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Pathways to green ammonia

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BCInsight

CONTENTS

PHOSPHATES AND POTASH INSIGHT

REGULARS

Editorial

Sounding the price klaxon

The war in Ukraine has caused 9,000 civilian deaths and created 5.7 million refugees. If this immense and spiralling human tragedy was not enough, the unprecedented shock inflicted on commodity markets continues to unfold.

"I've been covering the market for 20 years and have never seen anything like the last 2-3 weeks," Mike Nash, senior editor for fertilizers at Argus, told delegates at Fertilizer Latino Americano in Miami at the end of March (see page 26). At that time, the Argus fertilizer index had moved upwards by 100 points in the several weeks since the conflict began.

In fact, the rise in average fertilizer prices has been so precipitous they have now exceeded their previous 2008 peak. CRU's fertilizer price index, for example, reached 390 on 25th March – well above the previous record of 360 set in 2008. The index, although it subsequently fell back in the first three weeks of April, remains above 2008 levels at the time of writing.

This unfolding fertilizer price shock has been a white-knuckle ride. Urea, ammonia, phosphates and potash all charged upwards in the days following the invasion of Ukraine, as an already tight market faced further supply constraints.

This upwards spiral accelerated in mid-March. In a single week, prices across the board – from nitrogen through to phosphates, potash and sulphur – all surged dramatically, in some cases by triple digits, staggering rises which exemplified March's commodity market mayhem.

The economic fallout intensified as March progressed – upending energy, freight, agricultural and financial markets. Baltic ammonia prices surged by almost $400/t in a single week to join urea and potash at new records. By March 21st, CRU's fertilizer price index surpassed its previous 2008 high to set a new all-time record of 377, having climbed 30 percent since the start of 2022.

With prices now in uncharted territory, the index reached another new high (390) by March 25th. Potash exceeded all previous price norms as buyers in Brazil and Southeast Asia panicked at the lack of exports from Russia and Belarus. Urea prices also jumped in the Baltic, Black Sea and China. Phosphates prices in Europe and Latin America, meanwhile, approached record levels too.

As the fertilizer industry gets ready to gather in Vienna for IFA's annual conference at the end of May, there is some irony in the fact that the last time IFA convened in the Austrian capital the market was at the very pinnacle of the 2008 price rally.

The 2008 fertilizer price spike (and its aftermath) is not necessarily a reliable guide to the current price surge – or what will happen next. In 2008, it was a combination of strong demand, rising crop prices, high farm profits and good access to credit which spurred a price rally that accelerated fast towards the middle of the year. Whereas it is supply scarcity, both real and imagined, that is the key price driver currently.

Analysts like to talk of price signals. And March's off-scale prices certainly sent a loud and clear signal – a klaxon to warn the market of the high risk of supply shortages. The problem for the fertilizer market is that this price klaxon – no matter how deafening – can't instantly address a fundamental lack of product.

As CRU's Peter Harrisson rightly said (see page 52): "Higher prices are not going to solve the problem. They're not going to fill the market up with new supply."

Even if the underlying drivers are not the same, the events of 2008 do illustrate what happens when an unsustainable price bubble bursts. The fertilizer industry, in common with other commodity markets, suffered a cataclysmic reversal in fortunes between late 2008 and mid-2009.

The downturn that came, as 2008 ended and 2009 began, was swift and brutal. With the global economy faltering, fertilizer demand collapsed as cash-strapped farmers stopped buying inputs. Prices predictably plummeted as sharply as they had risen, leaving a supply chain choked with over-valued and unwanted stock. The resulting collapse in sales led to widespread production shutdowns.

14 years on from those events, high agricultural commodity prices are helping maintain farm profitability. Yet some still view demand destruction as increasingly likely due to high fertilizer prices and supply shortfalls.

While there were signs of the market stabilising in April, and even some price softening, ratings agency Moody's is forecasting that some fertilizer benchmarks will remain above $1,000/t well into 2023 (see page 8). That suggests the current price rally is beginning to look less like Everest and more like Table Mountain. ■

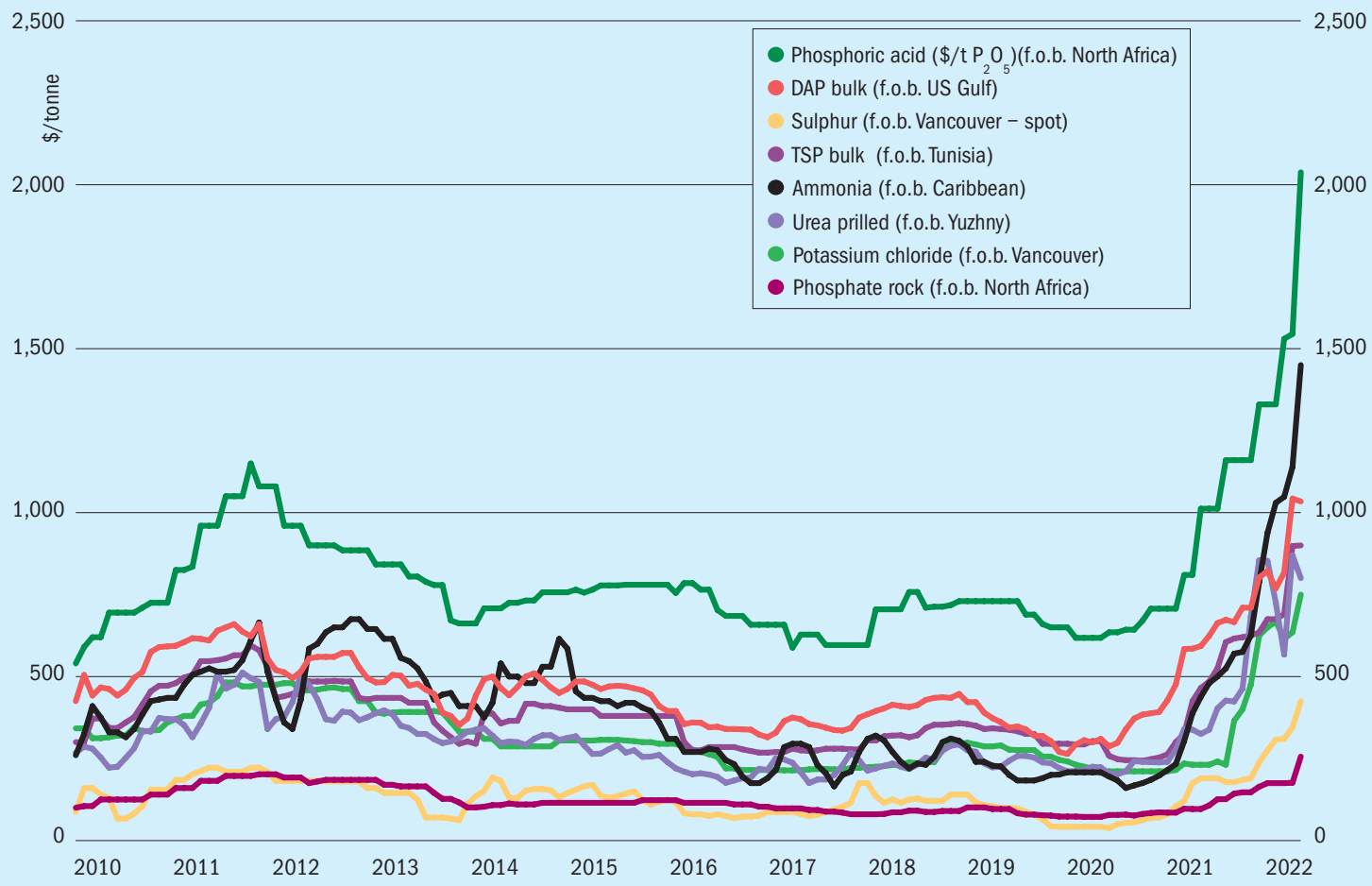
"The problem for the fertilizer market is that this price klaxon – no matter how deafening – can't instantly address a fundamental lack of product."

S. Inglethorpe

Simon Inglethorpe, Editor

Market Insight

Historical price trends $/tonne



Source: BCInsight

Market Insight courtesy of Argus Media

PRICE TRENDS

Urea: Prices dropped sharply in most markets at the end of April in the wake of the Indian purchase tender. The lowest bids on the east coast and west coast of India were $717/t cfr and $750/t cfr, respectively. Price levels in southeast Asia fell by around $100/t along with similar market falls in the Americas.

Trade overall lacks liquidity with small lots changing hands at sporadic intervals. But the pockets of demand that have emerged are likely to increase in coming weeks now that a price reset has happened.

Key market drivers: In a slow-paced global market, India's tenders are offering the opportunity to place significant tonnages. Despite curtailed demand, European supply remains fragile and geopolitical tensions surrounding the Russia crisis are continuing.

Ammonia: Supply and demand have started to rebalance two months after the removal of Black Sea ammonia exports from the market. Spot prices made steep losses west of Suez in late April following the $200/t drop in the Tampa May contract price. In the east, prices are stable with firmer contract prices. Some downside pressures remain, with the latest Indonesian sales tender, for example, attracting bids below last done spot business.

Key market drivers: Yara settling the Tampa contract price for May with Mosaic at $1,425/t cfr, a $200/t drop from April. OCP bought a 25,000-tonne ammonia cargo at $1,125/t cfr, most likely from Trinidad, for early-June delivery. Import demand from Turkey could pick up following news that producers there will be permitted to export CAN in May. India's confirmation of fertilizer subsidies is expected to bring fresh inquiries from the country's buyers.

Phosphates: India's government has raised the DAP subsidy for the 2022/23 by 52 percent. But subsidy levels are still set to pressure DAP importers, as break-evens remain slightly below recently traded levels ($920s/t cfr) and significantly below f.o.b. levels in major origin markets. Chinese DAP prices eroded slightly to $1,050/t f.o.b. at the end of April. Availability of Chinese DAP seems to have improved, but export restrictions remain in place with approvals still taking several weeks to obtain.

Brazilian MAP prices declined amid a lack of demand. Levels have fallen to $1,200-1,240/t cfr, down from $1,250-1,270/t cfr in late April. A change in crop fundamentals should lower barter rates and bring buyers back to the market in coming weeks.

Key market drivers: The rise in India's DAP subsidy for 2022/23 to INR 50,013/t, up from INR 33,000/t. Maximum retail prices, meanwhile, remained flat and at

Market price summary $/tonne – Start May 2022

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	1,350-1,375	-	f.o.b. E. Europe Port closed	f.o.b. US Gulf	952-990	-	-
f.o.b. Yuzhny	Port closed	Port closed	-	f.o.b. N. Africa	1,080-1,185	845-950	1,975-2,100
f.o.b. Middle East	975-1,150	700-850**	-	cfr India	975-1,100	-	n.a.*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	800-900	-	cfr US Gulf	200-275	f.o.b. Vancouver	430-470	-
f.o.b. Middle East	780-880	-	-	-	f.o.b. Arab Gulf	450-475	-
f.o.b. Western Europe	-	860-910	-	-	cfr N. Africa	435-500	-
f.o.b. Baltic	770-900	-	-	-	cfr India	460-515+	-

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

INR 27,000/t are squeezing importer margins. Soybean futures (CBOT) reached record-highs of ¢1,748/bu in late April and remain at similar levels.

Potash: Although MOP prices have flattened off in a quiet period for the market, buyers will soon be seeking second-half requirements. Most producers see no end to rising prices and are targeting monthly increases. SOP prices continue to rise in Europe, as Mannheim producers pass on their higher feedstock costs to customers.

Key market drivers: The 150 percent jump in India's MOP subsidy to INR 15,186/t ($198/t) for April-September, up from INR 6,070/t previously. Pupuk Indonesia is requesting 8-10 vessels of 25,000 tonnes each in an MOP tender announced in late April. Most producers (except BPC) are likely to participate. Offers are expected to start at over $1,000/t cfr for standard MOP.

NPKs: The Indian government has more than doubled the subsidy rates for all NPK/NPS products. The rates will apply for the first six months of the 2022/23 fertilizer year (April-September). This should help to bring importers of 10-26-26 back into profit and spur demand for the upcoming kharif season. Low stocks should also drive Indian demand. s. Indeed, India has entered the new fertilizer year with NPK/NPS stocks of around 1.6 million tonnes, about 2 million tonnes lower year-on-year. The country remains a key outlet for Russian NPK producers.

In Europe, meanwhile, demand has slowed with the end of the spring campaign. Buyers – particularly in central and eastern Europe – have nevertheless started making enquiries for the high-P and K grades, particularly 10-26-26, which are applied in the autumn. These are typically sourced from Russia and buyers are therefore planning ahead in anticipation that Russian product is likely to be absent from the market this autumn.

Key market drivers: Having upped its April-May export quotas, Russia will keep export quotas for certain fertilizers in place until the end of August, with the option to review these. Poland's Grupa Azoty will continue operating as planned, despite Gazprom's decision to halts gas deliveries to Poland and Bulgaria. The company says it has "contingency plans and operational scenarios" in place to deal with any potential gas supply disruptions.

Sulphur: Recently-announced Middle East prices for May have increased month-on-month. The Qatar Sulphur Price (QSP) for May increased by $30/t, while KPC lifted its May pricing by $35/t. Spot sales to China (Indian and Canadian origin) were concluded at around $500/t cfr, with expectations of $520/t cfr going forward for May cargoes loading from the Middle East.

Key market drivers: Announced Middle East monthly prices for May at $460/t f.o.b. Qatar and $470/t f.o.b. Kuwait.

OUTLOOK

Urea: The outlook looks weaker with demand mostly waiting in the wings. Supply should be more than sufficient to meet whatever demand does arise.

Ammonia: Fundamentals suggest that markets west of Suez will soon realign with those in the east. The market remains exposed to volatility in European gas pricing.

Phosphates: Significant demand is still expected from Brazil and south Asia in the coming months. The key question is when will importers start buying. Potential suppliers to India, for example, still face a break-even dilemma, with importers restricted by margins. Softness west of Suez is expected to end in the second half of May, as the return of buyers should prompt a price rebound.

Potash: Most major markets have plateaued – having already factored-in a drastic reduction in Belarusian and Russian MOP availability – while they await clarity on availability in the year's second half. An increase in MOP vessels leaving Russia will calm the markets and slow down price increases. While, conversely, a continued shortage of Russian and Belarusian MOP will push prices up into the second half.

NPKs: The market's bearish undertone is continuing as urea and phosphate prices weaken. Demand is nonetheless set to outweigh supply in the near term, helping to maintain and push up prices, with India expected to show the strongest demand in coming weeks.

Sulphur: Pricing continues to firm. The Indian DAP subsidy announcement, and an expectation that Chinese fertilizer export restrictions will be eased at some point, are fuelling the bullish sentiment. While lower-cost FSU tonnages are expected to be offered to the Chinese market, these have yet to make an impact on cfr conclusions, mainly because a supply chain has yet to be established and a long delivery period is anticipated. There is, however, an expectation that FSU availability will eventually weigh on premium price levels and ease the tightness in the market overall.

WORLD

Moody's expects NOLA prices to remain above $1,000/t

Certain fertilizer prices are likely to remain above $1,000/t well into 2023, according to Moody's.

In an assessment published on 18th March, the credit ratings agency linked its forecast of prolonged high fertilizer price levels to increases in natural gas prices and fewer fertilizer exports from Russia and Belarus.

Its price forecast is based on three US Gulf NOLA benchmarks: ammonia, diammonium phosphate (DAP) and potash. Ammonia could still be above $1,000/t at the start of 2024, according to this analysis.

Moody's had originally expected fertilizer prices to decline and normalise this year, after the highs posted in 2021. Instead, it now expects Russia's invasion of Ukraine to cause prolonged rises in fertilizer prices, which it links to increased demand pressures resulting from curtailed supply from Russia and Belarus.

"We expect significant increases in fertilizer selling prices and increased international demand as a result of the dramatic reduction in Russian and Belarusian exports." said Moody's. "Russia (including Belarus for potash) is one of the largest [fertilizer] suppliers to the global market."

The high-price environment for fertilizers and other commodities, including natural gas, is likely to have different consequences globally. US nitrogen fertilizer producers, for example, are expected to benefit as the country's vast natural gas reserves will act to limit their feedstock costs. Moody's is in fact predicting a substantial increase in earnings and cash flows for North American fertilizer producers in response to lower Russian and Belarusian exports.

European producers, in contrast, will face higher natural gas costs with some producers already curtailing ammonia production (*Fertilizer International* 507, p8).

"Russia's invasion of Ukraine will have a limited direct effect on North American chemical producers because neither country accounts for more than one percent of most producers' revenues, assets and raw materials," said Moody's.

Elsewhere, though, Moody's expected: "Higher oil and energy prices and the loss of Russian exports will increase commodity prices, exacerbating the inflationary environment and straining certain supply chains. This combination of factors will reduce margins for specialty [chemicals] companies and most companies' European operations."

SOURCE: MANHHAI/FLICKR

Ukrainian soldiers inspect a destroyed Russian tank in Bucha, Ukraine.

It added: "But many North American commodity producers will benefit, particularly fertilizer companies, because their raw material and energy costs remain relatively low.

Fertilizer prices on average have climbed by around 30 percent since the start of the year. CRU's fertilizer price index – a general market barometer – reached a record high of 377 in the third week of March. It easily surpassed the previous 2008 peak (360) in late March and then carried on climbing to reach 390 by the month's end.

"Potash hit new records as buyers in Brazil and Southeast Asia panicked at the lack of exports from Russia and Belarus. Urea prices jumped in the Baltic, Black Sea, China and elsewhere. Phosphates closed in on records in Europe and Latin America, while sulphur jumped in Brazil and the Mediterranean," CRU reported in late March.

As April progressed, however, the fertilizer price index did fall back by 10 points over several weeks, with CRU eventually recording a marked slump in urea and ammonia prices and weakening phosphate prices as April ended.

Indian and Latin American crops 'at risk'

Rabobank published its assessment of the Russia-Ukraine war's impact on global fertilizer markets in early April. The Netherlands-based agricultural bank concluded that higher fertilizer prices and/or a shortage of supply will not have an immediate impact on food prices and/or food production. This was partly because ocean shipments of fertilizers for the northern hemisphere's spring season were largely complete before the war began.

Instead, Rabobank expects India and Latin America to be the first 'at risk' crop-growing regions.

"India is partially out of danger, but Latin America is highly exposed. Potash availability for soybean production might be compromised as Belarus and Russia account for 40 percent of the world's potash production and exports," commented Rabobank.

"Consequently, Brazil's 2023 soybean harvest might be the first crop to experience direct negative impacts from Russia's war in Ukraine. The good news is that Latin American markets don't need fertilizers in their fields until September – which means fertilizers need to arrive at Brazilian ports in July-August," the bank added.

Rabobank concluded that this left industry players with several months to work out a solution to Brazil's fertilizer supply deficit. ■

CANADA

One million tonne potash production boost

Nutrien has announced that it is raising potash production from its Saskatchewan mines this year in response to uncertain supply from Belarus and Russia.

It now plans to increase its 2022 potash output by almost one million tonnes to approximately 15 million tonnes. Most of this additional volume is expected to be produced in the year's second half.

"Our thoughts and sympathies are with those impacted by the crisis in Ukraine and we hope for an immediate de-escalation of this conflict," said Ken Seitz, Nutrien's interim president and CEO. "The impacts of this conflict extend beyond Eastern Europe as a disruption in supply of key agriculture, fertilizer and energy commodities could have implications for global food security."

Seitz added: "Nutrien is responding to this period of unprecedented market uncertainty by safely expanding potash production to help provide our customers with the crop inputs they need. We continue to closely monitor market conditions and will evolve our long-term plans to ensure we utilize our assets in a safe and sustainable manner that benefits all our stakeholders."

Nutrien's 2022 potash production is now expected to increase by nearly 20 percent on 2020 levels, equating to more than 70 percent of the extra global production over this period. To deliver this extra output, the company is anticipating a small increase in capital expenditure at its Saskatchewan potash mines in 2022. The Canadian fertilizer giant will also be hiring additional employees to help it boost production.

Positive economics for Martison phosphate project

Canadian developer Fox River Resources Corporation has published a preliminary economic assessment (PEA) for its Martison phosphate project.

The proposed project is located in Hearst, Ontario, near to existing rail, power, and natural gas infrastructure. Construction plans include an open pit mine, beneficiation plant, slurry pipeline, road corridor and a fertilizer production complex. The latter is comprised of a phosphoric acid plant, a super phosphoric acid (SPA) plant, a granulation plant, a sulphuric acid plant, a warehouse and loadout facility, and a rail yard.

The PEA is based on production capacities of 221,000 t/a for super phosphoric acid (SPA), 474,000 t/a for granular monoammonium phosphate (MAP) and 247,000 t/a of granular NPS. According to the economic base case set out in the PEA, the project would have:

- Initial capital cost of $1.86 billion
- Average cash operating cost of $307/t
- Average opex plus sustaining capex of $329/t
- Net present value (8%) after tax of $1.47 billon
- Internal rate of return after tax of 17.4 percent
- Paypack period of 5.2 years.

The company plans to target markets in Eastern Canada, the prairies and northern US states. These should offer the Martison project a freight advantage relative to US and offshore phosphate producers, especially for the project's planned deliveries to nearby provinces.

Fox River Resources believes that now is the right time to advance the project. CEO Stephen Case said: "Western Canadian phosphate market demand has doubled in the past decade and remains the fastest growing market in North America, a market which the Martison project is designed to serve. With no current domestic production of finished phosphate products in Canada and a competitive operating cost, Martison is uniquely positioned to capture these markets that are primarily served by producers in central Florida, Idaho and the Gulf Coast."

INDIA

P&K subsidies rise to $8bn

The Indian government dramatically increased its nutrient-based subsidy (NBS) rates for phosphate and potash (P&K) fertilizers on 27th April. The subsidy increases are designed to protect India's farmers from rocketing global prices and will apply to this year's April-September Kharif season.

The planned NBS allocation for this six-month period has now been set at INR 609 billion ($8.0 billion). This is up 6.6 percent on the P&K subsidy budget for the entire 2021/22 season, estimated at INR 571.50 billion ($7.5 billion) by the Indian Department of Fertilizers (DoF).

India's decision to raise the NBS was taken after a further spike in global fertilizer prices (see our main story), following Russia's invasion of Ukraine at the end of February.

Diammonium phosphate (DAP) is India's most widely used fertilizer after urea. The new NBS subsidy rate for DAP has been set at INR 2,501 per 50 kg bag (around $654/t).

The latest DAP subsidy represents a $222/t increase on the previous Rabi special rate, according to an analysis by CRU. However, despite the latest NBS hike, DAP import offers at the end of April ($1,050-1,100/t cfr) still equate to a loss of around a $200/t on imports sold inland, CRU suggests. It calculates that the breakeven point for Indian DAP imports and domestic sales is around $875-900/t cfr currently.

India's farmers are heavily import reliant for their fertilizer supply. But escalating prices have sent import costs spiralling. ICIS, for example, reported that the cost of the country's fertilizer imports in March increased eightfold year-on-year to $1.66 billion, up from $204 million in 2021, due to the shortage of supplies globally and high prices.

IPL signs potash supply contract with ICL

Indian Potash Ltd (IPL) has signed a five-year potash supply deal with ICL Group.

The Israeli potash producer will supply IPL with 600,000-650,000 tonnes of muri-

PHOTO: MICHEL ARNAULT/SHUTTERSTOCK

Tea plantation, Munar, India.

ate of potash (MOP) annually from 2022-2027, India's Ministry of Chemicals & Fertilisers confirmed on 21st March.

The deal with ICL was welcomed by Mansukh Madaviya, the Indian government's chemicals and fertilizer minister. He said India's agriculture sector has "huge potential and provides ample opportunities to collaborate and innovate" with Israel.

ICIS has reported that India has been looking to source alternatives to Russian fertilizer imports, following the invasion of Ukraine, including supplies from Canada and Israel. This is to ensure sufficient fertilizer availability for the start of the subcontinent's summer sowing season in April.

In total, around 10-12 percent of India's fertilizer imports are sourced from Russia, Ukraine and Belarus. Previously, Russia supplied nearly 17 percent of India's MOP imports and around 60 percent of its NPK imports, according to trade data.

Record-breaking output at Paradeep

Major fertilizer producer Indian Farmers Fertilizer Collective (IFFCO) has revealed that its Paradeep plant produced 805,000 tonnes (P_2O_5) of phosphoric acid in 2021. This makes Paradeep the largest single site production plant for phosphoric acid in the world, according to the company.

IFFCO's single reactor phosphoric acid plant at Paradeep has a daily production capacity of 2,650 tonnes (P_2O_5). Its output is used in the production of downstream phosphate-based fertilizers including diammonium phosphate (DAP) and NPS products. The production of finished phosphates at the site reduces India's import dependency on imported complex fertilizers.

AUSTRALIA

Stamicarbon selected as NeuRizer project licensor

Stamicarbon has been selected as the licensor for the NeuRizer urea project (NRUP) in Leigh Creek, Australia. The site is located 550 kilometres north of Adelaide in South Australia.

NRUP is aiming to be Australia's first fully integrated, carbon-neutral urea production plant, having on-site availability for all the inputs (gas, power and CO_2) required for low-carbon urea production.

Stamicarbon will deliver the process design package (PDP) for the 2,850 tonne/day capacity urea melt and granulation plant, as part of the project's front-end engineering and design (FEED). NRUP will use Stamicarbon's Launch Melt™ flash design for the melt plant (with a pool reactor) and its Launch Finish™ granulation design for the granulation plant.

Stamicarbon's Launch Melt™ design significantly reduces the melt plant's steam consumption due to its high energy efficiency. Its Launch Finish™ fluid-bed granulation design also has favourable characteristics. These include low formaldehyde consumption, low dust and ammonia emissions, high product quality, and high on-stream times. Launch Finish™ also significantly reduces the physical footprint and capital cost of the plant by minimising the equipment required. Fewer equipment items also help cut maintenance costs and deliver operational savings.

Stephen Zwart, Stamicarbon's vice president of licensing, said: "This is the first new grassroots urea capacity in Australia in decades. It is a genuinely solid project with an innovative concept that has been built from the ground up. We are proud to be contributing to carbon neutral fertilizer solutions that will help close urea supply-demand in Australia, supporting farmers and food production across the country."

The NRUP is a nationally significant project for Australia, given its potential to deliver a secure, low-cost supply of high-quality, carbon-neutral fertilizer for both local markets and for export. Start-up is currently scheduled for 2025.

UNITED STATES

PVS to acquire Sackett-Waconia

PVS Chemicals (PVS) has entered into a definitive agreement to buy Sackett-Waconia. The deal to purchase the leading US fertilizer blending equipment manufacturer was announced on 4th April.

Having been established 125 years ago, Sackett-Waconia has a long track record in the design and manufacture of fertilizer handling, blending and process equipment. The company specialises in customised systems designed to match individual customer requirements. Sackett-Waconia's blending systems and equipment can be found throughout North America and around the world. Its robust equipment is engineered specifically for the rigours of the fertilizer industry and is designed with a long service life in mind.

Detroit-based PVS is a third generation, privately-owned manufacturer and distributor of chemicals, including fertilizers. It operates throughout the United States as well as in Asia and Western Europe.

David Nicholson, the president and CEO of PVS, said: "PVS is honored to be entrusted with the next chapter of Sackett-Waconia, a company that complements PVS' other lines of business. First and foremost, our goal is to continue to provide our customers and partners with the excellent craftsmanship and innovation that has been the foundation of Sackett-Waconia for the past 125 years. Additionally, PVS

PHOTO: SACKETT-WACONIA

Sackett-Waconia tower blending system for FCI, North Carolina.

is pleased that Larry Taylor, the current CEO of Sackett Waconia, will remain in his position for the foreseeable future, ensuring continuity and a seamless integration."

In reply, Larry Taylor said: "Sackett-Waconia's success is its partnership with its customers. I look forward to continuing what has made us successful for so long as part of the PVS family."

CHINA

Casale buys Green Granulation Ltd

Casale has acquired Chinese granulation technology provider Green Granulation Ltd (GGL). The company offers its own proprietary granulation technology and is a successful designer and constructor of urea and calcium ammonium nitrate (CAN) granulation systems. It is headquartered in Hong Kong with a subsidiary office in Beijing.

The takeover is part of a strategy by Casale to strengthen its market position by adding to its already comprehensive portfolio of fertilizer production technologies. The company is aiming to become a 'one-stop-shop' for the entire production cycle of nitrogen-based fertilizers, by offering complete technology coverage from raw materials through to final products.

Casale now owns the following assets as a result of the GGL purchase:

- The cold recycle granulation (CRG) granulation process
- A proprietary granulator and scrubber design
- A team of experts and qualified technicians
- The experience gained from several industrial references.

CRG fluidised bed technology is the most advanced granulation process available, according to Casale, being designed to accept a lower concentration of urea melt feed (circa 96% urea plus biuret). The technology also leads to lower build costs and higher efficiency, thanks to its unique plant design and horizontal layout. Additionally, adoption of the CRG process will provide Casale's customers with operational, economic and environmental benefits such as:

- Lower total investment costs
- Lower power consumption
- Simplified operations
- Higher operational flexibility for both urea and CAN granulation.

Federico Zardi, Casale's CEO, said: "This acquisition not only adds a new technology that perfectly fits into our portfolio, but it also strengthens our presence in the local Chinese market. Casale and GGL started cooperating some years ago and today's investment decision confirms our strong confidence in the CRG granulation process, which has been also incorporated in the new 594,000 t/a Casale urea plant that will be completed in the first half of 2025 in Yangiyer, Uzbekistan."

UZBEKISTAN

Construction agreement for Yangiyer ammonia-urea plant

Casale has entered into a construction agreement for the large-scale Yangiyer ammonia-urea plant in Uzbekistan's Syrdarya region.

The trilateral agreement is between Swiss-headquartered Casale, the Cyprus-registered investment company Ferkensco Management Limited and Singapore-registered construction company Enter Engineering Pte Ltd. It was signed in Tashkent at the end of March.

The state-of-the-art Yangiyer project incorporates an ammonia unit (495,000 t/a capacity) with urea production and granulation units (594,000 t/a capacity). Construction of the $500 million plant will create more than 500 local jobs and is scheduled for completion in the first half of 2025.

The construction agreement follows the award to Casale last year of all technology licenses and the front-end engineering design (FEED) contract for the ammonia, urea and granulation units. This was backed by European funding. Casale has also been named as the project's general designer. It will be supported by Uzbekistan's UzlitiEngineering design institute, a wholly owned subsidiary of Enter Engineering.

Lorenzo Pennino, head of the commercial division at Casale, welcomed the agreement: "We are grateful to have entered into a long-term partnership with Ferkensco Management and thus enhancing our international reach thanks to this collaboration in Uzbekistan. Our goal is to continue… providing top quality technical expertise with an unyielding focus on efficiency, reliability, and safety."

Alfonso Tengco, Enter Engineering's representative, added: "This agreement builds on a successful and longstanding relationship between Casale and Ferkensco Management in the implementation of this important project. We are proud to be part of this initiative and will leverage our EPC experience and expertise to ensure that Uzbekistan has a modern and efficient plant capable of providing its agricultural sector with high-value fertilizer products."

Timur Juraev, Ferkensco Management's representative, said: "We are delighted that our focus on long-term international cooperation with such reliable partners as Casale and Enter Engineering is bringing positive results. This modern facility, when completed, will produce highly efficient nitrogen mineral fertilizers, helping Uzbekistan meet domestic demand, and also expand foreign market trade."

JORDAN

New phosphoric acid plant planned

Jordan Phosphate Mines Company (JPMC) has signed a memorandum of understanding (MoU) with German industrial projects company LUMA-International to build a new phosphoric acid in southern Jordan, the country's Petra news agency has reported.

The agreement was signed in Amman on 30th March by Abdulwahab Rawad, JPMC's CEO, and Ralf Keller, the managing director of LUMA-International. Under the agreement, JPMC will supply the new phosphoric acid plant with its phosphate rock raw material needs, while LUMA has committed to buying all of the plant's output.

Two days previously, JPMC also signed a phosphate rock supply agreement with LUMA-International. It will sell 850,000 t/a of phosphate rock to the German company at international market rates. No information on the rock's ultimate use or destination was provided.

Muhammad Thneibat, JPMC's chairman, who was present at both signing ceremonies, hoped the deals would widen cooperation on phosphate fertilizers between JPMC and German companies. He stressed the importance of the agreements for increasing in-country manufacturing capacity and reducing production and export costs. He also said the agreements would boost JPMC's status and competitiveness in global markets.

In reply, Keller said that his company was looking forward to more cooperation with JPMC, including new partnerships to produce phosphoric acid and phosphate fertilizers. Keller praised JPMC's production and export achievements. He also expressed his appreciation of the company's openness to global markets and willingness to diversify its partnerships. ■

People

Italy's Maire Tecnimont Group has named **Alessandro Bernini** as its chief executive officer (CEO) and chief operating officer (COO). The announcement was made following the resignation of **Pierroberto Folgiero**, the company's previous CEO and COO, with effect from 15th May.

Interim appointments at executive level in Italy follow a formal process set out by the Italian Civil Code. The roles of CEO/COO passed to Alessandro Bernini when Folgiero's officially designated successor, **Alessandra Conte**, declined to accept these positions. Bernini, who has been the company's chief financial officer (CFO) since 2013, will remain as CEO/COO until the company's next shareholder meeting, in accordance with Italian law.

Bernini joined Ernst & Young as an auditor in 1980 and became a partner in 1994. He then joined Saipem Group as CFO in 1996, rising to become head of corporate governance in 2002. Bernini next became CFO of ENI Group in 2008, where he spent five years prior to joining Maire Tecnimont.

"The board of directors, the board of statutory auditors and all the management of the company and of the Maire Tecnimont Group thank Pierroberto Folgiero for the activity carried out and the important results achieved, expressing the best wishes for future professional challenges," the company said in a statement.

CF Industries has named **Martin A Jarosick** as vice president, treasury and investor relations, effective immediately. Mr Jarosick has served as vice president, investor relations, since joining CF Industries in 2017. In his new role, Martin will oversee the company's treasury organisation, as well as continuing to lead on investor relations. His new Treasury responsibilities include capital markets and banking activities, risk management, and credit.

Before joining CF Industries, Mr Jarosick was treasurer and vice president, investor relations at Axiall Corporation. He has also held various positions in treasury, strategic planning, and investor relations with The Home Depot and Progress Energy earlier in his career.

"Martin has been a strategic leader and valued voice within CF Industries as we have navigated the dynamic global nitrogen market and advanced our clean energy initiatives," said Christopher D Bohn, CF Industries' senior vice president and chief financial officer. "His leadership and experience in treasury operations will serve the Company well as we build on our track record of creating long-term value for shareholders."

Mr Jarosick replaces **Daniel L Swenson,** who retired from CF Industries on 31st March 2022. Mr Swenson had been treasurer of CF Industries since 2015, having joined the company as senior director, investor relations and corporate communications in 2012.

"I want to thank Dan for his commitment and dedication to CF Industries during his 10 years with the Company," said Christopher Bohn. "We wish him well in all his future endeavours."

Itafos appointed **Stephen Shapiro** and **Isaiah Toback** to its board of directors in mid-April. Toback is the new board nominee of the company's principal shareholder, CL Fertilizers Holding, replacing **Rory O'Neill**.

"We are pleased to welcome Stephen and Isaiah to our board. Both appointments add to the overall depth and skill set of the board and will be instrumental in providing oversight as the company continues to execute on of its strategic initiatives," said Anthony Cina, the chairman of Itafos. "On behalf of the board, I would also like to thank Rory for his leadership and contributions to the company."

Currently, Shapiro is also CFO at medical device company Cellview Imaging. Prior to joining Cellview, he had a 30-year career in investment banking, most recently leading the Canadian Industrials and Consumer Group for Wells Fargo Securities Canada. Prior to that, he spent 13 years with BMO Capital Markets, where he started and led the agriculture and fertilizer group. He is a Chartered Financial Analyst and holds a commerce degree from McGill University and an MBA from the University of Chicago.

Toback is a partner and the deputy co-chief investment officer at Castlelake. He was previously an investment banker with Goldman Sachs. He holds a BA in economics from Vanderbilt University.

Chris Paterson has joined the board of directors of Soilgenic Technologies. The Calgary-headquartered company is helping the agricultural industry reduce its greenhouse gas emissions and environmental impacts by offering climate-smart technologies.

Chris has been involved with agronomy and agribusiness in North America for 25 years. This includes experience with capital markets in emerging areas such as digitisation, sustainability and decarbonisation. He has also mentored companies through his involvement with groups such as AgFunder, Creative Destruction Lab, and Plug And Play. ■

Calendar 2022

! The following events may be subject to postponement or cancellation due to the global coronavirus pandemic. Please check the status of individual events with organisers.

MAY

30-1 JUNE

IFA Annual Conference,
VIENNA, Austria
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

31-2 JUNE

China International Fertilizer Show 2022,
SHANGHAI, China
Contact: CCPIT Sub-Council of Chemical Industry, Beijing
Tel: +86 10 84 255 960
Email: zhengyingying@ccpitchem.org.cn

JUNE

2-3

NH3 Event Europe 2022,
ROTTERDAM, Netherlands
Contact: Stichting NH3 event Europe,
Karel Doormanweg 5,
3115 JD Schiedam, The Netherlands
Tel: +31 10 4267275
Email: info@nh3event.com

10-11

45th AIChE Annual Clearwater Conference,
CLEARWATER, Florida, USA
Contact: Michelle Navar,
AIChE Central Florida Section
Email: vicechair@aiche-cf.org

20-22

4th European Sustainable Phosphorus Conference, VIENNA, Austria
Contact: Chris Thornton,
European Sustainable Phosphorus Platform (ESPP) secretariat
Tel: +33 474 93 07 93
Email: info@phosphorusplatform.eu

28-30

IFA Smart & Green, **Virtual event**
Contact: IFA Conference Service
49, Avenue d'Iéna,
75116 Paris, France
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

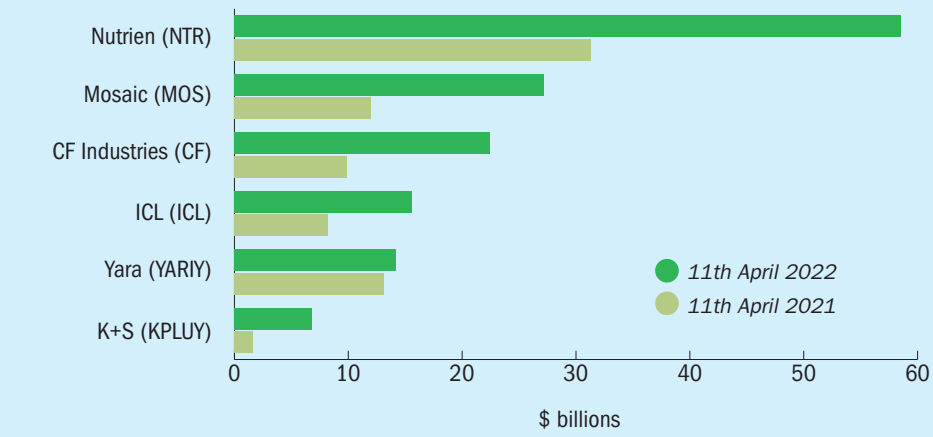
Fertilizer financial scorecard

We compare and contrast the 2021 financial performance of selected major fertilizer producers following the publication of fourth quarter results.

PHOTO: K+S

Dr Burkhard Lohr, the chairman of K+S (left), welcomed journalists and unveiled the company's 2021 financial results at its annual press conference in March. Dr Lohr described 2021 as a "very successful year for K+S".

Fig. 1: **Market capitalisation**



Source: YCharts

Record financial results for Nutrien

Saskatoon-headquartered Nutrien reported record financial results in 2021. Due to its unrivalled scale and global reach, the Canadian company's performance tends to exemplify and set the tone for the whole fertilizer industry.

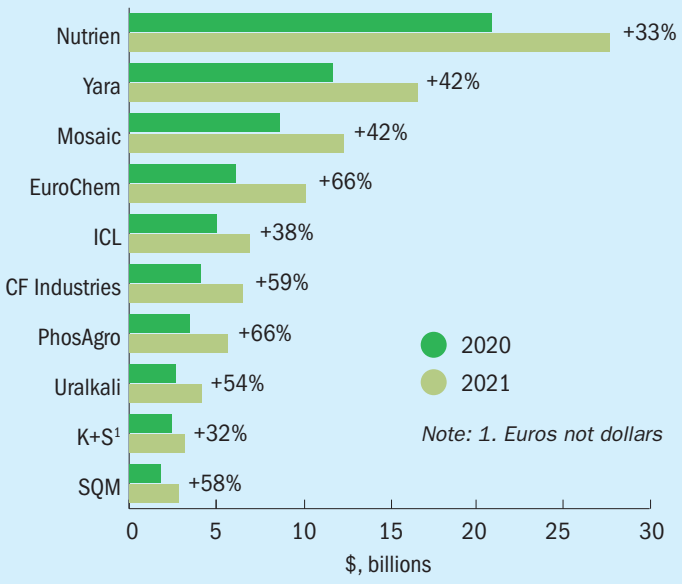
Nutrien's market capitalisation, at more than $58 billion, is more than double that of its nearest rivals (Figure 1). The world's largest crop nutrient company produces around 27 million tonnes of potash, nitrogen and phosphate products annually from operations and investments in 14 countries, distributing these to agricultural, industrial and feed customers across the globe. Its agriculture retail business also serves more than 500,000 farmers worldwide.

Across-the-board fertilizer price rises in 2021 were a key factor behind the company's record results, with Nutrien reporting:

- **Potash prices** increased in response to record global demand of 70 million tonnes in 2021, supply tightness, new project delays and uncertainty around sanctions imposed on Belarus by the US and European countries.
- **Nitrogen prices** have been supported by strong demand, soaring energy prices in Europe, government restrictions, and geopolitical risks in key export markets.
- **Phosphate prices** have been supported by export restrictions reducing supply from China and elevated raw material costs. These factors were compounded by tight inventories in key import markets such as India.

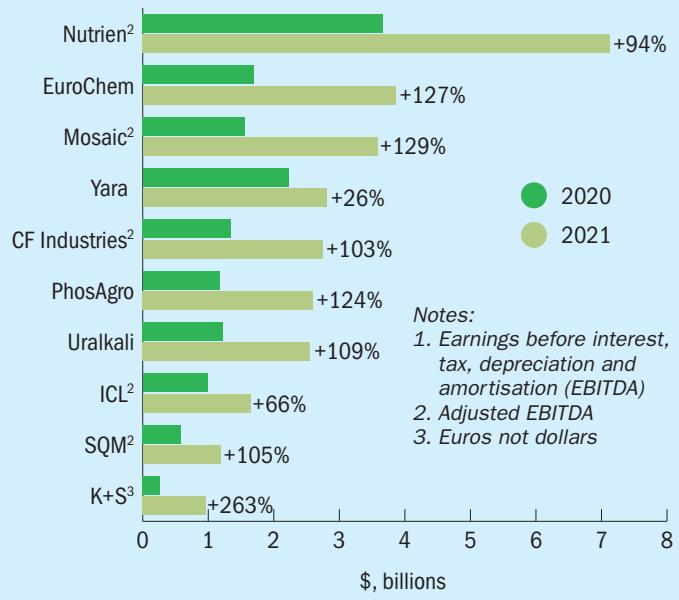
Nutrien's revenues grew by one-third year-on-year (y-o-y) in 2021 to $27.7 billion (Figure 2). Earnings growth (adjusted EBITDA) for the year was even more impressive;

Fig. 2: **Revenues, 2021 vs 2020**



Source: Company filings

Fig. 3: **Earnings[1], 2021 versus 2020**



Source: Company filings

Fig. 4: **Free cash flow, end 2021**

Source: Company filings

Fig. 5: **Net debt, end 2021**

Source: Company filings

it rocketed by 94 percent to $7.1 billion (Figure 3). Free cash flow – a measure of profitability – ended 2021 at $4.3 billion (Figure 4), versus $1.8 billion for the preceding year. Nutrien used the large cash sums generated in 2021 to strengthen its balance sheet. This included reducing its long-term debt by $2.1 billion to $7.5 billion (Figure 5).

"The advantages of Nutrien's integrated business were demonstrated in 2021 as we delivered record financial results. We utilized the scale and reliability of our world-class supply chain and the strong execution of our teams to ensure customers had the products and services they needed, when they needed them," said Ken Seitz, Nutrien's interim president and CEO.

Nutrien is the world's largest potash producer with a 21 percent share of global production capacity. The company achieved record potash sales from its six Canadian mines of 13.6 million tonnes in 2021. 8.5 million tonnes of these sales volumes were destined for overseas markets with the remaining 5.1 million tonnes being sold within North America. One million tonnes of this production volume were achieved using remotely operated and autonomous mining methods, thanks to Nutrien's roll-out of its Potash Next Generation initiative.

Potash contributed 38 percent to Nutrien's full-year earnings. Potash earnings at $2.7 billion (adjusted EBITDA) in 2021 were 130 percent higher y-o-y due to higher realised selling prices and record sales volumes, with Nutrien's full year pro-

duction rising by nearly one million tonnes. The company's potash manufacturing costs last year ($63 per tonne) were, however, up $4 per tonne on 2020.

Similarly, Nutrien's nitrogen earnings also increased by 114 percent in 2021 to $2.3 billion for the year. This was despite a slight drop (two percent y-o-y) in sales volumes to 10.7 million tonnes. Higher realised selling prices for nitrogen products in 2021 more than offset higher natural gas costs.

Earnings at Nutrien's retail business, Nutrien Ag Solutions, reached record levels in 2021's fourth quarter and surpassed $1.9 billion for the full year. A record earnings margin on sales of 11 percent was also reported for 2021. Full year retail sales via the company's digital platform also increased to $2.1 billion.

Looking ahead, Seitz said: "The outlook for global agriculture and crop input markets is very strong and we are well positioned to deliver significant growth in earnings and free cash flow in 2022."

Yara – higher realised prices offset energy cost crunch

With a current market capitalisation of $14.2 billion (Figure 1), Norway's Yara International is arguably the world's largest crop nutrients provider based on total product deliveries.

The Oslo-headquartered company produced 20.9 million tonnes of finished fertilizers and 7.3 million tonnes of ammonia from its global assets in 2021. Annual product deliveries decreased slightly to 37.8 million last year. These were divided between:

- 28.4 million tonnes of fertilizers
- 7.4 million tonnes of industrial products
- 2.0 million tonnes of traded ammonia.

Yara's revenues grew strongly in 2021, rising by more than 40 percent y-o-y to reach $16.6 billion (Figure 2). Yet earnings growth during the year was lower than many of its industry peers – increasing by 26 percent y-o-y to reach $2.8 billion (Figure 3). This partly reflected the extreme energy price volatility faced by European nitrogen producers during 2021.

"The financial results of 2021 show improved underlying performance," said Yara's president and CEO Svein Tore Holsether. "Higher prices more than offset increased energy costs, higher fixed costs and currency effects."

Yara's fixed costs increased in 2021 linked to high and volatile European natural gas prices. The Europe spot gas (TTF) in the fourth quarter, for example, increased by a staggering 489 percent y-o-y to reach $26.5/Mmbtu at one point. These record feedstock prices led to ammonia production curtailments in Europe in the latter part of the year.

Although market reference prices increased rapidly in 2021's fourth quarter (e.g., the 190 percent y-o-y increase in the urea price (f.o.b. Egypt) to $755/t), Yara said time lags meant these were not fully reflected in its realised prices. The company nevertheless reported the following double- and triple-digit price rises for its premium product offerings in the year's last quarter:

- +119 percent y-o-y increase in the realised price of calcium ammonium nitrate (CAN) to $441/t
- +52 percent y-o-y increase in the realised global compound NPK price to $642/t (average grade).

"The market [price] environment was supportive, as a result of strong demand and a tight global supply situation," Svein Tore Holsether commented. "However, high and volatile natural gas

prices continue to pose a challenge for the nitrogen industry in Europe."

Record earnings for Mosaic

Florida-headquartered The Mosaic Company is the world's leading combined phosphate and potash producer with a market capitalisation of $27.2 billion (Figure 1). The company sold around 26 million tonnes of products in 2021, with sales volumes split between three business segments:

- Potash segment: 8.2 million tonnes
- Phosphates segment: 7.7 million tonnes
- Mosaic Fertilizantes: 10.1 million tonnes.

Mosaic described 2021 as a year of record earnings. The company reported sector-leading earnings growth of 129 percent y-o-y to $3.6 billion (adjusted EBITDA) (Figure 3). This was achieved from full year revenues of $12.4 billion (Figure 2).

Phosphate earnings (adjusted EBITDA) totalled $1.7 billion in 2021, up 223 percent from 2020. This reflected a $258/t increase in the average realized selling price to $618/t for the year. Adjusted gross margin for phosphate production also increased dramatically to $173/t in 2021, up from $16 in 2020 – this, again, largely reflecting higher market prices. Sales volumes for Mosaic's MicroEssentials product also reached a record 3.3 million tonnes in 2021. Gross margins achieved from this premium product last year were on average $32/t above those of diammonium phosphate (DAP).

> **"Across-the-board fertilizer price rises were a key factor behind the record results reported in 2021."**

The company's potash earnings (adjusted EBITDA) totalled $1.3 billion in 2021, up 78 percent from 2020. Higher pricing more than offset lower volumes, which were down by 1.2 million tonnes on 2020. Mosaic expected to complete the ramp-up of its K3 potash mine in Saskatchewan by the end of March this year, enabling its total production output to reach five million tonnes in 2022. Mosaic's Colonsay potash mine in the province also successfully reached its annual output target of around one million tonnes, at a cash production cost of $85/t per tonne during 2021's last quarter.

Full year earnings (adjusted EBITDA) from Mosaic's Brazilian subsidiary Mosaic Fertilizantes, meanwhile, reached $821 million in 2021, up 74 percent on the preceding year.

"Mosaic delivered record EBITDA in 2021, and we expect strong performance to continue in 2022," said Joc O'Rourke, Mosaic's president and CEO. "As a result of successful investments like our new Esterhazy K3 potash mine, Mosaic Fertilizantes in Brazil, and our cost-structure transformation, we are generating tremendous value in the current environment."

Looking ahead, Mosaic confidently expects the upward pricing momentum to continue during 2022 – given that about 85 percent of first quarter sales are already committed and priced. Consequently, first quarter 2022 realised prices for phosphates (f.o.b.) and potash are expected to rise by $60/t and $125/t, respectively, relative to the fourth quarter of 2021. The company also anticipates first quarter phosphate and potash sales volumes of 1.6-1.8 million tonnes and 1.8-2.0 million tonnes, respectively.

CF Industries reports record free cash flow

Leading North American and UK nitrogen producer CF industries reported buoyant full-year revenues ($6.5 billion) and earnings ($2.7 billion) – these rising y-o-y by 59 percent and 103 percent, respectively, (Figures 2 and 3). Full year net cash from operating activities ($2.9 billion) and free cash flow ($2.2 billion, Figure 4) both set new company records

The Illinois-headquartered company has a market capitalisation of $22.4 billion (Figure 1). It linked its strong financial performance to an 84 percent hike in the average selling price in 2021, this rising to $498/t for the year versus $271/t in 2020. This in turn was linked to strong global demand as well as decreased global supply availability, with higher global energy costs driving global operating rates lower.

A fall in CF's full year sales volumes – 5.0 million tonnes in 2021 versus 5.5 million tonnes in 2020 – was attributed to:

- Lower supply availability due to higher than average maintenance activity
- Two significant weather-related production outages
- Production curtailments at the company's UK plants due to high natural gas costs.

"The CF Industries team delivered outstanding results in 2021 as strong global nitrogen demand, lower global operating rates and favorable energy spreads drove company-record free cash generation," said Tony Will, CF Industries' president and CEO. "We expect global nitrogen fundamentals to remain positive, underpinned by the need to replenish global grains stocks, increased economic activity and global energy dynamics."

Looking ahead, CF Industries expects the tight global nitrogen supply situation to continue. It linked this to high energy prices in Europe and Asia, along with export restrictions on some nitrogen products from Russia, Egypt, Turkey and China.

"Global nitrogen inventory entering 2022 is believed to be low following a year of strong demand and lower production due to the impact of energy-related production curtailments and shutdowns in Europe, weather-related disruptions in North America and stagnant production levels in countries such as India," the company said.

At the same time, CF also expects agricultural demand for nitrogen products globally to remain robust. "The need to replenish global grains stocks continues to support high… forward prices for nitrogen-consuming crops. These crop prices support high levels of planting and incentivize fertilizer application," it said.

Very successful year for K+S

Revenues at German potash and salt producer K+S grew by 32 percent y-o-y to €3.2 billion (Figure 2), while earnings (EBITDA) for the year grew by a sector-leading 263 percent to €969 million (Figure 3). The launch of subsidiary waste management company REKS, a new joint venture with Remondis Group, contributed a one-off €219 million amount to these earnings.

With a market capitalisation of €6.8 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 speciality fertilizers. These products are chloride-free and/or supplement potassium with other elements such as magnesium, sulphur, sodium and micronutrients.

"2021 was a very successful year for K+S," said its chairman, Dr Burkhard Lohr. "We have made the company more efficient, leaner, as well as more profitable, and strategically realigned K+S."

K+S said its performance was supported by increased sales volumes and higher potash prices worldwide. Potash prices globally reached a 13-year high during 2021's second half, it said. Fertilizer sales volumes also grew by around 300,000 tonnes in 2021 to 7.62 million tonnes, while average prices for the company's product portfolio increased by 28 percent y-o-y to €298/t. Potash prices in Brazil, for example, more than tripled during the year to breach $800/t, while Europe also recorded significant price gains. This helped boost revenues at the company's agricultural customer segment by 34 percent to €2.3 billion in 2021.

By drastically reduced its net debt during 2021, from €3.2 billion to 606 million, K+S has managed to cut its net debt/EBITDA ratio from 7.2 in to 0.6 (Figure 5). Debt reduction benefitted from €2.6 billion in net proceeds from the sale of the company's American salt business to Stone Canyon Industries Holdings. Encouragingly, free cash flow also moved out of the negative to reach €93 million (Figure 4).

"With the successful sale of the Americas operating unit, the significant reduction in debt, and the restructuring of our organization, we have accomplished essential tasks," said Dr Lohr. "We are focusing on our core business with potash and magnesium products and are working intensively on further optimizing our existing business."

Dr Lohr was optimistic about the year ahead. "We expect EBITDA from continuing operations to range between €1.6-1.9 billion in the 2022 financial year. This would represent the best result in the history of K+S. Adjusted free cash flow from continuing operations should also increase sharply to €600-800 million," he said.

ICL breaks records

Israel's ICL Group is a leading producer of potash, phosphates and speciality fertilizers with a market capitalisation of around $15.6 billion (Figure 1). The company's annual revenues grew by 38 percent to $7.0 billion in 2021 (Figure 2). Full-year earnings (adjusted EBITDA) also rose by 66 percent y-o-y to $1.6 billion (Figure 3). Operating cash flow, at $1.1 billion in 2021, was also up by one-third on the previous year (Figure 4).

ICL's potash ($1.9 billion) and phosphate ($2.4 billion) business segments contributed 27 percent and 35 percent, respectively, to overall company revenues in 2021. The company's speciality fertilizer business, Innovative Ag Solutions, also generated 18 percent of revenues ($1.2 billion).

ICL's total potash production (4.5 million tonnes) in 2021 was slightly lower y-o-y, down by just 20,000 tonnes. This was mainly due to lower output from ICL Dead Sea, albeit partly offset by increases in granular potash output elsewhere. Nevertheless, the company still benefitted greatly from a sharp hike in the average potash realised price to $487/t in 2021 – up 114 percent y-o-y – with recent price increases expected to continue to have a positive financial impact in the first half of 2022.

ICL's Spanish potash production increased y-o-y due to the completion of the ramp to the Cabanasses mine in 2021's first quarter. Polysulphate production at ICL's Boulby mine in the UK, meanwhile, also continued to rise. Production of this polyhalite product – 214,000 tonnes in 2021 – was up 36 percent y-o-y, while sales volume increased 42 percent to around 230,000 tonnes.

"The fourth quarter was a remarkable end to 2021, with sales of more than $2 billion and all-time record adjusted fourth quarter EBITDA of $575 million. In fact, all three of our specialty businesses delivered all-time record fourth quarter and annual results. We continued to benefit from our strategic focus on growing our long-term specialty solutions businesses, as performance in the quarter was also supported by increased demand and higher prices in most markets. All four of our businesses contributed, with double-digit growth in sales and EBITDA and, as a result, we were able to deliver yet another quarter of margin expansion and bottom-line improvement," said Raviv Zoller, ICL's president and CEO.

Looking ahead, ICL is predicting full year 2022 earnings (adjusted EBITDA) will increase to $1.85-2.05 billion, with $0.88-0.93 billion of this generated by its speciality businesses. This forecast was, however, made in early February prior to Russia's invasion of Ukraine.

Massive commodity market shock

Most fertilizer producers released their 2021 fourth quarter and full years results either shortly before or after Russia's invasion of Ukraine at the end of February. This event has subsequently inflicted a massive shock on commodity markets globally. This shock and its full market impact is still playing out. Yet, as Argus noted in early March (*Fertilizer International* 507, p4), the prices of fertilizers and fertilizer raw materials are likely to face yet more upward pressures:

"As US and EU sanctions on Russia ratchet up, all fertilizer products will face upwards price pressure – should sanctions directly target fertilizer HS codes, fertilizer producers, or their owners.

"In addition to any trade disruption, ammonia and other nitrogen fertilizer prices will undergo a substantial cost-push as the risk premiums on gas increase the industry's marginal cost of supply. Actual disruption to Russian gas flows has the potential to push gas prices and nitrogen costs higher still.

"Potash buyers in the west, having started to adapt to the sanctioning of Belarusian exports, now face the prospect of losing access to Russian supply as well, should the conflict continue and western sanctions begin targeting the Russian potash trade as well."

Unaffordable price levels?

Due to the market impacts of the war in Ukraine, average fertilizer prices recently exceeded their previous 2008 peak. This is leading to concerns over demand destruction.

CRU's fertilizer price index, for example, reached 390 on 25th March, up from 377 in the preceding week. This was well above the previous record of 360 set in 2008. The index, although it subsequently fell by 10 points to 380 in the first three weeks of April, remains above the 2008 record at the time of writing.

Record price levels are negatively affecting fertilizer affordability. CRU's global fertilizer affordability index – which benchmarks fertilizer prices relative to crop prices – shows that fertilizers are less affordable now than at almost any time in the last two decades. Going back 20 years, the fertilizer affordability index at the end of March has only ever been exceeded once before in 2008. ■

Authors note

Please also note that, due to the war in Ukraine, we are not providing a market commentary on Russian fertilizer producers currently.

Liquid fertilizers

Liquid fertilizers are emerging as a high growth, multibillion dollar market. Their growing use is linked to trends such as no-till farming and the greater adoption of precision agriculture. Leading producers and products are highlighted.

PHOTO: KOCH FERTILIZER

Koch Fertilizer recently commissioned a two-million-gallon ammonium thiosulfate (ATS) terminal at its Fort Dodge site in Iowa to support growing demand for liquid fertilizers.

Table 1: **Benefits of liquid fertilizers versus granular products**

Cost effective	● Liquid fertilizers are potentially less expensive to equip for application.
Transport & storage	● Very low risk of product degradation, unlike granules. ● Transporting liquids is generally easier than granules, i.e. pumps & piping versus belts & conveying.
Precision agriculture	● Ideally suited for precision delivery to the crop. Unlike granules, no risk of segregation or uneven application over the field. ● Liquids well suited to variable rate application (VRA) using GPS and nutrient field mapping.
4Rs nutrient stewardship	● Easier to deliver the right product at the right rate at the right time in the right place.
Time & labour saving	● The application of liquids can often be combined with other operations or applications, e.g., tilling, planting, irrigation, pesticide application.
Versatility	● Liquids can be applied in a variety of different ways, e.g., soil applied (injection and banding), fertigation (flood, drip and pivots), foliar, top dressing etc. ● Liquids can also be applied pre-planting, pre-emergence and post-emergence.
Conservation agriculture	● Liquids can be easily applied in reduced and no-till systems.
Plant availability	● Liquids enter the soil in solution and are hence immediately available to the plant unlike granules which must first break down and dissolve.

Source: Tessenderlo Kerley International

Compelling benefits

The use of liquid fertilizers has increased dramatically in recent years. Liquid products offer undeniable practical advantages. They are also cost-effective – providing savings in materials, handling and application costs.

Liquid fertilizers are high performing products, typically offering more precise and environmentally responsible crop fertilization. They are fully compatible with irrigation systems and can be applied simultaneously with other crop inputs such as pesticides and fungicides. Their ability to deliver nutrients to crops more precisely improves nutrient use efficiency. This, in turn, can result in higher yields and crop quality improvements.

"The number-one top benefit of fluid fertilizers is high value – their overall benefit relative to costs. And the totality of the benefits associated with fluid fertilizers far outstrips any difference in the purchase price of specific crop nutrients," comments the US-based Fluid Fertilizer Foundation.

The Foundation highlights the following benefits in particular:

- **Logistical advantages:** Fluid fertilizers provide unequalled handling convenience/efficiency and timeliness in crop production practices.
- **Accurate, uniform, and precise application:** This provides optimum crop nutrient distribution within a field, portion of a field and fertilizer band.
- **Unparalleled flexibility, versatility and adaptability:** Fluids are compatible with all crop production systems, all application methods, and any application timing.
- **Unsurpassed agronomic efficiency:** This offers superior agronomics, environmental stewardship and profitability.

Based on these merits, the Fluid Fertilizer Foundation advises that: "High value [liquid fertilizers] provide for prosperity – low cost [solid fertilizers] do not!"

Market drivers

In terms of what's been driving their adoption, a shift from solid to liquid fertilizers is seen by some as a logical market trend due to the following characteristics:

Table 2: **Potential benefits of liquid fertilizers versus water-soluble fertilizers**

Human error	● Liquids are supplied as ready-made formulations – with a much lower risk of human error compared to nutrient solutions made by manually dissolving water-soluble fertilizers
Ease of use	● Much easier to mix and blend liquids compared to water-soluble powders
Labour & cost saving	● No need to wait for liquid products to dissolve
Stability	● There is a risk that water soluble fertilizers will cake if stored incorrectly or for long periods
Safety & theft	● Liquids can be connected directly to the irrigation system, so reducing operator exposure, in contrast to water-soluble powders which have to be unbagged and poured into the dissolution tank ● Lower risk of farm theft for liquids, e.g. 1,000 litre IBC containing liquid fertilizer versus 25 kg bags of water-soluble products
Equipment advantages	● Liquids are much less likely to block the irrigation system and drippers compared to (poor quality) water-soluble fertilizers ● Less investment in fertigation/irrigation equipment is required for liquids – whereas systems for water soluble fertilizers usually require filters, multiple pumps and dissolutions tanks ● Liquids are also more suitable for modern foliar spraying equipment than standard water-soluble products
Versatility	● Liquid fertilizers can be applied to crops in a variety of different ways

Source: Tessenderlo Kerley International

- Liquids offer high precision nutrition with improved nutrient uptake and efficiency
- Have a low water requirement
- Makes good use of existing drip, sprinkler or flood irrigation systems and infrastructure
- Handling safety – products are safer for both the irrigation system and farmers
- Products are 'cleaner' with less impurities and are heavy metal free
- They are also flexible – offering more application choices to farmers
- Liquids can be applied without a lot of supervision or knowledge
- And have the potential to improve farmer incomes by avoiding inefficient fertilization and delivering better produce for less labour.

The specific benefits of liquid fertilizers versus granular fertilizers and water-soluble fertilizers are listed in Tables 1 and 2, respectively.

There are specific circumstances which will also tend to favour liquid fertilizers over water-soluble fertilizers. Liquid products, for example, can offer advantages to growers faced by the following:

- Increasing field size (or total area) to be fertigated
- Decreasing number of fertigations
- Decreasing water availability (and/or tank size)
- Increasing labour costs
- Desire or need to reduce the risk of human error
- Lower market premium for liquids compared to water solubles
- Increasing health & safety and a focus on product handling.

Greater adoption of liquid fertilizers is not solely down to changing product preferences either. The supporting infrastructure for reliably delivering liquid products also needs to be in place. The availability of customised/tailor-made liquid formulations is improving thanks to an increasing number of manufacturers and distributors who are now servicing the liquid fertilizer market – and are equipped and skilled to be able to deliver these products to growers.

Growers, in turn, are more receptive to buying liquid fertilizers if these are shown to deliver consistent crop benefits and:

- Support good profitability (e.g. for export crops, cash crops) and are reasonably priced relative to their granular and water-soluble alternatives
- Provide more concentrated nutrient solutions
- Are delivered in a form that is quick, easy and safe to handle.

Liquid fertilizers are generally associated with technically sophisticated and mature farming systems. Yet advocates also highlight the potential for greater adoption in emerging agricultural economies. Developing markets could, for example, benefit from liquid fertilizers due to:

- Falling groundwater levels and increased water scarcity
- Need to improve both nutrient use efficiency (NUE) and water use efficiency (WUE) of crops while boosting farmer income and profits.
- Increases in the area grown under drip irrigation due to favourable government policies
- Rises in the area of horticulture, floriculture and vegetable crops under fertigation, and the crop area under protected agriculture (green house cultivation)
- The rapid mechanisation of agriculture favours the injection of liquid fertilizers in soils
- Improving knowledge on soil fertility and fertilizer use.

Handling & storage

Liquid fertilizers are commonly sold as small packs (1-10 litres) or 770 litre- and 1,000 litre-size intermediate bulk containers (IBCs); 200 litre-size drums are also used. These liquids are typically transported to the farm in bulk tankers, in bulk flexibags inside a shipping container, or in IBCs. Storage tanks, such as stainless steel tanks (with or without a mixer), containment tanks and flexible tanks, are used for on-farm storage. These can be insulated and heated to avoid precipitation. Refilled IBCs are another storage option. Investment decisions for the grower include:

- Whether to rent or buy storage tanks from the supplier
- The need for pumping equipment
- Buying custom blended, ready-to-use nutrient solutions
- Investing in blending and mixing equipment for higher volume consumption of liquid fertilizers.

Application methods

A major advantage of liquid fertilizers is their suitability for a wide range of application methods. They can be applied easily via:

- **Fertigation** – drip irrigation, overhead pivots and sprinklers, in-furrow (flood) irrigation
- **Foliar treatments**
- **Soil application** – banding and injecting
- **Top dressing**.

Drip irrigation is arguably the most efficient way of delivering liquid fertilizers. This method maximises both water use and nutrient use efficiency by 'spoon feeding' crops. The use of liquids also minimises the risk of equipment blockages.

Liquids are effective in the drip irrigation of both small and large fields and are very simply to use. Application can be as simple as 'connecting the IBC and opening the valve', for example. Overhead pivots and sprinklers are more commonly used for pasture, field crops (potatoes, onion, carrots etc) and/or larger growing areas.

Foliar application of liquid fertilizers can be made from a tank-mix with pesticides. This method is better suited to lower dose applications (e.g., micronutrients). Providing nutrients in concentrated liquid form is also ideal for the low water volumes used to spray crop leaves.

Soil injection of liquid fertilizers allows very precise and even nutrient applications close to the crop. This is especially useful for less mobile nutrients such as phosphorus, calcium and magnesium. Suitable equipment is available for injecting liquid fertilizers at sowing. Liquids can also be injected via a mechanical weeder. When injecting liquids, however, care must be taken not to damage crop roots or inject too close to seeds or seedlings.

A top dressing of liquid fertilizers can be made pre-planting and at pre- and post-emergence. This phased application of nutrients helps improve nutrient use efficiency, particularly for nitrogen. Even and precise applications of liquid fertilizer can be achieved using specially designed nozzles mounted on spray machinery.

Product categories

Liquid fertilizers can be grouped into four main categories:

- **Pure liquid fertilizers.** These are chemicals that exist in a natural liquid state. Anhydrous ammonia (87-0-0) is the most common type and is typically soil injected using specialised equipment. Other categories of liquid fertilizer, in contrast, are concentrated pre-dissolved solutions of solids.
- **Liquid fertilizers without a solid/water-soluble equivalent.** Examples include thiosulfates and ammonium polyphosphate. Their solid equivalents are usually unstable and are therefore not sold or marketed.
- **Liquid fertilizers which do have a solid/water-soluble equivalent.** Examples include urea ammonium nitrate (UAN), a solution of urea and ammonium nitrate, and calcium ammonium nitrate (CAN), a solution of calcium nitrate and ammonium nitrate.
- **Suspension or emulsion fertilizers.** These are thixotropic liquids which are fully flowable when pumped but behave as a gel when static. Nutrients are mixed and suspended using a complex suspending agent to ensure homogeneity. By combining the high nutrient concentrations of water-solubles with the application benefits of liquids, this product category bridges the gap between liquid fertilizers and water-soluble fertilizers.

PHOTO: TESSENDERLO KERLEY INTERNATIONAL

Application of liquid fertilizers via a boom sprayer.

Selected products and producers

Primary ammonium nitrate (AN) production has been growing on average at 4-5 percent annually over the last two decades, rising (on a nutrient basis) to around 21 million tonnes N in 2019 (*Fertilizer International* 503, p30). Some 17 percent of this total is consumed in the production of urea ammonium nitrate (UAN) solutions.

UAN is manufactured by mixing non-concentrated AN solution with dissolved urea. The resulting solutions are generally offered in three different concentrations: 28 percent, 30 percent or 32 percent nitrogen content, respectively. The most popular form – 32 percent N – consists of a solution of 45 percent ammonium nitrate and 35 percent urea diluted with 20 percent water. UAN solutions are adjusted to neutral pH (7) using ammonia and nitric acid.

Major UAN producing countries include the US, Russia, Canada, Trinidad and Belarus. Around one third of international production was traded in 2019, with countries in Europe and the Americas being the main import destinations.

In the US, a preference for liquid fertilizers – when combined with tight regulations on the storage, transport and direct application of ammonia – has led to a rapid increase in demand for UAN solutions. As a result, the North American nitrates market is heavily skewed towards UAN. North America is also the most advanced global market for liquid fertilizers in general. Important liquid product manufacturers and distributors include:

- CF Industries
- CVR Partners
- Nutrien
- Koch Fertilizer
- Tessenderlo Kerley
- SQM
- AgroLiquid
- Kugler
- Triangle
- FoxFarm.

CF industries is the region's largest UAN manufacturer. It produced 6.8 million tonnes of UAN (32%) in 2021 from its

Donaldsonville, Port Neal, Verdigris, Woodward and Yazoo City sites in the US and Courtright site in Canada. CVR Partners also produced 1.2 million tonnes of UAN in 2021 from its Coffeyville, Kansas, and East Dubuque, Illinois, plants.

Nutrien sold 4.7 million tonnes of nitrogen solutions, nitrates and sulphates in 2021. The company markets the calcium ammonium nitrate product CAN17 as a flexible and fast-acting liquid fertilizer. CAN17 is a non-pressurised, odourless liquid that is simple to store and apply to a variety of crops. Nutrien and its predecessor companies have been selling this long-standing and established liquid product to fruit, vegetable and nut growers since 1995. Its key properties are as follows:

- **Nitrate-nitrogen.** The 11.6 percent nitrate-nitrogen provides fast-acting N for immediate uptake, while the 5.4 percent ammonium-nitrogen offers a longer term and prolonged N reserve for crop feeding.
- **Soluble calcium.** The 8.8 percent soluble Ca content improves water penetration, allowing available N and moisture to move easily into the root zone. Calcium is also critical for crop quality, promoting healthy cell development in fruits, roots and tubers.
- **Non-volatile.** Unlike UAN solutions, all of the nitrogen in CAN17 is non-volatile, so avoiding nutrient losses and lost nitrogen investment.
- **Non-pressurised.** Unlike liquid ammonia, CAN17 isn't stored under pressure. That makes storage and application easier. The product is also less corrosive to equipment than many other nitrogen fertilizers.
- **Easy to apply.** The product can be sprayed onto the soil surface with a ground rig, for example, or injected into the main line of irrigation systems.

Koch Fertilizer manufactures markets and distributes more than 10 million tonnes of nitrogen fertilizer products in North America annually. These include the liquid products UAN (32% and 28%), anhydrous ammonia, ammonium thiosulfate (ATS) and ammonium polyphosphate (APP). UAN is offered with the company's proprietary Anvol™ or Centuro™ nitrogen stabilizers to help prevent nitrogen losses from leaching, denitrification or volatilisation.

Koch is a major global anhydrous ammonia (82-0-0) supplier to fertilizer distributors and retailers around the world. This is manufactured at five North American plants and distributed via an extensive terminal and transportation network. The company also offers Centuro™ as a next-generation nitrification inhibitor for anhydrous ammonia.

Koch is also a major North American ATS supplier, offering three grades (12-0-0-26, 11-0-0-24, 15-0-0-20) targeted at corn and soybean growers. The company recently commissioned a two-million-gallon ATS terminal at its Fort Dodge site in Iowa. The new ATS storage tank is is connected to the site's existing automated UAN loadout infrastructure and is insulated with an internal coating to enable winter storage. ATS can be mixed with UAN or water at Fort Dodge to generate customised fertilizer blends for a single truck. The terminal will support 24-hour loading and will load a truck in approximately 20 minutes.

The extra storage and loading capacity at Fort Dodge allows Koch to supply customers throughout the corn belt with the ATS produced by Koch affiliate Flint Hills Resources at its Pine Bend refinery in Minnesota. This has the capacity to produce around 100,000 short tons of ATS annually.

"In the last few years, retailers and farmers have had difficulty finding adequate supply of ATS, and at the same time demand continues to grow," said Scott McGinn, Koch Fertilizer executive vice president. "By building on our relationship with Flint Hills Resources and our terminal expertise, we can provide additional ATS capacity to the region and better serve our customers into the future."

Koch also supplies liquid APP produced at its Brandon, Manitoba site in Canada. The Brandon plant is also a manufacturing centre for UAN and ATS.

Thiosulphates are becoming more widely-used as liquid sulphur fertilizers in the broad acre and speciality crop market in North America and Europe. Their use is also on the increase in Latin America.

Tessenderlo Group is a global leader in speciality liquid fertilizers and manufactures four main thiosulphate products:

- Ammonium thiosulfate, Thio-Sul® (12% N + 26% S)
- Potassium thiosulphate, KTS® (25% K + 17% S)
- Calcium thiosulphate, CaTs® (6% Ca +10% S)
- Magnesium thiosulphate, MagThio® (4% Mg + 10% S)

Thio-Sul® is suitable for most irrigation systems and, alongside nitrogen, delivers sulphur in the unique thiosulphate form. It can be added to urea ammonium nitrate (UAN) to improve nitrogen use efficiency by reducing nitrogen losses.

KTS®, another of Tessenderlo's leading thiosulphate products, is marketed as a high-analysis potassium and sulphur fertilizer for fertigation. It is suitable for booster or starter formulations and can also be applied as a foliar fertilizer when crop demand for potassium is high.

Thiosulphates offer sulphur in both immediately plant-available form and in slower release form available to plants over a longer period of time. Thiosulphates also have a modest acidification effect, benefitting crops growing on alkaline (calcareous) soils. Providing sulphur to crops by applying thiosulphates offers a number of specific benefits:

- Enhances crop protein and chlorophyll content
- Assists the synthesis and functioning of enzymes in the plant
- Optimises fertilizer efficiency by stabilising nitrogen
- Improves availability of nutrients in the soil, particularly phosphorus and micronutrients and their uptake by the crop
- Energy efficient assimilation in the plant
- Provides prolonged sulphur nutrition
- A controlled and localised pH adjustment effect in the soil.

Thio-Sul® has the most effective acidification effect because it combines the ammonium cation with thiosulfate. Thio-Sul® can be combined with UAN solutions to provide two main benefits:

- It brings sulphur as a nutrient into the mix – the correct N/S ratio being very important for most crops
- It acts as nitrogen stabiliser improving nitrogen use efficiency.

Studies have shown that both Thio-Sul® and CaTs® have the ability to inhibit the urease reaction, potentially reducing nitrogen loss through ammonia volatilisation, as well as slowing down nitrification and thus reducing the loss of nitrogen though nitrate leaching.

CaTs®, as well as offering a nitrate- and chloride-free source of calcium, and providing thiosulfate sulphur, also acts as a soil conditioner. Being a highly-soluble liquid form of calcium – unlike gypsum – CaTs® is effective at penetrating the soil profile where it acts as a flocculant, opening up soil pores and improving soil structure and drainage. It can also help displace undesirably high levels of sodium in soils.

HEALTHY SOILS EQUAL HEALTHY PROFITS

Edgard Jauregui and Dr Karl Wyant of Heliae® Agriculture explain how crops can benefit from the inclusion of PhycoTerra® – a soil microbial food – as part of a customised liquid fertilizer programme.

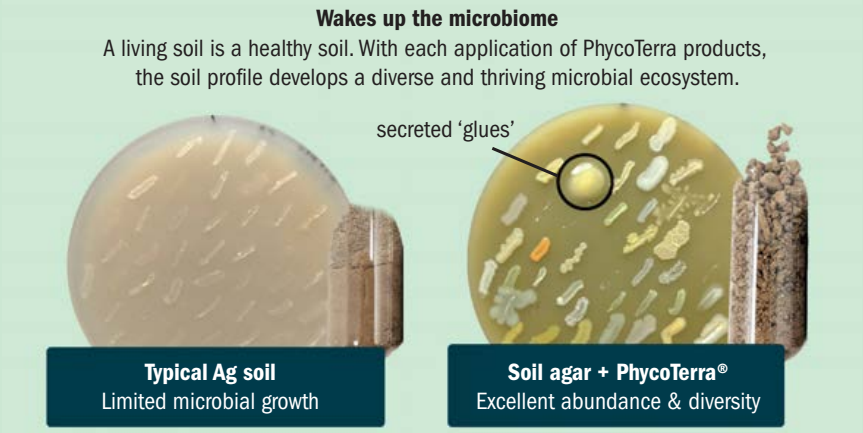


Fig. 1: In contrast to a typical soil (left), the application of PhycoTerra (right) improves soil aggregation and structure, as well as promoting a healthy soil microbiome as shown in the agar plate. By 'waking up' the microbiome, these improvements enhance the soil's ability to support crop growth.

Waking up the microbiome

Due to the lack of a proper food source, roughly 75 percent of microbes in soils are dormant or asleep. While dormant, these microbes cannot do their usual job, such as optimising nutrient availability and helping to alleviate water stress on the farm.

To overcome this problem, Arizona-based Heliae® Agriculture has developed PhycoTerra®, a superior soil microbial food manufactured from natural sources. This tailor-made microalgae product, manufactured using the company's proprietary technology, provides an ideal, balanced meal for the soil microbiome, including bacteria and fungi.

By feeding the dormant microbes in the soil, PhycoTerra® helps improve soil structure, nutrient availability, and water holding capacity on farm fields. A living soil is a healthy soil and – by waking up the microbiome – the application of PhycoTerra® helps the soil profile develop a diverse and thriving microbial ecosystem (Figure 1). This is important, given that an active microbiome is crucial for both healthy soils and therefore healthy farmer profits.

PhycoTerra® can be easily mixed with liquid fertilizers alongside other common crop inputs. This makes it simple to incorporate into existing nutrient management plans as a soil health building component. PhycoTerra® is also pasteurised and therefore safe and easy for retailers and growers to store and handle.

Benefits of liquid fertilizers

Liquid fertilizers help maintain crop productivity and long-term soil fertility by adding crucial nutrients to the soil. Different formulations can be applied at different crop stages during the growing season to match crop nutrient demands. Examples include:

- Ammonium polyphosphate (e.g., 10-34-0) applied with seed as a 'starter' or 'pop-up' phosphorus source to fuel early plant growth at the start of the season.
- Liquid nitrogen products (e.g., UN32, UN28, AN20, ATS, etc.) applied as a side-dress on corn to help meet the rapid mid-season increase in nitrogen demand.
- Specialty liquid fertilizers (e.g., KNO_3, KTS, CAN17, CN9) used to improve the quality and size of fruit and nuts as these crop develop and mature.

Liquid fertilizers are associated with high nutrient use efficiency because application timings can be closely aligned with actual plant demand. Nonetheless, liquid fertilizers can still benefit from the addition of a component, such as PhycoTerra®, that specifically promotes soil health and biological integrity (Figure 2). Its inclusion alongside liquid fertilizers has been shown to optimise nutrient availability in the crop.

Holistic soil management – by taking account of overlapping physical, chemical and biological properties – helps improve soil health and field performance. Custom liquid fertilizer blends can adopt this holistic approach by incorporating a soil microbial food. This helps integrate and achieve several soil management goals via a single product application.

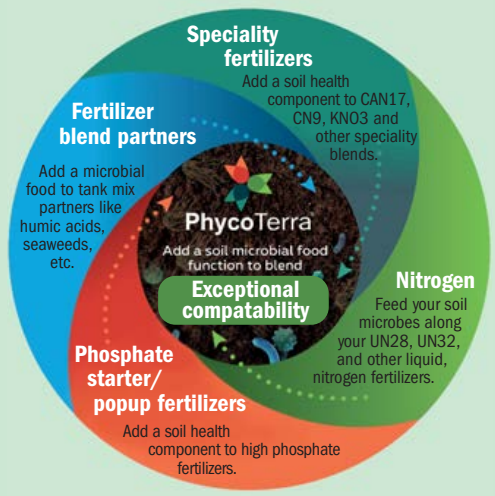


Fig. 2: A soil microbial food, such as PhycoTerra®, can be added to a wide range of different liquid fertilizers as a soil health building component.

Optimising liquid fertilizers

Another distinct advantage to liquid fertilizers is the degree of customisation that is possible by blending different components together. This flexibility and adaptability allows the final liquid mixture to deliver additional benefits beyond just crop fertilization, including waking up the soil microbiome and improving soil health. Adding PhycoTerra® to liquid fertilizer programmes allows growers to optimise their crop inputs by combining the addition of both nutrients and a pasteurised microbial food to soils (Figure 2).

PhycoTerra® is easily mixed with liquid fertilizers such as 10-34-0 or UN32. This not only provides the nutrients the crop needs but also allows the grower to improve their soil health at the same time. Applying these enhanced liquid blends allows the same farm infrastructure (e.g., tank, irrigation, liquid planter kit, etc.) to accomplish more work in the field without any extra complications.

Demonstrated soil quality improvements

Research trials and field results have repeatedly demonstrated the benefit of mixing PhycoTerra® with a liquid fertilizer programme. Many opportunities exist throughout the season to awaken soil microbes – from the beginning of the season with a high phosphate starter, to a mid-season side-dress nitrogen application. Doing so helps provide crops with the nutrients they need by improving soil health and quality. Adding a soil health building component to liquid fertilizer programmes is now becoming easier thanks to innovative technologies such as PhycoTerra®. ■

KTS® is one of the most concentrated forms of liquid potassium and sulphur available in the market. When combined with liquid ammonium polyphosphate (APP), it can be applied as a very effective starter fertilizer early in the plant's growth cycle. The presence of KTS® can improve phosphorus use efficiency by regulating the rate at which polyphosphates are transformed into orthophosphates and becomes plant available.

The new liquid potassium nitrate product Ultrasolution K® (3-0-10) from **SQM** is targeted at almond and strawberry growing – markets in which water quality and efficiency are a priority. This clear solution of chloride-free potassium and nitrate-nitrogen is compatible with most fertilizers and pesticides, according to SQM, making the product ideal for liquid blending or tank mixing in the field.

Europe is another major liquid fertilizer market. The region produces and consumes UAN in large quantities. France is a large-scale, well-established consumer of UAN, importing around 1.9 million tonnes annually, around half the EU total. Major European UAN producers include:

- Achema
- Azomures
- Fertiberia
- Nitrogenmuvek
- Yara International.

Other key European producers of liquid products include:

- Tessenderlo Kerley International
- Van Iperen
- Compo Expert
- Valagro
- Agrii.

Van Iperen, through its sister company Euroliquids, owns and operates north Europe's largest liquid fertilizer plant in the port of Rotterdam. This ISO-certified 90,000 t/a capacity plant produces high quality liquid products in more than a 100 different formulations.

Euroliquids has been producing liquid fertilizers for more than three decades, having started as a supplier to the Dutch hydroponics sector. Its Rotterdam site includes 90,000 cubic metres of storage capacity and a quality testing and R&D lab that develops new formulations. Products are packaged in cans and bottles ranging from one litre to 1,000 litres in size. These are marketed and sold under Van Iperen's FoliaStim, Meru, Maroa, Nitrofol and Pinta liquid fertilizer brands.

Norway's **Yara International**, the world's largest NPK and nitrates manufacturer, produced 917,000 tonnes of UAN in 2021. The company also markets a comprehensive range of nitrogen and NPK solutions under its Chafer liquid fertilizer brand. Many of these incorporate sulphur.

Yara's Chafer Nuram liquid nitrogen fertilizer, for example, combines two sources of nitrogen (both ammonium and ureic) that provide both rapid and longer-term release properties. Although primarily designed to be soil applied, the range includes liquid grades suitable for foliar applications and precision placement on salad and vegetable crops.

In European countries like the UK, Yara's liquid products are backed by comprehensive support infrastructure. This includes a network of production and storage sites offering prescription liquid blends and the manufacture of on-farm GRP (glass reinforced plastic) storage tanks. Advice on bespoke sprayer nozzles and stream bars, specifically designed for top dressing arable and grass crops, is also available.

Fertilizer Latino Americano 2022

More than 745 delegates from 335 companies and 50 countries gathered at the Hilton Downtown, Miami, Florida, 21-23 March, for the Fertilizer Latino Americano 2022 conference. The event was jointly convened by Argus and CRU.

PHOTO: BCINSIGHT/SIMON INGLETHORPE

Vibrant Miami was the setting for Fertilizer Latino Americano 2022, the region's biggest fertilizer networking event.

The Russia-Ukraine conflict

The Russia-Ukraine conflict and its impact on global fertilizer trade was a major conference talking point. This topic and the wider reaction on global commodity markets was addressed head-on in the conference's opening two presentations.

David Fyfe, Argus' chief economist, spoke of "huge levels of volatility" and the commodity price surge seen since the start of the conflict. Although there has been signs of this easing, commodity prices were still on average 20-40 precent above their pre-crisis levels.

He expected the conflict to have "a chilling impact on economic growth" by wiping 0.7 percent from GDP growth forecasts for the world economy. The crisis was adding yet "another layer of supply chain bottlenecks" and "very elevated levels of inflation", Fyfe added. This could spark a 2-4 fold increase in consumer inflation.

The EU was disproportionately vulnerable to the conflict – being reliant on Russia for 30 percent of its oil and 50-60 percent of its natural gas imports. Around 1.8 million barrels/day of Russian oil could get shut out of the market, for example. The EU was aiming to half its dependency on Russian natural gas, but higher bids would be required to attract substitute LNG cargoes from the US and Qatar.

Rabobank's executive director **Sam Taylor** presented a survey of 900 growers in Brazil.

"Brazil has an outsize exposure to Russian and Belarusian fertilizer supply," said Taylor. Overall, Latin America is the world's largest regional importer of fertilizers, with a 40 percent import dependency on Russian potash.

Yet, when questioned on the impacts of the Russia-Ukraine conflict, grower sentiment in Brazil was remarkably positive. Only five percent of respondents said they would cut their acreages if they didn't have adequate fertilizer stocks. Most would instead continue with planned plantings to take advantage of high crop prices.

While nearly half of growers (48%) had already purchased their fertilizer requirements for the season, only one in ten (11%) had received more than half of their deliveries. Many were looking at alternatives to mineral fertilizers – although less than one-fifth (17%) thought this would compensate for more than half of their nutrient needs.

Taylor's key takeaway from the survey was: "The high level of conviction [of growers] to planting and throwing down nutrients, despite price."

PHOTO: ARGUS

From left to right, Mosaic's Corrine Ricard, Yara's Marcelo Altieri and Gord McKenzie of Canpotex in discussion with Argus' Oliver Hatfield.

The importance of fertilizers to LatAm agriculture

The focus of this keynote panel discussion again turned to impacts of the unfolding Russia-Ukraine conflict.

"[Fertilizer] availability balanced by affordability will be a challenge for all of us," said **Gordon McKenzie**, the president and CEO of Canpotex. "Nutrien will be able to add one million tonnes [of potash output] in 2022." One of his concerns was: "Those who, at these price levels, will mine soils. In Brazil, Mato Gross, the nutrients are not there to mine. People will go hungry as a result of what's going on."

Corrine Ricard, the president, Mosaic Fertilizantes, said she didn't see any

intent by Brazil's farmers to stop applying fertilizers. Instead, it was "more about availability" in her view. She shared Gordon McKenzie's concerns. "Tropical soils deplete very rapidly compared to Illinois. It won't be affordability but availability that will stop it [fertilizer applications]," she said.

Ricard said availability worries could make food crops the focus of fertilizer applications in Brazil. Such a change, if implemented, could result in: "Degraded pasture not getting addressed, a yield impact on second corn and a policy change on sugarcane," she said.

"Brazil is 90 precent import dependent. So, there's a tremendous emphasis on developing the [domestic] fertilizer industry," said Ricard. Although she admitted there were no "fast solutions" on this, Brazil had been quick to set up a fertilizer industry council in March to prepare for potential fertilizer supply issues.

"I agree that the reliance on Rusia [for fertilizer supplies] must change," said **Marcelo Altieri**, SVP for Latin America at Yara International. "In markets like Peru, 90 percent of product comes from Russia."

What next for Brazilian agriculture?

Brazil has consistently increased it grains and oilseeds production in recent decades to emerge as a world-leading ag commodity exporter. In her presentation, **Flavia Bohone**, Argus' agriculture and fertilizer editor, looked at what's next for this global powerhouse economy.

Brazil is on course to set a new record this year by producing 265 million tonnes of grains and oilseeds (soybean and corn), according to the latest 2021/22 estimates. Overall, the country is expected to produce and export more corn but less soybean this year, in comparison to 2021. This follows a downgrade to soybean production estimates in March.

Brazil's wheat production has continued to grow in recent years from around five million tonnes in 2019 to just under eight million tonnes forecast for this year. But with domestic wheat consumption of more than 12 million tonnes expected in 2022, Brazil will still need to import a sizeable share of its domestic needs. Wheat prices surged to 14-year highs in March, yet more fallout from the Russia-Ukraine conflict. While most of Brazil's wheat imports are sourced from Argentina, according to Bohone, these will still be affected by near record prices.

Nutrients in focus

The Argus fertilizer index has increased by 100 points since the Russian-Ukraine conflict began on 24th February. The Brazil MOP price was also now at an all-time 30-year high: the $1,025/t price on March 22nd comparing to the previous 2008 peak of $1,007/t.

"I've been covering the market for 20 years and never seen anything like the last 2-3 weeks," said **Mike Nash**, senior editor for fertilizers at Argus. "For potash, it's the potential loss of Russian material adding to the loss of Belarusian supply."

He listed the main potash impacts so far as:

- Official sanctions on Belarusian product
- Self-sanctioning in which countries/companies voluntarily cease buying Russian product
- Russia potentially placing limits on its exports
- Shipping/logistics snags, especially rising freight rates from Black Sea and Baltic ports
- Soaring potash prices.

Brazil imports around 3.6 million tonnes of potash annually from Russia and 2.4 million tonnes of potash from Belarus – versus 4.2 million tonnes from Canada, with Israel and Germany supplying much of the remainder. At the time of the conference, potash supply to Latin American was continuing as normal, with MOP-laden vessels destined for Brazil still in transit from Russia and Belarus.

With potash supply concentrated in a handful of countries, centres of potash demand such as Brazil rely on all suppliers, said **David Riley**, Argus' senior potash analyst. In the event of the loss of Russian and Belarusian supply, Nutrien and Mosaic were, in his view, the only market producers with the ability to step in and make extra potash capacity available. ICL (Israel, Spain) and K+S (Germany, Canada), in contrast, only had a limited ability to ramp-up their potash output.

Argus phosphates editor **Harry Minihan** drilled down into Brazil's phosphate market dynamics. Brazil imported 5.1 million tonnes of monoammonium phosphate (MAP) last year. OCP and Russian producers ramped up their deliveries, accounting for around 70 percent of 2021 MAP imports into Brazil. China has also stepped-up its deliveries – exporting 3.25 million tonnes of phosphate products (MAP, NP, TSP) to Brazil last year.

Brazil's increasing dependence on OCP for its phosphate fertilizer supply has been a clear market trend. The phosphate market's overall reliance on OCP as a large-scale producer is another talking point currently, as the company is potentially facing ammonia sourcing issues due to the closure of Black Sea supply routes.

With Brazil now entering a critical buying period, seasonality was a key factor in the current price squeeze which has driven up MAP prices to around $1,200/t cfr. Minihan also highlighted the phosphate-nitrogen price link in Brazil, with the country's MAP price correlating strongly with its urea pricing. Plummeting barter ratios in Brazil were also negatively affecting affordability, he said.

Argus senior analyst **Sophie Mason** presented a short- and medium-term urea outlook. Although disruption to Russian urea trade was anticipated in the short-term, substantial new urea capacity additions during 2022 and 2023 – particularly in Nigeria and India – were expected to ease market tightness. Chinese urea exports are also set to return to the market.

In the medium-term, around 4.7 million t/a of new Russian urea capacity was now at risk of delays. There was, however, potential for Iran and Brazil to increase their urea output to balance this. The risk of high prices leading to demand destruction was another possibility, in Mason's view.

Urea plant re-openings

The imminent re-opening of two Brazilian urea plants was highlighted by **Luiz Faustino**, an executive officer at Unigel. The company already produces 350,000 t/a of ammonium sulphate (AS) – a popular nitrogen fertilizer in Brazil – a by-product of its acrylics production.

Following investment of around $100 million in the mothballed Sergipe and Bahia nitrogen plants, formerly owned by Petrobras, Unigel will soon operate 1.1 million tonnes of urea and 0.9 million tonnes of ammonia production capacity.

These two plants are due to re-start production in April and July this year, respectively. Unigel is also committed to further investment in the construction of a sulphuric acid plant in Brazil. This investment should bring extra AS capacity online.

Faustino believed that Brazil could produce more natural gas and even become self-sufficient. A ramp-up of investment in the domestic gas market would also

have the benefit of reducing the country's dependence on Bolivia, he suggested.

Low- and zero-carbon ammonia opportunities

Nutrien is positioning itself to take advantage of emerging markets for low-carbon ammonia, as **Ashley Harris**, the company's VP for environmental performance and innovation explained. These include:

- Ammonia as a substitute for coal-fired power – potentially a 30 million tonne market by 2050
- Ammonia as a marine fuel
- Ammonia as hydrogen carrier – potentially a 550 million tonne market by 2050.

Nutrien has, in fact, been a leading producer of low carbon ammonia for almost a decade through carbon capture and sequestration (CCS) at its North American ammonia plants in Redwater, Alberta and Geismar, Louisiana.

The company's 535,000 t/a capacity Geismar plant has a >90 percent CO_2 capture rate, thanks to access to the Denbury CO_2 pipeline. It captures more than 250,000 t/a of CO_2 and generates more than 200,000 t/a of low-carbon ammonia. The 925,000 t/a capacity Redwater plant, meanwhile, has a link to the Alberta Carbon Trunk Line. It captures up to 295,000 t/a of CO_2 and generates up to 245,000 t/a of low-carbon ammonia.

Nutrien has future plans to ramp up carbon capture to 1.8 million t/a CO_2 at Redwater and to more than 600,000 t/a CO_2 at Geismar. It is also collaborating with Exmar on an ammonia-fuelled vessel. This will be powered using low-carbon ammonia sourced from its Geismar plant and could be operative as early as 2025.

PHOTO: ARGUS

With the return to in-person events, this year's FLA exhibition proved as popular as ever.

Carbon farming

The decarbonisation of global farming could reduce annual carbon emissions from agriculture by one gigatonnes, thanks to a shift to regenerative farming. That's according to **Iule Arruda**, managing director, Brazil, for Agoro Carbon Alliance.

Agoro Carbon Alliance was formed by Yara in 2021. It is aiming to generate carbon credits as a new revenue stream for farmers globally. Companies in other sectors can then buy these credits to reduce their climate impacts.

Currently, carbon credits from agriculture are mainly sold through the voluntary carbon market (VCM). Carbon credits generated by farm practices such as better nitrogen management, reduced or no-tillage systems and the introduction of cover crops could provide farmers with nearly $90/acre in extra revenues, according to Agoro Carbon Alliance.

Carbon farming is set to take off in in Latin America with demand for VCMs in the region likely to grow by 100 times by 2050, Arruda suggested. This growth is likely to be accompanied by a move towards higher quality VCMs over time as carbon markets becomes more robust. The demand for government-regulated schemes – compliance carbon markets (CCMs) – is also expected to increase.

Clean power at sulphuric acid plants

Heat recovery systems at sulphuric acid plants have been providing carbon-free energy for decades now and continue to improve. There is also potential to combine the clean power generated at acid plants with hydrogen production from water electrolysis. This could provide the basis for green fertilizer production.

CHEMETICS

The green fertilizer complex

Rene Dijkstra

In this article, Chemetics introduces its green fertilizer complex concept. This integrates a sulphuric acid plant with green hydrogen and ammonia production to deliver carbon-free ammoniated phosphates at low cost with low emissions (*Sulphur* 399, p39). This practical solution for operators is outlined below.

Typical MAP/DAP fertilizer complex

In a typical phosphate fertilizer complex:

- Sulphur and ambient air are used to produce sulphuric acid
- This in turn is reacted with phosphate rock to produce phosphoric acid
- The phosphoric acid then reacts with ammonia to produce monoammonium phosphate/diammonium phosphate (MAP/DAP) or NPK/triple superphosphate (TSP) products.

A simplified version of this process is shown graphically in Figure 1.

Fig. 1: **Simplified MAP/DAP fertilizer complex**

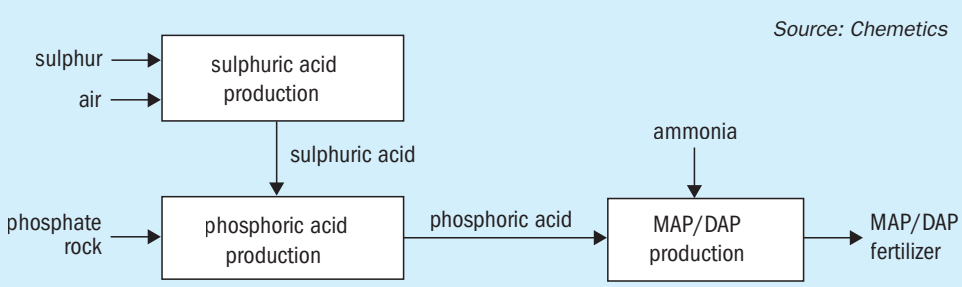
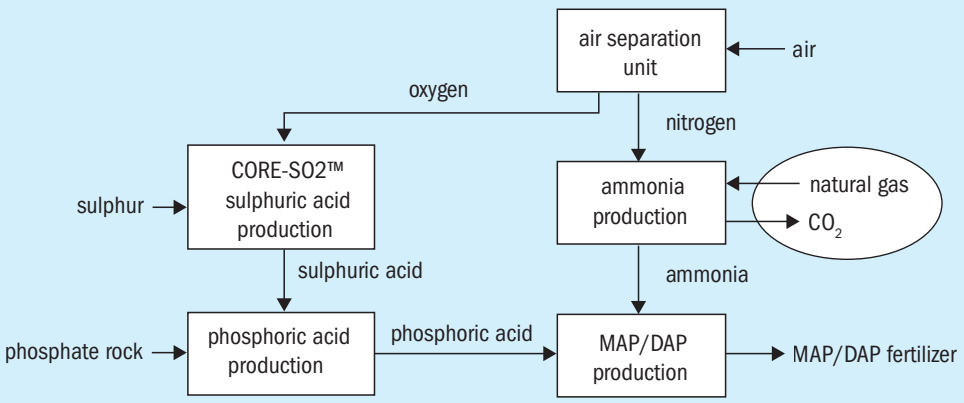


Fig. 2: **MAP/DAP fertilizer complex with ammonia production**



Source: Chemetics

Power generation and avoiding emissions

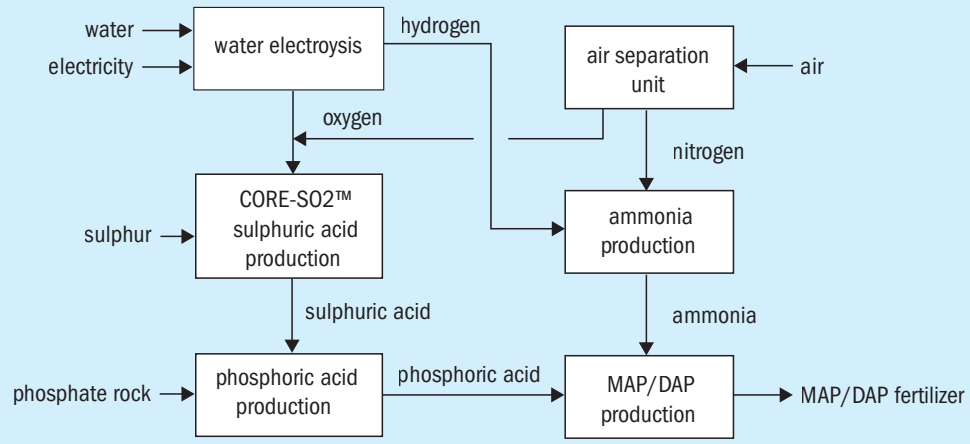
In this concept, the energy released in sulphuric acid production is recovered as high pressure (HP) steam. This is used to generate power to operate the other units in the complex. Any excess power – which is available in most cases – can also be sold externally. To avoid CO_2 emissions, it is also necessary to install an indirect drying process (e.g., steam drying) in the MAP/DAP granulation plant, instead of the direct-fired dryers that are more commonly used.

Integration of ammonia production

Further integration is possible when ammonia production is added to the complex (Figure 2). In the conventional steam methane reforming (SMR) process, ammonia is manufactured by combining hydrogen from natural gas with nitrogen typically supplied via an air separation unit (ASU).

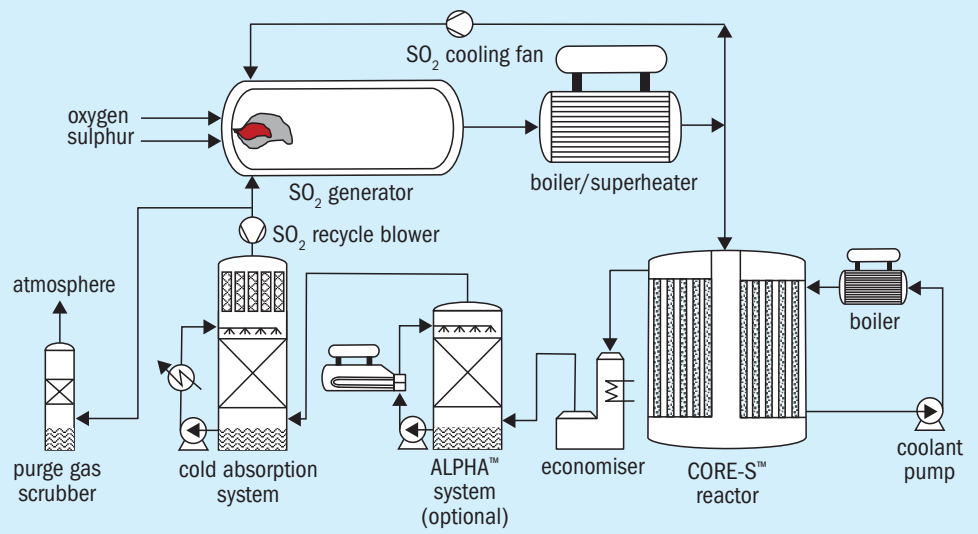
The use of an ASU significantly reduces the amount of process gas – which subsequently requires purification – leaving the reformer. It also allows other hydrogen sources to be easily incorporated. This line-

Fig. 3: **Carbon-free integrated MAP/DAP fertilizer complex**



Source: Chemetics

Fig. 4: **CORE-SO2™ process**



Source: Chemetics

up (Figure 2) offers additional benefits as the by-product oxygen from the ASU can now be used in a CORE-SO2 sulphuric acid plant.

In this integrated production process, no imported electrical power is required as energy released in the sulphuric acid and ammonia production units provides sufficient power for the entire complex. Nevertheless, it obvious that the conventional SMR ammonia process will still generate significant amounts of CO_2 due to its use of hydrocarbon feedstocks.

The green fertilizer complex

To make the fertilizer complex carbon free, it is therefore necessary to eliminate the CO_2 emissions from the production of ammonia. This is achieved by supplying a different carbon-free source of hydrogen. This is referred to as 'green hydrogen' when produced via water electrolysis using renewable energy.

Several green hydrogen production options exist. Both polymer electrolyte membrane (PEM) and alkaline water electrolysis are already used at industrial scale, for example, while solid oxide electrolysis, which operates at higher temperature, also holds promise for the future.

All these types of electrolysis technology split water into hydrogen and oxygen. The hydrogen generated is used as a feedstock for ammonia production, while the by-product oxygen (as with the ASU unit) can be used to produce sulphuric acid. This additional oxygen source can therefore be used in two ways – to produce more sulphuric acid or reduce the size of the ASU. The resulting green fertilizer production process is shown in Figure 3.

The CORE-SO2 process

At the heart of this fully integrated complex is Chemetics' CORE-SO2 process (Figure 4). This takes full advantage of the 'free' by-product oxygen generated by water electrolysis – by combining this pure oxygen source with sulphur to produce sulphuric acid. CORE-SO2 also provides all the power necessary to run all unit operations except the electrolyser.

The resulting fully integrated green fertilizer production complex – which now only uses air, water, sulphur and phosphate rock as raw materials – is capable of producing fertilizers without any CO_2 or SO_2 emissions.

Additionally, in locations with a limited fresh water supply, excess energy from the CORE-SO2 plant can power a desalination plant to generate high quality water for the electrolysis unit and steam boilers from sea water or brackish water.

It is worth noting that a conventional fertilizer complex (Figure 2) can be incrementally switched over to the green hydrogen process without any changes to the other operating units being required. In this way, on-site green hydrogen capacity can be gradually ramped up to replace hydrocarbon-based capacity, as and when additional renewable energy sources become available. As a further benefit, the sulphuric acid plant will generate lower sulphur emissions as green hydrogen output increases, as less inert gases (present in the oxygen from the ASU) will enter the process.

Optimising energy integration

The integration of the complex is not complete without optimising energy integration. The sulphuric acid and ammonia processes both produce excess energy. Most of the energy from high-temperature sources can be captured and used to produce superheated high-pressure (HP) steam. For a DAP-producing complex without an SMR, combined steam production at 60 bar(g) and 500°C generates approximately 1.40-1.45 kg steam/kg sulphuric acid.

Within the complex, deaerators, sulphur melting, phosphoric acid evaporators and the MAP/DAP granulation plants also require low-pressure (LP) steam at 5-7 bar(g). This is generally provided by combining steam extraction from the turbine-generator with steam generated by the ALPHA™ system in the sulphuric acid plant.

The process selected for the phosphoric acid plant is an important deciding

factor for LP steam requirements. This is because different processes such as di-hydrate (DH), hemi-hydrate (HH), hemi-dihydrate (HDH) will produce phosphoric acid at different concentrations (28-44%).

Consequently, if the main reactor generates phosphoric acid at higher concentrations – due to process selection – the phosphoric acid evaporators will require far less steam to reach the final merchant grade acid (MGA) concentration. A lower LP steam requirement also means the steam turbine can generate more electrical power as less (or no) steam need to be extracted. This is beneficial as it allows more base-load power to be dedicated to water electrolysis at the complex.

The recovery and use of the low-grade heat available at various units (e.g., by using a hot water network) offer further opportunities for energy integration. Although outside the scope of this article, these should be reviewed at an early stage in any new project.

Chemetics' CORE-SO2 process is setting a new benchmark by delivering a step change in emissions reduction for sulphur dioxide and sulphuric acid mist. The process also offers compelling economic advantages in terms of lower capex and opex resulting from small stack gas volumes. These economics are further improved by integrating the process to take advantage of the 'free' by-product oxygen available from other units. Importantly, the CORE-SO2 process, when fully integrated within a green ammonia plant, enables the production of carbon-free fertilizers at low cost and without sulphur emissions. ■

PEGASUS TSI

Clean energy from sulphuric acid production

Ricardo L. Sepulveda

This article outlines the technical and economic feasibility of utilising clean energy from a sulphuric acid plant to produce green hydrogen in a fertilizer complex. This, in turn, can be used to produce green ammonia.

Clean energy production

An industrial fertilizer complex offers good potential for clean energy production. This can be realised by using the energy recovered during sulphuric acid production to generate medium-pressure steam for clean electricity.

By installing heat recovery systems in two sulphuric acid plants of 3,400 t/d capacity, for example, it should be possible to generate an additional 300,000 lb/hr of medium-pressure (MP) steam, according to our calculations. This can be used by a condensation steam turbine to generate 24 MW of net electric clean power.

Green hydrogen

The clean power obtained can then be used to produce green hydrogen via water electrolysis. There are two industrial technologies available to do this: alkaline electrolysis (AEL), with a temperature and pressure below 80°C and 30 bar, and proton exchange membrane (PEM) electrolysis, with temperature and pressure lower than 100°C and 200 bar (Figure 1) .

AEL electrolysis units typically have a lower capital cost. Comparable PEM units, although requiring higher capital investment, are more efficient and can operate at higher current densities. In general, water electrolysis can deliver lower production costs at higher hydrogen production capacities.

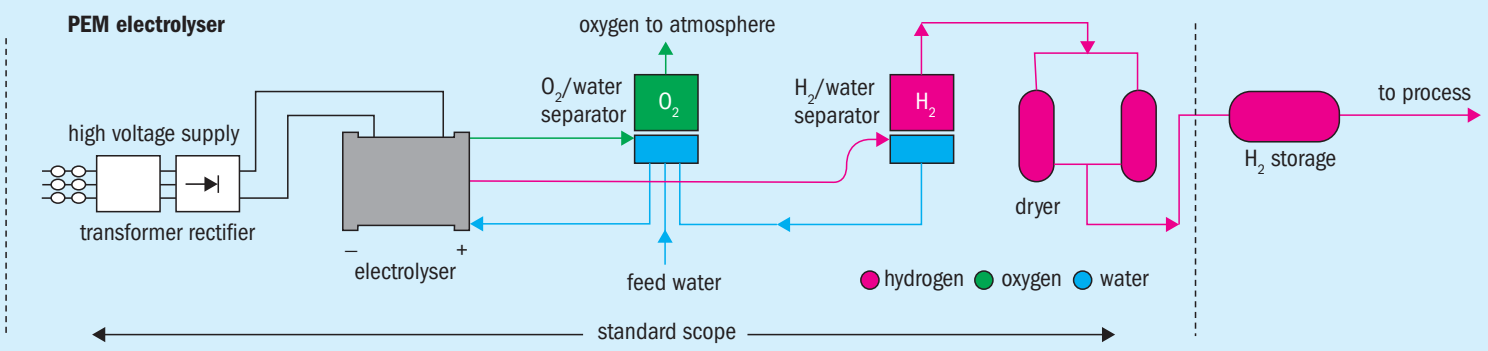
With 24 MW of clean power, a PEM electrolyser (Figure 1) can potentially generate 8.3 t/d of green hydrogen (3,000 t/a). This can be used to produce green ammonia and, subsequently, granular mono-ammonium phosphate (GMAP) fertilizer.

Green ammonia

In our example, the 3,000 t/a of green hydrogen generated is used to produce 16,800 t/a of green ammonia at a phosphate fertilizer production complex (Figure 2). Using green ammonia will have a positive impact by decreasing the CO_2 footprint of GMAP production. This is achieved by replacing ammonia conventionally produced via the steam methane reforming route, which has a CO_2 footprint of 2t CO_2/t ammonia.

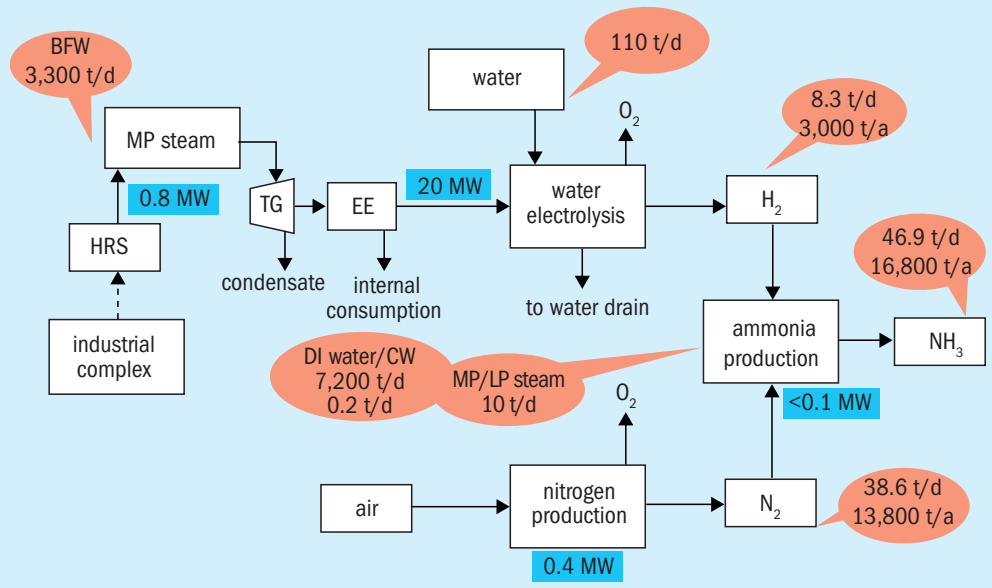
We have quantified the CO_2 emissions and footprint benefits of producing green ammonia in a fertilizer industrial complex (Table 1). If the 24 MW of clean energy from the sulphuric acid plant were used for green ammonia production, we calculate that the CO_2 footprint would be reduced by 35,784 t/a.

Fig. 1: **Green hydrogen production by and proton exchange membrane (PEM) electrolysis**



Source: NEL

Fig. 2: **Key data for green ammonia production at a phosphate fertilizer production complex**



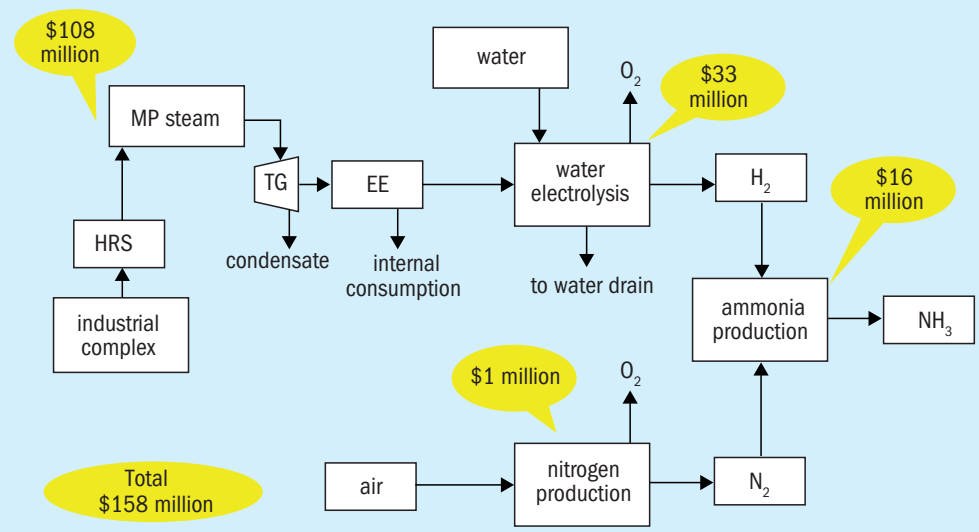
Source: PegasusTSI

Table 1: **Modelling results showing the carbon benefits of green ammonia production at a phosphate fertilizer complex**

	Ammonia
Energy production, MW	24
Production, t/a	16,800
Production/CO_2 footprint	2.13 kg CO_2/kg ammonia
CO_2 footprint decrease, t/a	35,784
Total CO_2 footprint decrease, t/a	35,784
Carbon capture + production plant, CO_2/MWh	178

Source: PegasusTSI

Fig. 3: **Capex for green ammonia production at a phosphate fertilizer production complex**



Source: PegasusTSI

Green ammonia economics

We estimate a total investment of $158 million is required to produce 16,800 t/a of green ammonia. This capex amount covers:

- The two sulphuric acid plant heat recovery systems
- The steam turbine systems
- The electrolyser
- The ammonia plant.

This cost breakdown is shown diagrammatically in Figure 3.

The economic feasibility of green ammonia production on this scale is based on the following parameters/assumptions:

- Investment: $158 million
- Green ammonia production: 16,800 t/a
- CO_2 footprint decrease: 35,784 t/a
- Return on investment (ROI): 8%

Discussion and conclusions

Currently, green ammonia can be produced at a cost of around $900/t. That compares favourably to the current Tampa contract price of $1,625/t (start April), although this is at a historical high, having risen from $545/t twelve months ago. The demand for fertilizer products with a lower CO_2 footprint is, in any case, likely to grow, independent of price competitiveness. The gradual conversion of existing ammonia plants to incorporate green hydrogen production, by lowering the capital investment barrier, could also improve adoption and project feasibility.

Technologies to decrease the CO_2 footprint of fertilizer production are already commercially available. Their economic feasibility will, however, depend on the ability of the market to pay a premium for green ammonia. Our preliminary analysis, as outlined here, suggests that green ammonia production at an industrial fertilizer complex could be an attractive proposition when high CO_2 emissions reduction is required at reduced capital investment.

The other option for increasing clean energy capacity and decreasing production costs, as part of a CO_2 emissions reduction strategy, is to introduce renewable energy sources, like wind or solar, to supplement the clean energy generated by the sulphuric acid plant's heat recovery system.

Author's note

A longer version of this article was published in the March/April issue of our sister publication *Sulphur* magazine (*Sulphur* 399, p44). This also includes an analysis of the feasibility of green methanol production.

ELESSENT CLEAN TECHNOLOGIES

Options for delivering more green energy

Colin Shore

Plant owners, neighbouring communities and environmental groups can all enjoy the green energy co-produced during the manufacture of sulphuric acid – thanks to the MECS® Heat Recovery System (HRS™). This technology has been enhancing the production of carbon-free energy throughout nearly 40 years of operation with over 100 units installed worldwide.

As the need for investment in green, carbon-free energy across the globe grows, MECS® HRS™ technology continues to improve and expand (*Sulphur* 396, p42). The production potential of various MECS® HRS™ steam generation technologies are summarised in Table 1.

Table 1: **Example of different MECS® HRS™ steam generation technologies**

	kg/h MP	t/t MP	kg/h HP	t/t HP
MECS® HRS® with no steam injection	47,000	0.47	130,000	1.3
Conventional steam injection	52,800	0.53	130,000	1.3
SteaMax™ HRS®	63,800	0.64	130,000	1.3
MECS® MAX3™	35,000	0.35	157,550	1.6

MP – medium pressure steam; HP – high pressure steam.
The example assumes that low-pressure steam is available at battery limits for steam injection.
The SteaMax™ HRS™ assumes 100% steam injection. The plant life is 30 years.

Source: DuPont Clean Technologies

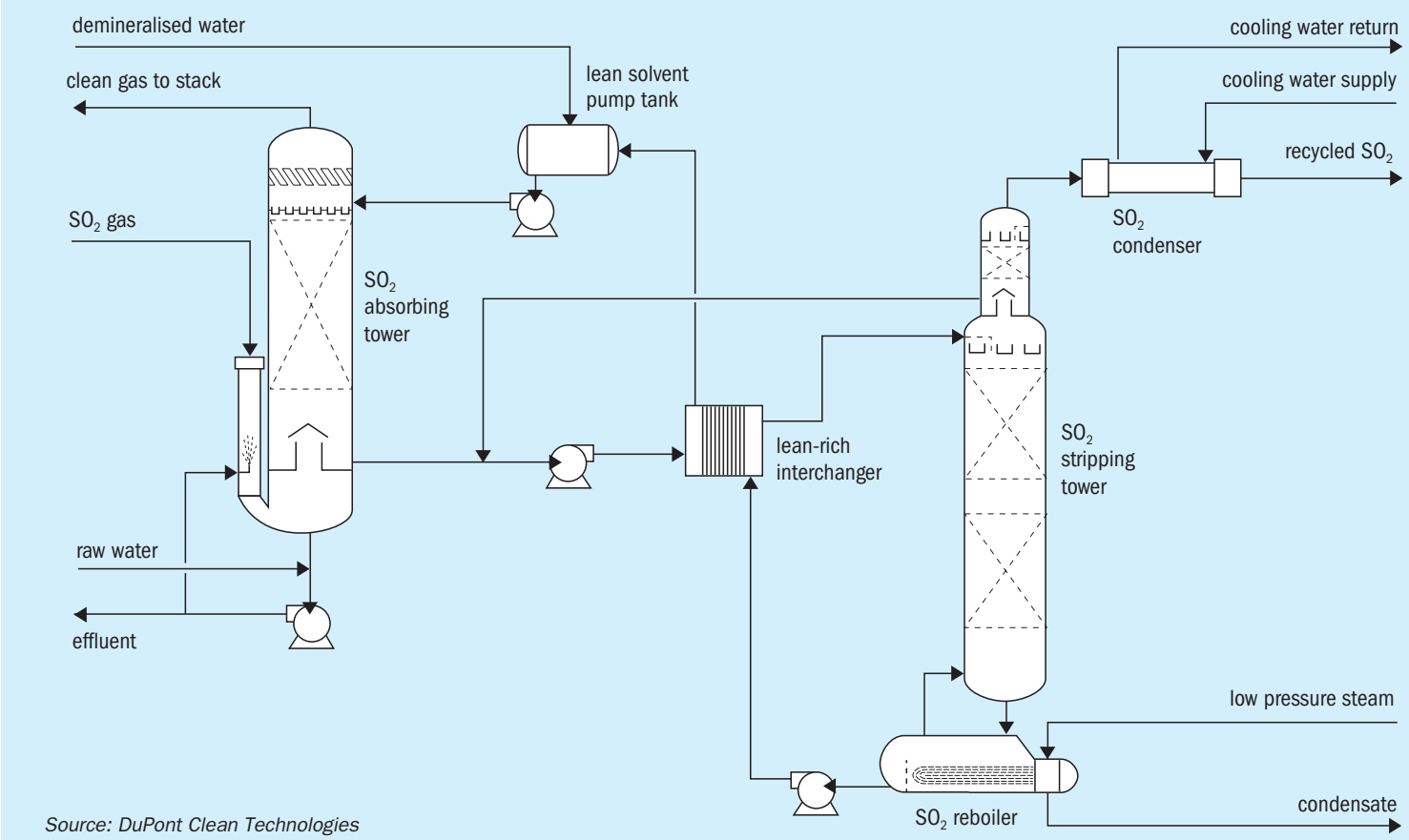
MECS® HRS™

In the sulphuric acid process, the energy released through combustion and other exothermic reactions is easily recovered as high-pressure (HP) steam. In contrast, it is normally uneconomical to recover low-level energy – like the heat produced during SO_3 hydration – and this is therefore dissipated at the cooling tower.

Yet with MECS® HRS™ technology, sulphuric acid plants can significantly increase their thermal efficiency by upgrading and recovering this low-level energy as medium-pressure (MP) steam (up to 150 psig (10 barg)). The amount of steam generated typically ranges from 0.4-0.6 tonnes of steam per tonne of acid produced, depending on the SO_2 concentration and the water balance. Typically, this steam can then be used to produce three megawatts of electricity per 1,000 t/d of acid capacity.

In the MECS® HRS™ design, heat is removed in the HRS™ boiler, with water and low-pressure (LP) steam added into the process to control the acid concentration. By heating water in the HRS™ heater and pre-

Fig. 1: **MECS® SolvR® system**



Source: DuPont Clean Technologies

energy transfer provides additional steam generation and reduces cooling water use in the plant as well.

MECS® SteaMax™ HRS™

MECS® SteaMax™ HRS™ exports more medium-pressure steam than a traditional MECS® HRS™ design. It increases medium-pressure steam generation by raising the ratio of dilution steam to dilution water. Low-pressure steam is added to the system for acid dilution. The energy in this low-pressure steam is then recovered as medium-pressure steam in the HRS™ boiler. This upgraded steam provides more value, as it offers plants greater flexibility in their steam use by allowing customisation to site-specific energy requirements and local conditions.

MECS® MAX3™

MECS® MAX3™ technology is the next stage in sulphuric acid plant energy upgrades – allowing up to 20 percent more high-pressure steam to be exported from the sulphuric acid plant. MAX3™ increases production of high value, high-pressure steam by employing a heat exchange networking system. This shifts a portion of the MECS® HRS™ energy – normally used to generate medium-pressure steam in the HRS™ boiler – to a high-pressure steam system instead.

Notably, MECS® MAX3™ technology incorporates the SolvR® regenerative SO_2 recovery system (Figure 1) – providing sulphuric acid plants with an ultra-low emission, high efficiency design, which is especially valuable for grassroots installations. This allows acid plants to produce high-quality acid, at or above nameplate capacity, while maintaining ultra-low greenhouse gas emissions. Additionally, the resulting low effluent rates minimise water losses. It is also a plant configuration that maximises carbon-free, green energy production, for either internal consumption or exported power sold to neighbouring sites.

Longevity and reliability

For sulphuric acid plant operators, energy efficiency and emissions reductions, while valuable, are only two on a long list of objectives. In a strong acid environment, for example, the longevity and reliability of equipment are also important considerations and cost factors. Beneficially, MECS® HRS™ and MAX3™ technologies can also satisfy these requirements, being designed with durability and low maintenance in mind, as the following case study illustrates:

- A sixteen-year-old plant with MECS® HRS™ technology operating in China has consistently produced an on-stream time greater than 98 percent
- Overall, downtime (including turnaround time) at this plant accounts for less than 2.5 percent of the overall cost of equipment replacement.

Combining equipment of known reliability with correct maintenance practices are key to a long plant life. State-of-the-art equipment such as Brink® AutoDrain™ mist eliminators and new catalysts can help to reduce overall maintenance costs and extend plant life.

In certain cases, adding new bolt-on systems at sulphuric acid plants can increase the amount of maintenance resources needed. Yet the other substantial benefits they provide – as discussed above – are very likely to far outweigh any incremental expenditure incurred over the life of the plant.

Enhanced mix-granulation in a single machine

The precision mixing and granulation of mineral and organic fertilizer ingredients are essential to meet growing market demand for high-value, complex crop fertilizers. Furthermore, the ability to mix and granulate in a single machine offers fertilizer manufacturers both operational and product quality advantages over traditional granulation methods.

Fig. 1: **Mix-granulation in a counter-current mixer**

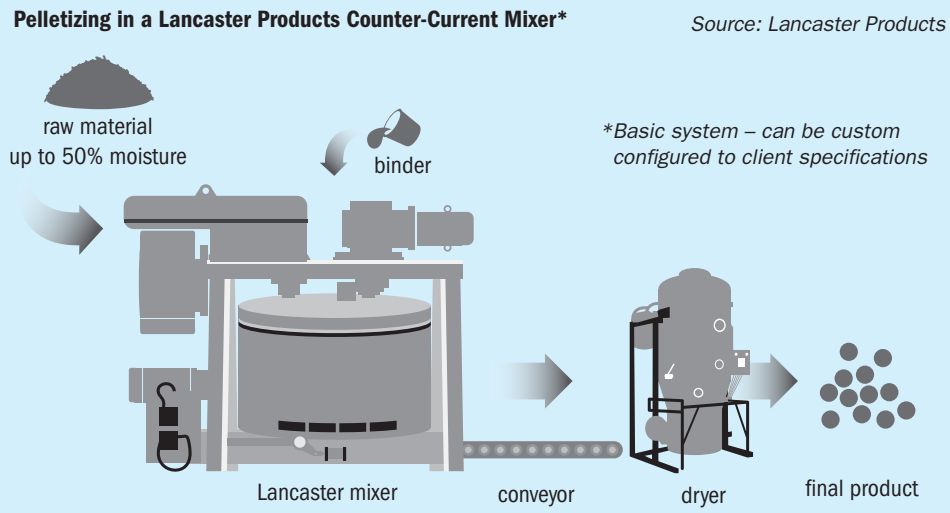


Table 1: **Operational advantages of mix-granulation**

Continuous process	Continuous process	Batch process	Lancaster Products continuous batch process
Continuous operation	✓	–	✓
High production rates	✓	–	✓
Multiple lines	✓	–	✓
Recipe optimisation	–	✓	✓
Multiple operations	–	✓	✓
High yield outputs	–	✓	✓
Higher product accuracy	–	✓	✓
Reduced mix times	–	✓	✓
Minimised additives	–	✓	✓
Mix homogeneity	–	✓	✓
Reduced expenses	–	–	✓
Reduced maintenance	–	–	✓
Equipment consolidation	–	–	✓

Source: Lancaster Products

Disc granulation vs mix-granulation

Disc granulation is the method commonly used to produce fertilizer granules. This two-stage process typically employs a pin mixer (or similar mixer type) to pre-mix powdered materials to provide the feed for the disc pelletiser. The process generally requires the addition of large amounts of binder and water to create the finished product. This traditional type of granulation process is often not ideal as it generates lower yields of on-size pellets (1-3 mm) leading to high recycle loads.

In comparison, high shear, counter-current mixers – unlike most granulation options – can rapidly mix and granulate materials in the same machine as a single-stage process. In mix-granulation equipment, such as those offered by Lancaster Products, the pan rotates in a clockwise direction, while the mixing tools rotate counter-clockwise direction. This design results in efficient counter-current mixing by creating the necessary shearing action within the mixing cavity.

The mixing tool's variable speed capability achieves the desired output by enabling different sized granules and densities to be created. A wide spectrum of granule sizes – from the micron range to as large as 8-10 millimetres – are possible depending on the feed materials. Mix-granulation is completed in batches and excels at producing highly repeatable homogeneous mixes and granules (Figure 1).

Reduced system complexity

Traditional fertilizer manufacturing typically requires multiple steps and many different pieces of machinery for drying, milling, mixing and agglomeration. Additionally, initial drying of high moisture raw materials is often required prior to processing – adding extra time and energy costs to the

Table 2: **Product advantages of mix-granulation**

Product advantages	Traditional system	Lancaster Products system
Homogenous spherical pellets	–	✓
Control of pellet size batch-to-batch	–	✓
High yields of on-size pellets	–	✓

Source: Lancaster Products

manufacturing process. Mixing and granulating in the same step in a high shear, counter-current mixer is advantageous as it reduces system complexity in several ways (Table 1):

- **Reduced physical footprint**. The continuous batch process offered by Lancaster Products requires very little square footage due to its vertical design which employs gravity for material transport.
- **Operates with high moisture materials**. Initial drying and subsequent milling in the manufacturing process can also be eliminated or greatly reduced as the mix-granulation process handles raw materials with up to 50 percent moisture.
- **Less maintenance and energy use**. The replacement of multiple machines typically found in traditional pelletising process lines with a single high shear, counter-current mixer translates into less maintenance, fewer points of failure and reduced energy usage.
- **Optimised ingredients and lower operating costs**. Precise batch recipes eliminate the ingredient waste that results from uneven mix distribution. Instead, much less binder and water is required because counter-current mixing technology is highly effective at thoroughly dispersing such additives throughout the main ingredients.

Enhanced product characteristics and reproducibility

In complex fertilizers, thorough mixing of individual nutrients (e.g., N, P and K macro-nutrients plus secondary nutrients and micronutrients) is required to ensure maximum agronomic effectiveness without over/under application to the field. The multi-tool mixing action in counter-current technology delivers this, providing homogeneous mixing with rapid mix times.

Because the pan, high speed rotor and plow are individually controlled, the mixer can create exact and repeatable conditions within the mixing cavity to produce specific products – e.g., granules of a specific size within a tight tolerance. Valuably, even slight adjustments to tooling speeds can produce different sized granules, shapes, densities, and yields.

Mix-granulation also offers the following product quality advantages (Table 2):

- Homogeneous pellets with improved ingredient distributions
- High yields of on-size pellets with substantially less need to reprocess off-size product

FERTILIZER GRANULATION CASE STUDIES

Methodology

Proof of concept testing optimises mix design by identifying product and process goals. Mix-granulation tests using a Lancaster Products mixer provide the opportunity to demonstrate granulation improvements over other mixing and/or agglomeration equipment. Design objectives can include:

- Mixing cycle times
- Binder and ingredient optimisation
- Homogeneity
- Particle hardness, moisture and air entrainment
- Particle-size distributions and yields.

In the following two fertilizer product case studies, the test metrics for mix-granulation included:

- Input moisture
- Operation cycle time (mix-granulation)
- On-size percentage yield.

Case study 1: potash-based fertilizer

Mix-granulation of a potash-based formula (see photo 1) in a Lancaster Mixer resulted in very effective granulation to the target size (2-4 mm) with an exceptional yield of 92.3 percent. Efficient mix-granulation occurred in a cycle time of 540 seconds (9 minutes).

Above: A granulated potash-based fertilizer formula.

Above left: Carbon-char blend 1. Above right: Carbon-char blend 2.

Case study 2: carbon char-based fertilizers

Mix-granulation was performed on two carbon-char based blends (see photos) with the following results:

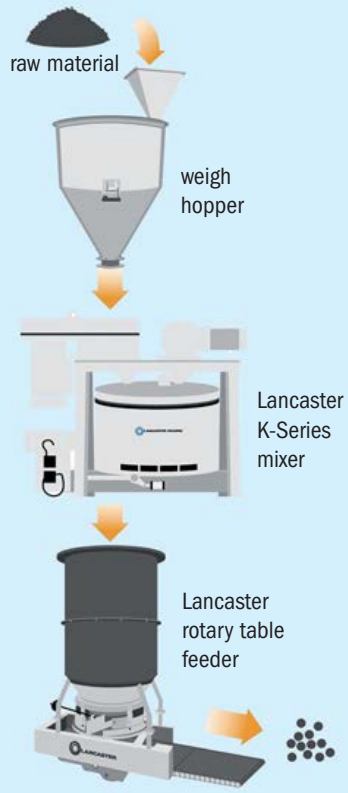
- **Experimental blend 1: water only**. Mix-granulation of dry ingredients (34% input moisture) with water resulted in exceptional yield (90.8%) within a tight pellet size range (1-4 mm) for a cycle time of eight minutes.
- **Experimental Blend 2: organic waste by-product used a binder**. This blend (28% input moisture) eliminated the need for any water addition. Target sized pellets (1-4 mm) were achieved at a high yield (88.5%) for a 10-minute cycle time.

Other organic and inorganic materials

Lancaster Mixers are being used to granulate both fertilizers and soil amendments using a variety of raw materials. These include:

- **Organic raw materials:** manure, chicken litter, biochar, animal meal, humic acid, compost, biosolids.
- **Inorganic materials:** lime, synthetic gypsum, phosphates, potash, humates. ■

Fig. 2: **Lancaster Products continuous batch processing system**



Source: Lancaster Products

- Versatility to control pellet size and characteristics on a batch-by-batch basis.

Increasing throughput with continuous batch processing

Batch processing of complex fertilizers offers both greater product accuracy and high yield outputs. The other key advantages of a batch process are recipe optimisation and mix homogeneity. In fact, there are no real downsides because – with a continuous batch configuration – these important benefits can be realised simultaneously with the consistent throughput and high production rates of a continuous production line.

A continuous batch processing system (Figure 2) is configured sequentially as follows:

- The process begins with pre-weighed raw materials and binders
- These are delivered to the mixer via a weigh hopper
- The high shear mixer runs through a dry mix, a wet mix and then continues to a granulation cycle
- The material is then discharged from the mixer to a conveyor or table feeder – this converting the batch process into a continuous flow of materials
- Parallel lines for redundancy, or systems with multiple mixers, can also be utilised to increase output capacities.

Conclusions

Rapid growth in worldwide agriculture markets is driving up demand for complex fertilizers. This increasing requirement for products with specific and/or novel ingredient formulations means fertilizer producers are in urgent need of efficient and flexible granulation techniques. Simplifying the fertilizer granulation process, while simultaneously increasing throughput and lowering costs, all contribute to delivering high value fertilizer products to customers, at increased profitability. Advanced technologies such as mix-granulation offer fertilizer manufacturers opportunities to achieve these objectives – by combining high shear, counter-current mixing with continuous batch processing.

Pathways to green ammonia

PHOTO: CF INDUSTRIES

The recently-published IEA *Ammonia Technology Roadmap* sets out a future pathway for decarbonising the nitrogen industry. New technology options for low-carbon ammonia production are emerging and project activity is on the rise.

CF Industries' Donaldsonville site in Louisiana is the world's largest ammonia production complex. It is also the location of North America's largest green ammonia project.

The *Ammonia Technology Roadmap* – a collaboration between the International Energy Agency (IEA), the European Bank for Reconstruction and Development (EBRD) and the International Fertilizer Association (IFA) – was published last October in advance of November's COP26 climate conference in Glasgow[1]. Recently described by IFA as its number one priority (*Fertilizer International* 505, p36), the roadmap sets out a plan to decarbonise ammonia production globally by 2050.

In this article, we look at future of ammonia production and the technology options needed to dramatically cut the industry's carbon emissions in under three decades. This will require massive and sustained investment and radical and rapid change.

"The world will need more ammonia but cannot afford the emissions that come with its production," said Timur Gül, the Head of the IEA's Energy Technology Policy Division, who designed and directed the roadmap. "The IEA is proud to have collaborated with the International Fertilizer Association to produce our roadmap for the ammonia industry, which sits at the nexus between the world's energy and agricultural systems."

An essential and widely-traded commodity

Ammonia is one of the world's most widely produced commodity chemicals and an essential feedstock in fertilizer manufacture. Currently, virtually all ammonia manufactured on an industrial scale is synthesised via the energy-intensive Haber-Bosch process.

Some 185 million tonnes of ammonia were produced globally in 2020. China is

Three possible futures

The IEA's *Ammonia Technology Roadmap* sets out three future scenarios for ammonia production – each with different sets of actions and outcomes by 2050 (see Figure 1)

- **Stated Policies Scenario (STEPS)**. The industry follows current trends and, while making incremental improvements, falls well short of a sustainable trajectory.
- **Sustainable Development Scenario (SDS)**. The sector adopts the technologies and policies required to put it on a pathway to meet Paris Agreement goals.
- **Net Zero Emissions by 2050 Scenario (NZE)**. A trajectory for the ammonia industry that reaches net zero global emissions by 2050.

While the STEPS scenario is a modest improvement on business-as-usual that only delivers marginal emissions cuts, both the SDS and NZE scenarios deliver desirable outcomes, according to the IEA, by achieving 70-95 percent emissions reductions. These two scenarios would, however, require the ammonia industry to either meet or go beyond Paris Agreement goals.

Stated Policies Scenario (STEPS)

This assumes that progress over the next 30 years is driven by currently stated government policies. This projection is based on current trends in consumption and production and commitments made at the COP-26 meeting in Glasgow. In this scenario:

- Ammonia production would increase by 37 percent by 2050, driven primarily by economic needs and population growth
- While emissions from production fall by about 10 percent
- Cumulative direct emissions from ammonia production between now and 2100 would amount to around 28 gigatonnes (Gt)
- This amount is equivalent to six percent of the emissions budget needed to limit global warming to 1.5°C.

The report assumes that actions under STEPS – because they do not improve enough on business-as-usual – are inadequate and would result in unsustainable outcomes.

Sustainable Development Scenario (SDS)

This assumes that governments and industry actions meet the goals of the Paris Agreement and limit the global temperature rise to well below 2°C. The two key elements in this scenario are:

- Cutting direct CO_2 emissions from ammonia production by more than 70 percent, relative to today
- Action on nitrogen use efficiency (NUE) to limit the growth in ammonia production and consumption to 23 percent by 2050.

Four main actions would make the following individual contributions to this 70 percent reduction in emissions:

- 45 percent achieved by deploying low-carbon technologies – including electrolytic hydrogen generation (30% of emissions reduction) and carbon capture and storage (CCS, 15%)
- Energy efficiency from the adoption of best available techniques (BATs) and operational improvements contributes 25 percent
- Fuel switching – from coal-based production to less energy intensive gas-based production – is responsible for 10 percent of the reduction

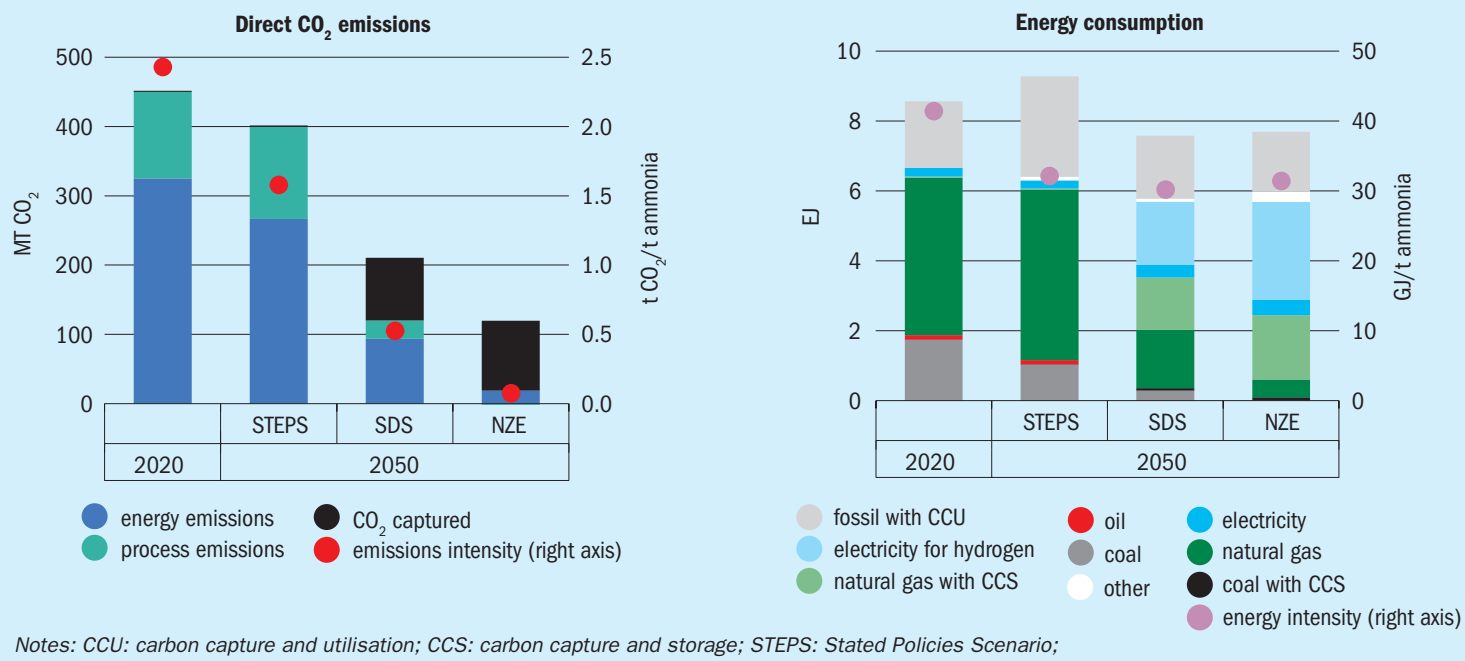
This ambitious scenario requires:

- $14 billion in annual capital investment for ammonia production to 2050
- The installation of more than 110 gigawatts (GW) of electrolyser capacity
- 90 million t/a of CCS CO_2 storage capacity.

Net Zero Emissions by 2050 Scenario (NZE)

This sets out a trajectory for a fall in ammonia industry emissions of 95 percent by 2050. The additional emission reductions in this scenario – compared to the ambitious SDS trajectory – are achieved by even more rapid deployment of electrolysis and CCS technologies. The main difference between NZE and the SDS scenarios is therefore one of degree. Indeed, the NZE Scenario requires only slightly higher annual investment: $15 billion per year to 2050.

Fig. 1: **Comparison of ammonia industry direct CO_2 emissions (left) and energy consumption (right) in 2050 vs 2020. Outcomes for three different future scenarios – STEPS, SDS and NZE*. See text for details.**



Notes: CCU: carbon capture and utilisation; CCS: carbon capture and storage; STEPS: Stated Policies Scenario; SDS: Sustainable Development Scenario; NZE: Net Zero Emissions by 2050 Scenario.

Source: IEA, 2021

the world's largest ammonia producer, accounting for 30 percent of global production and 45 percent of associated CO_2 emissions. The US, EU, India, Russia and the Middle East are the other major producing countries and regions, each accounting for a further 8-10 percent of production.

Ammonia is also a widely traded commodity, with global exports equating to about 10 percent of total production.

Key fertilizer feedstock

Fertilizers are by far the largest end market, accounting for around 70 percent of total ammonia demand. The remaining 30 percent is destined for a wide range of industrial markets, principally plastics, explosives and synthetic fibres.

Urea is the most common derivative, being responsible for around 55 percent of ammonia demand. Urea is mainly used:

- As a direct-application fertilizer (75%)
- In urea ammonium nitrate (UAN) production (5%)
- For industrial applications (20%).

Nitric acid is the other key derivative and accounts for much of the remaining 45 percent of ammonia demand. Subsequently, around 80 percent of nitric acid then goes on to be used to manufacture ammonium nitrate (AN) – with around two-thirds of the AN obtained ultimately ending up as fertilizer.

Energy intensive

Producing ammonia requires a lot of energy. On average, around 2.4 tonnes of carbon dioxide are emitted per tonne of ammonia produced, although this varies according to the hydrocarbon feedstock used. To put this in context, ammonia's per tonne emissions intensity is twice as high as steel, for example, and four times higher than cement.

Direct emissions from ammonia production currently total 450 million t/a of carbon dioxide equivalent (CO_2e) globally. This is comparable to the total energy emissions of South Africa. Indirect CO_2 emissions contribute a further 170 million t/a CO_2e per year. These stem from two main sources – electricity consumption and urea hydrolysis in soils – together with N_2O emissions from downstream nitric acid production. Overall, ammonia is responsible for 1.75 percent of global CO_2 emissions, taking into account its direct and indirect contribution.

Cutting production emissions

The IEA's roadmap identifies several emerging low-carbon technologies for ammonia synthesis – what it calls 'near-zero-emission production' routes. The most promising include:

- Water electrolysis
- Conventional production coupled to downstream carbon capture and storage (CCS)
- Methane pyrolysis
- Biomass gasification

"These emerging routes are typically 10-100 percent more expensive per tonne of ammonia produced than conventional routes, depending on energy prices and other regionally varying factors," the IEA comments[1]. "Existing and announced projects totalling nearly eight million tonnes of near-zero-emission ammonia production capacity are scheduled to come online by 2030, equivalent to three percent of total capacity in 2020."

The roadmap sets out two trajectories (see box) capable of delivering "a range of desirable futures for the ammonia industry":

- In the **Sustainable Development Scenario (SDS)**, direct CO_2 emissions fall by over 70 percent by 2050 relative to today
- While the **Net Zero Emissions by 2050 Scenario (NZE)** achieves a 95 percent cut in emissions by 2050.

Essentially, the SDS scenario would mean the ammonia industry would operate within the goals of the Paris Agreement, and therefore help limit the global temperature rise to below 2°C. The more exacting NZE scenario, meanwhile, would essentially transform ammonia production into a net zero industry (see box).

Under both these future scenarios, the IEA expects the deployment of low-carbon technologies to do most of the heavy lifting on emissions reductions out to 2050. In the SDS, scenario, for example, ammonia production by electrolysis would account for around one-fifth of global production globally by 2050 (versus less than 0.01% today), this share rising to above 40 percent in Europe, India and China. In the NZE scenario, meanwhile, the global production share for the electrolysis pathway doubles to more than 40 percent.

Carbon capture and storage (CCS) also looks set to play an increasing role, capturing 91 million tonnes and 101 million tonnes of ammonia industry CO_2 emissions annually by 2050 in the SDS and NZE scenarios, respectively.

These two low-carbon technologies would need to be "deployed at a rapid clip" according to the IEA's roadmap[1]. This is, if anything, an understatement. Under the SDS scenario, for example, more than 110 GW of electrolyser capacity and 90 million t/a of CO_2 transport and storage infrastructure would be needed by 2050. That equates to the installation of ten 30 MW electrolysers (the largest capacity currently in operation) per month on average, together with the completion of one large-scale CCS project (1 million t/a CO_2 capacity) every four months between now and 2050. Even more rapid deployment of these technologies would be necessary under the IEA's most ambitious NZE scenario.

Rapidly deploying these carbon cutting technologies at scale will not be cheap either – requiring of $14-15 billion to be invested annually for the next 30 years.

Another challenge will be massive industry investment already locked up in existing long-life assets. Ammonia production plants can remain in operation for up to 50 years. Globally, the current average age of installed ammonia capacity is around 25 years. This figure does, however, vary widely from region to region. In Europe, for example, the average age of plant capacity is close to 40 years – that compares to just 12 years in China, where most new capacity has been built in the past 20 years.

The IEA accepts there will be a need to tackle 'locked-in' emissions from existing ammonia production infrastructure by:

- **Retiring or underutilising existing assets early**, if these become uneconomic due to changing market conditions, or because of new regulations that force early closure or partial operation
- **Refurbishments and retrofits** which enhance process integration, energy efficiency and introduce emission reduction technologies by partly replacing natural gas with electrolytic hydrogen or implementing CCS.
- **Introducing fuel switching and fuel blending** to allow existing plants to run on less carbon-intensive fuels.

Changes In future demand

Globally, per capita nitrogen demand for fertilizers was estimated at 14 kg in 2018. Regionally, this varies from:

- 35 kg in the US
- 22 kg in Brazil
- 20 kg in China
- 13 kg in India.

In general, nitrogen demand per capita declines as a country's agricultural market matures and nutrient use efficiency (NUE) improves (see Figure 2).

Global nitrogen demand totalled 152 million tonnes in 2020. This is forecast to grow by another 40 percent by 2050 under the IEA's business-as-usual (STEPS) scenario, reaching 208 million tonnes. This is equivalent to an average annual growth rate of about one percent – albeit significantly below the 1.7 percent p.a. average for 2010-2020.

This business-as-usual assumption is underpinned by a slowdown in industrial ammonia demand from around 4 percent p.a. currently to 1.3 percent annually. Fertilizer sector demand for ammonia, meanwhile, is expected to continue to grow at its current rate of around 0.9 percent per year.

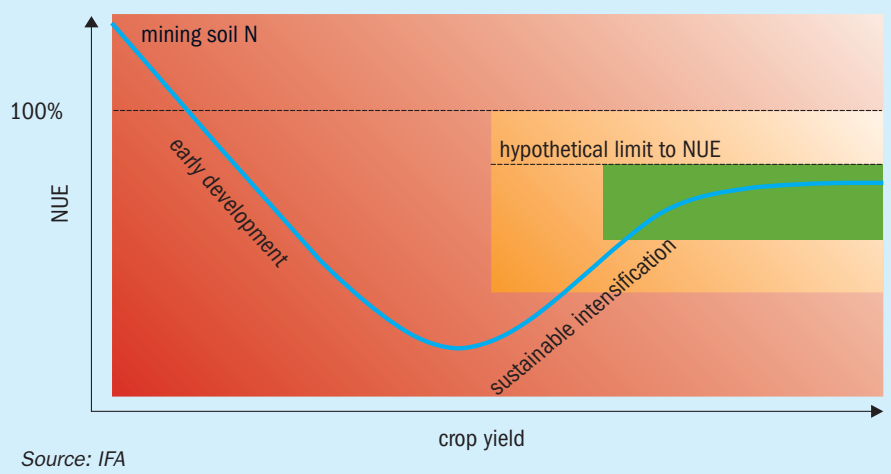
In contrast, in the IEA's SDS scenario, total nitrogen demand growth slows to 0.7 percent annually, leading to a less marked 25 percent increase in total nitrogen demand by 2050. This is linked to the adoption of measures to improve NUE. It also assumes that current usage of urea-based fertilizers declines by 28 percent by 2050, due to product substitution by ammonium nitrate (AN) and calcium ammonium nitrate (CAN).

Urea's current market dominance, versus rival nitrogen fertilizers, is largely explained by its higher nitrogen content (46%) and greater convenience when it comes to storage, transport and application. Yet urea also contains CO_2 – locked in during production – that is later released during hydrolysis after it's applied to soils.

This behaviour is likely to be an increasing disadvantage as energy and agricultural systems become more sustainable in future, given that the emissions released by urea during agricultural usage – around 130 million t/a CO2e in 2020 – are equivalent to about 30 percent of total ammonia production emissions. This is likely to prompt a partial switchover to AN and CAN, the IEA suggests, as these do not release CO_2 during their use.

Extra to current agricultural and industry usage, the IEA is forecasting rapid growth in demand for ammonia as an energy carrier, primarily in the maritime fuel and power sectors. Total ammonia demand is forecast to rise to 355 million tonnes annually in 2050, about twice the 185 million tonnes produced in 2020. This total includes 125 million t/a of demand for ammonia as energy carrier by 2050, in addition to 230 million t/a of conventional demand.

Fig. 2: **Nutrient use efficiency curve showing the U-shaped trajectory followed by many countries as their farming sector matures**



Source: IFA

Costs hold the key

As already indicated, there are two main emerging routes to a low carbon ammonia future:

- The deployment of carbon capture and storage (CCS) as a bolt-on downstream technology – the so-called 'blue' ammonia production route.
- A shift to water electrolysis-based production – the so-called 'green' ammonia production route.

Although slightly elevated, the costs of blue ammonia production tend to be broadly similar to conventional, unabated 'grey' ammonia production – because both are already located in regions with the lowest capex and energy costs. The slightly higher cost for the CCS production route – which adds 10-25% to the costs of natural gas-based ammonia production – is attributable to:

- Higher energy consumption
- CO_2 transport and storage costs
- Extra capex and opex costs of the carbon capture equipment.

For blue ammonia, the good news is that more than enough CCS capacity should be available globally to satisfy the needs of the ammonia industry, according to the IEA[1]:

"Substantial [CO_2 storage] capacity is expected to exist in Russia, North America, Africa and Australia, [with] global capacity far exceeding storage needs for the full energy system over the period 2020-2050. Therefore, regional availability of CO_2 storage capacity would not be a limiting factor for the deployment of this technology in the ammonia industry."

The costs for green ammonia production, in contrast, are mainly determined by the cost of the electricity used, with the electrolyser unit itself responsible for 90 percent of electricity consumption. The use of dedicated variable renewable energy (VRE) source, versus grid-sourced renewable electricity, also affects costs.

Solar and wind installations typically operate at capacity factors of between 15-50 percent. As a result, for those projects with a dedicated VRE source, electrolyser capacity generally needs to be oversized to compensate to allow for the intermittency. Hydrogen or electricity storage can also be used to ensure that a stable supply of hydrogen is supplied to the ammonia synthesis unit.

"Projects under development to produce electrolytic ammonia include those using a grid connection and others using

dedicated capacity," the IEA reports[1]. "For example, Yara's project in Norway and CF Industries' project in the United States will be grid-connected, while Yara's projects in the Netherlands and Australia and Enaex's project in Chile will be powered by dedicated solar or wind power."

The IEA roadmap identifies a number of promising low cost VRE sites globally[1]: "With respect to the levelised cost of electricity, in 2020 locations in Chile, Spain, the United States and Saudi Arabia have lower-cost solar resources; those in China and Morocco have a cheaper wind resource, and the locations in India, South Africa and Australia are more balanced. In 2030, however, solar PV becomes cheaper than wind power in all locations except the site in China."

For methane pyrolysis and biomass gasification – the other emerging production routes for low-carbon ammonia production – there are cost uncertainties because no commercial-scale plants are operative yet. The cost premium for biomass gasification is, however, likely be very large – owing to its very high energy intensity (37 GJ/t including feedstock) and the relatively high cost of bioenergy in general. Costs for methane pyrolysis can be offset by the revenue generated from sale of the carbon black co-product. This can raise around $360/t, although the market for carbon black is limited and unlikely to sustain product generated by a large numbers of pyrolysis-based ammonia plants.

How to get there?

Governments, by creating supportive policies, will need to play a central role – if the global ammonia industry is to transition to a low-carbon future and achieve emissions cuts on the scale set out in the roadmap. Legislators will need to introduce mandatory emission reduction policies and policy mechanisms that mobilise investment. According to the IEA, targeted policy is also required to:

- Address existing emissions-intensive production assets
- Create markets for low-carbon products
- Accelerate R&D
- Incentivise high nutrient use efficiency for fertilizer products derived from ammonia.

Governments are also uniquely responsible for the putting in place enabling conditions for the energy transition. This includes ensuring a level playing field exists for green and blue ammonia in global markets, providing the necessary infrastructure for hydrogen and CCS, and making sure that robust data on emissions performance are available.

While governments are the enablers, other key players will have to respond rapidly to their policy cues. In particular:

- Ammonia producers will need to establish low-carbon transition plans with emissions reduction targets, accelerate their R&D investment, and develop the infrastructure needed to support green and blue ammonia production
- Farmers and agronomists will have to implement best management practices (BMPs) that ensure more efficient fertilizer use
- Financial institutions and investors will need to devise instruments that efficiently target finance at emissions reduction
- The help of researchers and non-governmental organisations will also be necessary – to develop product labelling schemes, scale-up and demonstrate emerging technologies and galvanise support for these.

The proposed radical transformation of the ammonia industry will need to be pushed through at a dizzyingly fast pace. Near-term action in the current decade – from now to 2030 – will be critical. The IEA says time if of the essence and expects some 10 percent of cumulative emissions reductions needed by 2050 to take place in the 2020s.

Green ammonia – an enabler of decarbonisation

Future cost reductions for green ammonia are predicated on factors such as lower renewable prices, upscaling of the technology, access to financing and willingness to pay a 'green premium'. At the same time, production costs for conventional ('grey') ammonia look set to escalate in future due to increasingly stringent environmental regulations, carbon pricing and cost inflation.

Table 1: **Selected fertilizer industry green ammonia production projects***

- **Fertiberia and Iberdrola, Puertollano, Spain:** under construction, due to be online by end of 2021; 20 MW electrolyser, solar-powered; for use in the fertilizer plant to enable 10 percent reduction in natural gas requirements; three additional projects planned between 2023 and 2027 in Puertollano and Palos de la Frontera for a total of 800 MW electrolysis.
- **Yara, NEL Porsgrunn, Norway:** in partnership with Statkraft and Aker Clean Hydrogen; 25 MW electrolyser expected online in 2023; expanded electrolyser capacity will fully shift 500,000 t/a of ammonia production capacity away from natural gas between 2026-2028; grid-connected hydropower project.
- **Yara and Ørsted, Sluiskil, Netherlands:** at feasibility stage, expected online 2025; 100 MW electrolyser, 70,000 t/a ammonia capacity; offshore wind-powered.
- **Yara and Engie, Pilbara, Australia:** 10 MW electrolyser by 2023; solar-powered project.
- **CF Industries; Donaldsonville, Louisiana, US:** construction began 2021, completion expected by 2023; 20 MW electrolyser, 20,000 t/a ammonia capacity; grid-connected project.
- **Enaex and Engie, Mejillones, Chile:** pilot with 26 MW electrolyser and 18,000 t/a ammonia expected online by 2024; full-scale operation with 1.6 GW electrolyser and 700,000 t/a ammonia by 2030; solar-powered project.
- **Balance Agri-Nutrients and Hiringa Energy, Kapuni, New Zealand:** expected online mid-2020s; 7,000 t/a urea capacity; wind-powered project.

** Large-scale demonstration or first commercial projects, end-2021*

Notes: other planned and under development pilot-to-commercial-scale projects are taking place in Australia (Queensland Nitrates; Dyno Nobel; H2U; BP; Fortescue Metals Group; Origin Energy), Denmark (Skovgaard Invest; Copenhagen Infrastructure Partners), Trinidad and Tobago (Kenesjay Green Ltd), Germany (RWE), Chile (AES Gener; CORFO; Austria Energy), Oman (ACME) and Morocco (OCP Group).

Source: IEA (2021)

"The commercial feasibility of green ammonia projects will vary greatly depending on the time required to bring down opex and capex costs, the individual plant configurations, the business models and the locations of these projects. Developers need to consider delivered cost too, and prices in different geographical and application markets, to fully understand their projects," CRU's Willis Thomas commented recently (*Fertilizer International* 505, p36).

Green ammonia projects will also require strong business cases to win financing, according to Thomas: "The growing numbers of green ammonia projects globally will mean developers face increasing competition for financing. Thus, they must build and stress test their project business case both early and often."

By 2050, around 70 million tonnes of existing fossil fuel-based ammonia capacity will be shut down or converted to renewable inputs, according to Ammonia Energy Association estimates, while 500 million tonnes of additional green ammonia capacity is set to be developed using renewable inputs (electricity, biomass). The established fertilizer market supplemented by substantial emerging markets for maritime fuel, hydrogen carriers and fuels for electric power generation are all expected to ratchet up demand for 'clean' ammonia.

Current fertilizer industry green ammonia projects are shown in Table 1. Yet the scale of these is relatively minor compared to newly-announced non-fertilizer projects for green ammonia. These include the following mega projects (maximum ammonia and electrolyser capacity shown):

- **Asian RE Hub, Australia**: 9.9 million tonnes, 16 GW
- **Svevind, Kazakhstan**: 15 million tonnes, 45 GW
- **Aman, Mauritania**: <20 million tonnes, 30 GW
- **Al Wusta, Oman**: <10 million tonnes, 15 GW
- **Western Green Energy Hub, Australia**: 20 million tonnes, 50 GW
- **Grand Inga Dam, DRC**: >20 million tonnes, 40 GW hydroelectric.

Projects on this scale are going to be needed if shipping and other industries are going to be fully decarbonised over the next two to three decades, according to the Ammonia Energy Association. Even five percent decarbonisation of the shipping industry by 2030 – via the adoption of zero-carbon maritime fuels – would require 60 GW of electrolyser capacity making 30 million tonnes of green ammonia. Furthermore, the 93 percent decarbonisation of shipping by 2046 would necessitate one terawatt of capacity generating 300 million tonnes (*Fertilizer International* 505, p36).

"In various stages of development, we've got about 100 million tonnes of green ammonia underway from roughly 200 gigawatts of renewable electricity, with some more committed than others. When you're scaling up to this size, it's a lot easier to see how the economies of scale are going to come in, and how financing is going to enable a molecule like ammonia to actually support decarbonisation in industries like the maritime fuel sector," the Ammonia Energy Association's Trevor Brown said recently (*Fertilizer International* 505, p36).

References

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Fast delivery of productive, efficient green ammonia plants

By using modular construction, operational modelling and digital plant control, thyssenkrupp Uhde can offer customers fast-build, capital efficient green ammonia plants. **Dr Christian Renk** and **Dr Klaus Nölker** explain the company's innovative approach to plant construction, design and control.

PHOTO: THYSSENKRUPP NUCERA

thyssenkrupp nucera electrolysis assembly.

Future global demand for green ammonia is expected to be enormous, according to the latest market forecasts. This will require generation of green ammonia on a very large scale. Indeed, this is already being reflected by market activity. Every week, new supply contracts and production and storage projects are announced. Delivering worldwide production capacities for green ammonia from currently confirmed projects – and those coming down the track – will therefore be a huge challenge for the industry.

thyssenkrupp Uhde, as a major supplier of green ammonia plants, will need to respond to and meet this challenge. The company is deeply involved throughout the whole green chemicals value chain – with capabilities ranging from renewables to electrolysis (through its affiliate thyssenkrupp nucera), to green ammonia production and storage, as well as ammonia cracking for green hydrogen production.

This article explains how thyssenkrupp Uhde is delivering highly productive and operationally reliable green ammonia plants, in a rapidly growing market, by meeting the following three customer requirements:

- Fast and safe plant delivery
- Optimisation of hydrogen storage size versus plant capacity
- Improved digital control systems for plant operations.

Multiple challenges

Delivering the large numbers of green ammonia projects that will be necessary to satisfy future capacity requirements presents many challenges. This task will only be achievable, for example, if plants are built much faster than usual. Yet, at the same time, they will also have to be constructed to the same quality and safety standards applied by thyssenkrupp Uhde to its previously completed 130 grey ammonia plants.

Naturally, green ammonia plants will also need to be built in the best locations for harvesting renewable energy. These are mostly remote and wild places where intensive solar radiation, strong and steady winds, and enduring water flows can be found – either alone or in combination. Unfortunately, the present infrastructure in these distant sites is generally either very limited or non-existent! This makes the construction of green ammonia plants both very time consuming and cost-intensive.

Modularisation

If thyssenkrupp Uhde is to master the challenge of faster plant set-up at reduced costs, while maintaining high safety standards, the best option is to shift construction activities away from the project site – and move to off-site modular construction in fabrication shops or yards instead. thyssenkrupp Uhde already has excellent modularisation capabilities at its centre of competency, part of the company's Thailand subsidiary.

The ability to complete pre-assembled modules and racks demonstrates the value thyssenkrupp Uhde can offer customers, especially when combined with its proven planning, design, logistics, hook-up and commissioning processes. Options for modularisation are generally evaluated with the customer at the outset of every project. The most appropriate construction option is identified, after reviewing the client's needs, the project's size, the installation site and other factors.

thyssenkrupp Uhde has been offering green ammonia plants in two pre-modularised capacities (50 t/d and 300 t/d) for several years (*Fertilizer International* 488, p33). More recently, further pre-modularized capacities have been added to meet customer requirements and keep up with rising market demand.

The range of standard-size green ammonia plants now includes 600, 1200 and 3,400 t/d modular units. 3D models have been created for these larger size modules (Figure 1) and the necessary detail engineering is also in place. The ability to offer larger capacity production modules speeds up the bidding phase and makes this more accurate. They will also help fast track project engineering during the subsequent installation phase.

In summary, the modularisation of green ammonia plants offers the following advantages:

- Reduces construction time at the final site
- Reduces construction phase risks and increases construction safety
- Less on-site personnel are required during the construction phase
- Shorter commissioning phase due to use of pre-cleaned and pre-tested equipment/piping within the modules
- Allows modules to be fabricated in the best cost countries possible
- Modules generally show higher build quality due to better tool use in a controlled workshop environment
- Transportation limits can be overcome with correct module sizing
- Modularisation makes it possible to take advantage of serial production.

PHOTO: THYSSENKRUPP UHDE

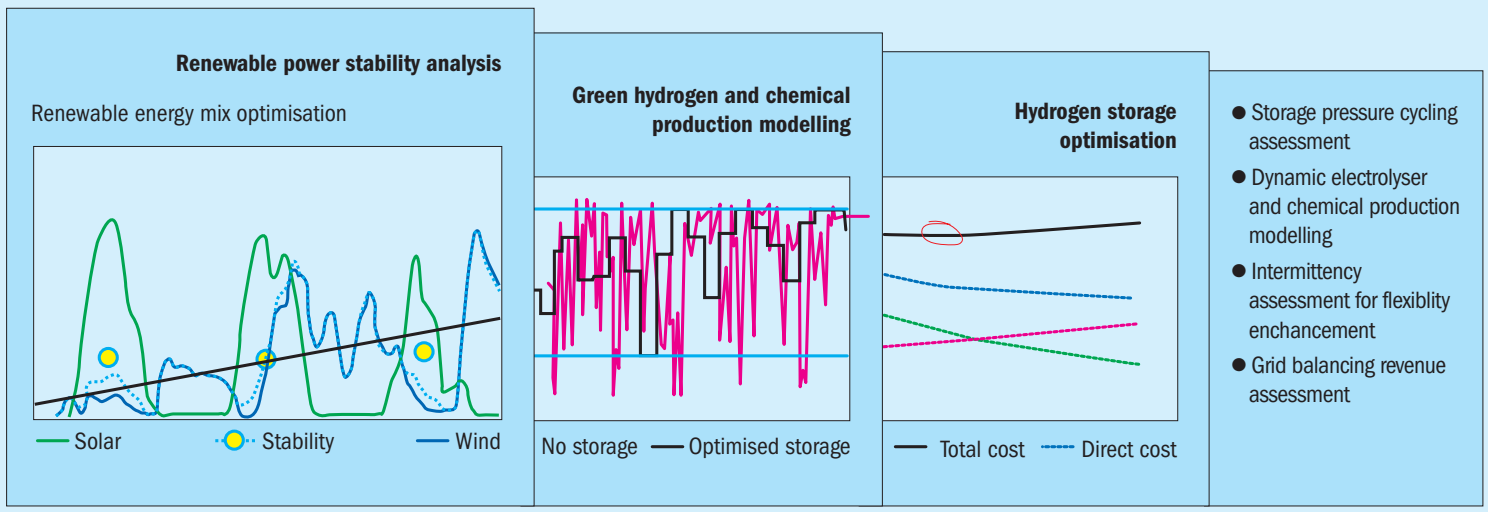
Fig. 1: Example of a thyssenkrupp Uhde small-scale modular green ammonia plant showing ammonia synthesis (centre) and pressurised ammonia storage tank (right).

Operational modelling

The variable and intermittent nature of renewable energy sources is a major production challenge for green ammonia, especially when it comes to powering the upstream electrolysis unit with renewables. Hydropower is more or less stable and, in theory, we can predict times when the sun provides solar energy to the plant. But what about clouds appearing – and how fast will wind speeds rise or fall? With all these combined variables creating uncertainties, predicting the supply of power from renewables comes down to statistics and probabilities.

Help is at hand, however, as thyssenkrupp Uhde's RHAMFS® modelling tool (Figure 2) can accurately simulate green ammonia plant and system behaviour. Based on the predicted energy availability profile, it determines the most suitable ammonia production capacity, and hence the required plant turndown and the load changes per day, and sizes the hydrogen buffer (storage capacity) accordingly. This combination of adjustments smooths the load profile and

Fig. 2: **Simulating green ammonia plant and system behaviour with thyssenkrupp Uhde's RHAMFS® tool**



Source: thyssenkrupp Uhde

compensates during periods of low or zero renewable power availability.

By tailoring plant parameters in response to fluctuating renewable generation, the RHAMFS® tool is used to set both plant capacity and to keep the required hydrogen storage to a minimum. Minimising hydrogen storage is valuable as cuts both capital costs and operating costs (by reducing the quantity of hydrogen that needs to be cooled and pressurised). Less storage also reduces the loss of highly volatile hydrogen. The ammonia plant controller also reacts very quickly to power fluctuations by adjusting the turndown ratio in the plant.

Essentially, to deliver the same production output over time from a given power profile, the green ammonia plant operates between two design extremes:

- **Sizing the plant for peak power availability:** this results in a high level of plant underutilisation over long intervals and therefore comes with a cost penalty
- **Sizing the plant for average power availability:** this requires large hydrogen storage capacity which also incurs a cost penalty

These two extremes are a good way of visualising the challenge presented by renewable power intermittency.

One function of the RHAMFS® tool is to determine the optimum plant characteristics for each customer – by combining a certain degree of overdesign with the optimum hydrogen storage size. Using this tool, the ammonia plant's turndown operation will improve as the hydrogen storage size becomes smaller.

The key features of the RHAMFS® tool (Figure 2) include:

- Economic modelling of both centralised and distributed hydrogen and chemical production units
- Real-time modelling of electrolyser utilisation and production
- Chemical export value chain modelling
- Hydrogen storage optimisation
- Sector coupling assessment
- Total cost of ownership
- Estimation of carbon emissions offsets.

With RHAMFS®, the customer will get a green ammonia plant with optimised capital investment, operating costs and production capacity. But how are the turndown ratios handled when the plant goes online? This is a critical operational issue for several reasons.

For example, extended residence times in the ammonia reactor due to lower turndown can risk creating hot spots inside the catalyst bed and/or inactive zones where under-utilised catalyst has cooled down. Instead, the catalyst needs to be kept hot and maintained within its active temperature range. This enables an accelerated and automatic resumption of production as soon as more feed gas is available. Catalyst crushing caused by thermal expansion and contraction is also avoided. Furthermore, a stable and sufficiently high overall circulation rate needs to be maintained to avoid channelling inside the catalyst beds and meet compressor surge limitations. Additionally, major pressure and temperature changes should be avoided to prevent equipment fatigue.

Digital plant control

In general, chemical plants are not designed for high turndown ratios and fast load changes. This is certainly true of a conventional ammonia plant. Yet experience shows that stable and continuous operation at 25 percent of design load is possible. This has been practically demonstrated at conventional thyssenkrupp Uhde ammonia plants without any technical modification. Furthermore, turndown ratios as low as 10 percent are possible, if requested by the customer and necessary for optimal plant operation, although design changes and additional control functions are required.

thyssenkrupp Uhde has developed an improved digital Master Controller for highly flexible ammonia synthesis. Using advanced digital solutions, this optimises plant operations for large-scale direct coupling with renewables.

The Master Controller adjusts ammonia production to the forecasted flow of green hydrogen. This ensures the minimal hydrogen storage installed is utilised in an optimum way. Furthermore, production ramp ups and ramp downs at the green ammonia plant are handled as quickly and as efficiently as possible. At the same time, all operations are conducted without any apparent pressure change in the ammonia synthesis section.

The improved digital Master Controller, by preventing the above-mentioned hot spots from forming in the most active first catalyst bed, also ensures that no unconverted gas is left for the downstream beds. This is achieved by increasing ammonia inlet content at higher separation temperature. This patented approach is combined with the sophisticated use of process bypass valves. An external heating source such as a start-up heater can also maintain the required temperature in the first bed.

Grid-supplied green electricity can also be used as an alternative power source during times of low renewable electric power availability (and hence low hydrogen). For example, around 1 MW of electric power can generate roughly 0.1 t/h of H_2/N_2 mixture (via electrolysis, air separation and compression to 20 MPa) which then releases about 0.08 MW of reaction heat to maintain the converter temperature.

If green electric power is not available, the same amount of reaction heat can be generated by directly applying 1 MW of standard grid power to electrically heat the converter. In this case, although the ammonia produced at the plant will be less green, it does keep the plant in standby mode ready to be quickly ramped up again when the renewable energy supply eventually recovers.

To summarise, the Master Controller – by precisely regulating process parameters in response to fluctuating renewable energy supply – creates a dynamic green ammonia plant which operates at optimum capacity for the customer.

Conclusions

By using modular construction, operational modelling and digital plant control, thyssenkrupp Uhde can offer customers fast-build, capital efficient green ammonia plants. These plants operate safely at near perfect productivity as they are designed to ensure that hydrogen storage and plant capacity are at an optimum ratio. These highly effective and practical engineering solutions are thyssenkrupp Uhde's contribution to the chaotically growing green ammonia market. By helping deliver a low-emissions future, they also deliver on our company purpose to "create a liveable planet". ■

About the authors

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The flexible green ammonia plant

Economically viable production of green ammonia requires plants that can react to fluctuations in renewable power thanks to their flexible design. Casale's **Francesco Baratto**, **Giovanni Genova** and **Sergio Panza** explain how new tools are helping design green ammonia plants that deliver the highest possible production at the lowest possible cost.

Developing a green economy has become a priority for many nations. This includes the large-scale expansion in renewable energy needed to meet 'net zero' climate and energy targets by 2050.

Indeed, recent growth in renewable energy in countries such as Germany, Uruguay, Chile and Brazil has exceeded forecasts. Other well-known countries such as Australia and Japan have also made renewable energy generation a strategic part of their future economic plans. Regions such as the Middle East, meanwhile, are already pressing ahead and developing large-scale green energy projects.

In future, the availability of abundant renewable energy will become crucial for the fertilizer industry – and potentially redraw the global production map by changing where ammonia can be economically manufactured. Despite its great potential, dealing with the variability and seasonality of renewable power sources remains a big challenge for ammonia synthesis.

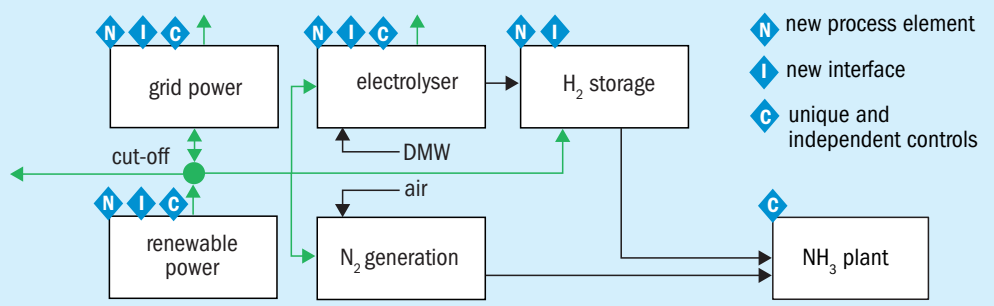
Casale's green ammonia technology

Casale is the world's oldest licensor for green ammonia technology, having built the first 'fully green' ammonia plant about 100 years ago in Italy. The electrolysers in this pioneering plant ran on hydroelectric power and provided a dedicated supply of hydrogen to an ammonia synthesis loop.

Today, Casale offers a wide range of modern technologies focused on but not limited to ammonia synthesis. Importantly for this article, these technologies encompass the full scope of green ammonia production.

Casale is also a supplier of engineering components for other sections of the green ammonia plant such as hydrogen and ammonia storage. The company also possesses expertise in the digitalisation and optimisation of green ammonia plants, green ammonia usage, and the subsequent conversion of ammonia into either green hydrogen or nitrogen fertilizers.

Fig. 1: **Plant control system embracing conventional and new elements**



Source: Casale

Designed for intermittency

The energy for green ammonia plants, unlike conventional (grey) ammonia plants, comes from renewable sources. These often fluctuate causing hydrogen and nitrogen generation to vary. Such operational interruptions can increase production costs if more capex is required to stabilise these fluctuations. To avoid this, the design of green ammonia plants needs to be more flexible to cope with intermittency and other challenges.

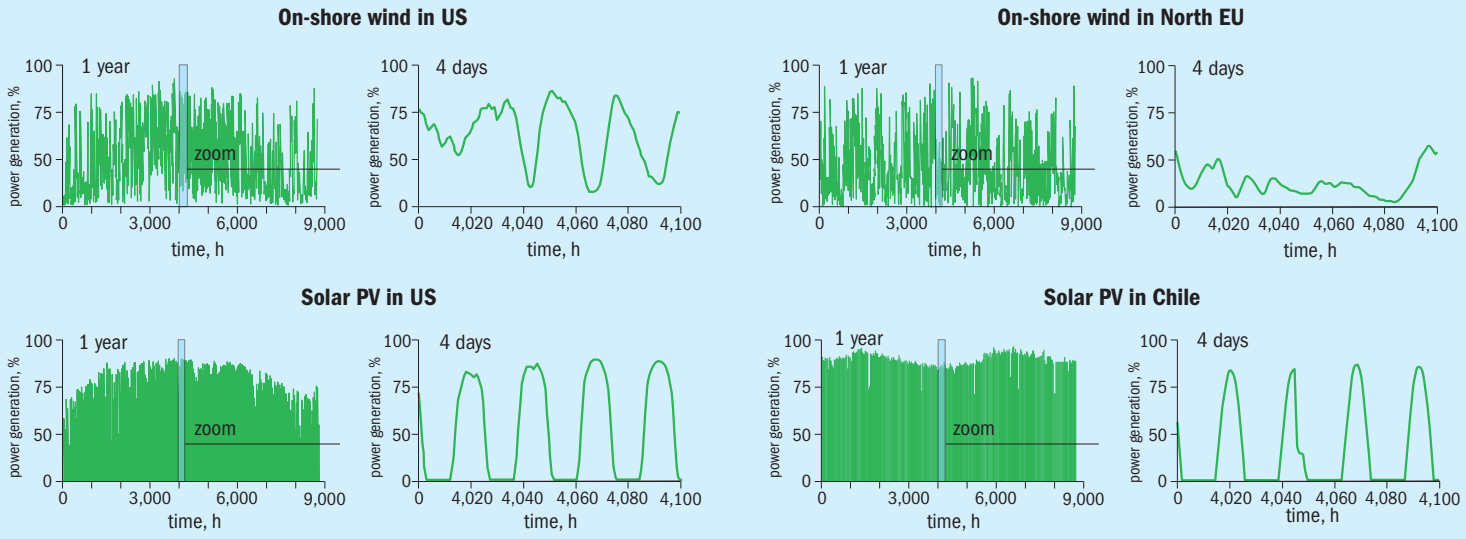
Casale's green ammonia plant design incorporates a number of innovations that make it more flexible to operate. These include new elements (e.g. electrolyser, hydrogen storage), new interfaces between these elements, and a unique control system (Figure 1). Its innovative and flexible design offers significant cost advantages, in comparison to conventional 'inflexible' green ammonia synthesis, by requiring less hydrogen storage capacity.

New dynamic tools to optimise design

Casale has been able to develop a uniquely flexible green ammonia process thanks to its understanding and mastery of the dynamics of ammonia production when this is powered by renewable energy. The company has developed new dynamic tools specifically for this purpose:

- **gNH_3 Optimiser:** this tool optimises energy utilisation and the pre-sizing of plant components. It also optimises overall process control so that the plant operates at the highest possible output and the lowest possible cost (levelised cost of ammonia, LCOA). Optimisation takes account of the yearly profiles for the renewable power unit and exploits the flexible design features of Casale's green ammonia plant.

Fig. 2: **Power profiles for two different renewable energy sources (solar PV and onshore wind systems) at four different global locations**



Source: Casale

- **gNH_3 Dynamic Model:** this tool is a dynamic process model of the plant which can simulate the process using scenarios based on real fluctuations in the renewable power profile. It allows fine tuning of the system, troubleshooting and scheduling.

These tools can dynamically analyse and determine the following:

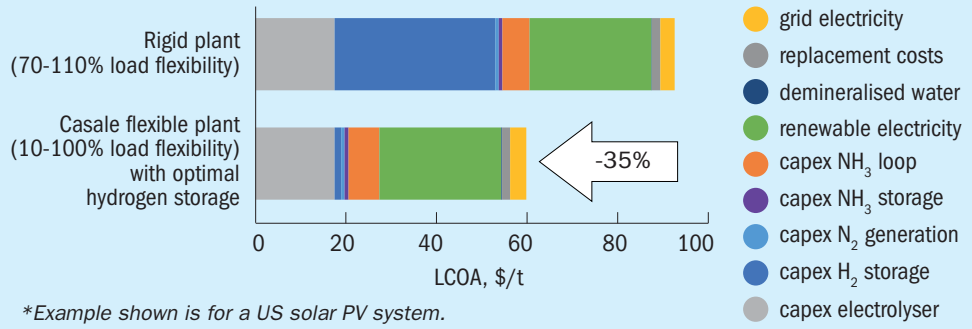
- Renewable power profile
- Grid power, if available, although 'off grid' island mode generation can also be an option
- Electrolysers: specifies their optimal size
- Hydrogen storage: including sizing, control philosophy and plant integration
- Ammonia plant: its unique and independent controls
- Nitrogen generation: suggests the optimal N_2 profile

Case study: analysing real power profiles

Casale has analysed real power profiles generated in strategic regions for renewable power production. These include profiles of onshore wind systems in the US and EU, and solar PV systems in the US and Chile (Figure 2). The aims were two-fold:

- To understand the impact of the location, source and availability of renewable power on the economics of green ammonia production
- To demonstrate how Casale's flexible approach to green ammonia production can generate ammonia output at the lowest cost.

Fig. 3: **Calculated production costs (LCOA) for Casale's flexible green ammonia plant vs a more rigid conventional plant***



**Example shown is for a US solar PV system.*

Source: Casale

To enable a proper comparison, it was assumed that each of the four different power profiles would need to cumulatively generate sufficient yearly renewable energy for a 45 tonne/day ammonia plant.

As might be expected, the two solar PV power systems have the same day-to-night profiles. However, the energy generation from the Chilean solar PV system, from a seasonality point of view, is more stable across the year compared to the US system. Comparison of the onshore wind profiles revealed that while the US system has a higher capacity factor, it also shows higher seasonality, relative to the system at the northern EU location.

The gNH_3 Optimiser tool was used to calculate the production costs (LCOA) achieved by Casale's flexible green ammonia unit. This is capable of operating at a 10-100 percent load range and a 100 percent load change per hour.

For the US PV system, Casale's flexible green ammonia approach reduced productions costs (LCOA) by up to 35 percent, versus a more rigid conventional green ammonia process (70-110% load flexibility) (Figure 3). The adoption of a flexible synthesis loop also reduced the hydrogen storage requirement by more than 20 times.

For the other power profiles, Casale's flexible green ammonia process similarly reduced production costs, although to different extents. The northern EU onshore wind system, for example, would benefit from a 35 percent LCOA reduction, versus a five percent LCOA reduction for the Chilean solar PV system.

In summary, the results of this economic analysis show that Casale's green ammonia process can achieve significant benefits. Its flexible synthesis loop, by adapting to fluctuating renewable power profiles, can deliver green ammonia at competitive production costs (final LCOA). ■

May-June 2022

phosphates & potash INSIGHT

CRU Phosphates 2022

More than 300 delegates from over 130 companies and 29 countries gathered for CRU's Phosphates 2022 conference, 7-9 March.

PHOTO: SIMON INGLETHORPE/BCINSIGHT

CRU Phosphates delegates were pleased to network in person for the first time in three years.

We report on the main keynote and market outlook presentations given at CRU's 14th Phosphates International Conference and Exhibition held in Tampa in March.

Phosphate prices to rise before they fall

The conference opened with a keynote address from CRU's Glenn Kurokawa. Glen's wide ranging phosphate market overview touched on trade, prices, supply, demand, projects and – inevitably –the Russia-Ukraine conflict.

"In the last few weeks, the Ukraine war, a major geopolitical event, has led to a lot of commodity prices rising – including crop prices, energy prices, phosphate raw material prices – and this is now impacting the phosphate market," Kurokawa said.

In fact, the phosphate market has been convulsed by frequent changes and disruptions over the last two years, such as:

- **The Covid-19 pandemic**. This was accompanied by halts in phosphate production and rises in commodity prices.
- **US countervailing duties (CVDs)**. Imposed on Moroccan and Russian imports in 20020, these have 'rewired' global phosphate trade
- **Rocketing prices**. As of early March, these were at their highest levels since the 2008 food and financial crisis and were still rising.
- **Chinese export restrictions**. These will last until June 2022 and are likely to be reimposed in late-2022.
- **Russia-Ukraine conflict**. Crop, energy and raw material prices have surged since Russia's invasion of Ukraine in late February. The war's effect on phosphates and the wider fertilizer market is still playing out with big uncertainties remaining.

The phosphate price rises of recent months have been underpinned by a number of factors, as Kurokawa noted:

"These have been supported by high crop prices, good demand, lower than expected phosphate production in key countries, including the US, increased Indian subsidies, low Indian stocks, raw material prices, particularly ammonia. On top of that, China restricted its exports which tightened the market even further."

"Phosphate prices have been going up since early 2020 and are currently at their highest level since the 2008 food and crisis," said Kurokawa. "So, they're pretty high and still rising, and there have been some new events lately [the Russia-Ukraine conflict] that could push it to those 2008 levels."

In term of trade, the Chinese export ban introduced in October 2021 had created international shortages by causing its phosphate exports to "slow to a trickle".

"These measures are supposed to last until the end of June 2022, but once the export ban is lifted there's probably going to be an explosion of Chinese phosphate exports onto the world market," said Kurokawa. However, with phosphate prices expected to remain at high levels throughout 2022, any resumption in Chinese exports is only expected to last for several months.

"We expect the Chinese government to reintroduce these phosphate export restrictions, as it's likely that Chinese farmers will require support again in late 2022," said Kurokawa. "That means Chinese exports this year are likely to be concentrated in a very small number of months over the summer."

Reductions in Russian exports are also on the radar in 2022, given the ongoing war in Ukraine. The country's international trade in fertilizers is significant with Brazil and India being its main export markets. Europe is also a major market for Russian compound fertilizers (NPKs, NPs and PKs) – with potential downside risks.

"Russia exports a significant amount. It's about 13 percent in 2021 for DAP and MAP and a little over 20 percent for compound NPKs and NPs. Russia exports a lot to countries like Brazil and India and some to Europe. Exports to Brazil and India might not be affected that much – but we'll have to wait and see, as this is a fast-changing situation," said Kurokawa.

"It's likely that phosphate prices will rise further before they start to fall. But there will be some [downward] pressure around mid-2022, and if prices don't start to decline then, maybe they will stabilise," Kurokawa concluded.

US phosphate shipments to fall back modestly?

Mosaic's **Bruce Bodine** provided a North American market update in his keynote address.

Globally, factors such as tight supply, high grain prices and depleted inventories have driven up phosphate prices to levels not seen in more than 10 years, said Bodine:

"The outlook for ag commodities and prices looks strong in 2022 – as it was in 2021 – and with higher grain prices driving higher fertilizer demand, higher fertilizer costs historically follow. That dynamic alone – based on history – would increase prices. Combined with recent global supply limitations, that really has pushed prices to levels not really seen in over a decade.

"The long story short here is that phosphate supply is tight with depleted inventories worldwide and any new investments in increasing production is going to take considerable time."

"Food security concerns and rising biofuels consumption are driving demand for corn and soybean as well as rice, wheat, coffee, palm oil and other agricultural commodities."

Essentially, it is the strength of crop markets, combined with global supply constraints, that have pushed fertilizer prices higher, in Bodine's view.

"Global demand for grain and oilseeds remains high while stock-to-use ratios are at the lowest point in more than a decade," he said. "In fact, the stock-to-use ratio, given the shortages in Soth America and the recent events in Russia and Ukraine, is very unlikely to recover in the short term."

Farmer economics in most global growing regions do, however, remain constructive. Although rising inflation and input costs are affecting profitability – which reached record levels in 2021 – recent crop price increases are nevertheless sustaining fertilizer affordability, said Bodine:

"As we head into North America's spring planting season, we're seeing normal buyer behaviour as demand continues to reflect strong underlying crop prices. In Brazil, fertilizer shipments in 2022 appear set to equal last year's record setting total. Grower economics [there] are improving thanks to rising crop prices, the availability of credit and a favourable exchange rate.

"In India, where the farmer demand remains very strong, availability is still lagging. Given the depleted Indian inventories, we see India as a pent-up source of demand going forward which should see phosphate and potash consumption growth in 2022."

In North America, strong ag commodity prices and high planted acres has seen on-farm fertilizer demand rise sharply in 2021. Consequently, North American phosphate shipments last year came in at just under 11 million tonnes – the highest year on record. Bodine expects the region's demand to fall back only slightly this year.

"As fertilizer prices and other input costs remain elevated going into 2022, there is the potential for fertilizer shipments to pull back modestly," he said. "But demand is not really the concern right now – it's the ongoing supply."

The world's ability to produce phosphate is becoming precarious, said Bodine. He pointed out that, in addition to the war in Ukraine, some countries are also pursuing nationalist policies "to keep fertilizer supplies at home".

China, for example, which accounts for between one-quarter and one-third of global phosphate exports, imposed export restrictions late last year. "Their decision to stop significant exports have impacted supply and demand globally, changing trade flows for every country importing and exporting this critical resource," Bodine said.

On imports, Bodine argued that the US phosphate market is now more balanced – suggesting there was now fairer trade and a more competitive market which, in turn, was providing American farmers with a larger range of suppliers. He pointed to the fact that 14 different countries supplied finished phosphate products to the United States in 2021 – about double the number in previous years.

"Last year, strong demand in the US attracted products from a much more diverse supplier slate and supply base for imports. US phosphate imports increased to a record level in 2021, increasing by 1.7 million tonnes (or 73 percent) relative to 2020 imports, even with the duties imposed on Russian and Moroccan imports," Bodine said.

Brazil and India – a study in contrasts

In a joint session, **Priscila Richetti** of Yara Brasil Fertilizantes and CRU's **Koyel Choudhury** presented market updates for Brazil and India, respectively

Brazil is a global agricultural powerhouse, being the world's number one producer and exporter of commodities such as soy, sugar, coffee and oranges. Dramatic increases in the country's grain and oilseed growing area and production over the last twenty years – from 96.8 million tonnes in 2001/02 to 268.2 million tonnes in 2021/22 – has driven fertilizer consumption upwards.

Total fertilizer consumption reached an estimated 46.1 million tonnes in 2021. On a crop basis, consumption is targeted at soybean (43.1 million tonnes), corn (18.6 million tonnes), sugar cane (11.5 million tonnes), rice (105 million tonnes), cotton (4.6 million tonnes) and coffee (4.2 million tonnes). Soybean's agricultural predominance, however, remains the primary driver of crop nutrient use.

"The dependency on soybean drives the nutrient consumption profile in the country," said Priscila Richetti. "K is still the major nutrient consumed with an almost 39 percent share followed by P with 33 percent and N with 29 percent."

The consequences of strong fertilizer demand growth can also be seen in Brazil's import dependency, said Richetti:

"In 2010, around 44 percent of Brazil's phosphate consumption was met by imported products. Nowadays, the portion of overseas product in the total consumption exceeds 78 percent.

"This has made Brazil one of the largest and most significant fertilizer importers in the world. The county is the top import leader in finished phosphate fertilizers."

Brazil has become a great opportunity for fertilizer producers in a fast-growing market, concluded Richetti, pointing out how the country has been transformed from a 16.4 million tonne market in 2000 to around 46 million tonnes in 2021.

Koyel Choudhury expects an initial fall in Indian phosphate consumption to eventually herald better longer-term prospects. "For the short-term, we expect P_2O_5 demand to reduce but in the medium-term it is going to recover after the slump," she said.

Low diammonium phosphate (DAP) availability in India last year led to P_2O_5 demand destruction. This situation – together with a similar lack of availability for NPKs – is expected to continue throughout this year and into next.

Despite this, CRU expects India's P_2O_5 demand to eventually get back on track and grow steadily over the medium-term as crops such as wheat and rice gain traction. This demand growth is expected to lead to ever larger import volumes.

Choudhury expected Indian import demand to remain strong in future "because of the low availability of [in-country] phosphate rock reserves and also the import dependency on phosphoric acid, ammonia and sulphur".

"Supply dynamics are expected to remain similar in the medium-term. Indian importers will continue importing more volumes. We do not see production increasing drastically – and thus we expect imports to maintain their share of volume into India," she said.

Choudhury discussed whether India would be able to produce more finished phosphate products domestically: "Upcoming [Indian] P_2O_5 capacity additions are low compared to global capacity additions. However, implementation of the DBT [direct benefit transfer system] is a key reform and – while complicated – can encourage new entrants to the market."

Geopolitical pressures and rising prices had inflicted hurt on Indian producers and importers in 2021. This will continue if the maximum retail price (MRP) set by the Indian government is not increased, said Choudhury:

"International prices often decide the consumption of fertilizers in India, and this is not good for demand in the longer run. Increasing subsidies is a knee jerk reaction – it's not good for government it's not good for supply, and it's not a sustainable solution for India."

Changes are required to address Indian phosphate demand in future, said Choudhury, with policy reform, especially the direct benefit transfer (DBT) system, holding the key. "Implementing the DBT – which also improves soil health – is going to take off some burden from the producers and importers, and give them more freedom to produce and import at will, and not be dependent on subsidy and making profits from the government anymore," Choudhury concluded.

Sulphur set to stay expensive

CRU's **Peter Harrisson** gave a nuanced global sulphur market update. He was very honest about the degree of uncertainty in the market at present. Yet he was equally clear that it was scarcity – or scarcity fears – and not underlying costs which were shaping current market sentiment.

"Summing up for price? This is super uncertain. The outcome on price for sulphur is almost anyone's guess. I think the key thing is that prices are going to be driven by scarcity," Harrisson said.

He added: "There will be short-term scarcity and there will be a fear of short-term scarcity this year. The important thing, though, is it's not cost-driven pricing – so stocks can play a role."

Harrisson pointed out that sulphur price rises could not address a fundamental lack of available product: "Higher prices are not going to solve the problem. They're not going to fill the market up with new supply."

Sulphur pricing would continue to shadow the DAP price, in his view, as long as this was affordable.

"The other thing that is really crucial is that where DAP prices move, then sulphur prices will almost certainly follow," said Harrisson. "Yes, affordability is at the upper limit of normal historical levels – but not at the absolute peak."

If this DAP-sulphur price relationship was maintained, then DAP at $1,000/t could prompt a rise in sulphur price levels to £400-450/t, while a sulphur price closer to $500-550/t was likely should DAP rise to $1,200/t.

"So, I think sulphur will stay expensive," concluded Harrisson. "But it's not, in our view, going to go beyond the level of DAP price change."

The war in Ukraine

The Russia-Ukraine conflict and its dramatic impact on commodity markets was undoubtedly the event's major talking point. Chris Lawson, CRU's head of fertilizers, gave delegates an update on this fast-moving situation.

"This is an incredibly fast-moving target, this is moving by the minute."

He started by highlighting the dramatic prices changes since the start of invasion, as illustrated by the price movements seen between the last week of February and the first week of March:

"Urea NOLA prices traded at $920/st today – last week the high end of the assessed price was $685/st. In the DAP markets, we currently see NOLA prices in the range $930-1,000/t, while last week that was assessed at $850-895/t."

CRU has identified ammonia as the commodity most at-risk from supply disruptions out of Russia. The country is responsible for around 23 percent of global ammonia exports with around two-thirds of that going through the Black Sea. This export route is now blocked following the closure of the OPZ pipeline, which passes through Ukraine, and the shutdown of Ukraine's Black Sea ports.

Lawson described the ammonia market impacts as "really grim" – and elaborated on the potential knock-on effects for phosphate producers:

"Morocco has around 180,000 tonnes of ammonia storage. They will be able to get that ammonia from elsewhere – they don't just buy it from the Black Sea – but that's going to be a very tough market to buy from in the coming months.

"With extraordinarily high [ammonia production] costs in Europe, there's a massive risk of that shutting down again. Ammonia is undoubtedly at the highest risk and this has implications for phosphate producers."

There was also "quite a lot of risk" associated with the phosphate supply coming out of Russia, Lawson said:

"When it comes to NPKs, Russia is about 24 percent of the traded market. That share is much smaller when it comes to DAP and MAP – only around 10 percent.

"But Russia is one of the lowest cost producers, right at the bottom of the cost curve. So that's 10 percent of cheap supply – which could be very difficult to source in future."

Russia is also an exporter of high-grade phosphate rock, with about seven percent of global traded supply.

"That's a very European exposed trade. [There's phosphate rock supply] going into Lithuania for EuroChem, into Belgium for downstream industrial acid and for EuroChem's NPK plant, and around half a million tonnes a year into Norway," commented Lawson.

The impact of Western sanctions was unlikely to be immediate either, in his view.

"It's going to take a long time for sanctions to set in and become established," said Lawson. "Fertilizer is also exempt from some of the sanctions, as fertilizer and energy have been carved out."

Despite this, the purchase and shipment of Russian fertilizers were already becoming increasingly difficult.

"Some buyers are just steering away from Russia completely, and marine logistics are very difficult as lots of shipping companies are unwilling because of the insurance premiums," said Lawson. "They're also taking a stand against the Russian government."

Technical presentations

Summaries of key presentations from this year's excellent technical programme can be found in the CRU Phosphates 2022 preview in our January/February magazine (*Fertilizer International* 506, p30).

Market information

Please note that market information and commentaries reported here date from the time of event in early March 2022. These should be interpreted with caution as market conditions are changing particularly rapidly at present due to the impact of the Russia-Ukraine conflict. ■

Who's who in pumps and pipes

We profile leading suppliers of tailor-made pumps and pipes to the phosphates and sulphur industries.

PHOTO: DÜCHTING

A half repaired pump impeller refurbished (left) using Düchting's unique SIConit refurbishment process.

Essential components

Phosphate and potash fertilizer manufacturing typically requires the handling of highly abrasive and/or corrosive liquids and slurries. Industrial pumps, as essential components of any P and K production system, therefore need to be robust and reliable enough to handle these.

Pumps are used to transfer fluids and suspensions from one stage of the production process to another. They need to cope with a wide range of temperatures, pressures and viscosities, often having to deal with different amounts and sizes of suspended solids too. Flow volumes and flow rates also vary greatly from process to process.

The challenge for fertilizer manufacturers is choosing exactly the right pump for each step in the production process. In extremes cases, getting the pump design or specification wrong can result in catastrophic failure – if there is insufficient flow and poor maintenance.

That makes selecting the correct type of pump, and ensuring pump capabilities closely match process requirements, vitally important. In most cases, pump requirements are largely determined by the properties of the liquid or slurry, including:

- Temperature and pH range
- Chemical characteristics, including contaminants
- Solids content, including amount (g/l), hardness, density and particle-size distribution.

Düchting Pumpen

Privately owned German company Düchting Pumpen has more than 80 years of experience manufacturing advanced centrifugal pumps specifically designed for service in corrosive and abrasive conditions.

Düchting offers best-in-class reliability and performance in challenging environments that expose pumps to severe erosive-corrosive wear. These include industries such as fertilizer production, flue gas desulphurisation, seawater desalination, mining and mineral processing, sand and gravel dredging and chemical pigment manufacturing.

In keeping with its company motto ('Quality through Experience'), Düchting's sophisticated pump products are highly valued by its industrial customers. The company combines expertise in hydraulic design – using high-performance computational fluid dynamics (CFX) software – with strong capabilities in pump construction, machining, assembly, testing and commissioning.

Düchting offers an extensive portfolio of single-stage and multi-stage centrifugal pumps. By providing customers with tailor-made, customised equipment as standard, the company aims to provide the best operational performance possible. Minimising maintenance and energy consumption also ensures the lowest lifecycle costs. Partnership arrangements in strategic global locations have also strengthened the company's reputation for efficiency, reliability, innovation and thorough after-sales service.

Düchting's portfolio consists of:

- Single-stage hard metal slurry pumps
- Multi-stage dewatering and high-pressure booster pumps
- Non-metallic low-pressure slurry pumps – these combining diamond-like abrasion resistance with a lifetime anti-corrosion warranty.

Metallic pumps are offered in either super duplex stainless steel or high chrome iron alloys, depending on the application and individual requirements and parameters. For highly challenging fertilizer production conditions, Düchting offers the SICcast mineral cast pump series together with SIConit aftermarket coating refurbishment capabilities.

SICcast is a unique proprietary technology designed more than 30 years ago to combat erosion-corrosion wear. The material consists of an engineered matrix of silicon carbide particles and epoxy resin binder that is mixed under vacuum and then heat cured into high precision moulds at Düchting's German production plant.

Once cured, SICcast's finished hardness is close to that of diamond on Moh's scale. SICcast is so hard that machine finishing with diamond-tipped tools is necessary to produce the wet end components for Düchting's MC and MCC pump lines.

SICcast is specifically designed to combine complete corrosion resistance with diamond-like abrasion resistance. SICcast pumps are ideal in challenging slurry mediums that shorten service life and reduce the reliability of hard metal (duplex stainless steel or high chrome/nickel alloys) slurry pumps that are more susceptible to erosive-corrosive wear. All wetted components in Düchting's MC and MCC pump lines are completely constructed of SICcast. This design eliminates any contact between the slurry medium and metallic components during operation.

Aftermarket refurbishment of existing worn equipment is also possible through the company's SIConit refurbishment. This repair service uses a unique coating technology that combines a SICcast

EP135 coating material with a cold curing chemical hardening agent. Once cured, SIConit can also be machine finished with diamond-tipped tools to completely revamp and repair existing worn components (see main photo). This returns them to as-new condition with SICcast's superior protection against corrosion and abrasion.

Düchting's SICcast mineral cast slurry pumps and aftermarket SIConit refurbishment capabilities are widely used in both phosphate and potash fertilizer production. This is due to their ability to combine optimal performance with equipment longevity and reliability in highly corrosive and abrasive services. Applications include:

- Phosphoric acid
- Sulphuric acid
- Gypsum slurry
- Phosphate rock slurry
- Tailings slurry
- Silicate/sand slurry
- Brine and salt slurries.

A wide range of fertilizer industry applications can also benefit from SIConit refurbishment. These include worn components from existing metallic slurry pump wet end parts, agitator mixer impellers, piping sections, reducers, collection basins, diverters, etc.

Andritz

International technology group Andritz manufactures plants, systems and equipment for the hydropower, pulp and paper, and metal and steel industries. Notably, it is also a specialist in solid/liquid separation for municipal and industrial applications. The company has nearly 30,000 employees and operates from more than 280 locations in over 40 countries worldwide.

Andritz has been an innovative pump manufacturer since the company began in 1852. It therefore has more than a century of expertise and process know-how in the manufacture and supply of pumps. This includes providing standard, project-specific and large, customer-specific engineered pumps. Its track record in major pumping projects includes:

- Providing sustainable water supplies to the megacities of Atlanta, Beijing and Las Vegas
- Helping India to irrigate 3.3 million hectares of agricultural land
- Installing efficient pumping systems for leading pulp and paper producers, and generating clean energy from low-temperature heat for this industry.

PHOTO: ANDRITZ

Andritz ACP single-stage centrifugal pumps are suitable for conveying many different media and available in a highly wear-resistant open impeller design.

Andritz pumps are operating successfully in many small- and large-scale industrial plants and projects worldwide. Its pumps portfolio includes the:

- ACP series of single-stage centrifugal pumps
- ASP series of axial split-case pumps
- ASPM series of multi-stage axial split-case pumps
- VLSP series of vertical line shaft pumps
- SU series of submersible motor pumps
- VVP and CVP series of vertical volute pumps.

These pumps are designed to meet different tasks in water resources management, e.g., the supply of industrial and drinking water, wastewater disposal, cooling in thermal power plants, land irrigation, flood protection, mine water removal and desalination.

Andritz is known globally as a single-source provider of high-quality and high-efficiency products, including pumping equipment. Its comprehensive product and service offering includes engineering, manufacturing, project management, commissioning, after-sales service and training. The company also has strong capabilities in development work, model tests and the industrial internet of things (IIoT).

Sulzer

Sulzer is a world-leader in pumping equipment and technology with a history dating back to 1834. Headquartered in Winterthur, Switzerland, the company operates from more than 180 production sites and service centres located in some 50 countries around the globe.

Sulzer manufactures and markets a wide range of pumps, mixers, and agitators for the sulphur and fertilizer industries. These durable and reliable pumps are used in the production of phosphate, potash and NPK fertilizers, acids and industrial chemicals. Sulzer offers:

- Process pumps
- Slurry pumps
- Wear resistant pumps
- Self-priming pumps
- Gas removal pumps
- Axial flow pumps
- Vacuum pumps
- Sulphuric acid pumps
- Vertical pumps
- Submersible pumps.

These incorporate advanced materials, a wide range of shaft seals and different sealing systems. Operating efficiency is a key priority for Sulzer and the company prides itself on making extremely reliable pumps that can operate maintenance-free.

Sulzer estimates that shaft seals are responsible for around 60 percent of the operational problems with centrifugal pumps. The shaft seal is therefore a critical component when it comes to the overall lifetime costs of a pump – including capital, operating, maintenance and downtime costs.

Dynamic seals, because of their ability to improve reliability, are a notable design feature of Sulzer pumps. They work as follows:

- When the pump is operating, the expeller generates a liquid ring in the annular seal chamber and evacuates the liquid pumped from the seal cavity
- When the pump stops, the static seal tightens against the thrust ring, preventing any leakage.

By avoiding mechanical wear, leakage and the need for a sealing liquid, dynamic seals helps improve reliability and reduce the costs associated with the operation of the pump. Sulzer pumps are widely-used in phosphate fertilizer production, particularly in the wet process stages involving phosphoric acid (*Fertilizer International* 493, p46).

Weir Minerals

Weir Minerals designs and produces a wide range of highly engineered pumps for high wear and corrosive applications. The company operates through manufacturing sites and research centres worldwide and is supported by an unrivalled global service network. This ensures Weir Minerals engineers

can provide customers with the assistance they require, wherever and whenever it is needed.

Weir Minerals' range of trusted and well-known brands include:

- Warman® centrifugal slurry pumps
- GEHO® positive displacement (PD) slurry pumps
- Linatex® rubber products
- Vulco® wear resistant liners
- Cavex® hydrocyclones
- Enduron® comminution equipment
- Delta Industrial™ valves
- Lewis® pumps and valves

With a history dating back to 1891, Lewis® pumps is a well-established brand in the sulphur, sulphuric, and phosphoric acid industries, with equipment installed in more than 120 countries.

Lewis® pumps and valves perform reliably in harsh sulphuric acid environments thanks to their construction from Lewmet® nickel-chrome alloys. Lewmet® provides superior erosion resistance and corrosion protection. It is specifically designed to withstand long-term exposure in the extreme operating environments of contact process sulphuric acid plants.

Sulphuric acid plant operations widely use Lewis® acid valves with Lewmet® alloy. Even in severe service applications, they offer reliable control, such as acid heat exchanger/cooler bypass and pump discharge flow regulation.

By eliminating shaft sealing issues, the vertical design of Lewis® sulphuric acid pumps avoids the safety and environmental problems frequently associated with horizontal pumps in the same application. Furthermore, vertical pumps are simpler to install as they do not need special foundations and suction piping that is normally required by horizontal pumps.

Weir Minerals offers tailored, engineered-to-order features for customer requirements, including rectangular or circular cover plates, optional suction extensions and custom lengths.

The Lewis 18HTH sulphuric acid pump.

PHOTO: WEIR MINERALS

ITT Rheinhütte Pumpen

Rheinhütte has more than 150 years of experience in the design and manufacture of pumps and speciality alloys for the fertilizer, chemical and sulphur industries. Its product range includes horizontal, vertical, axial flow and liquid ring vacuum pumps. These are manufactured in various materials, including metals, thermoplastics and speciality ceramics.

For the fertilizer industry, Rheinhütte offers a range of horizontal and vertical flow pumps, including:

- The flexible RN horizontal pump – a reliable and efficient chemical pump for use with corrosive media that are either free of or contain low level of solids
- The robust RCE horizontal pump – a highly abrasion-resistant pump suitable for media with a solid contents of up to 30 percent
- The RCEV cantilever pump – a vertical version of the RCE pump (see box)
- The GVSO vertical pump – an extremely reliable submersible pump for use with solids-free media or for media with a low solids content
- The axial R PROP vertical pump – a propeller circulation pump used for high delivery rates and low delivery head.

New York-headquartered ITT Inc – the well-established manufacturer of Gould Pumps – purchased Rheinhütte Pumpen from Aliaxis Group in 2019. ITT's two global pump brands – Rheinhütte and Gould – are extensively use in the sulphur and phosphate industries (see companion article on p58).

Mouvex

Mouvex is a leader in the design and manufacture of pumps and systems for the global energy market. Headquartered in Auxerre, France, Mouvex has representatives in more than 75 countries worldwide. The company forms part of Illinois-headquartered PSG, the pump manufacturing arm of US conglomerate

The Rheinhütte RCEV Vertical Pump

Rheinhütte's robust RCEV vertical pump is designed for heavy-duty applications which involve the transport of corrosive and/or abrasive media. It is a metal pump designed without a base bearing. This makes it is particularly suitable for pumping liquids, such as liquid sulphur, which are contaminated with solids.

Cantilever design

The RCEV is a cantilever pump. This means it is designed without a base bearing (foot sleeve bearing) and has a free-flying shaft. The solid roller bearing is fitted above the base plate. This design, by eliminating the foot sleeve bearing, avoids bearing wear and temperature increases in the hydraulics.

Although the maximum immersion depth of the RCEV pump is two metres, this can be extended with a suction tube, if necessary. The RCEV's heavy-duty design, which incorporates a double volute casing, ensures that radial forces are minimised. The pump can be equipped with an open or closed impeller with front and back blades, depending on the application. The open impeller is usually recommended for media heavily contaminated with solids to prevent clogging. The pump is also protected against dry running, due to its raised mounting and by not having a bearing in the pumped media.

Suitable for corrosive, abrasive, contaminated liquids

The demand for heavy-duty pumps for use in fertilizer production and sulphur pumping has increased steadily in recent years. While phosphoric acid, titanium dioxide slurries and copper digestion acids are extremely abrasive, heavily contaminated sulphur poses an even greater challenge for pump manufacturers.

Sulphur is typically stored as a solid but transported as a fluid. It can become contaminated with sand, small stones and other solids during dry storage. These remain present when sulphur is liquefied and transported. Fortunately, the absence of a base bearing in the RCEV design means that these solids do not cause wear on the pump. In addition, the shaft suspension tube and pressure pipe of the RCEV can be heated (130-160°C) to maintain sulphur in a liquid state. ■

PHOTO: MOUVEX

Mouvex offers its API 674 Series plunger pumps for the fertilizer manufacturing market.

Dover Corporation. As well as Mouvex, PSG is also an umbrella for a number of other leading pump companies and brands. These include Abaque™, All-Flo, Almatec®, Blackmer®, Ebsray®,EnviroGear®, Griswold®, Neptune™, Quattroflow™, RedScrew™ and Wilden®.

Many types of pump, such as external gear, progressive cavity, screw and radial/axial piston pumps, have all gained acceptance for use in the various liquid transfer processes that are common in fertilizer manufacturing. Yet plunger pumps can be an even better choice, according to Mouvex.

Indeed, the ability of plunger pumps to handle almost any fluid, even corrosive or hazardous types, makes them well-suited for use in fertilizer-manufacturing processes. One suitable application for plunger pumps, for example, is the ammoniation/neutralisation process during phosphate fertilizer production. This application requires the injection of ammonia solution into phosphoric acid.

Plunger pumps are reciprocating positive displacement (PD) pumps. These are equipped with one or more in-line plungers. They are configured horizontally and powered by an electric motor or an engine. Plunger pumps can be:

- Single-acting – where suction occurs as the plunger ascends and discharge takes place as the plunger is depressed; or
- Double-acting – in which the suction and discharge stages take place simultaneously on opposite sides of the plunger.

Plunger pumps are designed so that the length of the plunger is longer than its stroke. They should not be confused with piston pumps, as the length of the piston in these is shorter than its stroke.

Plunger pumps are capable of creating very high discharge pressures, in some cases up to 3,000 bar (43,000 psi), although the flow rates they produce are directly proportional to pump speed, not pressure. Conversely, the discharge pressure is not speed-dependent either, being solely determined by the design of the discharge piping. This combination of operational characteristics allows plunger pumps to achieve pumping efficiencies of up to 90 percent.

Component wear is also minimised in plunger pumps. This is because the pump's packing, being situated in the sleeve surrounding the plunger, not on the plunger itself, results in more uniform wear and longer life.

Other parts including gaskets, rings, bushings, check valves and springs also experience wear. However, with proper preventive maintenance, it is not uncommon for plunger pumps to operate for 20 years without any maintenance, other than the periodic replacement of the wear parts. Plunger pumps also have a small installation footprint. This makes them ideal for operations where the available installation space is limited.

Mouvex offers its API 674 Series plunger pumps for the fertilizer manufacturing market. These pumps adhere to American Petroleum Institute (API) standard 674 for reciprocating PD pumps. This standard defines maximum and minimum operating speeds, material requirements, and testing requirements for plunger pumps used in a wide range of industries, including fertilizer production.

Plunger pumps can be used with viscous liquids (up to 100 cSt) containing solid particles (up to 0.1 mm) at high temperatures (up to 200°C/392°F). These pumps, as well as meeting API 674 specifications, can also be operated in explosive atmospheres, a critical consideration in some fertilizer plants.

Butting Group

The Butting Group is a family-owned business headquartered in Knesebeck, Germany. The company is a 240-year success story, having originally started out as a coppersmiths in 1777. This long history is reflected by the company motto, 'Progress by Tradition'. Butting is a leading processor of stainless steels with more than 60 years' experience and know-how in this area. Its core competencies are in forming and welding techniques and materials engineering. Products made by Butting include:

- Stainless steel welded pipes
- Clad pipes

- Customised components
- Spools and plant construction
- Vessels, tanks and apparatus
- Assemblies.

These products are manufactured to high quality standards and sold to customers all over the world.

Butting processes around 100,000 tonnes of stainless steel and clad materials annually. As well as its Knesebeck headquarters, Butting operates from two other sites in Germany at Schwedt and Könnern, and from international locations in Brazil, China and Canada. The company employs more than 1,800 people worldwide.

The company's Knesebeck headquarters stores more than 5,000 tonnes of welded pipes produced in Germany. These are manufactured in more than 140 different sizes and in 15 different material grades.

Butting surface treats its products by chemical pickling as a standard procedure after production. This guarantees optimum corrosion resistance for the pipes and components delivered to customers. The company is quality assured, operating under the DIN EN ISO 9001 management system.

Butting's primary product is high-quality, longitudinally-welded piping. Important end markets for its products include the pump and valve industry – the mechanical engineering market in particular – as well as the food and pharmaceutical industries. For many years, Butting has been producing ready-to-install components for the world's leading pump manufacturers. These are offered in a wide range of different materials, sizes and lengths.

Butting's manufacturing capability combines a range of different production processes. These include laser, welding, forming and metal cutting technologies, along with surface treatment. The company creates ready-to-install corrosion-resistant pipe components using grinding or blasting, based on optical requirements, and robot-welding

Acid Piping Technology

Based in Arnold, Missouri, US manufacturer Acid Piping Technology (APT) specialises in engineered products for the global sulphuric and phosphoric acid industries. APT notably maintains the world's largest inventory of MONDI™ pipes and fittings, both for routine supply and emergency replacement.

The company stocks approximately 2,000 acid plant fittings. This includes standard elbows, tees and reducers in a full range of sizes for same day shipment. Stocks also include a wide selection of pipes (3-30 foot size range) and flanges (2-30 foot size range).

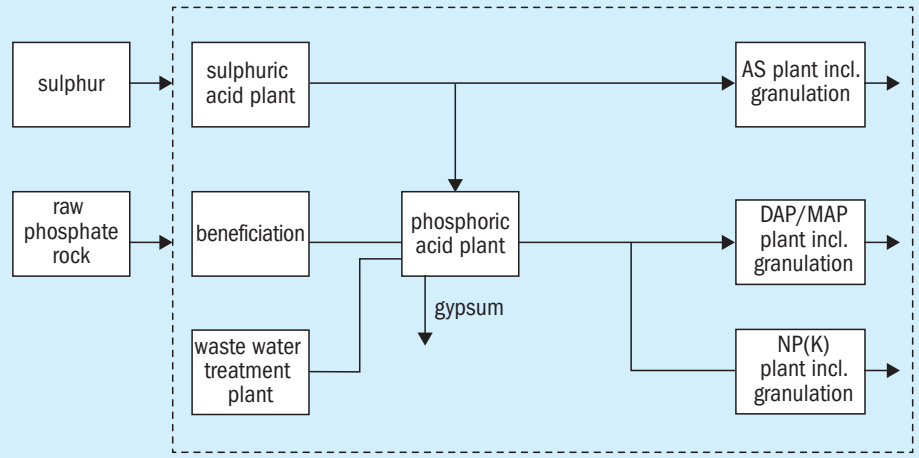
This large inventory enables APT to put together and despatch a complete set of components required by a specific project anywhere in the world as a single shipment. This saves time and costs as it avoids waiting for multiple shipments from the same or different suppliers. APT says it has sufficient inventory to replace the complete piping systems of two acid plants (3,000 t/d capacity).

APT also supplies valves and automated valve actuators. Valves stocked include gate, globe, check, plug, ball and butterfly types. These are available in iron, bronze, forged or cast steel, stainless steels (304, 316 and 310), alloy 20, hastelloys, chrome moly, titanium and Monel. These valves can also be supplied with PTFE, PFA and FEP linings. Additionally, APT stocks a range of internals for acid plant towers and converters, including ceramic packing and supports.

World-class pumps for phosphates production

Erosion and corrosion are two of the biggest challenges faced by equipment used in phosphate fertilizer production. This harsh operating environment requires exceptionally well-designed pumps made from sophisticated and robust construction materials. **Hani Tello** of ITT Rheinhütte and **Harvinder Bhabra** of ITT Goulds Pumps outline the range of options.

Fig. 1: **The phosphate fertilizer production process**



Source: ITT Rheinhütte Pumpen

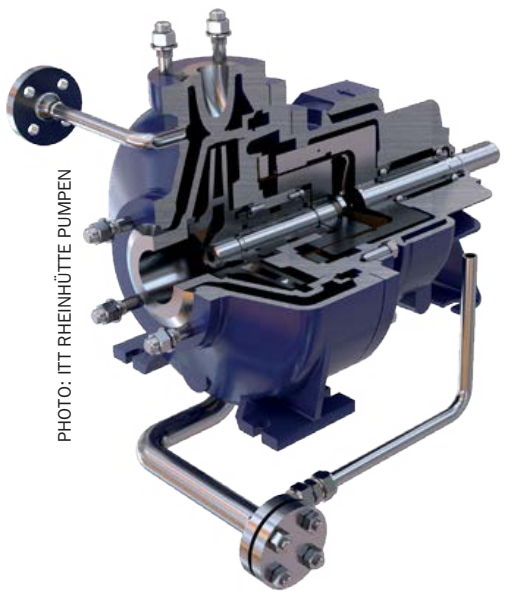


PHOTO: ITT RHEINHÜTTE PUMPEN

Fig. 2: The heated version of the RMKN magnetic drive pump is ideal for conveying molten sulphur.

Pumps and materials

ITT's two global brands, Rheinhütte and Goulds Pumps, offer a full range of metallic and non-metallic pumps. These are specifically designed to operate throughout every stage of the fertilizer production process, including the handling of:

- Molten sulphur
- Sulphuric acid
- Mined and beneficiated ore
- Phosphoric acid
- Phosphate fertilizers.

The company's robust and proven range of pumps, by incorporating world-class materials, delivers extended operational intervals between maintenance.

ITT offers many decades of applications experience and provides a single source of product expertise covering:

- **Pump types:** ANSI/API, DIN/ISO, slurry, axial flow
- **Advanced materials:** both metallic and non-metallic
- **Seals:** magnetic drive, hydrodynamic seals, mechanical seals.

Phosphate fertilizer production incorporates several discreet yet interlinked processes to obtain the finished phosphate product (Figure 1). In this article, we outline how pumps can be matched with different process requirements to deliver performance advantages for each of these production steps.

Molten sulphur

Because sulphur used in the fertilizer industry is classed as 'dirty sulphur', the design of pumps used in molten sulphur handling requires special attention, particularly their gland sealing. Horizontal pumps with a hydrodynamic seal are generally ideal. Horizontal seals need very little or no maintenance in this environment and – unlike the sealing rings in mechanical seals – are not prone to 'sticking' with solidified sulphur.

As well as RCEV cantilever type pumps, ITT Rheinhütte provides full pump coverage for the clean molten suplhur process. The heated version of the RMKN magnetic drive pump (Figure 2) is very suitable for conveying molten sulphur and meets *DIN*

EN ISO 15783 technical requirements. The GVSO (VS4) pump is similary well-suited.

Sulphuric acid

Vertical and horizontal centrifugal pumps are employed in sulphuric acid plants. These convey both liquid sulphur and dilute and concentrated sulphuric acid. These acids are corrosive and can contain sulphur dioxide and sulphur trioxide. Corrosion-resistant materials with high chemical stability are therefore required. Construction materials must be able to convey these fluid media safely, even at high temperatures, and withstand concentrated sulphuric acid (99%) up to 240°C.

ITT Rheinhütte has enjoyed several decades of good experience in handling sulphuric acid using horizontal pumps fitted with hydrodynamic seals. These pumps utilise a specialised material called Siguss. This is adapted to the highly demanding and stringent operating conditions at sulphuric acid plants and provides maximum 'erosion-corrosion' resistance.

Siguss contains around 15 percent silicon, up to 5 percent chromium, but no nickel, and is suitable for all concentrations of sulphuric acid up even at boiling temperature. Siguss is thus the only material that can pump sulphuric acid (and mixtures with minor amounts of chlorine gas or nitric acid) without forfeiting its outstanding durability. Siguss is also highly wear resistant.

Non-metallic materials are often used in pumps conveying sulphuric acid in the low concentration areas of the plant. This includes the pumping of washing acid – a mixture containing 15-75 percent sulphuric acid and sulphur dioxide. Non-metallic materials are generally superior to most metallic materials in this part of the process.

Mining and beneficiation

Phosphate ore is extracted using various methods, including underground, open pit, and strip mining, before being transported to a beneficiation plant for further processing. Ore transport depends on the mining method with belt conveyors used for crushed dry ore and centrifugal pumps used when the ore is in a slurry form.

Processing may not be required if the P_2O_5 grade of the run-of-mine ore is sufficiently high. Beneficiation is, however, usually necessary to upgrade the mined ore and generate phosphate rock concentrates. Processing typically takes place over several stages.

The ore firstly goes through a scrubbing process before being crushed and screened to reduce the particle size. It is then fed to a grinding mill for further size reduction. This liberates the target phosphate from unwanted gangue constituents. The resulting slurry then undergoes initial separation to remove slimes, usually with hydrocyclones, followed by several stages of froth flotation. The phosphate concentrate obtained is filtered and thickened in preparation for the phosphoric acid plant, the next step in the production process, while the waste materials are pumped away as tailings.

The various pump types used in mining and beneficiation include: mine dewatering pumps, rubber or metal lined slurry pumps, and process pumps for clear fluids. ITT's Goulds Pumps range (Figure 3) of horizontal and vertical pumps adequately covers all of these applications.

Phosphoric acid

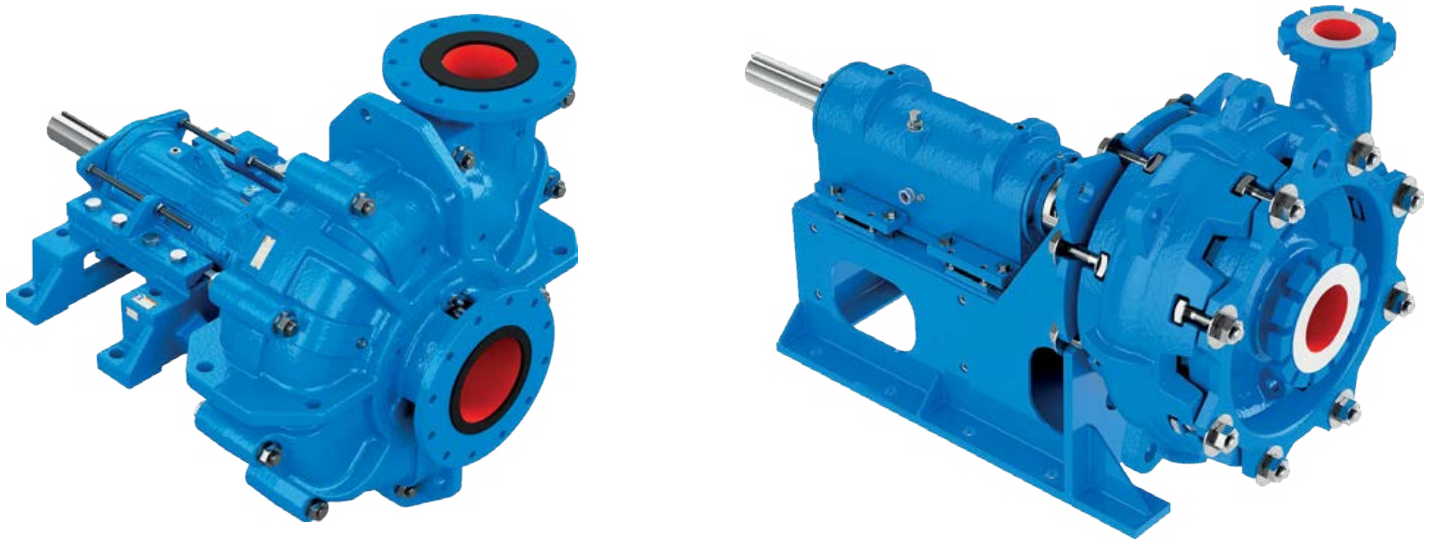
The wet phosphoric acid process is commonly used in fertilizer production. In this process, phosphoric acid (H_3PO_4) is generated by attacking the beneficiated phosphate rock concentrate with sulphuric acid (H_2SO_4) inside a reactor. In a highly exothermic reaction, the calcium present in the rock reacts with the sulphuric acid to form a calcium sulphate ($CaSO_4$) slurry. Flash cooler pumps are used to circulate the slurry to reduce the temperature. This mixture contains up to 40 percent solids of around 250 microns and has a pH of <1.0 at temperatures greater than 100°C.

The slurry is transferred to filters to separate gypsum crystals from the phosphoric acid which is then fed to evaporators for concentration. The main evaporation circulation pump is generally an axial flow type handling high flow rates at a relatively low head. The phosphoric acid product undergoes further concentration before finally being stored as a 54 percent concentrate.

Fluosilicic Acid (FSA) is also present in the phosphoric acid production process (*Fertilizer International* 504, p44). Overall, the process presents some very challenging applications for pumps in terms of corrosion and erosion.

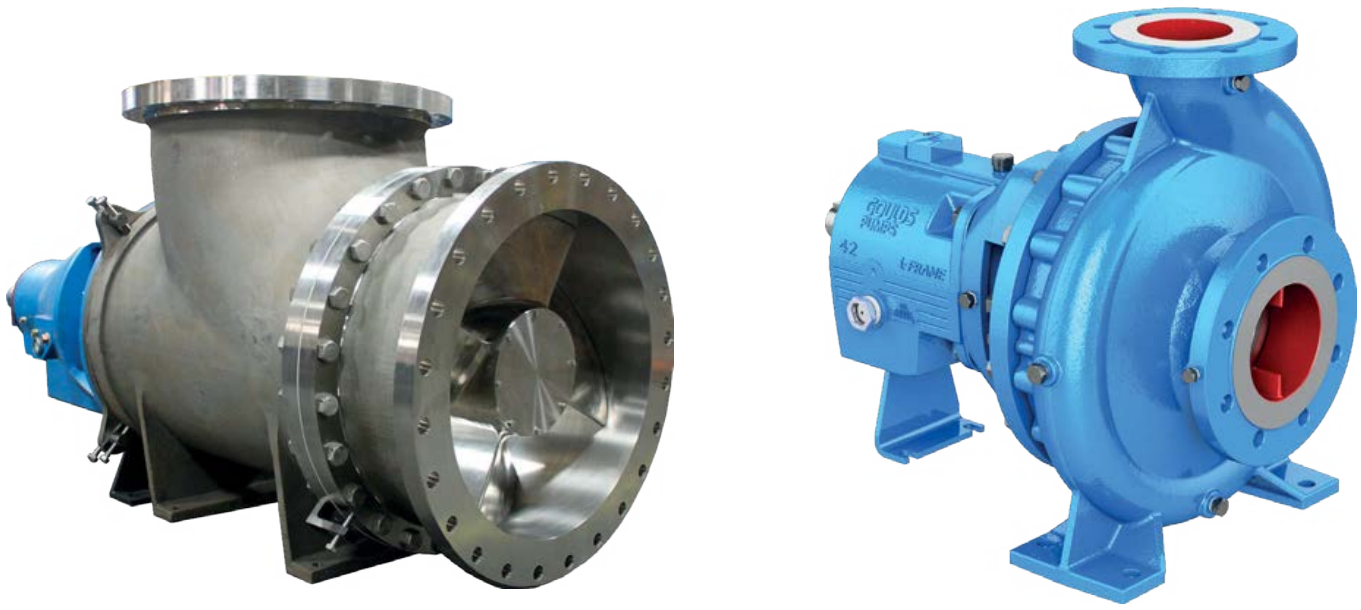
ITT offers non-metallic pumps that are a perfect fit for phosphoric acid applications. These offer a longer service life and are an economic option compared to high alloy materials. A range of end-suction pumps is also used during phosphoric acid production. These provide service water to the acid plant and the water treatment plant (for waste disposal and water recycling).

ITT has vast experience in all these applications and its Rheinhütte and Goulds Pumps brands (Figure 4) offer a complete package of suitable metallic and non-metallic pumps. Types rang from horizontal slurry and process pumps, to vertical pumps, and axial flow designs.



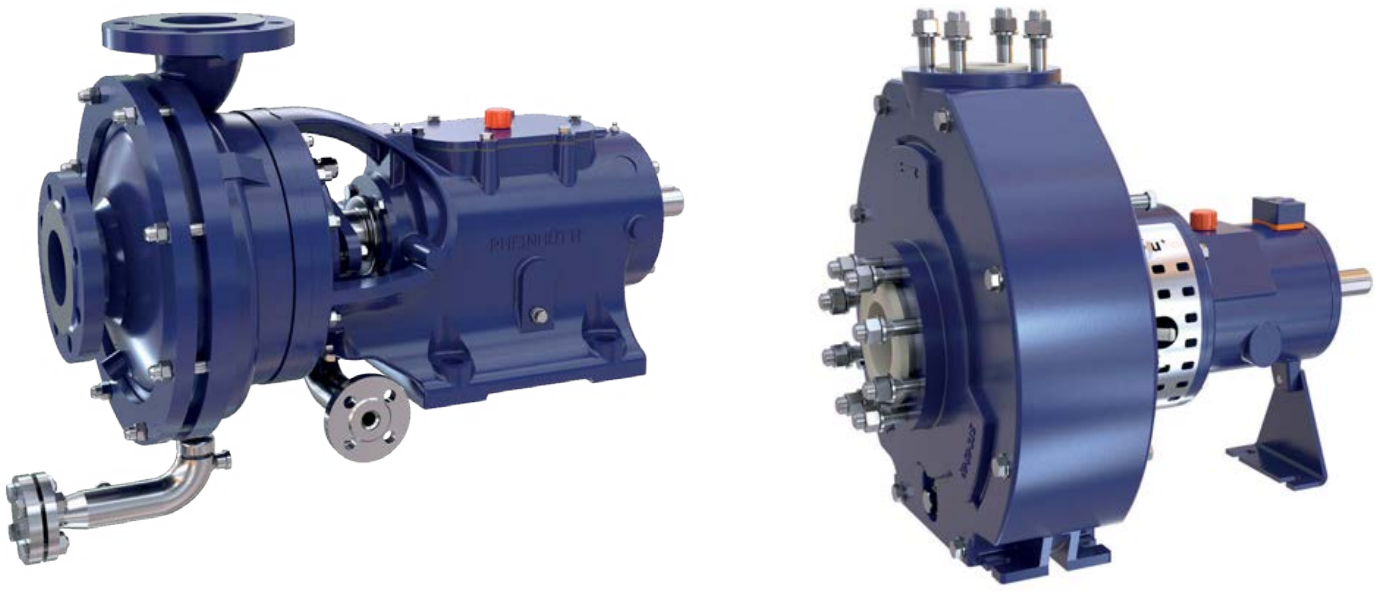
PHOTOS: ITT GOULDS PUMPS

Fig. 3: ITT's Goulds XHD pump (left) and Goulds 5500 pump (right) are widely used in phosphate ore mining and beneficiation processes.



PHOTOS: ITT GOULDS PUMPS

Fig.4: ITT's Goulds AF pump (left) and Goulds IC pump (right) are well suited to phosphoric acid plant applications.



PHOTOS: ITT RHEINHÜTTE PUMPEN/GOULDS PUMPS

Fig. 5: ITT's abrasion-resistant, heavy duty Rheinhütte RCE pump (left) and Goulds RCNKu pump (right) are suitable for chemically aggressive fertilizer production processes.

Phosphate fertilizers

Phosphoric acid is used as a feedstock in the production of various types of phosphate and compound NPK fertilizers. These include:

- Diammonium phosphate (DAP)
- Monoammonium phosphate (MAP)
- Triple superphosphate (TSP).

Production of these multi-nutrient fertilizers is very challenging for pumps, as it usually combines highly corrosive fluids at high operating temperatures in the presence of solids, with some very low net positive suction head (NPSH) requirements.

ITT has developed suitable products for the fertilizer production process and possesses long-standing experience in this application. Horizontal and vertical pump designs in various materials are generally used. Heavy-duty pumps with hydrodynamic seals are typically necessary to cope with the presence of solids and extend the life of both the pump and its construction material.

The Rheinhütte RCE pump (Figure 5) is designed for heavy-duty applications in chemically aggressive and abrasive media. It is the first choice in the basic chemicals industry – especially in fertilizer production – as well in the environmental technology sector and many other industries.

Summary

ITT offers a single source of pump products globally through its renowned Rheinhütte and Goulds Pumps brands. This wide-ranging portfolio is ideal for fertilizer industry customers looking for reliability, safety and innovative pumping options, and is supported by comprehensive process and applications knowledge.

ITT also has an active pump and materials research and development programme. This is designed to meet the changing needs of the phosphate fertilizer industry and evolving production processes. ITT's R&D programme is supported by state-of-the-art global manufacturing facilities and a sales and service network that is strategically located close to customers. ■

About the authors

Hani Tello is head of global product sales at ITT Rheinhütte. Harvinder Bhabra is the global product manager for slurry and axial flow pumps at ITT Goulds Pumps.

Cabbages being trialled with POLY4 at Naylor Farms, one of the UK's biggest producers.

PHOTO: ANGLO AMERICAN

Anglo American: driving sustainability excellence in the fertilizer sector

The Woodsmith polyhalite project in the UK is starting to benefit from Anglo American's ownership, with the mining major leveraging its key advantages to good effect. These include the company's operational size and financial stability, its vast mineral extraction experience, and premium product marketing expertise. The company also believes that the fertilizer sector will benefit from its leadership in mining industry sustainability.

Important, substantive changes are underway at Anglo American's under-construction Woodsmith polyhalite mine in northern England.

Mine redesign work to maximise the long-term value of the asset, for example, continues to be a project priority. Even more significantly, Tom McCulley was announced as the CEO of Crop Nutrients, replacing long time project lead Chris Fraser, who has moved to a strategic projects role within the company.

Mr McCulley brings with him 25 years' worth of international experience in major mining, oil and gas projects. Most recently, he led the construction of Anglo American's Quellaveco copper mine in the south of Peru. This mine exemplifies FutureSmart™ Mining – a transformational Anglo American programme that brings together technology, digitalisation and sustainability.

Quellaveco is Anglo American's first 100 percent digital mine and incorporates autonomous trucks, remote control drills and cutting-edge automated monitoring systems. The high-tech mine sits on one of the world's largest undeveloped deposits of copper which – because of its ubiquity in electronics – is central to global growth and the world's transition to a decarbonised economy.

The majority of Anglo American's output and investment capital is focused on 'future-enabling' products – with thermal coal moving out of the portfolio to be replaced by growth and new investment in copper, platinum group metals and crop nutrients.

Anglo American is well-positioned to operate as a sustainable and environmentally-responsible mining company while at the same time – through the disciplined use of capital – grow its production as a foundation for future returns.

The company views polyhalite as an integral part of its overall business strategy. For Anglo American, polyhalite is a mineral which will help the world grow more food from less land, more sustainably, to meet the needs of an expanding global population.

Changing perceptions

POLY4 (the commercial name for polyhalite) is a high purity ore (having no processing waste) with an ultra-low carbon footprint. It is also suitable for organic use.

These characteristics, and the low impact design of the Woodsmith mine itself, are an excellent fit with Anglo American's goal of becoming carbon neutral in operational emissions by 2040, as well as the company's ultimate ambition to build water-less, carbon-neutral mines with net positive outcomes for biodiversity.

The drive for more sustainable and environmentally friendly raw materials is a pressure acutely felt in the mining sector, given that a reputation for environmental harm is a legacy the industry has struggled to shake off. Similar perceptions are increasingly becoming associated with the fertilizer industry too, as governments and citizens become more aware of the environmental impact of the global food supply chain and the carbon intensive practices on which it depends.

Undeniably, the successful exploration, extraction and processing of potash and phosphates, as well as the invention of nitrogen fertilizers, have been miracles of industrialisation – by enabling the huge crop yield improvements that have underscored global population growth and health.

Now, however, questions are being asked by governments, consumers and farmers alike about the long-term environmental impacts of crop nutrient products and their production processes. This applies as much to outputs – crop nutrient products – as it does to the significant energy and carbon consumed during production.

Consequently, the industry needs to find a balance between crop yield and crop quality improvements as well as soil health, nutrient use efficiency, carbon sequestration and microorganism impact, along with many other environmental considerations.

The future enabling role of polyhalite

"The business case for polyhalite rests on our belief that these trends will become more and more important and will form an essential part of the calculation a farmer makes when deciding to purchase a fertilizer product," says Alex Schmitt, Chief Marketing Officer of Anglo American's Crop Nutrients business. "We see polyhalite's multi-nutrient, low carbon, low chloride, soil regenerative qualities as part of the answer to the major agricultural challenge facing the industry: how to maintain or increase yield and quality while positively impacting the soil and the wider environment."

Wide-ranging trial results for different crops show that, in addition to increasing yield, POLY4 can also positively affect both food quality and soil health. For example, Brazilian trials have demonstrated how POLY4 not only helps improve coffee productivity (a 6.8% yield increase) but also maintains coffee cup quality by boosting leaf magnesium levels. In citrus trials in China, POLY4 application also raised the soil's post-harvest calcium and magnesium levels (in addition to a 16% yield increase) – enabling both nutrients to supply citrus trees in the subsequent season.

The company has some work to do in order to educate farmers about POLY4, acknowledges Dr Schmitt. But he firmly believes the market need is there, with latent demand not being met by current market offerings, at least not at the scale that Anglo American believes is necessary. The inability to pigeon-hole POLY4 should be seen as a strength, he says. The fact that polyhalite is not classed as 'true' potash, for example, and yet is suitable for organic farming while also being a mineral fertilizer, is simply proof that traditional fertilizer product categories are not fit for purpose in Dr Schmitt's view.

"Once, we all drove petrol and diesel vehicles because that's all the automotive industry was capable of producing," says Dr Schmitt. "Now electric and hydrogen vehicles are coming to the fore because they are better solutions for our 21st century needs and consumer expectations."

He adds: "Regulations are changing as a result and the companies that anticipated those needs are now leaders. The same will become true for the fertilizer industry and Anglo American intends to be at the forefront of this change, with POLY4 as our vanguard product."

Dr Schmitt cites a recent visit to a food industry conference in the US as an example of where the industry needs to take its cue:

"People in that industry worry constantly about changing consumer demand: transparent supply chains, ingredient sourcing, food quality and availability, ethical pricing and, most of all, sustainability. Yet the fertilizer industry has barely begun to take this stuff seriously – but it's coming, it's inevitable.

"We need to be much more customer centric, sustainable, ethical and transparent, with reliable and environmentally conscious supply chains. This adds value for consumers and shareholders alike, allowing you to position your brand and product at a premium price, and just makes good business sense."

The bigger picture

The recent fertilizer supply chain and pricing shocks caused by the war in Ukraine and soaring energy prices have substantially raised the fertilizer industry's profile with governments and citizens alike. The situation has caused many governments to reassess whether products which depend on the use of fossil fuels are a desirable or even practical solution to food security challenges.

At the end of March, for example, the British Government announced plans to incentivise farmers to use 'greener fertilizers,' promising cash incentives to move farmers away from carbon-intensive products. Other governments will doubtlessly follow suit.

These latest moves provide evidence that Anglo American's market analysis is the correct one. Certainly, the Woodsmith Project's stable geography and POLY4's green credentials seem tailor-made for the emerging trends of these troubled times.

In addition, Anglo American has all the tools at its disposal to make POLY4 a success. These include the company's sheer operational size, its financial stability, stable resource portfolio, and its breadth of experience and expertise in mineral extraction and premium product marketing – it owns diamond producer and consumer brand DeBeers, for example.

Anglo American has also made great efforts to position itself as a leader in mine industry sustainability, embarking on several landmark projects to meet its ambitious carbon neutrality goals – initiatives which offer obvious transferable technologies and lessons for the fertilizer industry.

Anglo American's approach to sustainability

Anglo American launched its first sustainable mining plan in 2018 as part of its FutureSmart Mining™ initiative. This programme combines technology, digitalisation and sustainability, working hand-in-hand together, to deliver the step-change innovations necessary to transform the nature of mining. This sustainable mining plan is built around three major areas known as 'Global Sustainability Pillars':

- Healthy environment
- Thriving communities
- Trusted corporate leader.

The plan's objectives are aligned with the UN's Sustainable Development Goals (SDGs) and, similarly, each pillar has a defined set of targets called 'Global Stretch Goals'.

The approach set out in FutureSmart Mining™ goes far beyond compliance with mining law or regulatory requirements. It incorporates mutually reinforcing elements that positively transform the experiences of all business stakeholders, both locally and globally, and ultimately creates a much-reduced physical footprint for mining.

The under-construction Woodsmith polyhalite mine in the UK.

PHOTO: ANGLO AMERICAN

WOODSMITH MINE UPDATE

Anglo American's Chief Executive Mark Cutifani provided an update on progress at its under-construction Woodsmith mine earlier this year. The company expects to invest £440 million in the UK polyhalite mining project in 2022, Mr Cutifani told shareholders during the company's annual results in February. This follows the company's previous investment of nearly £390 million in 2021.

"This is a world class fertiliser project and a business segment that we are even more positive about than when we acquired the project," said Mr Cutifani. "It is a very long-life asset and a product for which we see increasing market interest as the commercial trials demonstrate its crop yield and numerous environmental qualities."

Construction and investment continues

Development of the project has continued to progress, with capital expenditure totalling $530 million invested in 2021. Excavation of the mineral transport tunnel from Teesside had exceeded 18 kilometres by the end of last year, beyond the intermediate access shaft site at Lockwood Beck.

The Lockwood Beck shaft is also complete, having reached its target depth of 383 metres, and shaft lining is currently underway. At the mine head itself, shaft boring has started in the services shaft, while progress is also being made on the production shaft infrastructure.

Anglo American has also been carrying out a detailed technical review of the Woodsmith mine project since mid-2020. This is to ensure the technical and commercial integrity of the project's design. Now largely complete, the review has confirmed that a number of design elements would benefit from modification to bring these up to Anglo American's safety and operating standards. Such modifications would also optimise the the long term value of the asset.

Mark Cutifani provided further details about these modifications. "The Woodsmith team is further developing the engineering to optimise the configuration of the project, recognising the multi-decade life of the mine," Mr Cutifani said. "Particular attention is on those aspects identified at the outset of Anglo American's ownership – namely, the sinking of the two main shafts, the development of the underground mining area, and the changes required to accommodate both increased production capacity and the more efficient and scalable mining method of using only continuous miners; such improvements will also require the installation of additional ventilation earlier in the development of the underground mining area."

More on-farm demonstrations

Anglo American also announced a renewed focus on its crop agronomy work in February. The company is accelerating the number of commercial-scale, on-farm demonstrations. Around 800 of these are either in progress or complete.

"The demonstrations continue to validate the efficacy of the product and the improvements it can deliver to farmers in terms of crop yield, quality or both. In addition, POLY4 has been shown in studies to enhance soil health through resilience to compaction, erosion and run-off, as well as improving nutrient availability to crops, helping to reduce nutrient waste into watercourses," Anglo American said in the briefing accompanying its annual results.

"POLY4 offers farmers a solution to agricultural efficiency and sustainability challenges, through its naturally low chloride multi-nutrient composition, its suitability for organic use and ultra low carbon profile, generating up to 85% fewer carbon emissions than the equivalent conventional nutrient products, with little to no waste generated in its production," it added. ■

Anglo American's purpose is 're-imagining mining to improve people's lives' – with its sustainability drive being seen as central to fulfilling that purpose. In the words of Chief Executive Mark Cutifani at a recent sustainability performance call with investors: "It's about purpose and profit together, not one before the other".

Since committing to carbon neutral operations by 2040, Anglo American has made significant strides in its 'green' energy use, introducing 100 percent renewable energy supply for its operations in Brazil, Chile and Peru. This means that 56 percent of the company's global grid supply is expected to be sourced from renewables by 2023.

Anglo American also recently pledged to secure 100 percent renewable energy for its South Africa operations by 2030 through a partnership with EDF Renewables. This will involve erecting several solar plants and wind farms to help power its in-country operations and provide green energy for local communities. The company expects these efforts will significantly help it reach its target to reduce greenhouse gas emissions by 30 percent by 2030 (from a 2016 baseline).

Anglo American's efforts to reduce its carbon footprint also extend to indirect emissions. This includes the ambition to halve 'Scope 3' emissions by 2040. Trials are underway to use sustainable biofuel in shipping, part of an ambition to achieve carbon-neutral controlled ocean freight. Meanwhile, a feasibility study launched in Australia is assessing the movement of bulk freight using hydrogen-powered trains. The company is also working to improve steel industry decarbonisation, and develop more carbon-efficient iron ore products, by linking up with its customers and technology partners.

To date, however, it is the trialling of hydrogen at scale which has been the most visible development of Ango American's sustainability drive. A hydrogen-fuelled mine haul truck was launched in South Africa in May this year – an initiative that is central to a commitment to displace 1.5 billion litres of diesel currently consumed annually by the company's trucks.

The South African truck scheme is part of a pledge to build a 'hydrogen valley' in the country. This would create a regional renewable energy system by developing hydrogen production and storage complexes around Anglo America's Mogalakwena platinum mine. This system will incorporate the largest electrolyser in Africa and a solar power field. It will generate approximately 140 megawatts of green power, eventually becoming one of many similar complexes that will serve as local and regional hubs for South Africa's emerging hydrogen economy.

The success of such ambitious schemes – part of efforts to turn an intensive carbon emitting sector into a sustainable, carbon neutral industry – is only achievable with the participation of companies like Anglo American and the other mining majors. Similarly, the growing presence of mining majors in the fertilizer sector will have significant implications for other major crop nutrient producers, by changing ambitions and expectations of what is achievable in the drive for more sustainable food production.

Building the Woodsmith Mine and successfully promoting and selling POLY4 is, of itself, a significant challenge for Anglo American. But doing so while achieving new standards for sustainability and environmental protection demonstrates the breadth of the company's ambition.

If there is one industry that truly understands what is required to change stakeholder perceptions about sustainability, it is perhaps the mining industry. The return of mining majors to the fertilizer sector will therefore undoubtedly result in significant changes, for both products and behaviours, in the years to come. ■

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