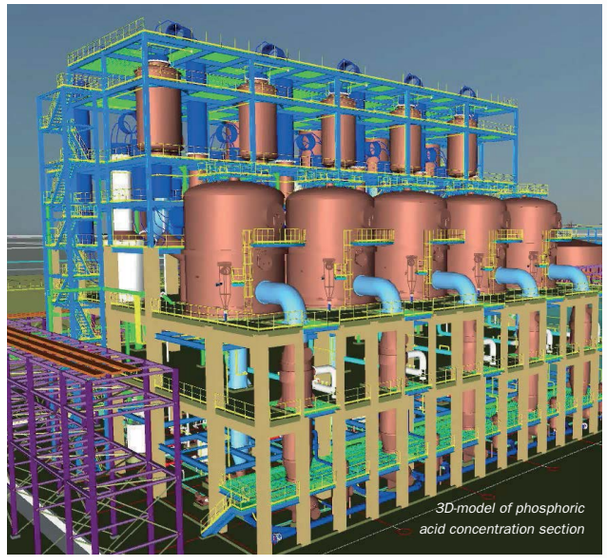

PHOTO: DE SMET AGRO

3D-model of phosphoric acid concentration section

Engineering activities

The engineering company (the licensee) will take the process design package (PDP) developed by the licensor and complete the process design. This includes developing detailed P&IDs (see box), finalising the process description and all of the control-related documents, these including the interlock descriptions, the causes & effects chart, the alarm & interlock list, etc.

Suitable materials are selected for rotating and static equipment, piping, and instruments. These are chosen based on in-house experience, good engineering practise and feedback from major equipment suppliers. Protection for the concrete and steel surfaces in the phosphoric acid plant is provided by selecting acid-resistant brick and rubber linings.

All the above requirements are then set out in detail by the engineering company in datasheets, drawings and high standard specifications. These cover mechanical and electrical equipment, piping, valves and instrumentation.

3D-model

The engineering company is responsible for preparing a 3D-model of the phosphoric acid plant. This is based on the production process, as defined by the licensor, while also taking account of the maintenance needs of the client. The following design elements are completely integrated within the 3D-model:

- Civil and steel structural design of the buildings and substation
- Concrete foundation of the storage tanks
- Steel structure supporting the storage tank agitators
- Acidic cooling tower with cooling water basins
- Pipe racks and cable trays.

Phosphoric acid plant operations – as is well known in the industry – are highly maintenance sensitive. The periodic flushing of pipelines, visual inspections and the replacement of worn parts are all necessary. Attention must therefore be given to these maintenance requirements during the early stages of plant design. For example, space needs to be reserved inside and around buildings to allow cleaning and easy maintenance access using manual or motorised hoists and mobile cranes.

The model, by including 3D-drawings from equipment suppliers, can also offer a high level of precision for the connecting piping. Additionally, the model is a helpful tool during HAZOP analysis and the training of plant operators, as it allows virtual walks to be made inside the plant.

The 3D-model is reviewed by the engineering company with the licensor and the client to derive the following:

- 3D views from all required angles
- 2D plot plan, floor, and section view drawings
- Piping isometrics
- Material take-off (MTO) for civil & structural elements, all ducts, piping & fittings, electrical & instrumentation wiring cable trays.

Preliminary MTOs, developed at the front-end engineering design (FEED) stage, are used to calculate a robust project capex estimate. While final MTOs, prepared at the end of the engineering phase, are provided to the installation contractors and bulk materials suppliers for supply and construction purposes.

Conclusion

Delivering operationally effective and maintenance-friendly phosphoric acid plants requires a combination of expertise and experience. Having an experienced engineering company (licensee) completing the process design package (PDP) provided by the licensor – and completely engineer the off-site sections and plant utilities – is therefore of prime importance.

As highlighted by this article, the successful and reliable operation of a phosphoric acid plant requires a well-engineered, easy to maintain plant. This includes:

- Well-designed phosphate rock unloading, storage and dosing facilities
- A correctly sized gypsum filtration, storage and disposal system
- The proper selection of acidic cooling water equipment
- A well-matched electrical substation
- Customised loading equipment for end-products.

Author's note

This article is based on the De Smet Ago presentation by Sébastien Bernard at CRU Phosphates 2024 International Conference & Exhibition, Warsaw, 26-28th February 2024. ■

PIPING & INSTRUMENTATION DIAGRAMS (P&IDs)

Piping & instrumentation diagrams (P&IDs) are key process documents that are essential for developing the detailed engineering design of the phosphoric acid plant. These are prepared by the engineering company based on the process flow diagrams, mass balance and equipment list provided by the licensor.

The first diagram, usually called the legend P&ID, includes all the standard symbols and abbreviations and tagging for the instrumentation, equipment, electrical motors, valves, pipelines and accessories for the plant's process and utility lines. A pipeline number, for example, needs to include at least the following information:

- Pipe size in mm or inches
- Abbreviation for the fluid
- Abbreviation for the pipe class
- Presence of insulation and/or tracing
- A unique sequential number.

P&IDs cover all the process and utility equipment. They show important information (e.g., pipelines and flow direction, pipeline slope requirements, ducts, control valves and manual valves, instruments, control loops, interlocks, etc) and include vital notes. Two types of notes are usually provided:

- **General notes**. These are identical notes made on every P&ID. Notes included with the legend P&ID, for example, will explain the symbols and abbreviations used, and indicate what vents and drains are required at each high and low point, respectively, on a pipe.
- **Specific notes**. These refer to specific actions or precautions that are necessary during installation and particular operations.

The P&IDs are an excellent illustration of the value that an engineering company's accumulated experience, gained over many years, can bring to detailed engineering design. This knowledge is shown on P&IDs by indicating where mandatory bypasses, flushing lines and sloped lines for solid charged liquids are required, as well as the use of the proper type of valves for specific fluids, etc. As many pipelines run cross several P&IDs, the diagrams need to show which P&ID the pipelines continue onto next.

Part of a piping & instrumentation diagram (P&ID).

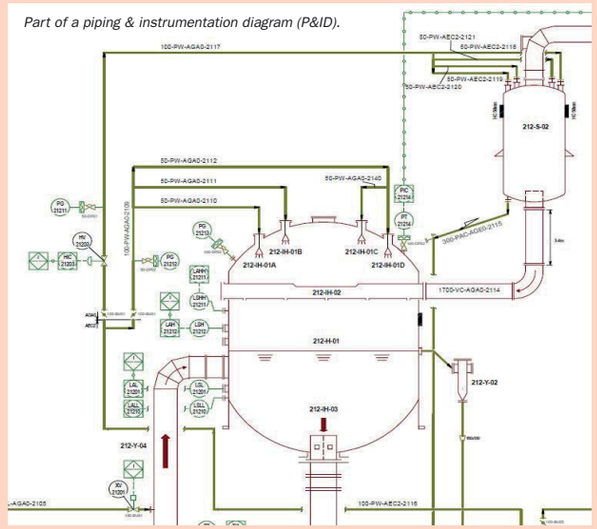

IMAGE: DE SMET AGRO

The P&IDs, together with the process and interlock descriptions, are the most important documents reviewed and discussed during the hazard and operability (HAZOP) analysis by the engineering company, the licensor and client process engineers. HAZOP analysis is carried out during the detailed engineering phase to systematically identify potential process hazards and possible plant operability problems.

Software can extract and generate useful lists from the P&IDs such as the:

- Equipment list
- Pipeline list
- Control valves list
- Manual valves list
- Accessories list
- Instrument list
- Interlock list

Additionally, the P&IDs correlate with the 3D-model to help ensure consistent plant design and engineering.

Once prepared, the P&IDs are crucial working documents for the piping & instrumentation installation contractors. Site inspectors will also check the final installation against the P&IDs and make red mark-ups to show any deviations, these being inevitable due to installation constraints. This marked-up version is later used to prepare the 'as built' P&IDs. These final P&IDs are vital documents that are always kept in the control room of the phosphoric acid plant together with the operating manual. ■

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KBR's proprietary phosphoric acid purification technology

KBR designs and builds customised phosphoric acid purification plants tailored to the individual demands of clients. **Christopher Heikkilä**, KBR's Business Development Manager, outlines the process design requirements and the challenges associated with impurities removal.

Overview

Phosphoric acid is commonly produced by the wet process to different quality standards. Green or merchant-grade acid (MGA), for example, can be directly used in fertilizer production without further purification, whereas most other applications require the removal of impurities to produce purified phosphoric acid (PPA).

Technical-grade PPA, for example, can be used to produce sodium tripolyphosphate (STTP), water-soluble fertilizers (WSFs) for fertigation and foliar applications, various other crop nutrient products, detergents, and animal feed additives. Food-grade PPA suitable for food industry and pharmaceutical applications requires further purification.

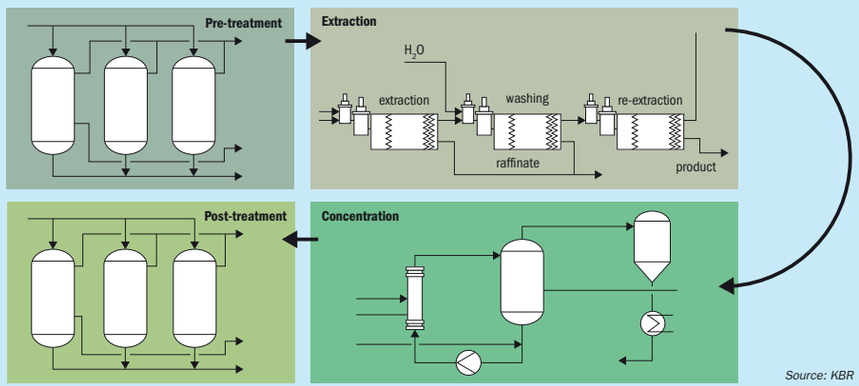
Addressing impurity removal challenges

The impurities present in green phosphoric acid, such as fluoride, chloride, iron, aluminium, sulphur and organic matter, can cause corrosion, erosion-corrosion, and scaling in industrial equipment. The removal of these impurities is a complex process that involves a range of methods (solvent extraction, precipitation, stripping, absorption etc.). These are selected, as follows, according to the types of impurity present and their concentration:

- **Solvent extraction** is used for removing impurities such as F^-, Cl^-, and Fe^{3+} from phosphoric acid.
- **Precipitation**, while a suitable removal method for Fe^{3+} and Al^{3+}, is not effective for other impurities such as F^- and Cl^-.
- **Stripping and absorption** are mainly used to target and remove specific impurities to reach high purity requirements.

Selecting the right method is crucial for efficient and cost-effective purification. A typical four stage process (pre-treatment, extraction, concentration, post-treatment) is shown in Figure 1.

Fig 1: **Typical process flow sheet for a phosphoric acid purification plant**



Source: KBR

Technical-grade and food-grade PPA production

KBR has the key design advantages necessary to produce both technical- and food-grade PPA from green phosphoric acid.

- **Firstly, thorough lab testing and piloting** are crucial steps in PPA production. By defining an optimised process flow sheet, they help to ensure that the final product meets the required quality standards.
- **Secondly, project experience and references** play a crucial role in ensuring high-quality phosphoric acid production. KBR's experienced team of professionals can leverage this to optimise the production process, reduce costs, and improve the overall quality of the product.
- **Careful material selection** is yet another area where KBR has a key design advantage due to its extensive knowledge gained from applied processes. This ensures that the plant has long lifetime, with minimal downtime for maintenance, while delivering a final product of the highest quality.
- **Energy recovery** is also important for cost reduction and improving the overall efficiency of the production process.
- **All KBR plants are tailor-made** and optimised for specific client needs. This eliminates unnecessary or overdesigned equipment.

> **"KBR worked with a Middle East client to design a phosphoric acid purification plant to convert phosphoric acid from merchant-grade to food-grade using its proprietary purification process."**

Project case study

KBR worked with a Middle East client to design a phosphoric acid purification plant to convert phosphoric acid from merchant-grade to food-grade using its proprietary purification process.

Through extensive lab testing and piloting campaigns, KBR obtained valuable data for designing and engineering the phosphoric acid purification plant – ensuring the client's specifications for the purified product were met.

The phosphoric acid purification plant was designed to produce 51,667 t/a (100% P_2O_5) of purified food-grade phosphoric acid. The proposed plant consisted of a single production unit comprising of following sections:

- Pre-treatment including the precipitation of SO_4, F and As followed by solids separation, organic removal and concentration of the pre-treated acid.
- Solvent extraction including extraction, scrubbing, stripping and scrub raffinate concentration.
- Post-treatment including concentration, fluoride removal and decolourisation stages.
- Raffinate washing with kerosene to remove entrained solvent (tributyl phosphate).

The purification plant was designed to deliver a final purified phosphoric output (62% P_2O_5) from a merchant-grade phosphoric acid feed (50-54% P_2O_5). ■

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