Number 504

September | October 2021

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Fertilizer INTERNATIONAL

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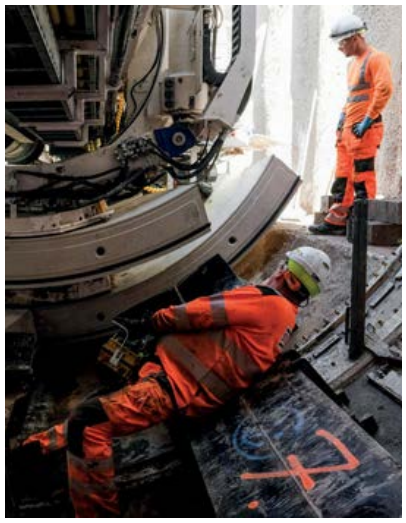
Low-carbon fertilizer production

The benefits of boron

Phosphoric acid co-products

Woodsmith mine update



Cover: Woodsmith mine project tunnel boring machine, Wilton, UK.
Photo: Anglo American

EMT urea hopper, ISAOSA blending plant, Mexico

Under-construction AHF plant, Aurora, North Carolina

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Published by:
BCInsight

Fertilizer INTERNATIONAL

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REGULARS

These are the good times

“The key questions for the fertilizer market currently are what’s driving the current price rally – and, crucially, will it last?

2021 is turning out to be a very good year for profits and earnings. Take Nutrien and Yara International, for example, the fertilizer sector’s two biggest companies by market capitalisation.

Nutrien generated record earnings of $3.0 billion and free cash flow of $1.9 billion in the first half of 2021. These represent year-on-year rises of 36 percent and 40 percent, respectively, compared to the first half of last year.

“We delivered record earnings across our global business for the second quarter and first half of 2021 and expect the remainder of the year to contribute to a full year record,” commented Mayo Schmidt, Nutrien’s president and CEO. He attributed the company’s record earnings to a strong operating performance and, importantly, its ability to capitalise on higher fertilizer prices.

Similarly, Yara International’s first-half 2021 earnings were up by 27 percent to $1.4 billion, while its net income rose from $105 million to $553 million. Furthermore, the Norwegian-headquartered company has generated a mighty $3.0 billion in free cash flow over the last four quarters. Yara specifically credited higher product prices for boosting its financial fortunes.

And what a year it’s been for fertilizer prices, as the following mid-August benchmarks show: potash cfr Brazil ($678/t), DAP f.o.b. Tampa ($669/t) and urea f.o.b. NOLA ($423/t) being up by 180 percent, 102 percent and 80 percent, respectively, year-on-year.

Unsurprisingly, the key questions for the fertilizer market currently are what’s driving the current price rally – and, crucially, will it last?

Analysts have previously advised that market fundamentals could keep fertilizer prices elevated throughout 2021. As Chris Lawson, CRU Group’s head of fertilizers, commented in our March/April guest editorial (*Fertilizer International* 501, p4): “This is very much a demand driven rally. Capacity will respond to high prices and bring the market back to balance.” As always, the main question was when.

As recently as mid-June, CRU’s advice was to: “Beware the bubble – this is no commodity price supercycle.” Yes, fertilizer prices are still on an upwards trajectory and delivering robust margins for producers. Yet, in CRU’s view, enough capacity will eventually emerge to burst the current price bubble.

“Capacity is ample, and more is being built across the nitrogen, phosphate and potash segments. High crop prices are expected to continue well into 2022 – but we anticipate oversupply to pull fertilizer prices lower by the turn of this year,” said CRU.

While CRU still believes there is no commodity supercycle, some of its key identifiers – namely demand disruptors and capacity constraints – could eventually support this happening.

Foremost among emerging ‘demand disruptors’ is the accelerating green ammonia revolution (see article on page 20). This, in turn, is being driven by what CRU calls the astonishing level of interest and investment in green ammonia, with new projects being announced almost daily.

CRU therefore expects the potential for a fertilizer price supercycle to increase as the market for ammonia as a low-carbon fuel and hydrogen carrier expands in future. Nevertheless, green ammonia is still unlikely to have a significant demand impact until much later this decade.

So, what of the more immediate outlook for prices? Rabobank in its recent *Semi-Annual Global Fertilizer Outlook* expects high fertilizer prices to remain for the rest of 2021.

Fertilizer prices, notes Rabobank, are currently at their highest levels since 2012. This rally, in turn, is linked to rocketing soybean, corn, and wheat prices. These have either more than doubled or nearly doubled between mid-2020 and mid-2021 – prompting farmers to increase fertilizer application rates in pursuit of higher yields and revenues. These fertilizer demand pressures have also undoubtedly been exacerbated by supply constraints.

“After several years of low margins, farmers in the US took the opportunity to refill soil nutrients, which further incentivized heavy applications,” says Matheus Almeida, senior analyst – farm inputs at Rabobank.

Despite this, Rabobank expect higher availability to pressure urea prices in 2021’s second half, while excessive phosphate price levels are eventually expected to soften demand and prompt a price decline. Potash is expected to buck this trend, however, with a tight balance sheet spurring further prices rises in 2021.

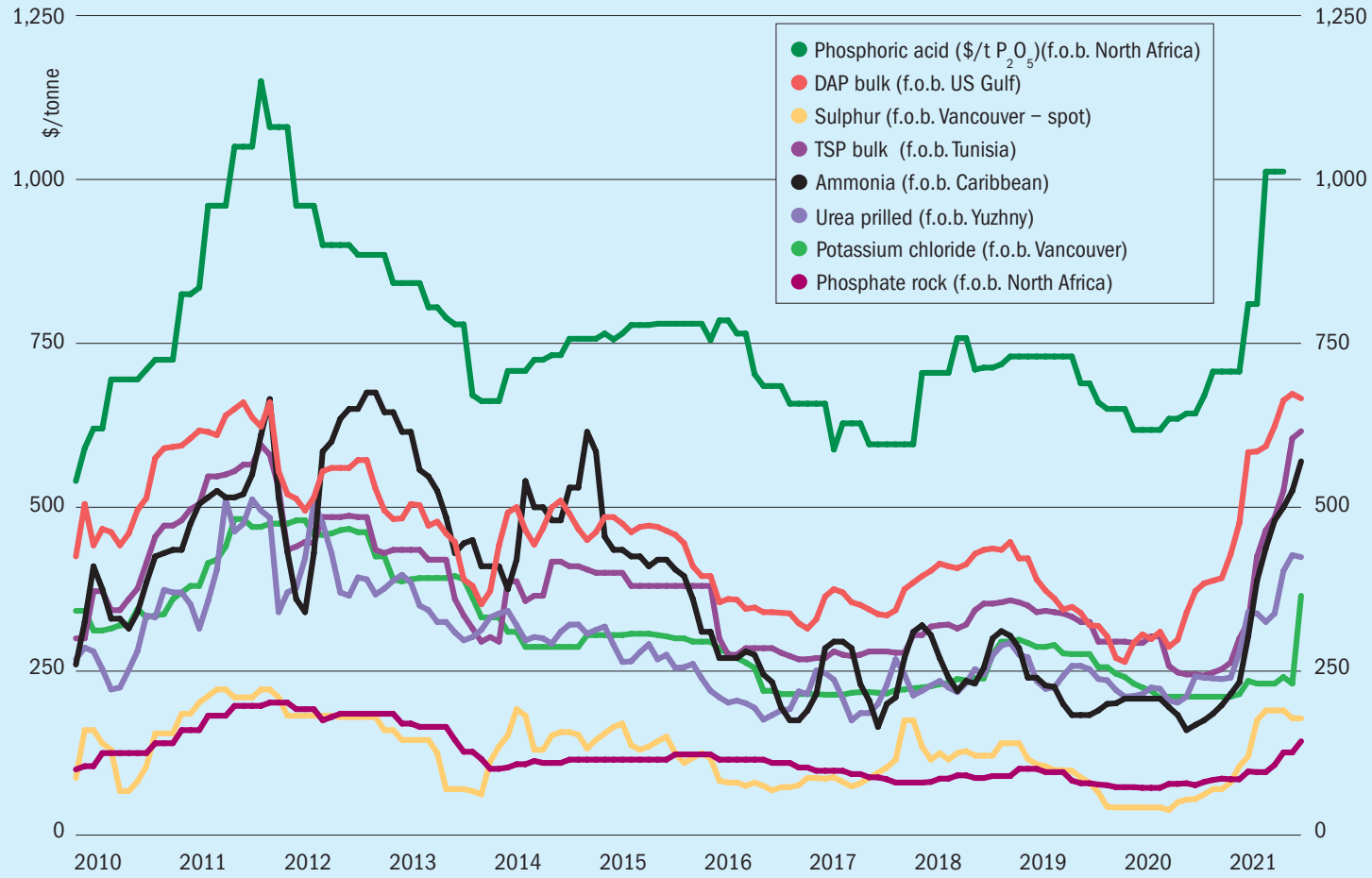
In the short-term, any downward price correction also looks like being relatively minor. On that basis, the good times of 2021’s first half should translate into a very good year overall. ■

S. Inglethorpe

Simon Inglethorpe, Editor

Market Insight

Historical price trends $/tonne



Source: BCInsight

Market Insight courtesy of Argus Media

PRICE TRENDS

Urea: Prices generally fell in mid-August, moving downwards on thin demand, high freight rates and an overall lack of market fervour. In China, some short selling of prills for September loading occurred at below $430/t f.o.b. Trade from Algeria, though, held up at around $449/t f.o.b., similar to previous business. Brazil also bucked the general trend, with prices there rising on steady demand to reach $480/t cfr in mid-August.

Key market drivers: High freight rates, with ocean shipping costs escalating again, are likely to continue challenging f.o.b. prices. Indian tenders – or the lack thereof – remain a key pillar of support, while natural gas price in Europe reached almost $16/mn Btu in mid-August, up by five percent on the previous week.

Ammonia: East Asian delivered prices fell for the first time since December 2020, falling $10/t on the week as global supply steadily improved. Nevertheless, only a few spot cargoes are being agreed at fixed prices currently. Counterparties are favouring formula-priced agreements instead, until the production outlook has firmed up, particularly from Saudi Arabia. Although Ma'aden's MPC plant remains offline, there are signs it could restart in the last week of August, with a vessel nominated to load from Ras al Khair on 24-28 August. An Indonesian spot sale confirmed for Luwuk-loading indicates improving availability from southeast Asia.

Key market drivers: Improving Indonesian supply, Ma'aden's MPC plant remaining offline and high feedstock costs.

Phosphates: The focus has remained on south Asian DAP markets, with further DAP cargoes lined up by both Pakistan and India driving up cfr prices. One trader sold 60,000 tonnes of Russian DAP to an Indian buyer at $648/t cfr – the first Russian cargo to head to India since late last year. In Pakistan, a major importer purchased a vessel of DAP and MAP, with the DAP priced at around $660/t cfr. A second DAP sale to Pakistan from China was reported at $667-668/t cfr.

MAP prices, meanwhile, have continued to soften in the absence of demand. Brazilian MAP fell to $720-730/t cfr and MAP prices in Argentina dropped to $730-740/t cfr.

Key market drivers: Indian DAP stocks falling as a result of low imports, Pakistan still needing DAP for the *rabi* season, and producers changing destination markets.

Potash: Although MOP continues to be in short supply in most regions, the seasonal drop in demand has relieved some short-term price pressure. Freight rates are still climbing, partially offsetting MOP f.o.b. price increases. The market remains unsure of the impact of sanctions against Belarus. These have nevertheless caused some buyers, mainly from the US and Europe, to hesitate before ordering from BPC.

Key market drivers: BHP approving the Jansen potash project and China's review of 2022 commodity export tariffs. These have been at zero for several years but could potentially curb SOP exports if reinstated.

Market price summary $/tonne – End August 2021

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	540-560	-	f.o.b. E. Europe 180-205	f.o.b. US Gulf	655-667	-	-
f.o.b. Yuzhny	560-610	390-435	-	f.o.b. N. Africa	636-680	600-630	1,120-1,200
f.o.b. Middle East	590-640	439-470**	-	cfr India	630-660	-	1,160*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	350-390	-	cfr US Gulf	200-260	f.o.b. Vancouver	170-190	-
f.o.b. Middle East	400-451	-	-	-	f.o.b. Arab Gulf	164-190	-
f.o.b. Western Europe	-	582-690	-	-	cfr N. Africa	194-215	-
f.o.b. Baltic	400-445	-	-	-	cfr India	195-225+	-

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.*

Sulphur: The rapid rise in Chinese domestic prices in mid-August was a key development, as was the accompanying bids for import tonnes. Domestic prices reached Yn1,950-1,970/t ex-works by 19 August, equivalent to around $245-250/t cfr. Bids for imported tonnes reached $230/t cfr. Some tonnes traded in the low-mid/$220s/t cfr mid-August before offers firmed to a minimum of $240/t cfr. Chinese buyers are now willing to pay as much as $20-30/t above cfr levels in other markets.

This firming has been reflected by the bidding levels in the Qatari sales tender, with an award for 35,000 tonnes believed to have been made at just above $180/t f.o.b. for September loading.

Key market drivers: Firming price expectations and the Muntajat tender award.

OUTLOOK

Urea: Greater clarity on f.o.b. prices, following India's next tender, should lead to a fresh wave of buying interest from other regions. Despite the recent Indian tender absorbing 1.2 million tonnes of urea, a further 700,000 tonnes is due to ship from China. This confirms that Chinese urea will continue to provide export market liquidity, despite concerns that intervention by Beijing could limit export availability in the second half of 2021.

Ammonia: With most key demand hubs now sufficiently covered in September, the improving supply situation may add to downward pricing pressures in October. Despite this, seasonal demand and high feedstock costs in the west are likely to limit any potential price deterioration.

Phosphates: Import demand in India and Pakistan will support DAP prices in coming weeks. The Indian DAP maximum retail price (MRP) is expected to rise, given that domestic prices and subsidy rates have been unable to offset rising cfr prices. Both India and Pakistan will need to secure further DAP shipments to avoid shortages during the upcoming *rabi* season. At the same time, a seasonal lull is set to pressure MAP prices in Brazil and Argentina.

Potash: While price increases have slowed in Brazil and the US, there is still potential for higher prices if supply remains tight. Europe, Africa and southeast Asia prices are still some way behind the US and Brazil. This is likely to limit supply to those regions – if producers can move volumes to regions where netbacks are higher – fuelling expectations of steeper price rises.

Sulphur: With Chinese port congestion beginning to ease by the end of August, pricing is expected to peak in September. The run down in stock levels to below 1.6 million tonnes, and the low levels of domestic product on offer, has triggered an early buying round in preparation for China's domestic season.

An uplift in prices is expected at the beginning of the fourth-quarter, as fertilizer producers move to replenish stocks. Prices will then most likely soften again, once stock levels increase and Chinese buyers return to hand-to-mouth buying. ■

CANADA

BHP greenlights Jansen potash mine

The Jansen project is located 140 kilometres east of Saskatoon, Saskatchewan, and is BHP's most advanced under-development project.

PHOTO: BHP

BHP has finally given the go ahead for stage one of its Jansen potash mine project in Saskatchewan, Canada.

The delayed final investment decision, made on 17th August, commits the Australian mining giant to a further $5.7 billion investment to bring the project into production.

The 4.35 million t/a capacity Jansen mine is now expected to produce its first potash ore in 2027, following a six-year construction phase. The mine will then take a further two years to ramp-up to full capacity.

BHP expects stage one of the Jansen mine (Jansen S1) to generate an internal rate of return (IRR) of 12-14 percent – equivalent to a payback period of around seven years – and operate at a healthy earnings (EBITDA) margin of around 70 percent.

"Jansen is located in the world's best potash basin and is expected to operate for up to 100 years. Potash provides BHP with increased leverage to key global mega-trends, including rising population, changing diets, decarbonisation and improving environmental stewardship," BHP said in a statement.

Mike Henry, BHP's CEO, said Jansen would help the company grow its portfolio of large, low cost and expandable world class assets.

"This is an important milestone for BHP and an investment in a new commodity that we believe will create value for shareholders for generations," Mr Henry said. "In addition to its merits as a standalone project, Jansen also brings with it a series of high returning growth options in an attractive investment jurisdiction."

He added: "Jansen is designed with a focus on sustainability, including being designed for low greenhouse gas emissions and low water consumption."

The extra $5.7 billion investment in Jansen S1 covers the design, engineering and construction of a complete underground potash mine and all of its associated surface infrastructure. This includes a processing plant, a product storage building, and a continuous automated rail loading system. Jansen's potash product will be shipped to export markets through Westshore in Delta, British Columbia, with the project's new funding also covering the necessary port infrastructure.

BHP said Jansen S1 is timed to arrive at an opportune moment for new potash supply: "We anticipate that demand growth will progressively absorb the excess capacity currently present in the industry, with opportunity for new supply expected by the late 2020s or early 2030s. That is broadly aligned with the expected timing of first production from Jansen."

BHP predicts that Jansen will operate competitively, being positioned in the first quartile of the industry's cost curve, especially given that it expects long-term potash prices to be set by Canadian solution mines. These tend to have higher operating and sustaining capital costs than conventional mines like Jansen, as well as consuming more energy and water.

BHP has already invested $4.5 billion of capital in the Jansen project to date. This includes a $2.97 billion investment in shaft construction and associated infrastructure, plus the funding of engineering and procurement activities, and preparatory work on underground infrastructure.

BHP acknowledged that the full project would yield a much lower IRR if its investment to date was included. "This resulted in a significant initial outlay and… our approach would be different if considering the project again today," the company said.

The construction of Jansen's two shafts is 93 percent complete currently, with both shafts and associated infrastructure due to be finished sometime next year. BHP estimates that around half of all the engineering required for Jansen S1 has now been completed, significantly de-risking the project.

Following a fresh valuation of its potash asset base, and a new calculation of the value of its investments in Jansen to date, BHP included an impairment charge of $1.3 billion ($2.1 billion after tax) against its potash assets in its latest financial results.

The Jansen S1 mine will convert approximately 20 percent of BHP's 5.23 billion tonnes of measured and indicated resources into potash ore reserves. The mine's earnings potential is based on average potash price assumptions for the decade 2027-2037 supplied by CRU ($341/t) and Argus ($292/t). Sustaining capital for Jansen Stage 1 is expected to be approximately $15/t, plus or minus 20 percent for any given year.

Rival Canadian potash giant Nutrien appeared sanguine about BHP's decision to bring Jansen into production. "It will take another decade for Jansen to have significant production," Ken Seitz, CEO for potash at Nutrien, said in a statement. The company expects global potash demand to grow by 2-3 percent annually out to 2030.

Reuters reported in May that Nutrien and BHP were weighing up a partnership on the Jansen project, although this potential link-up was not confirmed by either company (*Fertilizer International* 503, p9).

BHP's final investment decision comes at an auspicious moment for potash prices. The Brazil cfr benchmark, for example, is close to $700/t, a ten-year highpoint and a dramatic turnaround from the below $300/t levels seen at the start of this year. ■

BRAZIL

EuroChem buys Serra do Salitre from Yara

EuroChem Group has agreed to buy the Serra do Salitre phosphate project from Yara International. A share purchase agreement to buy the project for $410 million in cash was announced by both companies on 1st August.

Serra do Salitre is an integrated phosphates project located in Minas Gerais, Brazil. It combines a 1.2 million tonne capacity phosphate mine – and access to more than 350 million tonnes of reserves – with a one million tonne capacity phosphate fertilizer plant. This is capable of manufacturing MAP/NP and SSP/TSP products.

The project also includes a sulphuric acid plant, a phosphoric acid plant, and a 400,000 tonne capacity storage unit for granulated fertilizers such as urea and potash.

Although Serra do Salitre is well advanced, and has been under construction since 2015, Yara estimates that further capital expenditure of around $410 million could be required to complete the project. “Salitre remains an attractive project, but as previously communicated the project progress has been impacted by Covid 19, and significant construction time and capital expenditure remains to reach completion,” Yara said in a statement.

The project’s mine and beneficiation plant are, however, already operational (*Fertilizer International* 502, p26) and currently producing around 500,000-600,000 tonnes of phosphate rock. This is generating positive earnings from third-party concentrate sales. The under-construction phosphate production complex, meanwhile, is now due to become operational in 2023.

Brazil is an agricultural powerhouse with a high demand for phosphate fertilizers due to the scale of crop production and its crop mix, particularly the prevalence of soybean cultivation. As a domestic producer, Serra do Salitre should be strong position to capture market share, given that the country currently depends on imports for half of its phosphate requirements. The project is also strategically located within Brazil’s agricultural heartland, where domestic fertilizer demand is strong.

“This expansion will allow us to reduce dependency on third-party phosphate supplies, and also creates the potential for phosphates and complex fertilizer production in Brazil,” said Vladimir Rashevskiy, EuroChem’s CEO. “It significantly improves our competitive position in Brazil, and enables us to leverage the extensive blending and distribution capabilities brought by the acquisition of Fertilizantes Tocantins, which we completed last year.”

Yara said the divestment was a strategic move that would allow the Norwegian fertilizer giant to focus on new priorities such as premium products and the hydrogen economy.

Once brought on-stream and fully ramped-up, Serra do Salitre will add an extra one million tonnes to EuroChem’s existing annual phosphate and complex fertilizer output of five million tonnes. EuroChem already operates two phosphate mines – the Kovdorskiy GOK facility in northern Russia and EuroChem Fertilizers in Kazakhstan. The Swiss-headquartered company currently manufactures a range of premium-quality MAP, DAP, NP and feed phosphates at several production sites in Russia and Lithuania.

Both parties expect to complete the project sale in approximately six months, subject to the necessary regulatory approvals and customary closing conditions.

Yara's Herøya plan.

PHOTO: DAG FRODE HEILAND/YARA

EUROPE

Cost warning for EU's 'Fit for 55' climate package

The EU's new 'Fit for 55' climate plan will increase carbon costs and capital expenditure, according to Fitch Ratings. This would affect EU fertilizer producers as well as producers exporting into the European single market, it said.

The European Commission unveiled its 'Fit for 55' policy package in mid-July. In a document spanning thousands of pages, this sets out exactly how the EU plans to reach its legally-binding target to cut emissions to 55 percent below 1990 levels by 2030.

The policy package still requires the approval of the European Parliament. Nevertheless, Fitch expects the European carbon price to increase further, should the 'Fit for 55' pass in its current form. The EU carbon price has already risen dramatically this year – more than doubling over the last 10 months, increasing from below €25/t at the end of October 2020 to reach record levels of €55-60/t currently.

In an analysis published on 19th July, Fitch identified the EU fertilizer industry as one of several sectors which it expects to be particularly badly hit by the European Commission's new policy package. This includes proposals to cut free carbon allocations, lower the annual emissions cap for the Emission Trading System (ETS), and introduce a Carbon Border Adjustment Mechanism (CBAM) to tax high carbon imports.

"EU domestic metals and fertilizer producers will be most affected by a steeper free annual carbon allocation reduction of 4.2% – instead of 2.2% currently – and a lower emissions cap," said Fitch Ratings. "Carbon prices have already reached new records this year and are likely to increase further as the policies are implemented."

As well as facing rising carbon costs, fertilizer producers will need to increase investment to decarbonise their operations and protect their market position. But companies which already have credible sustainability strategies may be able to mitigate their costs via access to attractive green financing – and could even capitalise on the policy changes by using 'first-mover advantage' to develop new products and technologies.

The introduction of the CBAM is designed to avoid carbon leakage by imposing costs on carbon-intensive EU imports, including fertilizers, that mirror the carbon costs for domestic products. Following the initial roll out of the CBAM from 2023 onwards, importers will be expected to start making payments from 2026 – a measure which may spur EU trading partners to consider their own carbon trading systems, suggests Fitch.

Several northern African and Russian fertilizer producers, who are among the largest fertilizer exporters to the EU, will be exposed to the CBAM, according to Fitch. Russia's PhosAgro and EuroChem both sell just over 25 percent of their production into the EU, for example, while Morocco's OCP exports about 20 percent of its output to the bloc. Despite this, all three companies are well positioned to absorb new carbon costs, notes Fitch, due to their very low cost bases. Nevertheless, it is likely that some costs incurred by the 'Fit for 55' package will be passed onto customers eventually.

The proposed expansion of the ETS to encompass shipping, meanwhile, may benefit fertilizer producers such as Yara and OCI who are currently investing in low-carbon shipping fuels such as green ammonia and green methanol.

EU industry group Fertilizers Europe was generally critical of the 'Fit for 55' package, saying it "falls way short of what is needed by not recognizing the need for competitiveness of European industry".
The trade body was particularly concerned that rising carbon costs for EU fertilizer producers would place them at a disadvantage to their major global competitors. It said the policy package in its current form, instead of promoting decarbonisation, actually increased the risk of carbon leakage. Despite these reservations, Fertilisers Europe said: "The European fertilizer industry supports the Green Deal's ambition of climate neutrality by 2050 and is committed to play its part."

"Through investments in low carbon technologies and production of green and blue ammonia, our sector can play a vital role in the decarbonisation of the economy," said Jacob Hansen, Fertilizers Europe's director general. "But the road to get there is very challenging and tremendous efforts and

capital investments will be required to move from fossil to renewable based production".

He added: "In recent weeks, we have seen surging prices of gas and ETS carbon costs – all putting competitive pressure on our sector. The 'Fit for 55' package will only add to this pressure."

The introduction of a CBAM was broadly welcomed by Fertilizer Europe as a step towards ensuring importers were on a level playing field. But, to ensure fairness, free allowances to CBAM sectors needed to be allocated at the same level as other sectors, at least until 2030, in Hansen's view. "[This] is absolutely crucial for the competitiveness of the fertilizer industry," he said.

Hansen signalled that European fertilizer producers would continue to adopt a constructive approach to EU climate and agricultural policy: "We are determined to do our part in upscaling low carbon ammonia production thereby assuming the role of work horse for the hydrogen economy, and we will contribute to making agriculture more sustainable in Europe."

NORWAY

Yara launches HEGRA decarbonisation partnership

Yara and two Norwegian partners have set up HEGRA, a new company to electrify and decarbonise its ammonia plant at Herøya, Porsgrunn, Norway.

HEGRA, an acronym standing for HErøya GReen Ammonia, is an equal partnership between Yara, Aker Clean Hydrogen and Statkraft. The decarbonisation project will be Norway's largest climate initiative – and is aiming to reduce CO_2 emissions by 800,000 tonnes annually.

The HEGRA partnership, launched in August, brings together Norway's leading experts in ammonia, project development and energy markets. The decarbonisation project at Porsgrunn could be delivered within 5-7 years, according to Yara, subject to the availability of renewable power at the site and assuming the necessary public co-funding is also in place.

HEGRA is specifically designed to help meet the EU's ambitious target to cut emissions by 55 per cent by 2030, as set out recently in the European Commission's 'Fit for 55' climate policy package (see above).

The new venture marks the first step in developing a Norwegian value chain for green ammonia and hydrogen, according to Auke Lont, the chair of HEGRA's board. HEGRA will help Norway achieve its climate goals and provide the country with a competitive advantage within the renewable energy and hydrogen sectors, he said.

The generation of green ammonia from renewable electricity at Herøya would enable carbon-free fertilizer production and provide a supply of zero-emissions shipping fuel. Norway's maritime industry is looking to cut its emissions in half by 2030, with access to emissions-free fuels holding the key to reaching this goal.

Svein Tore Holsether, Øyvind Eriksen and Christian Rynning-Tønnesen, the CEOs of Yara, Aker and Statkraft, respectively, all gave their backing to the new venture and attended its launch. In a joint statement, they said HEGRA will provide Norway with a competitive advantage in the growing global hydrogen economy, establish green jobs for the future and create the basis for a future Norwegian export industry

A 2020 report by The Confederation of Norwegian Enterprise suggested that the development of a hydrogen economy could significantly increase Norway's export industry, potentially providing a turnover of NOK 10 billion in 2030 and NOK 70 billion in 2050.

GERMANY

Kingenta sells COMPO

Private equity firm Duke Street completed the acquisition of Germany's COMPO from Kingenta in early August. The Münster-headquartered company is Europe's largest producer and distributor of consumer gardening products, including soil, fertilizer, plant and lawn care products.

In particular, COMPO has pioneered the use of organic products and peat substitutes in the European horticulture market. The previous owner, Chinese speciality fertilizer producer Kingenta, purchased COMPO from private equity group Triton in 2016.

"We are thrilled to complete the acquisition of COMPO, a market leader in traditional and bio-based gardening products in continental Europe – and a brand that has carved out a clear ESG leadership position with its bio products, including a full range of peat substitutes," said Paul Adams, partner, Duke Street. The London-based private equity company has invested over €2.5bn in more than 50 companies over the last 25 years, achieving strong returns on these investments.

Stephan Engster, CEO, COMPO, said: "We at COMPO look forward to partnering with Duke Street and delivering the next chapter of our growth story. Natural and sustainable products will always remain at the heart of our business as we stay true to our values and as sustainably-conscious consumers increasingly prioritise such offerings."

German speciality fertilizer producer COMPO EXPERT is an entirely separate company from COMPO. It is currently owned by Poland's Grupa Azoty who purchased the business from Goat Netherlands BV in 2019.

UNITED STATES

Go ahead for UAN import probe

The US International Trade Commission (ITC) has given the greenlight for an investigation into Russian and Trinidadian urea ammonium nitrate (UAN) imports.

In a vote on 13th August, the ITC judged that there is a reasonable indication that imports of UAN from Russia and Trinidad are materially injuring the US domestic UAN industry. This decision will enable the US Department of Commerce (DoC) to continue with its investigations.

The ITC was responding to a petition on UAN imports filed with US authorities in June by CF Industries, the country's largest UAN producer. This urged the DoC and ITC to impose antidumping and countervailing duties on US imports from Russia and Trinidad, citing supposedly unfair natural gas subsidies and tax breaks.

In its petition, CF presented evidence supporting claims that Russia producers EuroChem and Acron, and Trinidad producer Methanol Holdings Trinidad Limited (MHTL), are dumping UAN onto the US market at margins up to 392 percent and 159 percent, respectively.

"The preliminary ITC decision is an important step towards levelling the playing field for U.S. UAN producers and their workers," said Tony Will, CF Industries' president and CEO. "CF Industries will continue participating actively in the ongoing investigations in order to restore fairness to our highly competitive industry and ensure that American UAN producers remain a reliable source of fertilizers for American farmers for years to come."

Russian and Trinidadian UAN deliveries into the US market have surged in recent years and together account for close to 90 percent of total UAN imports.

Antidumping investigations remain at an early stage, however, with final determinations by US authorities typically taking one year. Nevertheless, if the US does eventually decide to impose countervailing duties on UAN imports from Russia and Trinidad, these would remain in place for at least five years.

EGYPT

thyssenkrupp to revamp Abu Qir 3

thyssenkrupp Fertilizer Technology has won a contract from Abu Qir Fertilizers to revamp the Abu Qir 3 urea granulation plant in Alexandria.

thyssenkrupp's *UFT* fluid bed granulation technology will be used to increase the plant's nameplate urea granulation capacity from 2,000 t/d to more than 2,500 t/d. A proprietary horizontal cross flow scrubbing system will also minimise urea dust and ammonia emissions by handling exhaust streams from both the urea granulation plant and the urea synthesis plant.

thyssenkrupp will supply the technology license, the process design package and the necessary equipment for the project. The revamp is scheduled to be completed and return Abu Qir 3 to full capacity by 2025.

Saad Ibrahim Abu El-Maati Hassan, the chairman and managing director of Abu Qir Fertilizers, said: "With this expansion, Abu Qir Fertilizers will reinforce its position as a leading nitrogen fertilizer producer in Egypt. We chose thyssenkrupp again to use the most up-to-date technology. Their state-of-the-art process and know-how give a significant boost to our plant capacity while simultaneously lowering the power consumption per produced tonne of granular urea and reducing direct emissions at the same time."

PHOTO: TKIS

Abu Qir granulation plant, Alexandria, Egypt.

The 2,000 t/d Abu Qir 3 urea granulation plant was originally designed in 1996. While the revamped plant will be capable of producing 2,500 t/d of granulated urea, it could reach 2,750 t/d output due to its inbuilt design margin.

thyssenkrupp's successful *UFT* fluid bed technology has proved to be a popular urea granulation choice for producers, with a current market share above 70 percent of installed capacity.

RUSSIA

Acron triples Talitsky potash project investment

Acron Group is ramping up investment and speeding up construction at its Talitsky potash mine project in Russia's Perm Krai region.

In a major step change, the company is more than tripling its capital investment in the project during 2021 and 2022, raising this from $60 million to $222 million. The company has also brought forward first production at the two million tonne capacity potash mine to 2025.

"Shafts are currently being reinforced and finished, construction of a motorway is near completion, and construction has started on the Ural 220/10/6 kV main step-down substation," Acron said in a statement on 16th August.

Acron also revealed that it is currently tendering for equipment suppliers and contractors to fit-out the Talitsky mine, its surface complex, and external infrastructure. The project has also secured a package of Russian government support due to it positive impact on the regional economy.

Alexander Popov, Acron's chairman, said: "In the current circumstances, we believe it is possible to accelerate construction to obtain the first batch of the product in 2025. Prior to the acute phase of the Covid-19 pandemic, we managed to dramatically improve the project's risk profile by finalising the sinking of the shafts. Now, we can conduct construction operations both underground and on the surface at the same time.

"The project's budget has been clarified. Remaining investments are estimated at $1.3 billion. Of this amount, approximately $700 million will be spent before the first batch of potash is produced. All of the project's engineering and design solutions provide for further expansion of the mine's capacity from 2.0 million to 2.6 million tonnes per annum of potash."

UAE

Adnoc sells first blue ammonia cargo to Japan

Adnoc has sold its first blue ammonia cargo to Japanese trading company Itochu for use in fertilizer production.

The shipments were sold at an attractive premium to grey ammonia, according to Adnoc, and underscore the favourable economics for blue ammonia as an emerging source of low-carbon energy. Blue ammonia is produced in the same way as conventional grey ammonia, except that the carbon dioxide by-product is captured downstream of the process and stored.

The blue ammonia will be supplied by Fertiglobe from its 1.2 million t/a capacity Fertil ammonia plant in Ruwais, Abu Dhabi. Fertiglobe is a joint venture between Adnoc, Abu Dhabi's state-owned national oil company, and Netherlands-based fertilizer producer OCI.

The Japanese shipments represent the first production milestone of a planned scale-up of blue ammonia production capabilities in Abu Dhabi. This is expected to include a low-cost debottlenecking programme at Fertil.

"Today's announcement builds on Adnoc's commitment to expand the UAE's position as a regional leader in the production of hydrogen and its carrier fuels, meeting the needs of critical global export markets such as Japan," said Sultan al-Jaber, Adnoc's chief executive. "Through the expansion of our capabilities across the blue ammonia value chain, we look forward to furthering our legacy as one of the world's least carbon intensive hydrocarbon producers and supporting industrial decarbonisation with a competitive low-carbon product portfolio."

Masaya Tanaka, Itochu's executive officer, said: "We are pleased that Itochu, a leading general trading company in Japan, is contributing to a low-carbon society together with Adnoc. Starting with this trial of blue ammonia for fertilizer applications, we aim to create a wide range of ammonia value chains for existing industrial applications as well as future energy use.

"By collaborating with Adnoc and Fertiglobe, we expect to initiate and enhance our industrial portfolio in the fertilizer sector while achieving our commitments towards decarbonization activities in other industries".

Fertiglobe has partnered with Adnoc and ADQ on a project to develop a new world-scale one million tonne capacity Ta'ziz blue ammonia project at in Ruwais (*Fertilizer International* 503, p8). This will combine conventional ammonia manufacture with carbon capture technology. The final investment decision for the Ta'ziz project is expected in 2022, with start-up pencilled in for 2025. ■

People

Connor Dyck.

The Sulphur Institute (TSI) has appointed **Connor Dyck** of Koch Sulfur as the chair of its board. The appointment was announced in August and follows TSI's annual general meeting held in May.

Connor Dyck said: "It is an honor to be named TSI's chair. I look forward to working with the Institute and its members to advocate on behalf of the sulphur and sulphuric acid industries."

John Bryant, TSI's president, welcomed his appointment: "We are excited about Connor being named TSI's chair. His enthusiasm for the Institute will help execute our newly formed strategy and I am looking forward to working closely with him."

Uralkali has appointed **Natalia Soboleva** as interim chief financial officer (CFO). She was previously Uralkali's deputy CFO and replaces **Anton Vishanenko**, who has left Company.

Vitaly Lauk, Uralkali's CEO, said: "During his time at Uralkali, Anton Vishanenko has made a significant contribution towards the company's development and positioning. We remain very grateful to Anton for his professionalism and hard work and wish him all the best in his future professional undertakings."

CF Industries has elected **Jesus Madrazo**, founder and chairman of Kompali Farms, as an independent director. Prior to founding Kompali Farms, Mr Madrazo served for more than two decades in global leadership roles at Monsanto Company. More recently, he was executive vice president, public affairs and sustainability, for the Crop Science division of Bayer.

"We are pleased to welcome Jesus to the CF Industries' board," said Stephen A Furbacher, the chairman of CF Industries. "With his strong leadership experience, a global perspective, a passion for sustainability, and a deep background in agriculture serving customers, and as a farmer himself, Jesus will serve the board and our management team greatly. We look forward to his contributions as we work together to create long-term value for our stockholders."

Mr Madrazo holds a law degree from the Instituto Tecnológico y de Estudios Superiores de Monterrey in Mexico and postgraduate degrees from the Universidad Nacional Autónoma de México (UNAM) and the University of Arizona. He also holds an MBA from the UK's Cardiff Business School.

Mr. Madrazo's election raises the membership of CF Industries' board of directors to 12.

Amit Roy has been named executive director of the newly launched Global Phosphorus Institute (GPI), located in Benguerir, Morocco, which he will lead and help develop. His role at the GPI will include creating a consortium for cutting-edge phosphorus research projects, building global coalitions, and establishing research hubs around the world.

"We are pleased that Amit joins GPI to direct this new global initiative," said Hicham El Habti, the president of both Mohammed VI Polytechnic University, Morocco (UM6P) and the GPI. "His vast experience combined with his enormous breadth of knowledge, research work and experience in managing the International Fertilizer Development Center are valuable assets to GPI. I am confident that his qualifications will make him succeed in building out this Institute"

Dr Roy has been involved in phosphorus research for more than four decades. His previous roles include a stint as CEO of the International Fertilizer Development Center (IFDC) where he oversaw a number of major publications – including *Fertilizer Raw Material Resources of Africa*, *World Phosphate Rock Reserves* and *Resources and Sustainable Phosphorus Management, A Global Transdisciplinary Roadmap*. While CEO of IFDC, Amit set up more than 20 international branch offices to enable global collaborative research. Dr Roy also spearheaded the landmark 2006 Africa Fertilizer Summit held in Abuja, Nigeria.

"I am honored and excited to develop GPI into the global convener of all things phosphorus," commented Amit Roy. "This platform will be available to anyone from the local dairy farmer to the climate scientist to the chemistry student to the food manufacturer interested industries because we must ensure that phosphorus, a non-substitutable vital element, is responsibly managed and available for future generations."

Calendar 2021/22

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.

SEPTEMBER

15-16

GPCA Agri-nutrients Conference,
Virtual event
Contact: Jovelyn Sadoguio
Tel: +971 4 451 0666 ext. 153
Email: jovelyn@gpca.org.ae

20-22

TFI World Fertilizer Conference 2021,
BOSTON, USA
Contact: Mariana Gallo
Tel: +1 202 962 0490
Email: mgallo@tfi.org

20-23

CRU Sustainable Fertilizer Production Technology Forum, **Virtual event**
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

27-29

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

MARCH 2022

7-9

CRU Phosphates 2022,
TAMPA, Florida, USA
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

21-23

Argus/CRU Fertilizer Latino Americano 2022,
MIAMI, Florida, USA
Contact: Argus Media
Tel: +44 (0)20 7780 4340
Email: conferences@argusmedia.com

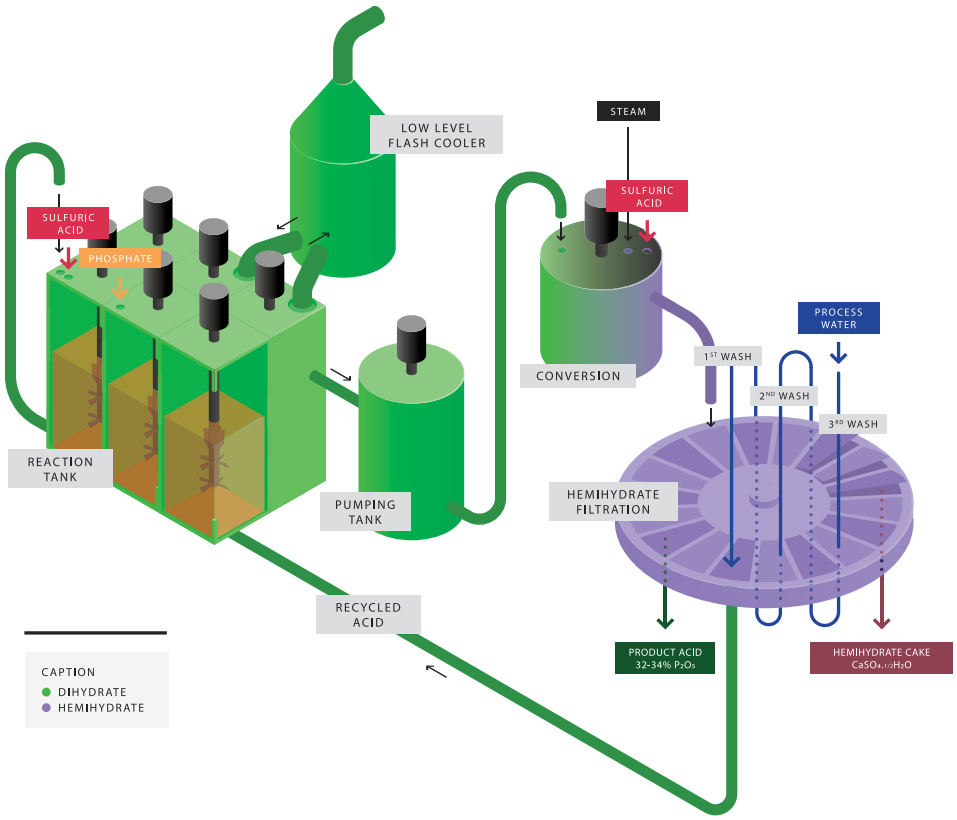
LEADER IN THE LICENSING OF PHOSPHORIC ACID PROCESSES

PRAYON

Prayon Technologies

ecophos by PRAYON

EXPERTS TEAM | **PROCESSES & TECHNIQUES** | **WORLDWIDE REFERENCE**



DA-HF Process - New Process for Improved Phosphoric Acid Production*

PHOSPHORIC ACID PROCESS ROUTES

New DA-HF*

Dihydrate (DH)

Hemihydrate (HH)

Central Prayon (CPP)

Hemi-dihydrate (HDH)

OTHER PROCESSES LICENSING

New DCP Production from low-grade phosphates

Phosphoric acid treatment (F, As, S, Mg, Fe, Al, Cd)

Fluorine recovery

Gas scrubbing

Gypsum treatment

CONSULTING

New Long-term collaborative program for assistance (P_2gether)

Plant operation simulator tool

*Dihydrate Attack-Hemihydrate Filtration

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State of the US fertilizer industry

We report on the state of US fertilizer production and supply. The US industry – the second-largest finished phosphates producer and third-largest urea producer globally – has grown and developed alongside North America's mature and sophisticated domestic farming sector.

The US fertilizer industry contributes almost $131 billion to the domestic economy and directly employs more than 100,000 full time staff, according to The Fertilizer Institute (TFI).

In 2018, the country's fertilizer producers:

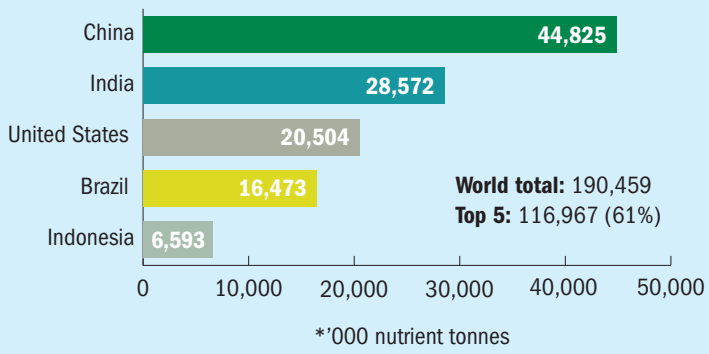
- On average, invested a total of $2.4 billion annually in capital expenditure projects
- Captured and reused 29 percent of their greenhouse gas (GHG) emissions
- Recovered over 101 million gigajoules (GJ) of waste heat, equivalent to almost 41 percent of total energy use
- Recycled 282 billion gallons of water
- Invested $1.2 million in the 4R nutrient stewardship fund
- Sold almost 437,000 tonnes of enhanced efficiency fertilizers (EEFs), on a nitrogen tonnage basis
- Reported a lost time incident rate of 0.48, meaning that US fertilizer manufacturing is 2-3 times safer than its industry peers.

These economic, environmental and social performance indicators were updated yearly for participants in TFI's annual *State of the Fertilizer Industry Report* This report was published for five consecutive years between 2015 and 2019, with TFI opting to release a more limited set of sustainability metrics last year. The fifteen fertilizer manufacturing companies who contributed to the 2019 report collectively accounted for 91 percent of total US nitrogen, phosphate, and potash production capacity[1].

Overview

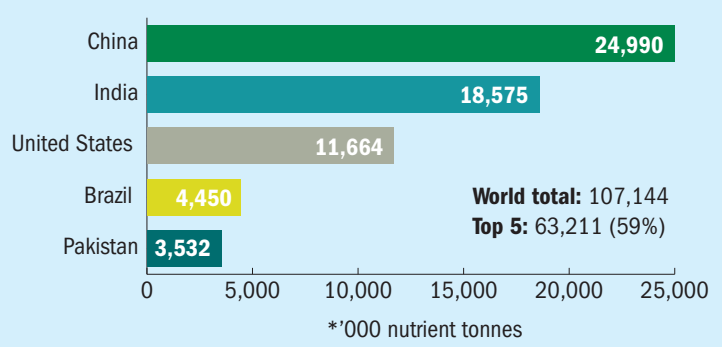
The United States is the world's third-largest fertilizer consuming region, being responsible for almost 11 percent of global consumption and ranked behind only China and India globally (Figure 1). On an individual nutrient basis, the country is also the world's third largest nitrogen and potash

Fig. 1: **Top five fertilizer-consuming countries*, 2019**



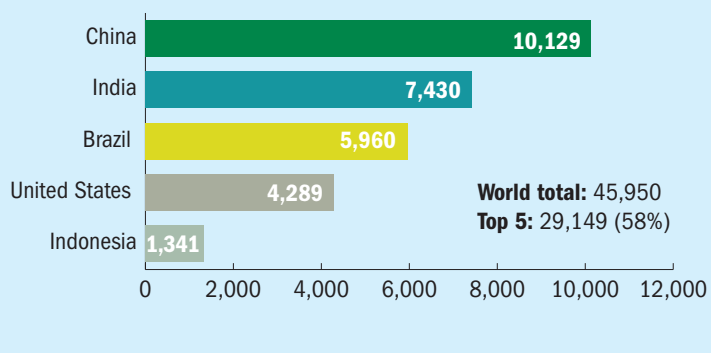
Source: Nutrien (2020)

Fig. 2: **Top five nitrogen-consuming countries*, 2019**



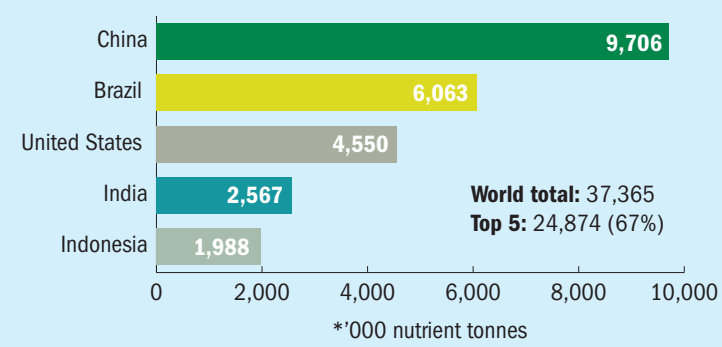
Source: Nutrien (2020)

Fig. 3: **Top five phosphate-consuming countries*, 2019**



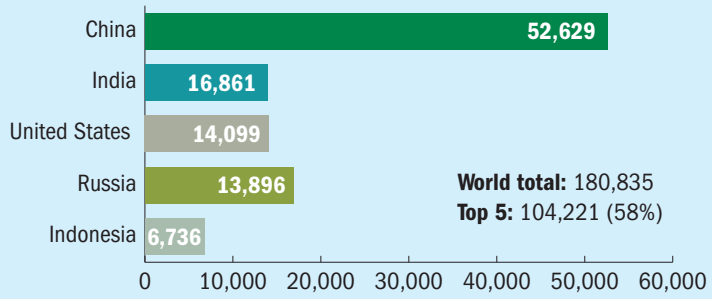
Source: Nutrien (2020)

Fig. 4: **Top five potash-consuming countries*, 2019**



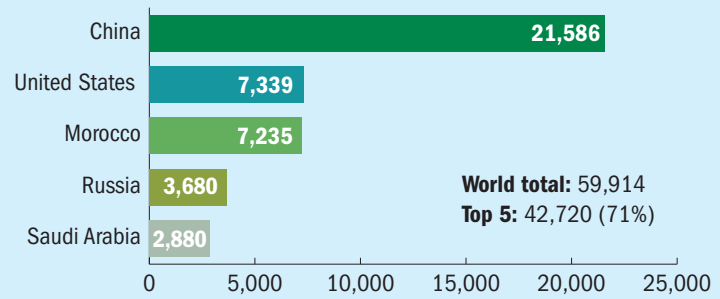
Source: Nutrien (2020)

Fig. 5: **Top five nitrogen-producing countries*, by capacity, 2019**



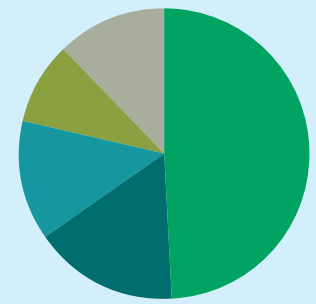
Source: Nutrien (2020)

Fig. 6: **Top phosphate-producing countries*, by capacity, 2019**



Source: Nutrien (2020)

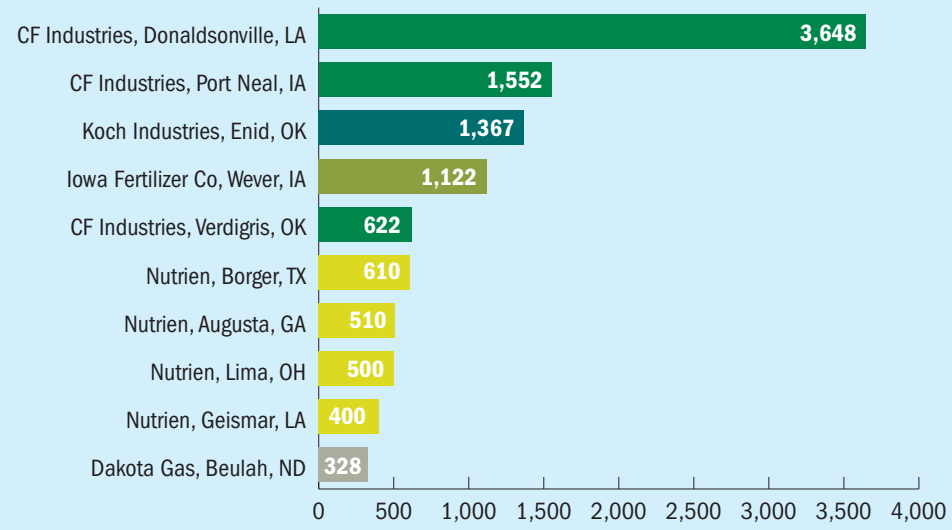
Fig. 7: **Major US urea producers, by capacity*, 2019**



Total US capacity: 12,422
*'000 tonnes product

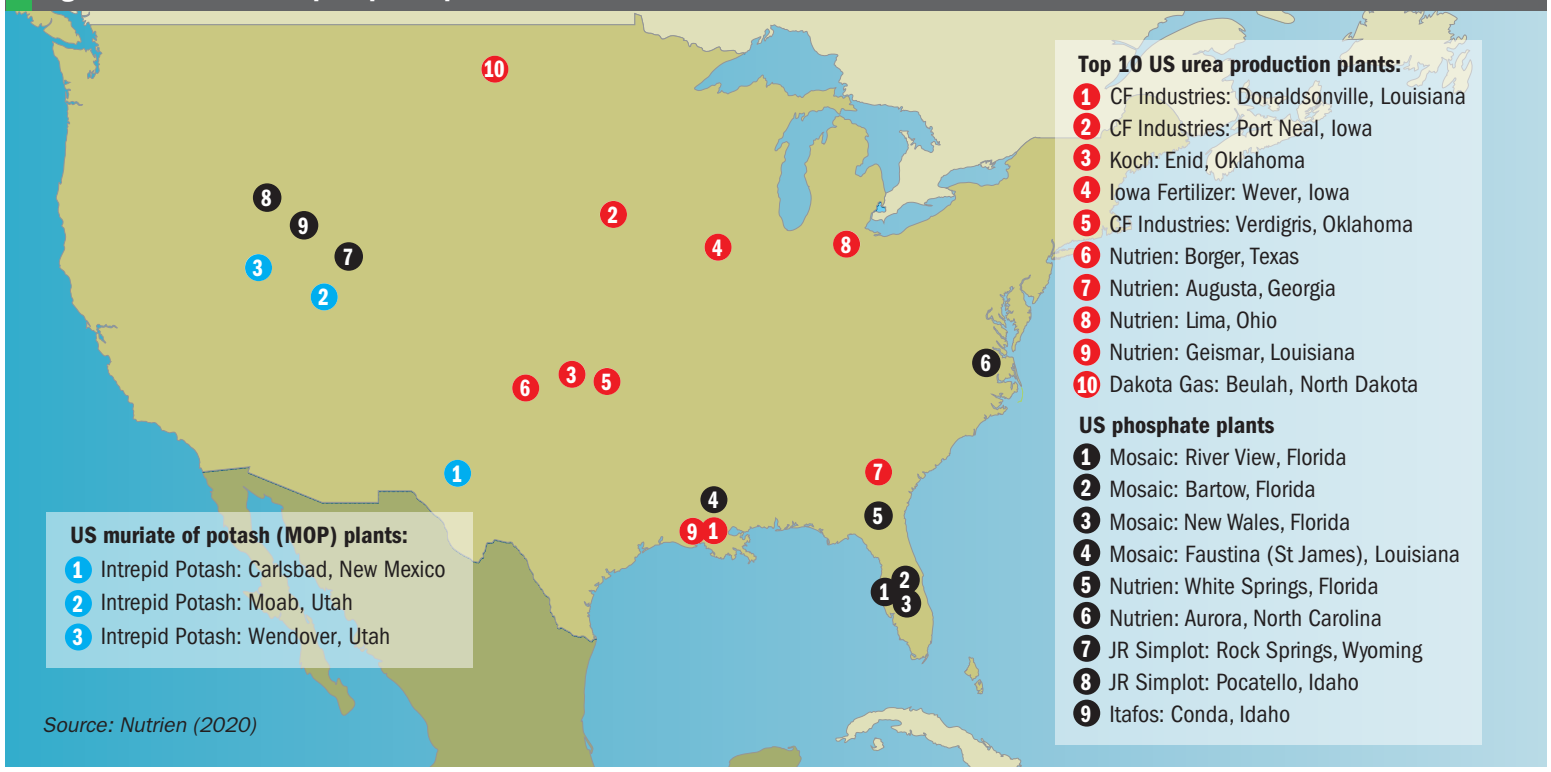
Source: Nutrien (2020)

Fig. 8: **Top 10 US urea production plants, by company, location and capacity*, 2019**



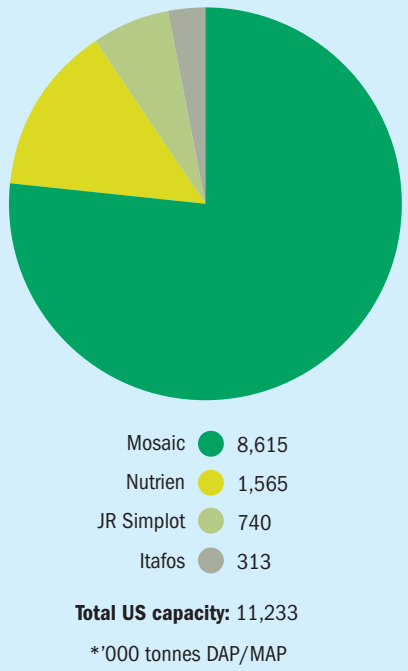
Source: Nutrien (2020)

Fig. 9: **North American phosphate plants**



Source: Nutrien (2020)

Fig. 10: **US phosphate producers, by capacity*, 2019**



Source: Nutrien (2020)

consumer and fourth largest consumer of phosphates (Figures 2-4).

The United States has developed a large-scale and technologically advanced domestic fertilizer industry to satisfy the high demand generated by its sizeable, sophisticated and mature agricultural sector. By capacity, the country is the world's second and third largest phosphate and nitrogen fertilizer producer, respectively (Figures 5-6), as well as being the tenth largest potash producing country globally.

Overall, the US fertilizer industry, is ranked fourth globally, in terms of total production capacity (22.2 million nutrient tonnes), exceeded only by China (81.3 million nutrient tonnes), Russia (31.7 million nutrient tonnes) and its northern neighbour Canada (26.9 million nutrient tonnes).

Urea production

The US operated 12.4 million tonnes of urea production capacity. This is mainly in the hands of CF Industries, Nutrien, Koch industries and the Iowa Fertilizer Co, with these four companies combined owning 88 percent of domestic urea capacity (Figure 7). This group of powerhouse companies also operate nine of the 10 largest US urea production plants (Figures 8 & 9). Illinois-headquartered CF industries is the largest US nitrogen fertilizer producer by far, owning almost half (49 percent) of domestic urea capacity, more than three times the scale of its nearest rival Nutrien.

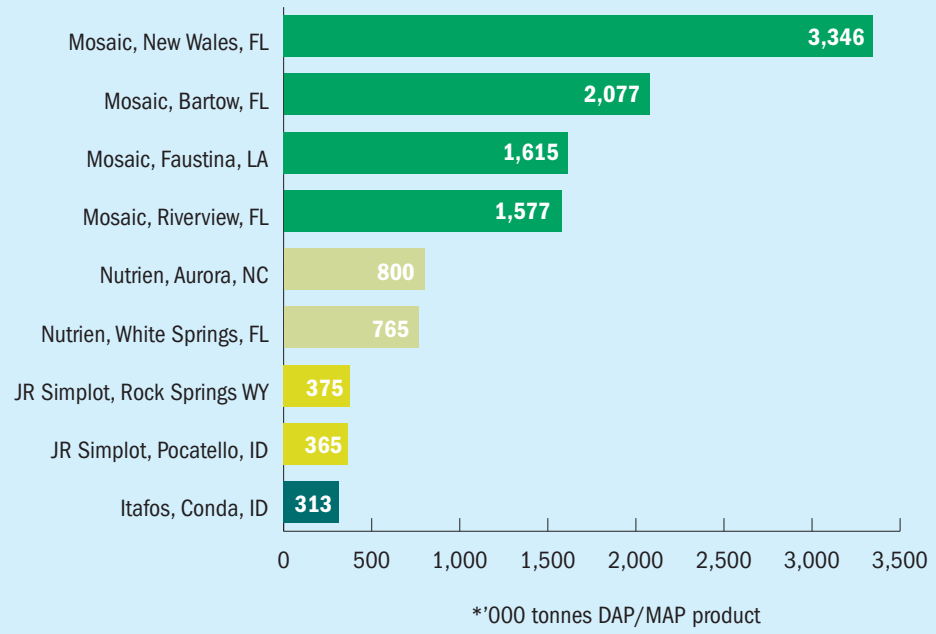
Phosphates production

The US can draw on 11.2 million tonnes of domestic production capacity for diammonium phosphate and monoammonium phosphate (DAP and MAP). Following several decades of consolidation, phosphate industry ownership is highly concentrated (*Fertilizer International* 496, p40) with just four companies – Mosaic, Nutrien, JR Simplot and Itafos – operating nine DAP/MAP production sites across Florida, Idaho, Louisiana, North Carolina and Wyoming (Figure 9).

"The US fertilizer industry contributes almost $131 billion to the domestic economy and directly employs more than 100,000 full time staff.

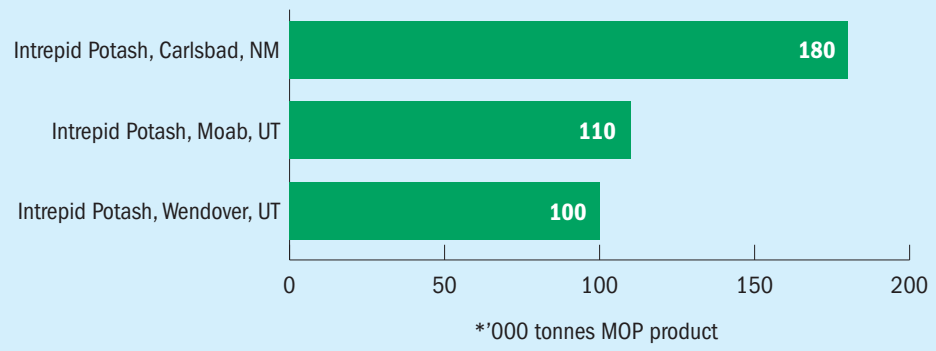
Florida-headquartered Mosaic is the dominant US phosphates market player (Figure 10). It operates around 8.6 million tonnes of DAP/MAP capacity from four sites in Florida and Louisiana. This includes New Wales, the country's largest phosphates production complex (Figure 11).

Fig. 11: **US phosphate production plants, by company, location and capacity*, 2019**



Source: Nutrien (2020)

Fig. 12: **US muriate of potash (MOP) production plants, by company, location and capacity*, 2019**



Source: Intrepid Potash

Potash

Intrepid Potash is the sole US supplier of muriate of potash (MOP, KCl). The company has the capacity to produce around 390,000 tonnes of potash annually via solar evaporation from three mining sites (Figures 9 and 12):

- The HB solution mine in Carlsbad, New Mexico
- The Moab solution mine in Utah
- The brine recovery operation in Wendover, Utah.

Imports and exports

Due to its limited domestic production capabilities – versus the scale of agricultural demand – the US is the world's third largest potash importing country, after Brazil and China. The country imported 7.8 million tonnes of MOP in 2019, sourcing much of this from neighbouring Canada as well as Belarus and Russia.

The US falls well outside the global top 10 list of urea exporting countries, exporting just 575,000 tonnes in 2019. That compares to domestic production for the year of 10.9 million tonnes of urea, supplemented by imports of 4.6 million tonnes. Indeed, the US is a major urea import market currently, being ranked the third largest globally. The country's top three urea suppliers in 2019 were Qatar, Canada and Saudi Arabia.

In recent years, the US has been both a major importer and exporter of phosphate fertilizers. In 2019, the country was ranked the world's fourth largest DAP/MAP exporter (4.0 million tonnes) and the world's third largest DAP/MAP importing country (2.9 million tonnes). Overall, the US ran a DAP/MAP export surplus of 1.1 million tonnes in 2019 out of a total domestic production of 7.0 million tonnes.

Import tariffs and shifting trade patterns

The imposition of US import duties on Moroccan and Russian phosphate fertilizers towards the end of 2020 (*Fertilizer International* 500, p8) has had a major market impact, both on the US market and global trade flows. Both Russia and Morocco have essentially stopped exporting to the US, causing domestic phosphate shortages and price hikes. Consequently, US prices are now at a premium in comparison to international price levels.

To make up the domestic shortfall, the US is expected to import more phosphate products from Saudi Arabia, Australia, Mexico, Jordan and Egypt in future. Some US exports are also likely to be diverted away from Brazil and Canada and be earmarked for the home market instead, to be replaced by Moroccan and Russian product (*Fertilizer International* 502, p42).

"US countervailing duties are likely to remain through 2025, perhaps longer, and phosphate trade will consequently remain disrupted. This new pattern of trade is expected to last," CRU analyst Glen Kurokawa commented in March.

The imposition of phosphate duties followed the successful petitioning of US authorities by The Mosaic Company (*Fertilizer International* 497, p8). Similarly, CF Industries is currently petitioning the US Department of Commerce for tariffs to be imposed on imports of urea ammonium nitrate (UAN) from Russia and Trinidad and Tobago.

References

1. TFI, 2019. *2019 State of the Fertilizer Industry Report*. The Fertilizer Institute, Washington.
2. Nutrien, 2020. *Nutrien Fact Book 2020*. Nutrien, Saskatoon, September 2020.

Low-carbon fertilizer production

Major fertilizer industry players such as Stamicarbon, Nutrien and CF Industries are ramping up investment in 'green' and 'blue' fertilizer production. Consequently, low-carbon production technologies are being scaled-up and deployed commercially.

STAMICARBON

Stamicarbon's road to green fertilizers

The world is facing a climate challenge, with the global fertilizer industry accounting for 2.5 percent of global greenhouse gas emissions. Therefore, as countries move towards a carbon-free, sustainable future, the fertilizer industry has to contribute to both reducing emissions and accelerating the transition to a green economy.

With these aims in mind, Maire Tecnimont Group – inspired by the United Nations Sustainable Development Goals – launched its sustainability strategy in early June this year. The strategy embraces a concept of innovation that is economic and social in nature, not just technological.

The strategy is also designed to position Maire Tecnimont as an enabler of the energy transition worldwide – with a focus on people, their well-being, as well as the communities in the various geographies in which the company operates. From this sustainability perspective, Stamicarbon, the innovation and licensing company of Maire Tecnimont Group, is determined to embrace innovation and invest in sustainable, carbon-free fertilizer production. Stamicarbon is pursuing this through:

- The introduction of Ultra-Low Energy technology to reduce plant steam and cooling water consumption, while reducing biuret content in the final urea product.
- The *MicroMist*™ Venturi Scrubbing system to significantly reduce particulate matter and ammonia emissions.
- The Stami Green Ammonia technology package to enable carbon-free fertilizer production using renewable energy resources.
- The development of the first commercial renewable power-to-fertilizer plant in Kenya.
- Its participation in the INITIATE project. This is bringing about more sustainable steelmaking by re-using captured carbon dioxide from steel mills in the production of blue ammonia and/or urea.
- Working to enable continuous production of green hydrogen using renewable power as a partner in the European PROMETEO project.

Stami green ammonia

Ammonia is produced in massive volumes across the globe as a basic chemical. This large-scale, highly energy-intensive industry also consumes natural gas and coal as feedstocks in large volumes.

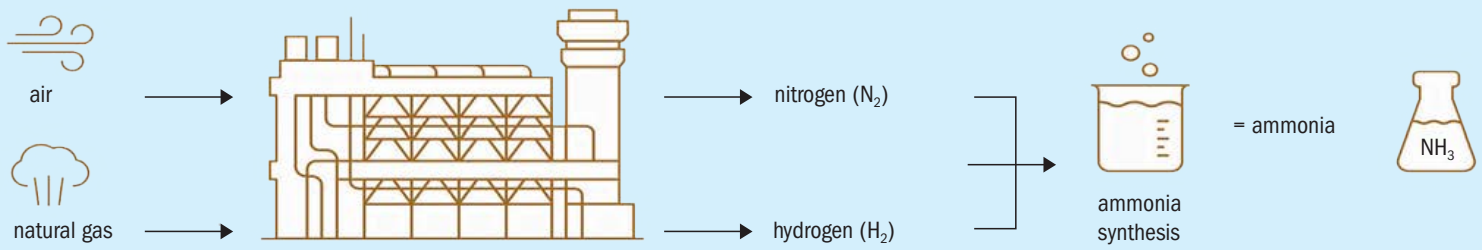
Over 80 percent of the ammonia produced globally is destined for nitrogen fertilizer manufacture. This, in turn, accounts for more than one-half of the worldwide fertilizer market. Unsurprisingly, given its production scale, conventional ammonia manufacturing contributes significantly to climate change.

However, through its introduction of the Stami Green Ammonia technology package, Stamicarbon is supporting the ammonia industry's transition away from hydrocarbons and towards renewables instead. This technology makes it possible to produce 'green' ammonia economically from renewable energy sources – for use as a raw material in the manufacture of 'green' nitrates.

From grey to green ammonia

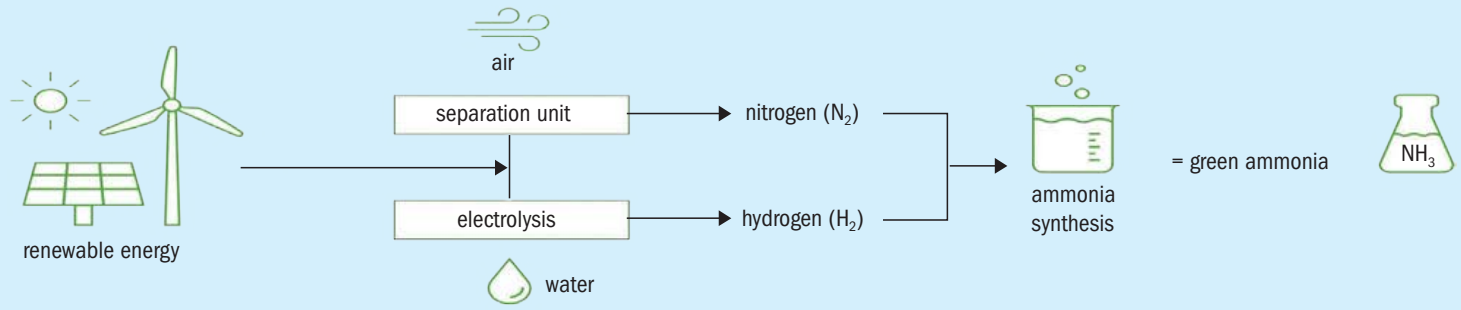
Green ammonia technology offers a sustainable alternative to conventional 'grey' ammonia production via the Haber-Bosch process. This captures nitrogen from the air and combines it with hydrogen derived from hydrocarbons (most commonly natural gas) through a conversion process known as steam reforming (Figure 1).

Fig. 1: **The 'grey' ammonia production process**



Source: Stamicarbon

Fig. 2: **The 'green' ammonia production process**



Source: Stamicarbon

The use of fossil fuels as feedstocks for ammonia production generates carbon monoxide alongside hydrogen in the first step of the process. While hydrogen is consumed further on in the process during ammonia synthesis, carbon dioxide, having no further role to play, is mainly released into the atmosphere.

Green ammonia production, in contrast, eliminates carbon from the process by using water electrolysis to derive hydrogen, then adding nitrogen sourced from the air, and powering the rest of the production process with renewable energy sources. No fossil fuels are involved in electrolytic separation of water into hydrogen and oxygen as the electricity used is derived from renewable sources such as solar, wind, water, and geothermal energy (Figure 2).

In short, with Stamicarbon's Green Ammonia technology package, sustainable, carbon-free ammonia can be produced from natural elements like the sun, air and water. The process needs a constant supply of renewable energy – meaning the location of the plant needs to be considered carefully. It is usually best to build a green ammonia plant near the energy source to optimise the financial model. Other alternative power options include: obtaining renewable electricity by connecting the plant to a green energy grid or hydropower, capturing surplus energy and storing it for later use, using geothermal energy, and even by burning green ammonia itself.

Stami Green Ammonia technology – key features

A Stami Green Ammonia plant offers a viable solution for tackling the global carbon challenge by using renewable energy to power ammonia synthesis instead of fossil fuels. This first-of-its-kind technology is configured using a modularised approach, making it perfect for small-scale plants. It is offered under an exclusive cooperation agreement with Argentinian-based Raybite S.R.L. to commercialise its proven ammonia technology package.

The package is available in two proven, small-scale ammonia production design capacities – 100 t/d and 200 t/d of – but can be scaled upwards. The resulting Stami Green Ammonia plant has a lean and compact design, with a footprint of approximately 15 by 30 metres, including the compressor building, and consumes about 35-70 megawatts (MW) of power, depending on the plant's capacity (Figures. 3 & 4).

In recent times, technological developments in the fertilizer industry have typically focused on economies of scale and delivering ever higher fertilizer production outputs. However, now that the industry is moving towards greener technologies, new factors such as the availability of renewable electricity and the limits on electrolyser production capacity must be considered, as these are not yet sufficient to supply large-scale projects at short notice. Stami Green Ammonia technology currently has four operating references. This is the strongest reference list for the small-scale ammonia plant concept, providing a good basis for its further development in future.

In summary, the technology incorporates the following key features:

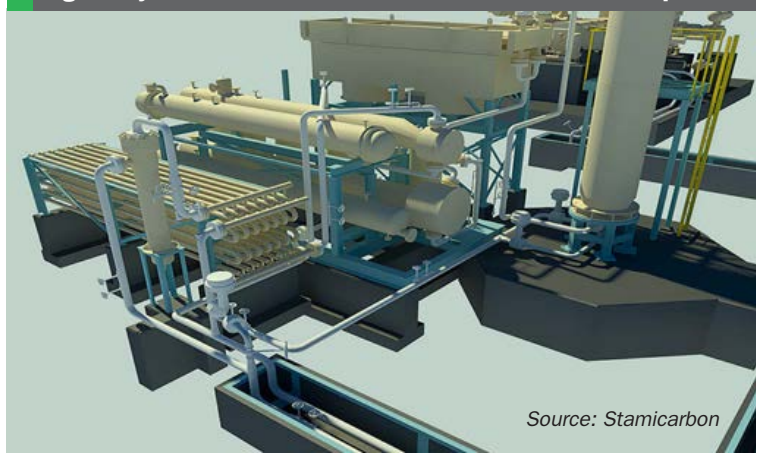
- Capex efficiency
- Strong reference base with four small-scale plants in operation
- Lean, compact, modularised design
- High plant reliability with a proven track record
- Full compliance with environmental standards.

The main technological feature of Stami Green Ammonia is the use of a high-pressure ammonia synthesis loop (synloop) operating at approximately 300 bar. This has been customised to deliver the most efficient small scale plant design. This efficient design allows ammonia to condense

Fig. 3: **3D model of a Stami Green Ammonia plant**

Source: Stamicarbon

Fig. 4: **Synthesis section of a Stami Green Ammonia plant**



Source: Stamicarbon

with the cooling water, eliminating the need for a refrigerating compressor. As a result, the plant operates using just one proven and reliable electric-driven reciprocating multiservice compressor. The minimal amount of equipment needed to operate the plant delivers a substantial Capex saving, which is generally an important consideration for small-scale applications.

Overall, the technology package offers a competitive solution for local, small-scale production and, when used in combination with Stamicarbon's existing urea and mono-pressure nitric acid technologies, can produce ammonia-based fertilizers such as greener urea (using recycled or recovered CO_2) and green ammonium nitrate. By applying this same technology towards blue ammonia and urea production, Stamicarbon also plans to help other industries such as steelmaking become more sustainable.

The first renewable power-to-fertilizer plant project

Go ahead has been given for the construction of the first commercial Stami Green Ammonia plant at the Oserian Two Lakes Industrial Park in Kenya, 100 kilometres from the capital Nairobi (Figure 5). Stamicarbon will contribute both its new green ammonia and its existing nitric acid technologies to this renewable power-to-fertilizer project. The company is working alongside other Maire Tecnimont subsidiaries, MET Development and NextChem, to build the world's first commercial nitrate fertilizer plant operating at industrial scale (circa 200,000 t/a) powered exclusively by renewable energy sources. By demonstrating the viability of the renewable power-to-fertilizer concept today, this pathfinder project will pave the way for future projects and growth in green fertilizer production.

The plant will be powered by 70 MW of renewable power, primarily geothermal and solar energy. This will cut emissions by 100,000 tonnes CO_2 annually, compared to a conventional fertilizer plant powered by natural gas.

Preliminary engineering work on the project has already begun. NextChem also plans to start front-end engineering design (FEED) by the end of this year, with commercial operations scheduled to begin in 2025. Once built, the new plant will produce 550 t/d of calcium ammonium nitrate (CAN) and NPK fertilizers to supply local agricultural demand.

Fig. 5: **Location of the first renewable power-to-fertilizer plant**

The first-of-its-kind green fertilizer plant at Oserian Two Lakes Industrial Park will support local fertilizer production in Kenya, helping to secure the availability of domestically-produced fertilizers throughout the country's agricultural season.

Oserian Two Lakes Industrial Park is a 150-hectare sustainable development project in Nakuru County, Kenya. The privately-owned park, operated by the Oserian Development Company, is drawing in businesses and investors to support the sustainable industrialisation of East Africa. It already contributes greatly to Kenya's development and broader economy and is set to generate hundreds of jobs locally. The park is a part of a larger mixed-use development called Oserian Two Lakes. Spread across 7,500 hectares, this combines horticulture, industry & commerce, residential properties and tourism with wildlife conservation.

Participation in European green initiatives

Stamicarbon is participating in the EU-funded INITIATE project – the acronym standing for 'innovative industrial transformation of the steel and chemical industries of Europe'. The project is examining the use of carbon-rich off-gases from steel mills as feedstock for urea production. Modular carbon-capture utilization-and-storage (CCUS) technology is at the core of this process, as it allows the conditioning of steel gases to be integrated with ammonia synthesis.

Stamicarbon will be responsible for the project's commercial implementation plan and will also supply its small-scale urea and green ammonia technologies. These will be demonstrated at a pilot plant currently under construction in Luleå, Sweden. The initial objective is to judge the viability of the project's concept and prove the ammonia production capability before advancing to build a urea production reference plant in the next stage. The project consortium includes various steel, chemical and energy transition companies, research institutions, universities, and industrial partners active in the fertilizer and steel industries.

Stamicarbon is also applying its green ammonia technology as part of the PROMETEO venture. This European Horizon 2020 project aims to develop an innovative prototype for the continuous production of green hydrogen via high-temperature electrolysis powered by renewable energy. This innovative solution will address intermittency in the supply of solar power by managing energy conversion and re-generation. Green hydrogen produced in this way will contribute to green ammonia and green fertilizer production.

The future is sustainable

The world's population will grow to nearly 10 billion people by 2050. By this date, hundreds of countries globally will also have to achieve their net-zero emissions targets under the Paris Agreement. In future, ammonia, an integral component of nitrogen fertilizers, will also need to be produced sustainably – if it is to minimise environmental impacts, comply with new legislation and meet climate commitments. Stami Green Ammonia provides a 'futureproof' gateway to carbon-free ammonia production, as well as delivering a smart, sustainable, renewable feedstock for the production of nitrogen fertilizers. ■

NUTRIEN

Low-carbon ammonia – harnessing decarbonisation on a global scale

Blake Adair, Senior Manager, Innovation and Environmental Performance

At Nutrien, our purpose is to grow our world from the ground up. As the world's largest provider of crop inputs, services and solutions, we play a key role in feeding the future by helping growers sustainably increase food production. It's a role we take seriously, because by 2050, there will be about 10 billion people to feed around the world.

The development of low-carbon ammonia for use in agriculture, industry and as an energy source is a key strategic pillar of our aspirations to be a leader in sustainability across the agriculture value chain and in emerging energy markets.

Agriculture

The economics of farms across the planet are beholden to local and international commodity pricing. It is uncommon for farmers to be financially rewarded to lower the carbon intensity of their products. This needs to change if we are to drive-up the adoption and widespread use of low-carbon ammonia and its derivative fertilizer products. Late last year, our retail group launched a new carbon programme for our farmer customers. This provides them with end-to-end support to drive sustainable agriculture while boosting their profitability – using a combination of science, technology and a carbon credit system that builds a new market around positive carbon outcomes. We believe that, over time, this will de-risk the positive changes in farm practice required, by providing growers with the incentives they need to make the most sustainable fertilizer choices, allowing us to rapidly decarbonise the fertilizer industry.

Ammonia's potential role in the decarbonisation of our current energy system is an exciting opportunity. But it must be developed in lock-step with the United Nations Sustainable Development Goals (SDGs). As outlined in the SDGs, it is critical that we implement climate solutions that do not threaten food security. If our food systems are put at risk, we would subject the world's most vulnerable populations to undue hardship. Responsible development must also be mindful to neither increase the utilisation or construction of coal-based ammonia capacity. Low-carbon ammonia's development should be viewed as an opportunity to address climate change, but also serve as a catalyst to help eliminate hunger and poverty.

As the economics of using renewable energy sources improve over time, there is potential for significant investment and development of green ammonia technology. This could be powered by renewable electricity, an abundant resource in many

regions globally, including the developing world. As technology costs decline and efficiency improves, small- and medium-scale green ammonia plants could also be a supplier of commercially viable ammonia for agricultural use at a local level across the globe.

Earlier this year, we announced a collaborative effort to explore flexible zero-carbon ammonia production. Nutrien is one of 15 organisations involved in the US Department of Energy-funded Renewable Energy to Fuels Through Utilization of Energy-Dense Liquids (REFUEL) integration and testing programme. which is working to create a carbon-free process for generating ammonia. The partners are developing a one metric tonne-per-day, low- and zero-carbon ammonia facility. This will produce ammonia for use in agriculture, electricity generation and/or as a fuel.

There are also viable low-carbon blue ammonia pathways that can drive meaningful emissions reductions today. These include steam methane reforming of natural gas with carbon capture and permanent sequestration, as well as emerging methane pyrolysis technology. There is also significant potential to hybridise existing steam methane reforming facilities. A portion of the necessary hydrogen can be supplied via electrolysis of water using carbon-free electricity. The oxygen produced from the electrolysis unit can be directed to the reforming process to reduce the amount of required fuel gas and their associated greenhouse gas (GHG) emissions.

The goal of all low-carbon ammonia stakeholders should be the development of a functioning and economically viable global supply chain that meets emissions reduction targets. This will necessitate the development of low-carbon ammonia technology that plays to the strengths of regional geography, resources, and regulatory environments. Debating the merits of blue vs green, or blue then green, is counterproductive. We need all pathways to be responsibly developed across the globe now.

Taking action

Nutrien continues to advance its climate strategy. The company has defined several commitments and targets and identified numerous opportunities to reduce our emissions, all of which are supportive of a low-carbon transition plan. Specifically, Nutrien intends to reduce its GHG emissions intensity by 30 percent and invest in low-carbon fertilizers as two of the six 2030 commitments in its *Feeding the Future* plan. Nutrien supports the goals of the Paris Agreement and has made a commitment through the Science Based Targets initiative (SBTi) to set a science-based target.

In line with our commitments, the development and use of low-carbon ammonia figures prominently in our strategy. This is unsurprising, given our status as one of the largest producers of low-carbon ammonia in the world today. It also supports the range of strategies needed to meet society's wider decarbonisation goals. Nutrien has been pursuing the development of low-carbon ammonia for more than a decade, possessing approximately one million tonnes of production capability through its Redwater and Joffre, Alberta operations, as well as its Geismar, Louisiana facility.

Fig. 1: **Hybrid blue ammonia production at Geismar, Louisiana – how it works**

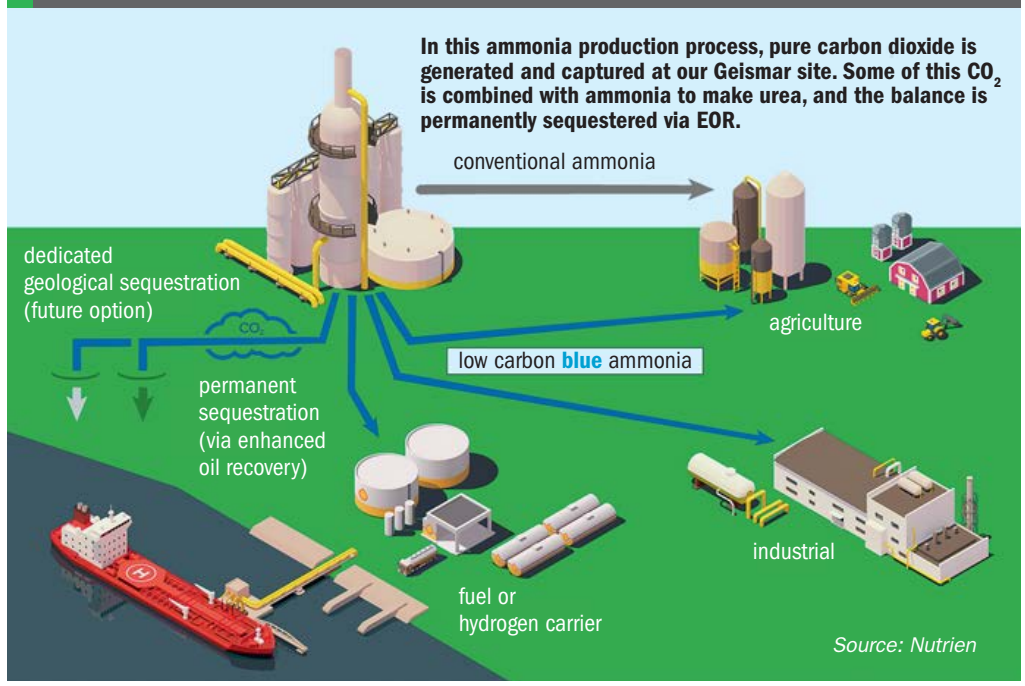


Fig. 2: **Nutrien's Geismar, Louisiana, facility has tidewater access**

PHOTO: NUTRIEN

Low-carbon ammonia hub

Nutrien's Geismar location has the potential to become a low-carbon ammonia hub. Our operations are tied into a CO_2 pipeline network that transports CO_2 mined from underground reservoirs for use in enhanced oil recovery (EOR). In 2013, Geismar began directing previously vented process CO_2 into this pipeline network for permanent sequestration. As the US Gulf Coast's CO_2 infrastructure matures, dedicated sequestration will be a viable alternative to EOR, especially when supported by regulations such as the 45Q tax credit.

Nutrien's Geismar ammonia plant (Figure 1) is a hybrid Carbon Capture and Sequestration (CCS) facility that makes two grades of ammonia – conventional grey ammonia and low-carbon blue ammonia. The grey ammonia is primarily upgraded into urea

to supply the agricultural market. The low-carbon blue ammonia has a range of end-markets being suitable for use in agriculture, industry or as a fuel or hydrogen carrier

Location advantage

Low-carbon ammonia produced on the US Gulf Coast can be rapidly scaled to significantly cut emissions. Geismar has the capability to produce 200,000 tonnes of low-carbon ammonia annually. The site is well positioned to expand production through regional access to abundant and low-cost natural gas, a skilled workforce and world-class carbon capture and sequestration infrastructure. In addition, Geismar has tidewater access (Figure 2) that can accommodate a wide variety of ammonia vessels, including Nutrien's existing fleet of four ammonia vessels equipped for global distribution. With these geographical advantages, the low-carbon ammonia produced will drive significant and meaningful emissions reductions, doing so at a competitive cost for use in agriculture, industry or emerging fuel markets.

"Nutrien is positioned to supply emerging low-carbon markets in agriculture, industry or for use as a fuel. Our recently announced collaborations will leverage Nutrien's geographical advantages, technical expertise and global scale to help move the needle on low- and zero-carbon ammonia production, reduce maritime emissions and will set the stage for a globally decarbonised ammonia supply chain in the years ahead," comments Raef Sully, Nutrien's EVP & CEO, Nitrogen & Phosphate.

Partnership to decarbonise shipping

Nutrien supports the decarbonisation of shipping and the International Maritime Organization's (IMO) greenhouse gas strategy to reduce emissions. Nutrien recently announced a collaboration with one of its global shipping partners to develop and build a low-carbon-ammonia-powered vessel by 2025, marking an important step forward in this journey. We believe it will provide a repeatable pathway for wide adoption of low-carbon ammonia as a clean fuel for the maritime industry.

When compared to conventional fuels, the use of Nutrien's existing low-carbon ammonia is expected to achieve GHG emissions reductions of up to 40 percent. Further emissions reductions of up to 70 percent can be achieved with the development of low-carbon ammonia using proven, scalable, best available technology and the permanent sequestration of CO_2. We are confident that development of a vessel powered by low-carbon ammonia can align with IMO's GHG emissions reduction goals for 2050. Indeed, we expect deep decarbonisation of the maritime industry to be achievable prior to 2030.

Safety

Nutrien has been shipping ammonia safely for more than three decades, having transported about 45 million tonnes of ammonia over that time across the globe – to North America, Africa, Latin America, Europe and Asia. On average, Nutrien's fleet of four ammonia vessels complete about 60 voyages per year. Nutrien will continue to conduct its operations and processes in a way that builds on its excellent safety record.

Looking forward

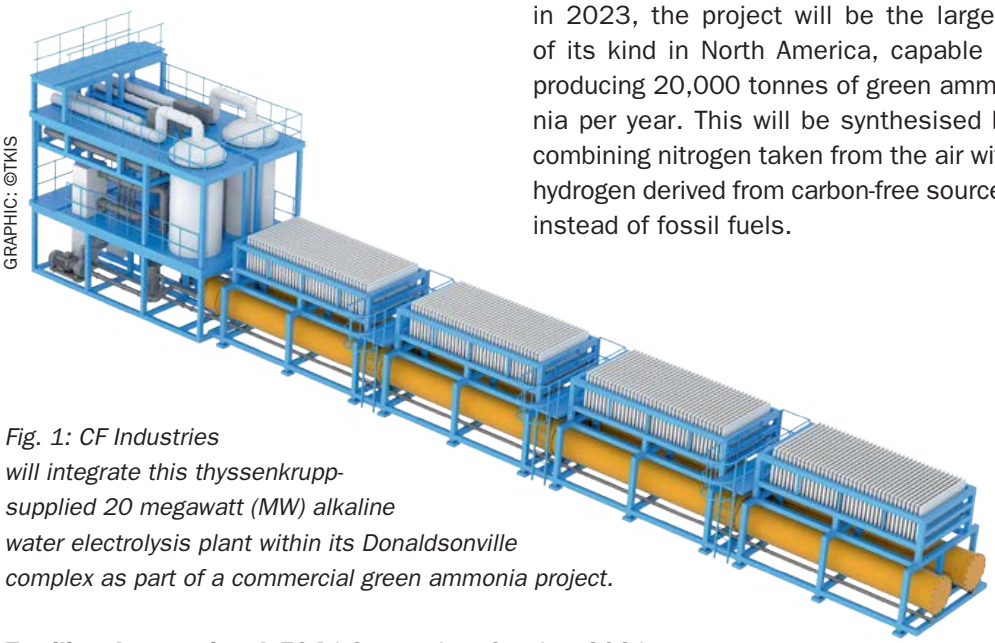
In summary, low-carbon ammonia can pave the way to developing a functional global supply chain, leading to the integration of zero-carbon ammonia as projects and technology for its manufacture are developed.

Nutrien will continue to assess the scope and investments required for transformational low-carbon ammonia production pathways, including exploring technology partnerships, investing in internal research and pursuing scalable pilot projects to enable commercial-scale production in the future. ■

CF INDUSTRIES

Charting a path towards decarbonisation

The world's largest ammonia producer is at the beginning stages of a project that will help chart the path forward for the fertilizer industry as it seeks to reduce its carbon footprint.



GRAPHIC: ©TKIS

Fig. 1: CF Industries will integrate this thyssenkrupp-supplied 20 megawatt (MW) alkaline water electrolysis plant within its Donaldsonville complex as part of a commercial green ammonia project.

CF Industries is constructing commercial-scale green ammonia production capacity at its Donaldsonville site in Louisiana, the world's largest ammonia manufacturing complex. When completed in 2023, the project will be the largest of its kind in North America, capable of producing 20,000 tonnes of green ammonia per year. This will be synthesised by combining nitrogen taken from the air with hydrogen derived from carbon-free sources instead of fossil fuels.

The Donaldsonville green ammonia project is one key aspect of CF Industries' strategy to help accelerate the world's transition to clean energy. To do this, the company is committed to decarbonising its ammonia manufacturing network through the production of both green and blue ammonia, and by pursuing other greenhouse gas reduction projects. Blue ammonia is generated by removing by-product carbon dioxide via carbon capture and sequestration (CCS).

"As countries and industries continue to develop plans to achieve net-zero carbon emissions, there is broad interest in clean hydrogen and ammonia to help meet the world's clean energy needs" said Tony Will, CEO of CF Industries. "Our green ammonia project highlights the competitive advantage our world class ammonia production network offers to industries sourcing carbon-free energy and reinforces our

CF Industries' Donaldsonville site in Louisiana is the world's largest ammonia manufacturing complex.

PHOTO: CF INDUSTRIES

commitment to make significant progress in reducing our carbon footprint by 2030."

Donaldsonville green ammonia project overview

CF Industries initially received approval for the green ammonia project from its board of directors in October 2020. Subsequently, in April this year, the company signed an engineering and procurement contract with thyssenkrupp to supply a 20 megawatt (MW) alkaline water electrolysis plant to produce green hydrogen (see Figure 1). This electrolyser will use renewable electricity to separate water into hydrogen and oxygen. It will be integrated into the existing ammonia plants at Donaldsonville and then produce green ammonia by fixing atmospheric nitrogen with carbon-free hydrogen.

> **The company's commitment to clean energy is exemplified by its ambitious goals on reducing carbon emissions.**

The electrolyser is based on thyssenkrupp's world-leading chlor-alkali electrolysis technology and benefits from the German company's decades of experience in large-scale industrial electrolysis. To simplify the construction of new hydrogen plants and keep costs down, thyssenkrupp's electrolysers come in prefabricated skid-mounted modules. The modular nature of the technology allows additional units to be added, enabling green ammonia production to be scaled-up in the future, while also taking full advantage of the Donaldsonville site's existing infrastructure.

"By integrating the water electrolysis plant into existing ammonia production at Donaldsonville, we will build on our ammonia manufacturing expertise and identify efficiencies that will allow us to scale production in the future," said Ashraf Malik, senior vice president, manufacturing and distribution at CF Industries.

Today, CF Industries purchases a substantial volume of renewable energy across its network – far more than will actually be needed to supply the new electrolyser being constructed in Donaldsonville. The company also continues to pursue additional opportunities to procure renewable energy when and where it is available.

In August this year, the company announced that, beginning in late 2021, 100 percent of the electricity purchased for the company's manufacturing complexes in the United Kingdom will be from renewable sources, up from 23 percent currently. This commitment should increase the total amount of electricity the company procures from renewable sources from 22 percent to 38 percent, based on CF Industries' electricity purchases across its entire network in 2020.

Decarbonising to meet clean ammonia and hydrogen demand

The current focus on climate change and greenhouse gas (GHG) emissions globally has created a push to decarbonise more than just ammonia production. Indeed, to achieve global climate goals and cut GHG emissions, the world needs to dramatically increase and scale-up clean energy technology. CF Industries believes decarbonised ammonia can help meet these objectives by creating a multiplier effect – replacing fossil fuels as an energy source for other industries, as well as reducing GHG emissions from ammonia production

CF Industries views the prioritisation of clean energy as a natural evolution of its existing strategy. As the company works to aggressively decarbonise its production and distribution network, it expects to provide carbon-free nitrogen fertilizer that will continue to feed the crops that feed the world. Additionally, CF Industries expects to provide a clean energy source to support and accelerate adoption of a broader clean energy economy by enabling other industries to move away from carbon-intensive energy sources.

The company's commitment to clean energy is exemplified by its ambitious goals on reducing carbon emissions. The company has committed to decarbonising its production network, with the goal of reducing emissions intensity by 25 percent by 2030,

relative to a 2015 baseline.

The green ammonia project will contribute to this goal, as will a list of further GHG reduction projects that CF Industries has promised to identify by the end of 2021. The company has also set itself the goal of becoming a net zero carbon business by 2050.

To achieve these goals, CF Industries is pursuing multiple paths for decarbonisation in addition to green ammonia production. This is important given that some still see green ammonia as being many years away from economic viability. Indeed, blue ammonia is seen by many industries as a potential alternative clean energy source that can be economically viable on a much shorter time frame. This is especially true for certain sectors that have traditionally been major contributors to carbon emissions.

Several industries are exploring ammonia as a fuel, including aviation and maritime transport as well as utility power generation. CF Industries is participating in a Joint Study Framework established by Itochu Corporation. This is identifying common issues faced by those wishing to use ammonia as a maritime fuel and then working towards solutions to these. In the initial phases of this effort, the company will contribute its expertise on ammonia production as well as the safe handling, transport and storage of ammonia.

In a further confirmation of its serious interest in ammonia's clean energy potential, CF Industries has also signed a memorandum of understanding with Mitsui, a leading global ammonia marketer, to jointly explore the development of blue ammonia projects in the United States. The two partners plan to execute preliminary studies covering areas such as:

- Blue ammonia supply and supply chain infrastructure
- CO_2 transportation and storage
- Expected environmental impacts
- Blue ammonia economics and marketing opportunities in Japan and around the world.

Green ammonia project timeline

All of the above initiatives are taking place in parallel with CF Industries' green ammonia project. The company, which is managing project construction and installation itself, expects to begin site preparation work this year. This includes the building of a storage warehouse for construction materials ready for when equipment deliveries begin next year.

CF Industries is already benefiting from the natural learning process required by this new project. One discovery has been the larger space requirements that are necessary for green ammonia production versus the conventional process. Eugene Britton, director, technical services at the Donaldsonville complex, likens this to the extra space needed to install solar fields or wind turbines for green energy production versus the space needed for a power plant.

"Our engineering team has worked hard to understand the underlying technology to ensure safe and efficient integration of the electrolysis process into our operation," said Britton. "There's a lot of work that goes into developing the equipment design and operating process to make sure we are simultaneously meeting CF safety standards, but we are proud to say that once finished, it will be the largest unit producing green ammonia in North America."

CF Industries expects green ammonia production to begin at Donaldsonville by the end of 2023. ■

The benefits of boron

U.S. Borax operates California's largest open pit mine in Boron, California.

PHOTO: U.S. BORAX

Boron is a key micronutrient required by fruit and vegetables and crops such as corn, cotton, rice, soybean and sugar cane. The agricultural importance of boron and the wide range of products on the market are described.

An attractive and growing market

Boron dominates the global agricultural market for micronutrients. The application of boron in agriculture reached 300,000 tonnes (B_2O_3) in 2018, equivalent to around 15 percent of global consumption. That compares to total global sales volume of around 65,000 tonnes for chelated micronutrients[1].

The main boron-consuming regions are East Asia, Latin America and Europe (Figure 1). About 35 percent of Chinese soils are thought to be boron deficient. Brazil's acid soils also tend to be deficient in boron as do the acid and sandy soils of Northern Europe.[1]

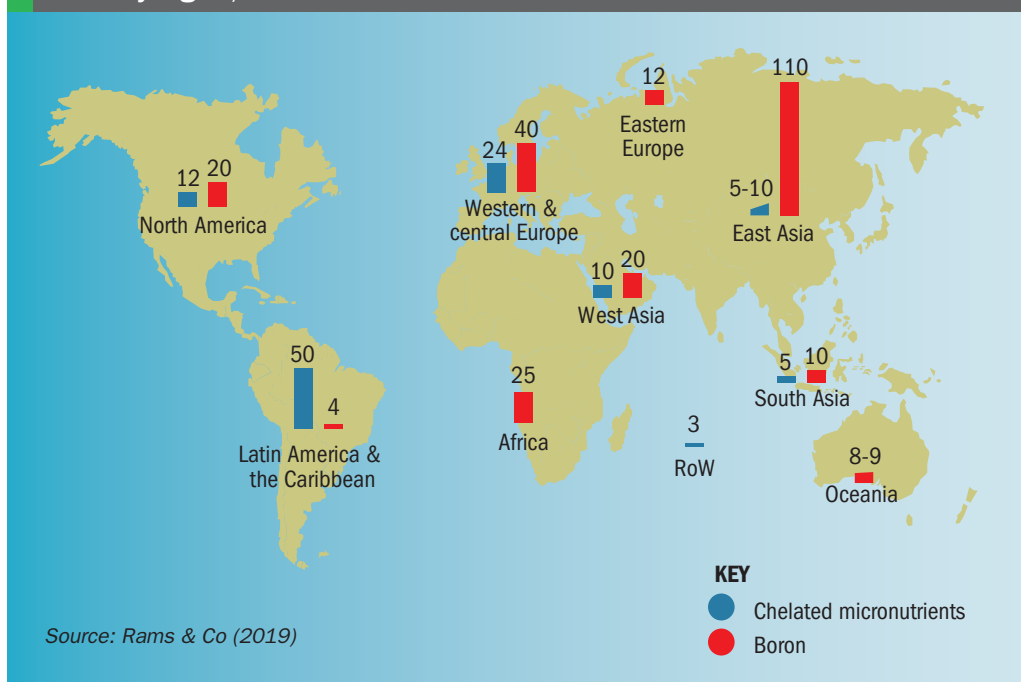
Boron is typically applied to crops at 0.25-3 kg/ha with higher rates generally required for broadcasting than for band applications or foliar sprays. Legumes and root crops usually require 2-4 kg/ha, while lower rates are advised for maximum yields in other crops[2].

Borax or other soluble borates are usually applied to soil before planting. These and other boron fertilizers should not be placed in direct contact with seeds or applied at levels that may be toxic to crops. Boron availability is negatively affected by drought conditions and the liming of acid soils[2].

The margin between deficiency and toxicity for boron is narrower than for other essential nutrients. That makes its application at the proper rate and with proper placement critical. Corn most effectively uses boron when it's applied through broadcast applications to soil, although foliar applications can be superior in other annual crops[2].

Boron, while classed as a micronutrient, can deliver major improvements in crop yields. In trials commissioned by U.S. Borax and others, boron fertilizers have been shown to multiply corn yields and increase cotton yields by hundreds of kilos per hectare, for example. Yet boron deficiency remains one of the most widespread of all crop deficiencies globally, affecting many major crop types.

Fig. 1: **Agricultural consumption of boron vs that of chelated micronutrients, by region, 2018**

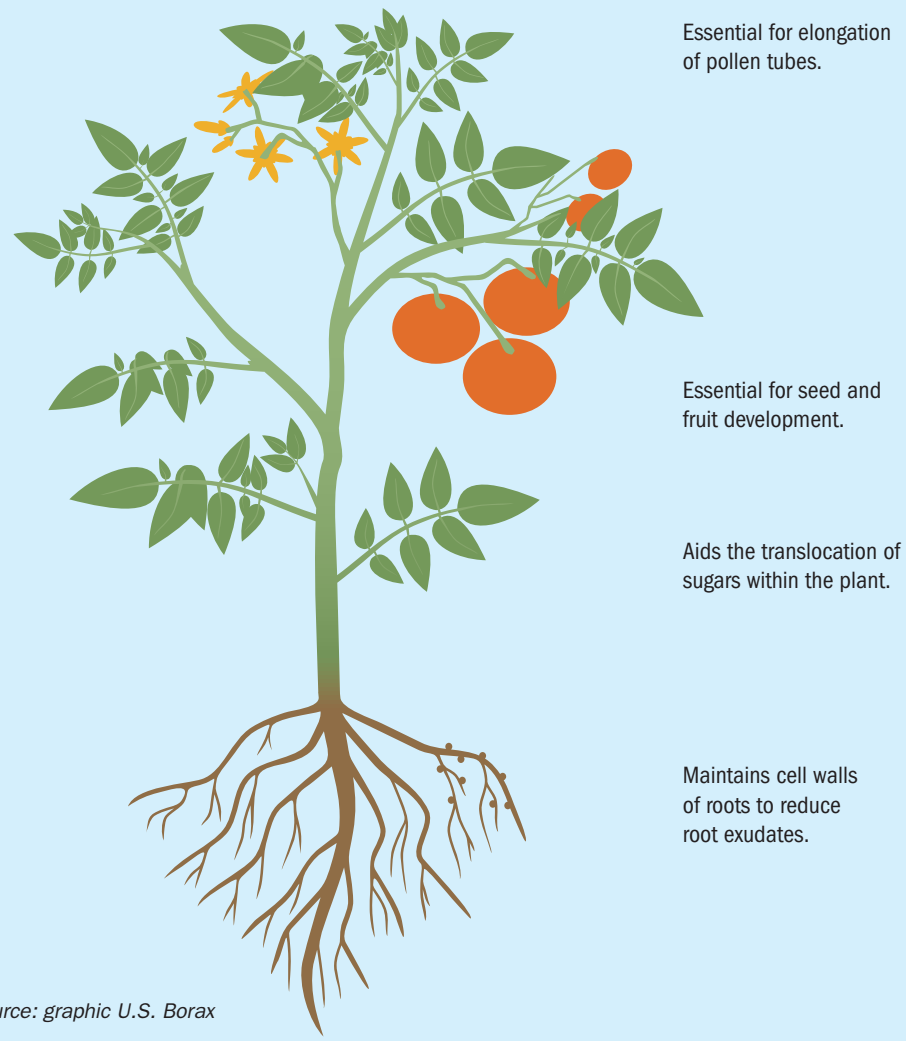


Essential for plant growth

Boron helps plants to synthesise structural carbohydrates and build strong, stable cell walls. Boron also enables sugars to form in leaves and then helps transport these to those parts of the plant where they are most needed – especially new growth and the root system.

In crops, boron plays a particularly vital role in the development of seeds and fruits – controlling flowering, pollination, reproduction, germination and fruit development. The

Fig. 2: **Boron's role in plant nutrition**



Source: graphic U.S. Borax

formation of root nodules in legumes also depends on an adequate supply of boron.

Boron's promotion of pollen tube growth is another key function. This is because successful pollination leads to good seed set and ultimately to abundant fruit, nut and grain yields. Boron's many influences as a plant nutrient can be summarised as follows (Figure 2):

- Aids production of sugar and carbohydrates
- Enables the translocation of sugars within plants
- Regulates metabolism of carbohydrates
- Helps synthesise nucleic acids
- Essential for cell division and development
- Maintains integrity of root cell walls
- Speeds up the onset of plant maturity
- Essential for elongation of pollen tubes
- Improves seed set
- Essential for fruit set and development
- Required for nodulation and nitrogen fixation in legumes
- Enhances the uptake of other nutrients such as Ca, Mg and K.

Boron, by maintaining the function and structure of root cells, is linked to improved uptake of phosphorus and potassium from soil. It is also believed to play a role in root colonization by *Mycorrhizal* fungi, another influence on phosphorus uptake. There is also evidence to suggest that boron helps protect plants against aluminium toxicity in low pH soils.

Widespread deficiency

Boron deficiency is the second most widespread micronutrient deficiency in soils globally after zinc. Unsurprisingly, deficiency is particularly prevalent in those crops with higher-than-normal boron requirements. Notably boron-hungry crops include alfalfa, canola, coffee, corn, cotton, oil palm, olives, peanuts, rice, soybean, sugar beet, sugar cane and tree fruits.

Deficiency is mainly associated with soils low in organic matter and, due to the potential for boron leaching, coarse-textured and well-drained sandy soils. Soils with high nutrient adsorption and retention capacities – such as high pH soils and those rich in clay minerals and iron or aluminium oxides – can also cause crop deficiency.

Organic matter generally increases boron availability as it typically acts as a store for plant-available boron in soils. Boron deficiencies are exacerbated by low soil moisture and drought periods because of the general decrease in root activity. Balanced crop fertilization generally helps to optimise boron uptake by improving plant vigour and healthy root growth.

Signs of boron deficiency firstly appear at new growth points. Water absorption, root growth and translocation of sugars are all negatively affected. Deficiency is damaging as it commonly results in empty pollen grains, poor pollen vitality and a reduced number of flowers per plant. Low boron supply can also stunt root growth – in soybean and canola (rapeseed) crops, for example. Common deficiency symptoms in crops include:

- Poor seed set or fruit set
- Breakdown of growing tip
- Yellowing between veins on young leaves
- Stunted new growth and dieback of shoot tips in vegetables
- Short bushy cotton plants
- Missing kernels in corn
- Yellowish to reddish yellow discolouration of the terminal foliage in alfalfa
- Root crops such as beets and turnips develop a corky dark discolouration
- Poor *Rhizobia* development in the roots of legumes.

Selected products and producers

Notable suppliers of boron fertilizers include:

- U.S. Borax
- Eti Maden
- The Mosaic Company
- Koch Agronomic services
- Nachurs Alpine Solutions
- ATP Nutrition
- Omex.

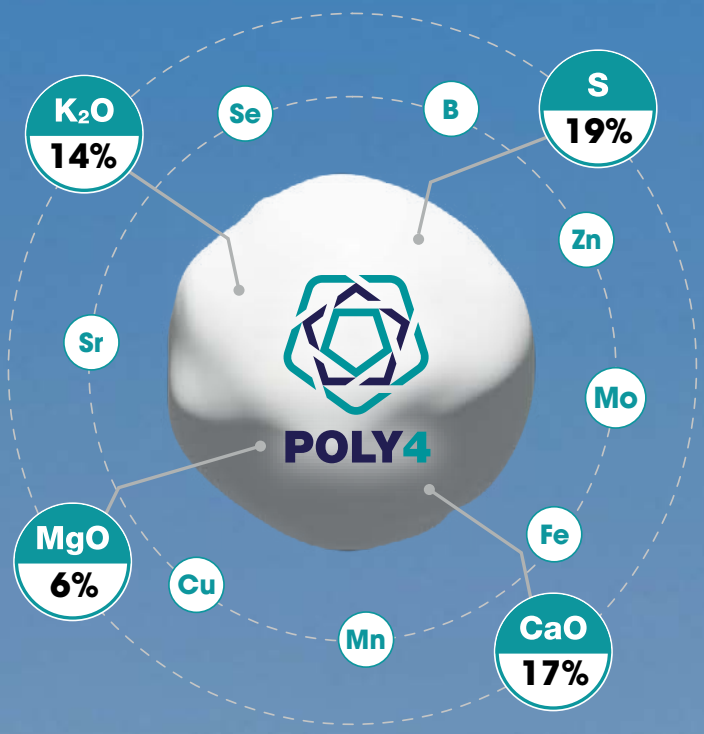
It is no coincidence that many of these companies are North American, given that boron deficiency affects crop production and quality across the region, according to **The Mosaic Company**. To address this, Mosaic launched *Aspire*, a boron-enhanced potash fertilizer, in 2014 (*Fertilizer International* 486, p18). This first-of-its-kind premium potash fertilizer (0-0-58-0.5B) combines potassium chloride (58% K_2O) with boron (0.5%).

Aspire is formulated to provide season long boron availability by containing both

Reimagining crop nutrition

POLY4

Our mission is to help farmers around the world to increase crop production by improving their **efficiency, effectiveness, flexibility, and sustainability.**



POLY4 is a multi-nutrient, low-chloride fertiliser derived from a naturally occurring polyhalite mineral. With no chemical processing and low carbon footprint during manufacturing, POLY4 is suitable for organic farming and offers season-long crop nutrition by supplying four essential nutrients – potassium, sulphur, magnesium, and calcium – in one product.

This balanced nutrition, backed up by years of global agronomic data, will help increase yields, improve crop quality, and enhance structure and nutrient legacy of soils.

From uniform granule packed with nutrients to uniform nutrient distribution on the field, POLY4 offers solutions and supports sustainable agricultural practices.

Whether you are a farmer or agronomist, blender or fertilizer distributor, discover POLY4 online at www.poly4.com.

POLY4™ is a registered trademark of Anglo American.

AngloAmerican

Beyond yield,

POLY4 improves crop quality

Soybean

14% increase in the number of pods per plant.

Larger soybean seeds are better for subsequent planting.

0.9% advantage in thousand grain weight.

Citrus

Improved fruit colouration, fruit size and healthier trees after POLY4 application.

5% more fruits.

3% sugar content increase and 8% higher vitamin C concentration.

Tomato

93% of evenly ripe tomatoes with POLY4 compared to 83% with SOP – better maturity improves mechanical harvesting.

Calcium supplied by POLY4 enhanced crop's disease resilience.

Less than 2% had blossom end rot disease compared to 10% with SOP – better marketable yield increases farmer economics.

Tea

48% of leaves graded as 'fine' compared to MOP+S's 38% – 'fine' graded tea leaves are of the best quality and receive higher value.

The proportion of damaged leaves was decreased from 22% with MOP+S to 13% with POLY4.

Better flavour and improved taste valuation scores.

quick-release sodium borate and slower release calcium borate. Boron is also uniformly distributed within potash granules using Mosaic's proprietary *Nutriform* technology. Aspire is being targeted at crops such as alfalfa, corn, cotton, potato, sugar cane and soybean, and has demonstrated significant yield improvements for these crops in field trials (*Fertilizer International* 486, p18).

U.S. Borax is the world's leading supplier of borates for agriculture. The company has conducted numerous agronomic studies and field trials for cultivated crops across the world, making it a technical leader in the industry. Part of London-based Rio Tinto Group, U.S. Borax operates California's largest open pit mine at Boron in the Mojave Desert (see main photo). This is one of only two world-class borate deposits globally, and supplies nearly one third of the world's demand for refined borates.

U.S. Borax constructed a boric acid plant at its Mojave site in 1980, helping secure the company's position as the world's leading boric acid producer. The company manufactures and markets three main products for use in agriculture: *Fertibor®*, *Granubor®* and *Solubor®*.

Fertibor is a sodium borate (15.0% boron) used in the manufacture of ammoniated, granulated, and suspension fertilizers. It works best in fertilizer suspensions broadcast before planting but is also the main source of boron in compound NPK fertilizers. *Granubor* is a granulated form of sodium borate (14.3% boron) for use with bulk blended fertilizers. It is suitable for dry blends broadcasted prior to planting. *Solubor* is a soluble form of sodium borate (20.5% boron) designed for liquid fertilizers and foliar sprays. It can be dissolved in water and applied to soils or directly on crops, with or without pesticides.

U.S. Borax also launched two new fertilizer products, *Anhybor®* and *Zincubor®*, on the market earlier this year – see interview on page 36. These have been created for fertilizer blenders and other companies wishing to produce micronutrient-enriched products (*Fertilizer International* 503, p20).

Anhybor® is manufactured from borax using a dehydration and fusion process. The product can be used to coat the different fertilizer constituents of NPK blends, with the aid of a binder material, or applied directly to soils. The high boron content of *Anhybor®* is an advantage, according to U.S. Borax, as less product is required to reach the target boron level.

Zincubor® is a two-in-one product that helps avoid the negative effects of zinc deficiency. It combines zinc and boron in "a perfect 2:1 ratio to meet the exact zinc and boron demands of most crops", says the company. *Zincubor®* can be used as a micronutrient coating for fertilizers, with the aid of a binder, or applied directly to soils. Valuably, the product can also be used to produce suspension fertilizers.

Eti Maden IGM is Turkey's biggest national mining company. It was established in 1935 to take advantage of the country's vast boron deposits – these holding almost three-quarters of world reserves. The company has since become the world's leading boron minerals and boron chemicals producer, and the largest exporter of refined boron products and minerals globally.

Eti Maden – previously known as Etibank and Eti Holding – set up a joint venture (JV) with the Finnish mining and multi-metal company Outokumpu Group in 1982. Known as Ab Etiproducts Oy, being

Omex MDS coatings

Boron is required for crop growth and reproduction. Deficiencies affecting more than 100 plant species have been reported in over 90 countries globally. **Andrew Lawrence**, export manager for fertilizer coatings at Omex Agrifluids, explains how boron deficiency and its impacts can be addressed.

During the early stages of crop development, boron deficiency will retard new growth and the development of roots, with symptoms usually showing in young leaves initially. As the crop develops, boron deficiency has clear negative effects on flowering response and pollination, leading to reduced seed, tuber, or fruit set. Maturation is often delayed, while reduced starch accumulation slows crop development and greatly increases the risk of structural problems in seeds and fruit. Boron deficiency is also associated with reduced tolerance to drought and heat stress, two factors which are likely to become more frequent due to climate change.

Hence, boron, alongside other nutrients, is acknowledged as being important to crop health. Calcium is another essential nutrient with a vital role to play in cell growth, development and tissue protection. By combining calcium with boron, to further enhance pollen tube elongation, it is possible to promote successful pollination and, crucially, avoiding unnecessary abortion of flowers. Recent product research by Omex Agrifluids has confirmed the important nutritional inter-relationship between boron and calcium. This realisation has enabled the company to move away from straight boron products and provide growers with more advanced product solutions that address broader nutritional requirements throughout the crop cycle.

It is well understood that addressing any lack of boron at the earliest possible stage of plant development pays dividends later. With this in mind, Omex's calcium enriched *MDS Boron* product allows growers purchasing granular fertilizer to apply boron as a fertilizer coating saving time and effort during the planting season.

The application rate of *MDS Boron* (8% B w/w) can be quickly adjusted to correct any specific deficiency identified by soil testing, allowing custom applications to be easily applied while controlling input costs. As the crop advances, *Omex Calcium Boron* (15% Ca & 3% B w/v) and the solution fertilizer *Omex Foliar Boron* (11% B w/w with nitrogen) can be very effective at correcting any remaining deficiencies, especially during times of environmental stress.

MDS coatings are typically concentrated suspensions specifically formulated to evenly coat the surface of each fertilizer granule. These coatings, by providing accurate field distribution, make vital nutrients available at the earliest stage of crop development. *Omex MDS* coatings are very easy to apply commercially with existing blending equipment. Additionally, at small holder farm level, the manual coating of fertilizers is also possible with only minimal investment in equipment required.

Omex *MDS* coating products include the full range of micronutrients and are compatible with a wide range of granular fertilizers – including NPK blends, compounds, and straights. Furthermore, trace micronutrients, typically selenium, cobalt and molybdenum, can also be included with *MDS* for a safe and accurate application to fertilizer materials. ■

the first foreign entity of Eti Maden IGM, this Finland-based JV is responsible for the international marketing and sales of the boron products produced by Eti Maden. The company initially sold into the Scandinavian market, although its marketing and sales activities have expanded greatly over time. Ab Etiproducts Oy's exclusive sales area now covers the Scandinavian and Baltic countries, Germany, Poland, Ukraine, Moldova, the whole of the African continent and Arab Gulf states.

To meet different crop requirements, Eti Maden offers several types of boron product in its agricultural portfolio. Boron can generally be provided to plants in two ways: typically being applied either in solid, granular form to soils; or in liquid form directly onto plant leaves. Agricultural products are generally either quickly dissolving sources of boron, such as *Etidot-67* and boric acid, or slow-release granular products (2-4mm size) such as colemanite and ulexite. Eti Maden's portfolio also includes such products as *KBor*, which contains one percent potassium chloride in combination with boric acid, and *Etifert*, a micronutrient fertilizer.

Application methods and product selection depend on several external factors, such as soil conditions, rainfall and the target crop. Ab Etiproducts Oy therefore always advises that an agronomist is consulted prior to application. ■

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Maximising boron efficiency with *Wolf Trax®*

The coating product *Wolf Trax® Boron DDP®* offered by Koch Agronomic Services (KAS) can supply boron efficiently to crops around the world, as **Matias Ruffo**, the company's senior agronomist for Latin America, explains.

Globally, boron is the second most widely used micronutrient and can have a direct economic impact if a crop experiences a boron deficiency. Due to its behaviour in the soil and crop, it can be a difficult nutrient to manage. Much like other micronutrients, boron faces similar challenges when it comes to segregation and lack of uniform distribution when applying granular micronutrient fertilizers alone or in bulk blends.

For most crops, boron is immobile within the plant which means the best way to supply boron to meet crop demand throughout the season is through root uptake (soil application). In contrast to its immobility in the plant, boron is very mobile in the soil and can be lost due to leaching, especially in sandy soils, high rainfall areas or under irrigation. This makes it challenging to supply boron over the entire growing season (and typically requires annual applications). Since plants are not very effective in regulating boron uptake, there is a very small range of optimal boron availability because high soil boron concentrations can result in phytotoxicity. This makes it critical to have a uniform boron distribution across the field.

To help address these management challenges, *Wolf Trax® Boron DDP®* (dry dispersible powder) is one solution capable of efficiently supplying boron to crops around the world. *Wolf Trax Boron DDP* features three exclusive proprietary technologies, *Evencoat®*, *Plantactiv®* and *Dual Action*, that help to efficiently deliver the boron nutrition that today's crops require to meet their genetic yield potential.

Boron and other micronutrients, when applied in bulk blends with macronutrients (NPKs), can suffer from segregation, resulting in uneven application rates of the micronutrient in the field. The *Evencoat* technology featured in *Wolf Trax* products ensures that boron is thoroughly and homogenously coated onto each granule of the fertilizer blend, thus eliminating the risk of segregation and its negative effects. With *Wolf Trax Boron DDP*, boron gets applied over the entire field at the precise and accurate rate.

Even when segregation is minimsed, bulk blends which incorporate granular boron products result in uneven distribution, with only a few granules of boron per square foot. This creates two issues. Firstly, the creation of high boron concentration 'hot spots' can cause phytotoxicity (which is typically not an issue for other micronutrients) where the boron granule falls. Secondly, very few 'feeding points' are available where roots can take up boron. This has a knock-on effect on crop nutrition – and explains why the typical boron application rate is much higher than the crop's actual requirements.

In contrast, the uniform, even distribution of boron achieved by coating every fertilizer granule with *Wolf Trax Boron DDP* results in more points of interception for the plant's roots to take up boron. This gain in efficiency allows for lower concentration rates compared to bulk blends. In addition, with *Wolf Trax Boron DDP*, the risk of boron toxicity is minimized as it doesn't generate the 'hot spots' that can occur with bulk blend applications.

As mentioned earlier, unlike other micronutrients such as, zinc or copper, boron is highly mobile in the soil profile and can leach past the root zone, particularly in sandy soils which are also typically boron deficient. Therefore, applying a highly soluble boron fertilizer can be cause for concern since it can be lost and, in some situations, lead to toxicity. Conversely, using a less soluble boron source has the risk of not supplying the boron that rapidly growing crops demand to reach high yields. To address these issues, *Wolf Trax Boron DDP* is formulated to safely deliver boron to crops throughout the growing season. The technologies found in *Wolf Trax* products provide three forms of boron with a range of solubilities to help ensure nutrients are available when crops need it most.

To help meet crop nutrient demands, *Wolf Trax Boron DDP* technology also provides unparalleled flexibility when it comes to customising the formulation to suit individual fields and crops. Conversely, compound or complex fertilizers that only supply boron at a fixed micronutrient-to-macronutrient ratio make it difficult to apply boron at the right rate.

To summarise, *Wolf Trax Boron DDP* helps address the most critical challenges for efficient boron crop nutrition, with in-built technologies that provide value, convenience and flexibility – both to the farmer and the fertilizer blender. ■

A better boron boost

Too many micronutrients are over-applied and under-utilised, but none more so than boron, says British plant scientist **David Marks**. Boron is one of the latest micronutrients to benefit from the 'functional fertilizer' approach developed by his company Levity Crop Science.

There is no simpler way to state it: boron is essential for healthy crops. An intrinsic part of the cell wall structure, this trace element is also vital in fruit and nut crops at flowering, pollen tube development and seed formation, for flag leaf development in cereals, and tuber bulking in potatoes.

"It's fair to say that a great many crops around the world rely on boron for robust yields, marketable quality and overall plant health," Dr Marks points out. "It's not that farmers aren't aware of the importance of boron; it's just that many of them don't see it as a problem, because boron's quite deceptive once it gets into the plant."

Crops readily absorb boron when it's available, Dr Marks explains, after which it's stored in leaves. "Growers are encouraged to tissue test for boron. Often the results will indicate ample boron levels, but that's not the whole story.

"Boron's mobility once in the plant is highly dependent on the individual crop. It can even change within the same crop according to growth stage or external environmental factors. The biggest mistake a grower or an adviser can make is in assuming boron behaves the same way, all the time.

"In avocados, for example, boron transport in the phloem relies on binding with complex sugars. But at times of stress, or when there's a need to conserve energy for flowering and fruit development, complex sugar production is turned off because it's carbon – i.e. energy – intensive."

In these circumstances, despite adequate levels, boron often won't reach the parts of the plant where it's most needed. This either encourages over-application, either in quantity or frequency – which can be risky, given boron's fine line between deficiency and toxicity – or no application at all because previous usage has appeared ineffective, notes Dr Marks.

> **"Growers are encouraged to tissue test for boron. Often the results will indicate ample boron levels, but that's not the whole story.**

Levity's expertise is in functional, or 'smart' fertilizers. Designed to improve not just yields and quality or, in the case of soft fruit, shelf life and brix, its products are designed and formulated to 'hijack' existing biochemical pathways within the plant. Nutrients such as calcium, molybdenum and another recent new development, silicon, are notoriously difficult to manage in many crops – something that Dr Marks aims to resolve.

"There's deep farmer frustration out there," acknowledges Dr Marks, "that crops often don't respond to these very simple trace elements and micronutrients, especially when they are so influential in determining overall and marketable yields.

"But with an understanding of exactly where the limiting factor lies, and how it manifests itself, we can design a product that gets the plant to do the heavy lifting, by making use of existing pathways.

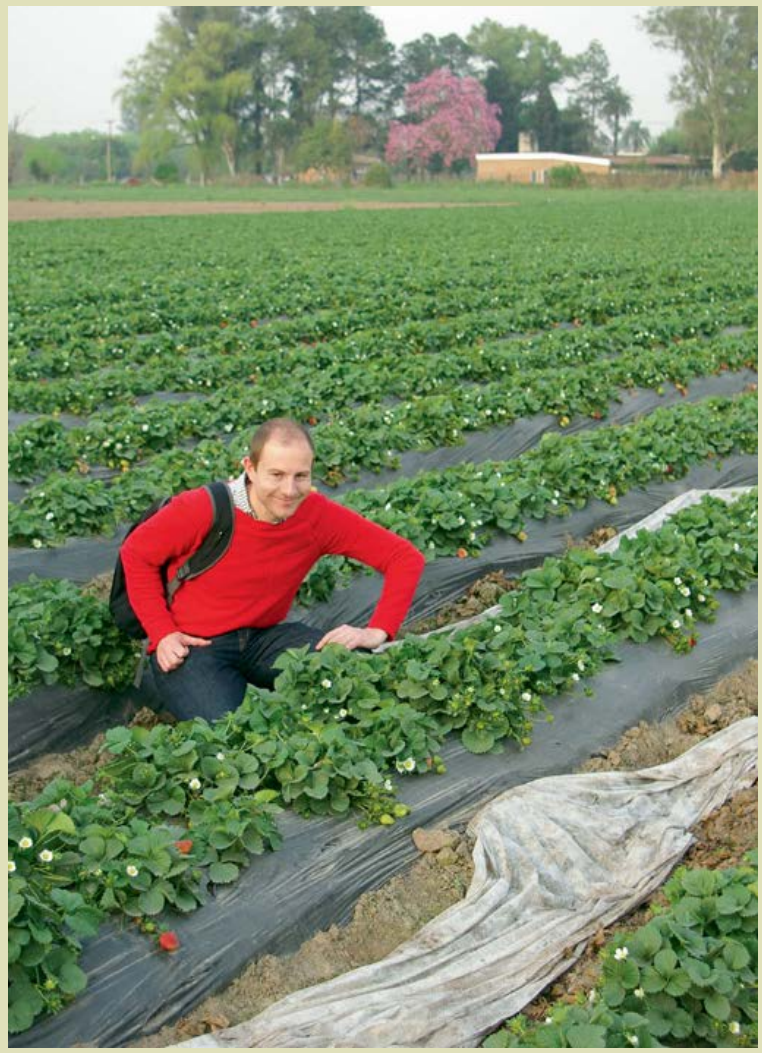

PHOTO: LEVITY CROP SCIENCE

Dr David Marks, founder and managing director of Levity Crop Science, inspects a UK strawberry crop.

"Take our calcium delivery product *Albina*, which contains proprietary *LoCal* technology. It improves marketable quality and shelf life in top and soft fruit. To make that work, we created our own calcium transport stimulant that emulates the plant hormone auxin – which is crucial in calcium transport."

Damu, Levity's boron product, takes a similar approach. Dr Marks and his team formulated a low-rate product that would avoid any phytotoxic effects, while adding a specially developed stimulant that triggers the plant to use and direct the boron where it's needed.

"In potatoes, for example, the best timing for *Damu* is during periods of excess vegetative growth, when it can 'train' the plant to focus on root and tuber growth instead. Meanwhile the low rate allows frequent applications to keep levels constant and replenished – allowing small amounts to be applied but ensuring highly efficient use of those applications with very little wastage."

Already enjoying success with some of Britain's leading potato producers, *Damu* is also finding favour with farmers in countries and crops beyond Levity's British base. "Peppers, tomatoes, avocados, citrus – these are all crops in which good, well-timed use of boron can deliver good fruit set and size," Dr Marks explains.

"What's more, we're doing all of this without harsh chemicals, thanks to identifying and working with the natural processes already present in the plant. It's an aspect that resonates with more and more growers, whether through pressure from buyers or their own commitment to changing the way they farm." ■

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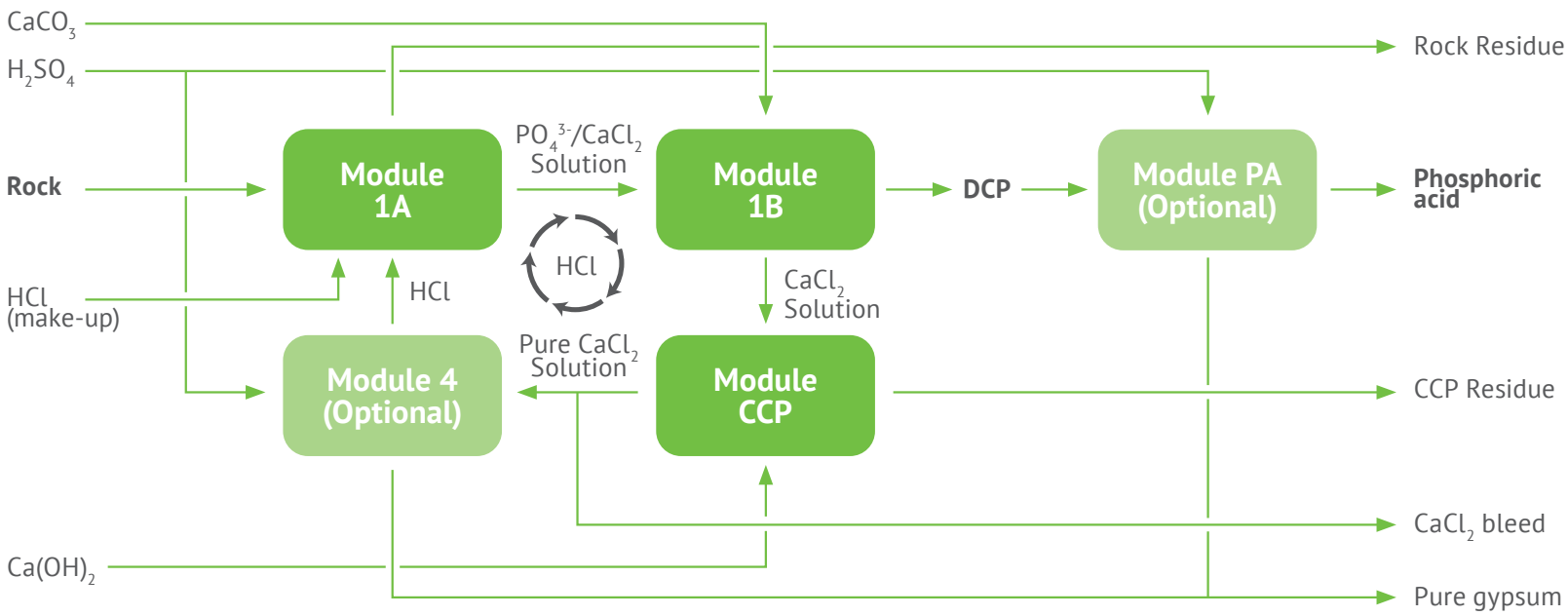

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PHOTO: U.S. BORAX

Wendall Boehlje, technical sales agronomist at U.S. Borax/ Rio Tinto.

U.S. Borax expands its agricultural portfolio

U.S. Borax operates California's largest open pit mine and a boric acid plant at Boron in the Mojave Desert.

In an exclusive, broad ranging interview, **Wendall Boehlje**, technical sales agronomist at U.S. Borax (part of Rio Tinto), talks to *Fertilizer International* about the launch of two new agricultural market products by U.S. Borax earlier this year.

> **A lot of farmers in our marketplace ask specifically for U.S. Borax when they need boron – because we're the ones who told them boron needed checking when others didn't.**

U.S. Borax launched two new boron products, *Anhybor*® and *Zincubor*®, in March this year. These are being offered alongside the company's three main pre-existing agricultural products, *Fertibor*®, *Granubor*® and *Solubor*®. What was the thinking behind their launch?

Anhybor is anhydrous borax. *Anhybor* is the answer to our competition. It's an excellent way to get boron into the soil solution or the system you're farming with.

One distinctive thing that we did in launching *Anhybor* was to experiment with the different binders used to stick anhydrous borax onto fertilizer granules and publish a technical bulletin with the test results. So, along with introducing these products, we have documentation to present to our customers showing there are inexpensive ways that you can bind these small particles of boron.

If you're going to use this kind of coating, we've done the research to show that you should use a binder to make sure that it stays attached. The U.S. Borax way is not just to offer products, but also send information on how to use them and why.

In the case of *Zincubor*, we sell zinc borate for industrial applications and looked at it closer for agriculture. We realized that the amount of zinc that's there, in relation to the amount of boron, is pretty much the exact ratio that you would want to add.

If people are adding zinc, they're adding boron, and here we have a product that has both of them included. So, let's offer it into the ag market directly.

***Anhybor* and *Zincubor* can be applied in several ways. For example, they can be directly applied to soils, incorporated to produce boron-enriched compound fertilizers, or used as a coating in NPK blends with the help of a binding agent. Is this flexibility a real strength?**

Different go-to-market strategies are needed with fertilizers in different regions or countries, right? They might not need the substantial amounts of boron provided in other products, as it's easier to over apply a granular product that's 100 percent soluble.

We want to avoid the risk of over application of boron where the science says we need a little less. That's where these two products fit in. Especially for those places where they're compounding fertilizers in large quantities.

The level of boron that's available in soils is really declining in most places in the world. How do we make sure that we have adequate boron for plant nutrition.

Water-soluble NPK fertilizers used in drip irrigation, for example, typically contain magnesium, sulphur and micronutrients as standard. Yet boron and other micronutrients, at least traditionally, have been less commonly applied in conventional broad acre agriculture. Is that still largely true – or is the situation rapidly changing, in your view?

I believe there is a realisation and understanding for every crop, when we test the soil here in North America, that boron is very, very consistently under the five parts per million threshold. There's really no available boron in the soil solution.

Some farmers even call me to tell me it's really low and ask how much boron they should apply. Other folks that are pushing the yield envelope, meanwhile, all of a sudden discover that boron's the thing that's keeping them from getting to that next plateau of yield attainment.

For commodity crops, there's been a real awakening in the last few years with steady advancement in the use of liquid boron products. Sales of boric acid into that market continue to totally outpace anything else.

Our customers are describing 2021 as a banner year in liquid boron applications. Their sheds are empty after the North American season. What that shows is pent up demand to use boron as soon as the commodity prices will reward that extra application. Farmers are going to do that this year because the economics are there and products are just flying out the door.

Boron dominates the global agricultural market for micronutrients, reaching around 300,000 tonnes (B_2O_3) in 2018, according to some estimates. Are there particular crop types and particular regions or countries where boron has made great inroads in recent years?

Being North American, I would say the Americas, right? But, yes, I believe there is a general awareness across the world that boron is the limiting factor for the higher yields that farmers are trying to reach now.

In India there's definitely a significant uptick in demand for borates, and 35 percent of Chinese soils are thought to be boron deficient too. Almost anywhere where they've been farming for a long time, as they certainly have in China, is depleted.

Growing up in Iowa, I'm aware that we're a nation of corn and soybean growers. Farmers who are really pushing yields are quickly realising that the amount of boron that's necessary to reach those really high yields in a crop like corn is pretty substantial – as that's how they get to an almost unbelievable 400 or 500 bushels per acre.

The same goes for soybeans. The flowering structures are where the greatest demand for boron is in the plant. Soybeans have a lot of flowers and you can't get a lot of bean pods without lots of flowers and can't get a lot of flowers if you don't have enough boron.

To what extent is technology – precision agriculture, fertigation and foliar fertilization – also driving up boron usage?

I wouldn't necessarily say that the use of precision agriculture is driving people to look at micronutrients. In fact, it's probably the other way around.

As people become more aware and understand that a micronutrient may be their limiting yield factor they look to the tools that are on the table today. Precision ag lets you build a prescription that includes micronutrient applications – so, I think it's more of a driver in the other direction.

Farmers with remote sensing are probably the one exception to that. They're understanding the need for micronutrients more quickly and asking questions that will lead to correcting micronutrient deficiency as the answer faster.

Many fertilizer manufacturers now offer growers a complete package that integrates the selling of plant nutrient products with agronomic information and services. How true is that of U.S. Borax – and how crucial is it to get a strong, positive message about boron out into the market?

Clearly, in the world of boron manufacturers and marketers, U.S. Borax stands out in that we actually have resources around the world, including people like myself. We pass on the message about the agricultural need for boron to our partners.

We are active in the ag market with those resources and with digital marketing too. That's been successful because a lot of farmers in our marketplace ask specifically for U.S. Borax when they need boron – because we're the ones who told them boron needed checking when others didn't.

> **"The U.S. Borax way is not just to offer products, but also send information on how to use them and why.**

We sell through distributors who have armies of agronomists on their staff. The boron message flows through those agronomists, who are consulting both with farmers and with us at the same time.

To grow the market for boron, is there also a need for strong partnerships – informal or formal – with fertilizer manufacturers, distributors and retailers as well?

Not only do we distribute directly to agronomy retailers, we also sell through our distributor partners who do resell our products to manufacturers.

We have some very large retail partners that we work with to get the right product mix. In North America the liquid product segment has been a huge part of the business, one that we've sold mostly boric acid into.

We now recognise that we also need to have our own branded products because of the sheer demand that's out there.

The launch of *Anhybor*® and *Zincubor*® demonstrates the commitment of U.S. Borax to innovation. What other new developments are we likely to see from the company in the way agricultural boron is marketed and sold?

There are two ingredients in 10 percent boron solution – boric acid which is dry and monoethanolamine (MEA) which is the liquid petroleum part. Well, recently there's been a shortage of MEA and that's revealed a couple of things.

Firstly, the supply chain is a little more fragile than anticipated and, secondly, there's probably room in the market for another formulation of liquid 10 percent. And it just so happens that U.S. Borax has one, *Solubor Flow*, that we're bringing back into the market.

In North America we'll be launching *Solubor Flow* again this year. It's actually a relaunch as it was first launched here 20 plus years ago.

On top of that, because the liquid market is robust, *Solubor Flow* plus potassium will also be coming onto the U.S. market next year. We've already patented its manufacturing and are also likely to lodge an applications patent for this product too. ■

Who's who in fertilizer handling, bagging and blending

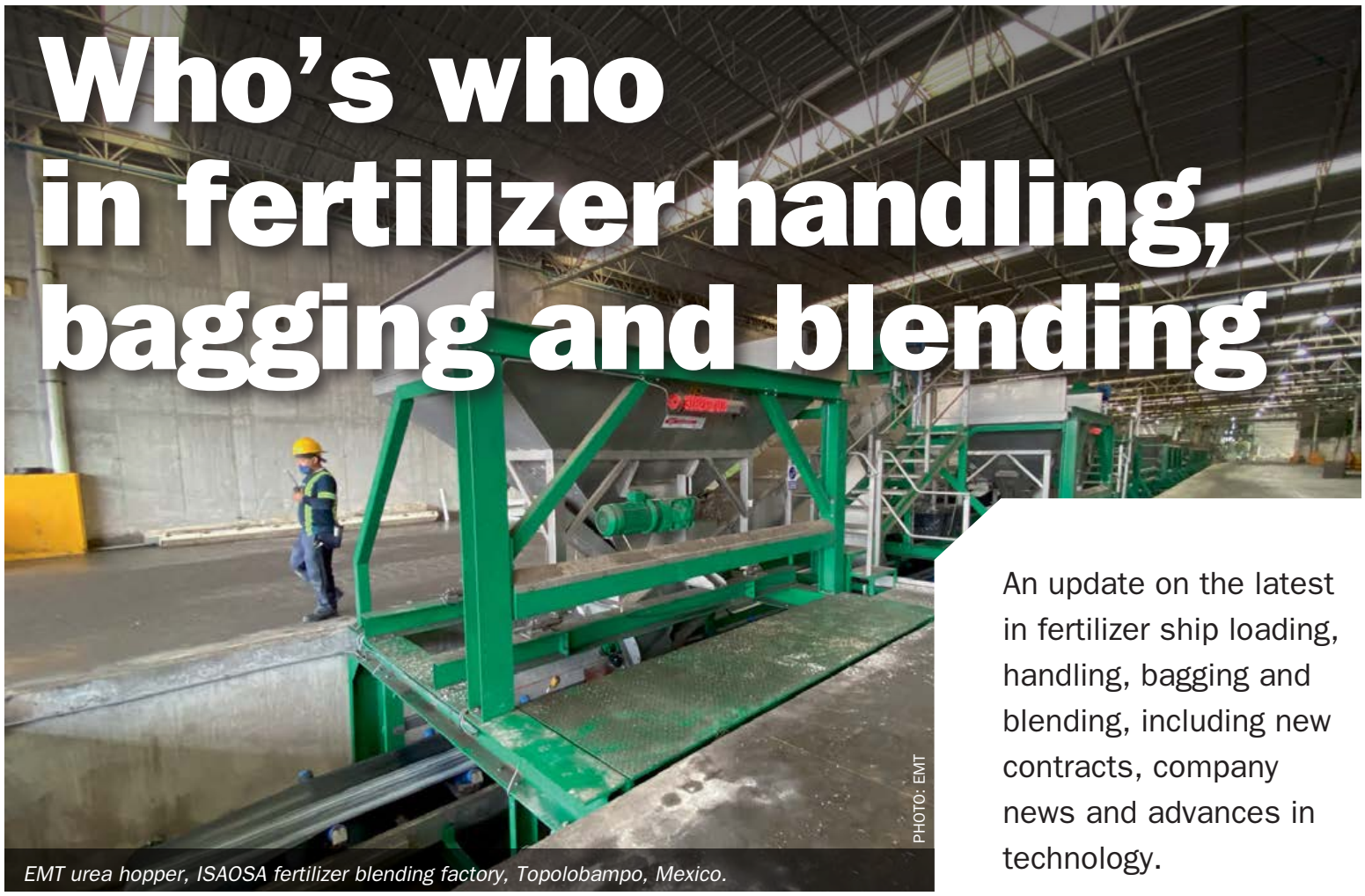


PHOTO: EMT

EMT urea hopper, ISAOSA fertilizer blending factory, Topolobampo, Mexico.

An update on the latest in fertilizer ship loading, handling, bagging and blending, including new contracts, company news and advances in technology.

AMECO has over 80 years of experience in the bulk handling business. Notably, the company designed and manufactured the world's first portal reclaimer for Morocco's phosphate mines in 1965. The Alsace-based French firm also went on to start-up the first portal reclaimer in the United States in 1969.

AMECO currently supplies stackers, reclaimers, blending systems and shiploaders for fertilizer, pulp, biomass and coal power plants and port terminals. In 2020, the company secured a contract to design and deliver a portal reclaimer for Keyera at Canada's largest sulphur handling facility. This was due to be delivered in the first half of 2021 in partnership with Tri Innovations, a leading engineering firm based in Calgary.

The 2,000 t/h reclaimer, based at the South Cheecham Sulphur Handling Facility (SCSHF), will handle a 20,000 tonne stockpile of prilled sulphur – and is hardened to withstand both extreme Northern Alberta temperatures and corrosive sulphur dust. It comes installed with automation and remote-control features that help increase safety by minimising on-site human intervention. Both the reclaimer and the SCSHF were scheduled to begin operations in the first half of 2021.

"I am very excited that our first collaboration with Tri Innovations and Keyera has led to such a successful outcome. This deal highlights how well our teams – from sales and marketing to engineering and project management – can get things done as well as the momentum our company has despite challenges due to Covid-19," said Stephane Killian, AMECO's CEO.

Bedeschi shiploading system for Borealis

Bedeschi is a well-established supplier of crushing and handling machines for cement, steel, coal, mining and other industrial processes. The Italian industrial manufacturer moved into the marine sector 15 years ago and now offers a range of large-scale onshore shiploading equipment.

An innovative feature of Bedeschi's shiploading technology is the sealed conveyor and telescopic chute system developed by the firm. The system is highly effective at dust prevention during the port-side unloading, handling and bagging of fertilizers.

In 2020, Bedeschi installed a new shiploading system for Borealis in the port of Rouen, northern France. The company's contract also covered the installation of the conveyors needed to transport products from the Borealis-owned manufacturing plant to the port. The project presented Bedeschi with some notable challenges:

- The product being handled – calcium ammonium nitrate (CAN) – is extremely aggressive in terms of corrosion
- A special rubber tyre mounted shiploader machine was necessary, because of the limited space available on the dock
- Project management, particularly health and safety, was also a major concern, as the shiploader would need to be installed while the production plant remained in operation
- Finally, the time available for delivery, installation and commissioning of the equipment was extremely short.

In September 2020, Bedeschi also secured a contract to supply Egypt's first fertilizer export facility at the Port of Sokhna in the Red Sea. This was awarded by Petrojet, the main contractor for fertilizer producer NCIC. The contract covers automatic storage with the stacking and reclaiming of up to 100,000 tonnes of fertilizers from NCIC's nearby phosphate production site. A complex system of belt conveyors then transports the fertilizer to the quay where a 900 t/h capac-

ity mobile shiploader on rubber tires loads awaiting ships. Bedeschi was selected as the only company being able to provide both the stacking and reclaiming system and the shiploading machines.

In November 2019, also in Egypt, Bedeschi installed a complete handling system on behalf of KIMA at its ammonia-urea complex at Aswan. The project, developed with long-standing partner Tecnimont, was designed to transport urea coming from the granulation plant to either bagging silos or to urea bulk storage, as well as reclaim urea from bulk storage to bagging silos. Specified equipment included:

- A reclaimer with a 240 t/h capacity
- A belt conveyor line with a total length of one kilometre
- Three tripper cars
- Diverters
- A dedusting system for each transfer point
- Vibrating screens
- Belt weighers
- A complete control system.

Bedeschi has also strengthened its presence elsewhere North Africa. In October 2019, Morocco's OCP Group once again chose Bedeschi as its engineering, procurement and construction (EPC) contractor for an expansion project at its Jorf Lasfar complex and port – with the aim of increasing sea freight capacity for shipping out fertilizers. The project consists of a five kilometre long, 2,000 t/h capacity conveyor line for fertilizers and phosphates. Bedeschi is providing the engineering, design, assembly and commissioning of the new conveyor line and will also integrate it with the OCP's existing handling systems at Jorf Lasfar.

Bruks Siwertell's healthy order book

Bruks Siwertell has successfully secured several fertilizer and sulphur industry contracts since the start of 2019. These have included repeat business from US company Martin Operating Partnership in Beaumont, Texas. This contract covered the installation of a new shiploader capable of safely and reliably handling sulphur prills at high capacities.

The new rail-travelling loader will be used for loading prilled sulphur into ships at a capacity of up to 1,200 t/h. It is ideal for terminals where space is at a premium, being capable of filling every ship's hold without the vessel needing to move along its berth.

"Martin Operating Partnership returns to Bruks Siwertell as a trusted and reliable partner, and we are delighted to renew our strong 15-year business relationship with them," said Ken Upchurch, vice president, sales and marketing, Bruks Siwertell Americas. "Our proven technological capabilities and our commitment to deliver the loader within the space of nine months were all factors that secured the contract."

Martin Operating Partnership handles various sulphur cargoes. Prilled sulphur, usually destined for agricultural applications, can be stored and loaded in open air – although minimising sulphur dust emissions remained a key concern for the company. Fortunately, the shiploader's fully-enclosed conveyors, as well as its dust suppression systems, provide a high level of environmental protection.

"At Bruks Siwertell, we handle sulphur under many conditions and in different climates," said Upchurch. "The foundation of our robust, reliable designs is their ability to withstand demanding operating conditions and also to handle cargoes without damage and spillage."

EMT's 200-metre-long blending plant in Mexico

Netherlands-headquartered **EMT** is one of the world's largest fertilizer blending and bagging equipment producers. In the first half of 2021, the company installed a state-of-the-art fertilizer blending factory, for ISAOSA (Insumos y Servicios Agrícolas de Occidente S.A.) at the port city of Topolobampo in the Gulf of California, Mexico.

ISAOSA helps Mexico's farmers create value by offering completely balanced nutrition programmes for strategic crops. These incorporate blended mixtures of fertilizer products precisely tailored to match soil conditions and crop yields. This is now possible thanks to the best available blending and bagging technology provided by EMT. **Zico Zeeman**, EMT's business development manager, picks up the story.

Installation of the factory commenced in the last quarter of 2020 and was finished in July 2021. All of the factory's equipment was manufactured in the Netherlands and shipped to the end user in no fewer than twenty five 40-foot-long shipping containers.

The completed machine is designed to operate at a capacity of 300 t/h and is more than 200 metres in length. This high capacity is achieved by running two lines in parallel. This ensures the blend quality is perfect and also allows the machine to be filled by multiple front loaders simultaneously.

In line with the latest advances in fertilizer treatment, a liquid inhibitor is applied as a direct coating to urea prior to blending. Initially, a conditioner is added to break up any lumpy urea material via a liquid injection point installed above a direct blending screw. By weighing both the urea conditioner and the inhibitor, the flow of both liquids is constantly monitored and adjusted to ensure the treatment of the end-product is exactly as required.

The inhibited urea is received on the central conveyors allowing other weighing hoppers to dose any extra constituents required directly on top of this material. In this way, the inhibited urea can be incorporated within a blend of other products. A total of 12 dosing hoppers and six liquid dosing units are available per line. Another blending screw ensures that all the constituents are properly mixed before they are directed over a coarse screen. A fine screen with a bypass option can also be used to sieve dust out of the blend.

PHOTO: EMT

EMT train filling shuttle conveyor, ISAOSA blending plant, Topolobampo, Mexico.

The final blended product is transported to one of the five stainless steel bulk hoppers, each with a capacity of 30 tonnes, or placed directly onto the train filling shuttle conveyor. This conveyor can move over the outer fence of the compound to fill trains which are positioned on the railroad directly next to the production facility. Once the train is full, the conveyor can be retracted inside the compound's borders.

The complete blend line is computer controlled and can easily be operated with one operator from the central office. With this new machine line, ISAOSA can triple its annual production to 300,000 t/a capacity.

As well as the granular fertilizer blending plant, EMT is also installing a second blending unit at the ISAOSA warehouse. This is solely dedicated to blending various water-soluble fertilizers (WSFs) according to precise recipes. This WSF blending unit is currently being commissioned and is expected to enter full production in September this year.

The new WSF machine line consists of 11 weighing hoppers which can be filled with big bags, small bags or in bulk. Again, this machine enables the product to be screened for large lumps and allows liquid to be added in the blending screw. A shuttle conveyor can discharge the material into five different bagging units for either small bags or big bags. ■

In August 2019, Bruks Siwertell also secured a contract with Ashdod Port Company Ltd for the delivery of a Siwertell *ST 490-M* screw-type ship unloader for Israel's largest sea port.

The was ordered as part of the port's major expansion plans. The machine will be rail-mounted and used to discharge sulphur and pet coke at continuous capacities of 600t/h and 500t/h, respectively, from vessels up to 60,000 dwt. The totally-enclosed unloader was the only system that could meet the company's environmental protection standard together with safe, high-capacity throughput.

"Ashdod Port Company chose Siwertell technology to secure its substantial and growing dry bulk cargo volumes for a number of reasons," said Bertil Andersson, Siwertell sales manager. "Most significantly, our Siwertell unloaders are the only proven solution for safe, enclosed and continuous sulphur unloading. They also meet the port's strict environmental requirements, handling materials without dust or spillage."

Sulphur is highly toxic, volatile and corrosive. Its containment also creates the potential for fires and even explosions.

"We know how to deal with these dangers," said Andersson. "Our sulphur-handling ship unloaders have been supplied to the market for over 30 years. All these units are fitted with the Siwertell Sulphur Safety System (4S), which detects and extinguishes fires early, shutting down the system to stop their spread, and safely containing them before they can become a full-blown blaze. To contain explosions, steel casings are reinforced and explosion-venting valves are fitted along the conveyors to relieve pressure."

The delivery of the new ship unloader to Ashdod's bulk terminal was scheduled for April 2021.

Bruks Siwertell previously installed a new 600 t/h Siwertell ship unloader at Yara International's Glomfjord fertilizer terminal in Norway, just inside the Arctic Circle. The installation and performance tests were completed on schedule in July 2019. The rail-mounted Siwertell *ST-490M* ship unloader is being used to offload various types of phosphate rock from vessels of up to 20,000 dwt. It will also handle potash fertilizers.

"Yara is well aware that it can expect a lifespan of many decades from its new unloader, thanks to a previous Siwertell installation for the company that has been in service since 1980," said Peter Goransson, former sales manager and senior advisor, Siwertell. "It also knows that it

can trust the operational and environmental performance of Siwertell technology."

Glomfjord is exposed to high winds and very cold temperatures. Being within the Arctic Circle, it is also subject to stringent environmental legislation to protect the surrounding coastline from harmful shipping pollution.

"The Siwertell screw-type ship unloader was not only chosen for its ability to safely handle sensitive dry bulk material like phosphates, and for its environmental credentials, which include high levels of efficiency, and a totally-enclosed conveyor system, eliminating dust emissions and spillage, but also for its impressive through-ship capacity," said Goransson.

Solex expands into bulk materials handling

Solex Thermal Science is a world leader in high-efficiency, indirect heat exchange technology for the heating, cooling and drying/conditioning of free-flowing granular materials such as solid granules, pellets, beans, seeds and particles. For more than 30 years, the Canadian-headquartered company has installed more than 800 heat exchangers in more than 50 countries worldwide with applications such as fertilizer, oilseeds, sugar and industrial materials.

Building on this track record and experience, Solex has announced its expansion into the bulk materials handling market. The company recently launched a new line-up of in-house fabricated standalone feeders for industries such as fertilizer, food products and industrial materials.

"This move is a natural evolution for Solex Thermal Science given our 30 years' of experience in moving solids such as prills, granules and pellets through heat exchangers with incredible precision," says Solex Thermal Science CEO Lowy Gunnewiek. "This experience will be foundational for us as we expand our growing line-up of high-quality, high-performance and robust equipment solutions to new markets and new customers."

The highlight of the company's initial product offering is an oscillating gate design that's already in active use within the fertilizer industry. Indeed, more than 80 of Solex's oscillating gate feeders are currently operating as part of vertical heat exchangers in nearly a dozen countries around the world. More than two-thirds of these are in fertilizer applications

PHOTO: SOLEX THERMAL SCIENCE

Standalone Solex bulk materials feeder with oscillating gate design.

such as urea, NPK, MAP and potash.

Solex's oscillating gate splits the product into the two symmetrical mass flow funnels. These are created by the device's fixed outer walls and its moving inner walls at the centre. These form a pair of slotted shaped openings through which the material flows.

"The gates look like a trouser leg. The product flows downward by gravity and divides into two streams. Those gaps are controlled by a common shaft that, when rotated, moves the walls inward or outward depending on the desired flow rate," says Jason Gass, technical design & project specialist at Solex Thermal Science.

"And like all of our discharge feeders, we've taken a practical, scientific design approach to the oscillating gate that also accounts for the transition between the bottom of a storage bin or feed hopper to the discharge feeder, as well as the spatial constraints and equipment used to convey the bulk solids after being discharged."

According to Gass, the benefits of the oscillating gate design include its short height, gentle product handling – as well as its reliability within the dusty conditions typical in most fertilizer applications.

In addition to fertilizers, Solex's oscillating gate is well suited to handling minerals and other high-density granular solids.

Solex's other two standalone feeders include the vibrating louver and sliding frame designs.

The vibrating louver is designed for lighter material applications such as sand, sugar or plastics. It uses a series of partially overlapping louvers carefully positioned within a self-supported frame. These vibrate linearly to offer a full live-bottom discharge system.

This feeder ensures mass flow by allowing product to flow along the multiple overlapping shallow louvers into a series of slot openings.

The sliding frame, meanwhile, is designed for medium-duty applications such as seeds, beans or delicate granules. It incorporates a fixed component made up of a series of small mass flow hoppers. These feed the material toward the sliding frame and, as the sliding frame moves horizontally back and forth, the hoppers subsequently discharge their solids.

"Whether it's urea granules or soybeans, reliable, uninterrupted mass flow of bulk solids plays an important role in material handling systems efficiency while maintaining product quality. Our world-tested equipment can be tailored to different material flow properties, while providing operators with maximum control and a guaranteed first-in-first-out flow sequence," says Gunnewiek.

Virtual commissioning

The virtual commissioning of blending and bagging systems has helped surmount the challenges presented by the Covid-19 pandemic, as **Brett Binnekade**, development engineer at Bagtech International, explains.

It's March 2020, and the South African President has just announced a 21-day lockdown. Our mechanical and electrical teams are on-site in Lagos installing a new fertilizer blending plant. Our systems engineer is about to fly out to carry out the final commissioning when all physical travel is halted. Much to our surprise, this would be the first plant that we commission virtually.

Luckily for **Bagtech International**, virtual commissioning was something we'd been pursuing for some time. Remote assistance and service has always been a high priority for the company – we select the automation components in our plants based on this. Each component is connected to a multi-layer OT (operational technology) network, allowing our technical support team to access them remotely. It is this modern architecture that gave us the means and ability to start commissioning our plants virtually. Yet the Covid-19 pandemic pushed us to do it much sooner than expected. We know many companies who share the same sentiment!

Since the start of the pandemic, our systems engineers have not physically been on-site to commission a machine. Even with the opening of borders and travel, virtual commissioning is now our standard practice. This offers some immediate benefits to our clients and us – like reduced cost of travel and accommodation, significantly faster commissioning times, and reduced risk of Covid-19 infections. However, virtual commissioning is more than just remotely accessing machines from thousands of kilometres away. We have been able to do this for years – remote access being just the final stage in a three-stage virtual commissioning process.

The first two stages generally happen behind the scenes and involve simulation and modelling of hardware and software – checking for errors and bugs and cycling back through the stages if any are found. These first two stages are entirely virtual – allowing engineers to run as many tests as they wish to uncover and fix issues. This is all done before installation, thus reducing the time required on-site. Since there is no physical machine running at this point, there is no safety risk, and the delays in conforming to on-site safety standards are negated.

At this point, If you are familiar with the term 'digital twin', the concept of virtual commissioning may seem the same, but it's not. Virtual commissioning, as the name implies, is just for the commissioning phase of a plant. In contrast, a digital twin exists throughout the entire plant's life cycle – being fed with live data from the physical plant to create a live digital copy. Digital twins do exist in the development and design stage of a physical machine or plant. But they continue to add value after their physical counterpart has been commissioned by providing a deeper level of insight into the system.

Fertilizer blending and bagging, particularly at high production rates, is prone to many variables. External variables, like temperature and humidity, raw material variables, like density and particle size, even variables linked to power or maintenance can cause undesired effects. Nowadays, all these variables are already measured most of the time, even when no dedicated sensors are in place. That's because some devices have a plethora of sensors inside for their own use. For example, the servo controllers we use are fit for their purpose – which is to drive servo motors. However, they also contain sensors to measure variables like power supply voltage, frequency, temperature, humidity and many more. Now, because they are connected to an OT network, the data from these sensors is available to link to digital twins, internet of things (Iot) applications, machine learning algorithms and, importantly, for virtual commissioning.

As soon as a value from a sensor is digitised, it can be sent via the internet, and the systems engineer can view and analyse it in real-time. With this much data available, there is no need for the system engineers to be on-site anymore. Power problems are prevalent in African countries and a recent plant installation posed some challenges, as the voltage from the local power utility was too high. This meant the entire commissioning and pre-production runs were done using a diesel generator. The generator was new, it was a reliable brand, and our plants are designed to run on generators. Yet, we still faced faults related to power problems. All available test equipment on-site showed flawless power. However, our system engineer could tap into various sensors around the plant and present time-series data showing large voltage spikes, frequency variations and a poor waveform. It was these data that assisted our client in finding the root cause.

September-October 2021

phosphates & potash INSIGHT

Phosphoric acid co-products

PHOTO: NUTRIEN/ARKEMA

The under-construction anhydrous hydrofluoric acid (AHF) plant at Nutrien's Aurora site, North Carolina. This will consume fluorosilicic acid (FSA) generated on-site as a co-product of phosphoric acid production.

The latest developments in the recovery and commercialisation of fluorosilicic acid, rare earth elements (REEs) and uranium co-products associated with phosphoric acid production.

Cost and waste reduction have become increasingly important imperatives in phosphate fertilizer production. Greater resource efficiency has also risen up the industry's agenda with the emergence of the circular economy and policies on waste prevention.

This has resulted in renewed interest in the commercial recovery of rare earth elements (REEs), uranium and fluorosilicic acid (FSA) during the phosphate manufacturing process. As well as improving process efficiency and reducing costs, the sale of such co-products can generate extra revenues for phosphate producers.

Rare earth elements

The rare earth elements (REEs) consist of the group of 15 lanthanide elements, with atomic numbers 57 to 71, together with yttrium and sometimes scandium. REEs are generally classified as heavy, medium or light according to their atomic number and relative abundance (Table 1).

These 17 elements commonly occur together and, as a consequence, are typically mined and processed collectively to produce an initial rare earth oxide (REO) product. Individual REEs, due to their similar physical and chemical properties, then need to be painstakingly and expensively separated from this REO intermediate for their different end uses via multi-stage solvent extraction[1].

Global rare earth oxide (REO) production has risen strongly over the last decade, increasing from 132,000 tonnes to 210,000 tonnes between 2017 and 2019, for example[2].

Rising production in recent years has been spurred by growing demand for REEs from three distinct end-use markets – the low-carbon, automobile catalyst and digital technology sectors – as follows[2]:

- Neodymium (Nd), dysprosium (Dy), and praseodymium (Pr) are used in the manufacture of temperature-resistant permanent magnets, while Pr, gadolinium (Gd), europium (Eu) and erbium (Er) are used in nanoparticle-based materials which enhance power conversion efficiency
- Lanthanum (La), cerium (Ce), and Nd are commonly used as stabilisers in vehicle catalysts
- Eu, terbium (Tb), and yttrium (Y) are also used to manufacture video displays.

Table 1: **Classification of heavy, medium and light rare earth elements by atomic number**

Name	Atomic no.	Symbol
Light REEs (LREEs)		
Lanthanum	57	La
Cerium	58	Ce
Praeodymium	59	Pr
Neodymium	60	Nd
Promethium	61	Pm
Samarium	62	Sm
Medium REEs (MREEs)		
Europium	63	Eu
Gadolinium	64	Gd
Terbium	65	Tb
Dysprosium	66	Dy
Heavy REEs (HREEs)		
Holmium	67	Ho
Erbium	68	Er
Thulium	69	Tm
Ytterbium	70	Yb
Lutetium	71	Lu
Yttrium	39	Yt

Source: CRU

K-Technologies, Inc.

Florida's K-Technologies, Inc. has developed a range of proprietary recovery technologies for uranium, REE and fluoride recovery at bench, pilot plant and commercial scale. These cover the following phosphate industry applications:

- Uranium recovery from phosphoric acid using conventional solvent extraction (SX) or advanced extraction methods such as impregnated substrates (IS) and/or ion exchange (IX)
- Recovery and purification of rare earths from wet process phosphoric acid using ion exchange and continuous chromatographic techniques.
- Fluoride recovery from phosphogypsum pond water or barometric cooling water systems via ion exchange.

K-Tech has been involved with REE recovery and separation since the early 1980s. The company offers technologies able to recover REEs from wet process phosphoric acid and, more importantly, purify these to produce individual rare earth products. In the initial process step, non-solvent extraction methods concentrate REEs in a low volume intermediate solution. A continuous process is then used to separate individual REEs from each other and produce purified materials such as europium oxide, terbium oxide, yttrium oxide, etc.

K-Tech possesses extensive in-house expertise on uranium (U_3O_8) recovery from phosphoric-acid. The company was instrumental in the development and commercialisation of the so-called 'second generation' solvent extraction technology implemented from the 1970s onwards.

Following the closure of second-generation systems in the 1990s, due to economic pressures, K-Tech subsequently developed advanced third generation recovery techniques for uranium. These are based on the application of continuous non-solvent extraction – such as modified solid sorbent systems. This new simplified process results in a smaller plant footprint and lower capital and operating costs.

Adopting third generation uranium recovery technology can cut operating costs by 25-35 percent, according to K-Tech. It is also likely to be applicable to more concentrated phosphoric acid streams, such as those originating from the hemi-hydrate process.

Simultaneous recovery of both REEs and uranium makes economic sense, according to K-Tech, by providing phosphate producers with the option to diversify and add-value to their production processes. ■

REEs are mined from various mineral deposit types. The majority of global REE production comes from China, which produced 132,000 tonnes of REO in 2019, equivalent to almost two-thirds (63%) of total world output. Other important REE production centres include the US, Myanmar and Australia, which account for around 12 percent, 11 percent and 10 percent of global production, respectively[2].

While there is some variation from mine to mine, most orebodies comprise of[1]:

- Large proportions of **light 'industrial' rare earths** (Ce and La) – which typically make up 60-75 percent of the final product volume
- Moderate amounts of **light 'magnetic' rare earths** (Nd and Pr) – typically 15-30 percent by product volume
- Small fractions of **medium/heavy rare earths** such as dysprosium, samarium, europium, terbium etc – although levels can be much higher in some exotic orebodies, as well as for specific elements such as yttrium.

When it comes to the economic feasibility of REE mine projects, the emphasis is on cerium, lanthanum, neodymium and praseodymium recovery. That is because, for an average orebody, these four elements collectively account for 94 percent of production volumes and generate 90 percent of mining revenues[1].

A tale of two markets

In recent times, two element pairs – the 'industrial' REEs Ce/La and the 'magnetic' REEs Nd/Pr – have operated as parallel, separate markets due to their contrasting end uses. Demand for Ce/La, for example, is concentrated in polishing powders, steelmaking and alloy manufacture, and as a support bed for catalysts. Usage of Nd/Pr, meanwhile, is mainly for the high-powered permanent magnets (NdFeB type) found in wind turbines, electric vehicles (EVs), portable electronics and many other applications.

Demand growth in the separate Ce/La and Nd/Ps markets has diverged in recent years. Annual growth in NdFeB magnet demand, for example, grew at around 5-6 percent annually between 2012-2020, according to CRU, due to the widespread installation of wind turbines and rapid growth in EV sales. Growth in Ce/La demand, in contrast, has languished at just one percent per annum over the same period[1].

This divergence has created marked differences in REE prices and revenues. Nd/Pr prices are now 250-300 percent higher in real terms than they were in 2008, while Ce/La prices have declined by 20 percent on their 2008 levels. This has had a knock-on effect on REE mining revenues in recent years – with the extraction of La/Ce now generating just 10 percent of revenues, down from around half of total revenues previously[1].

REE recovery from phosphates

The history of REE recovery from phosphate rock, phosphoric acid and phosphogypsum waste dates back decades. Notable landmarks include[3]:

- The commercial recovery of REEs from phosphate rock in Finland by Kemira Oy in the late 1960s and early 1970s
- Solvay's extensive experimental work on uranium and REE extraction from phosphoric acid in the late 1970s and early 1980s, culminating in the establishment of an industrial-scale pilot plant in Rouen
- The pilot-scale recovery of REEs from phosphoric acid evaporation sludges, via nitric acid leaching and solvent extraction, trialled in South Africa in the late 1980s and 1990s.

More recently, the Florida Industrial and Phosphate Research Institute has carried out systematic studies of REE recovery from phosphate mining and production streams, including:

- Waste clay
- Amine flotation tails
- Phosphoric acid
- Phosphogypsum
- Sludge from phosphoric acid concentration and clarification.

To date, however, most pilot scale trials have failed to translate into viable commercial REE

Arkema and Nutrien's innovative partnership

Arkema and Nutrien have teamed up on an innovative new project. Construction is well underway at Nutrien's phosphate complex in Aurora, North Carolina, on a new plant that will produce anhydrous hydrogen fluoride (AHF) from fluorosilicic acid (FSA). This will be sold as a raw material to Arkema and used to produce a variety of materials at the company's facility in Calvert City, Kentucky.

The world's primary source of fluorine is fluorspar, a mineral mined in Mexico, South Africa and China, but the second-most-available source is phosphate rock. The fluorine in phosphate ore is extracted as FSA through the phosphoric acid production process. New technology – the first of its kind to be commercialised in the Americas – will allow Nutrien to use this FSA as feedstock to produce AHF.

The AHF produced at the new plant will be used as a key raw material for Arkema's fluorogas and fluoropolymer product lines. This family of products includes *Forane*® foam blowing agents as well as *Kynar*® polyvinylidenefluoride (PVDF) resins and co-polymers.

Forane® is used in a variety of applications that reduce energy consumption of both residential and commercial buildings. They include *Forane*® refrigerants for stationary air conditioning, chillers and refrigeration. *Kynar*® is used in several of the world's most challenging applications. These include binders for lithium-ion batteries, flame resistant wire and cable jacketing, inert piping and fittings for corrosive chemicals, back sheets for long life solar panels, and high durability coatings for skyscrapers.

The design and engineering of the AHF plant was completed in October 2020. Construction is due to be completed by the end of this year, with the plant up and running by the first half of 2022. Long-term partners Arkema and Nutrien are excited about the many benefits of this project.

"It is very gratifying to see this project with our strategic partner Nutrien near commissioning," said Anthony O'Donovan, Regional Group President, Fluorochemicals Americas at Arkema. "Replacing the use of mined fluorspar with a co-product of an existing process for our fluorinated products platform reflects Arkema's continued focus on sustainable growth and reducing the environmental footprint of the raw materials that are required to make our key products."

Arkema is committed to sustainable growth and has made corporate social responsibility (CSR) an integral part of its strategies and activities. External stakeholders have recognised the company's CSR approach and achievements. This notably includes Arkema's listing in the *FTSE4Good* non-financial global index. The partnership with Nutrien is also well-aligned with Arkema's ambitious targets to reduce its environmental footprint, and develop technologies and solutions that can help address major societal challenges.

With this new process, Arkema will be significantly reducing its dependence on a mined product produced in a much more resource-intensive fashion. The long-term supply agreement with Nutrien will also provide Arkema with a stable, secure and competitive supply chain for this vital material. In Nutrien's recent *Feeding the Future* plan, the company committed to achieving

PHOTO: NUTRIEN/ARKEMA

Nutrien's Aurora phosphate production complex in North Carolina. The site of an innovative new plant that will produce anhydrous hydrogen fluoride (AHF) from fluorosilicic acid (FSA).

a 30 percent reduction in its greenhouse gas (GHG) emissions intensity by 2030. The partnership with Arkema helps Nutrien double down on this target and other efforts to reduce its environmental footprint.

Phosphate rock is the largest global source of fluoride, and the new technology will allow Nutrien to convert a greater amount of fluorine. It's also a more sustainable process for producing AHF compared to the more typical route, which converts it from fluorspar. And with higher utilisation of the existing mining operation at Aurora, it reduces overall energy consumption and GHG emissions.

The high-quality equipment and materials used in the new plant will feature proven technology that ensures comprehensive environmental protection and safe operation.

Safety is a top priority for Nutrien, and the company's high safety standards and long-term operational experience will provide a solid foundation of safety at the new plant. The Aurora site has 55 years of operational excellence, and Nutrien's project management team has more than 150 years of construction management experience. Likewise, Buss ChemTech AG, the project's technology provider, has six decades of experience in construction of hydrofluoric acid and derivatives plants around the world.

As part of their agreement, Arkema is funding construction of the new plant at the Aurora site and Nutrien will operate and manage it. The strong relationship formed between the two companies – and the hard work of the many teams involved on both sides – were instrumental in bringing about this ground-breaking deal and innovative project.

"It is very exciting to get this project across the line," said Raef Sully, Nutrien's Executive Vice President and CEO, Nitrogen & Phosphate. "This strategic partnership with Arkema demonstrates our commitment to innovation and finding solutions that not only use co-products for industrial use, but also drive reductions in GHG emissions intensity. "

recovery from phosphate sources. This has mainly been attributed to technical challenges and the prohibitive recovery costs linked to the low REE content of phosphate rock[3].

Nevertheless, the potential for REE recovery from phosphates remains high. The global phosphates industry consumes in excess 250 million tonnes of phosphate rock annually. This could translate into potential yearly REE production of around 125,000 tonnes, based on an average rock concentration of 0.046 percent, although this tonnage is skewed upwards by the presence of heavy REEs[3].

Below, we highlight some of the most promising current REE recovery projects.

Phalaborwa rare earth project

Rainbow Rare Earths Limited is developing the Phalaborwa rare earths project in South Africa. This aims to recover REEs from approximately 35 million tonnes of phosphogypsum waste, a historic legacy of the country's igneous phosphate mining and processing industry. This PG waste has an average *in situ* REO grade of 0.6 percent, some 30 percent of this comprising high-value Nd/Pr. Rainbow is co-developing the Phalaborwa project with Bosveld Phosphates Limited.

The company is also trialling REE mining operations at its Gakara project in Burundi. Gakara is currently Africa's only active REE production site and, according to Rainbow, produces one of the highest-grade REE concentrates in the world – typically 54 percent total rare earth oxide (TREO). The Gakara concentrate is also heavily weighted towards Nd/Pr. This accounts for around 20 percent of overall TREO content, while representing 80 percent of its value.

In a technical update released in November last year, Rainbow announced that the Phalaborwa project's pilot plant, developed by Sasol Limited, had successfully produced three tonnes of mixed rare earth carbonate and associated cerium oxide. The grade of the rare earth carbonate product obtained was found to be significantly higher than conventional mining concentrates, such as that produced at the company's Gakara project in Burundi.

Initial estimates suggest that the proposed full-scale process to treat two million t/a of Phalaborwa phosphogypsum could deliver 10,000 t/a of mixed rare earth carbonate. This REE concentrate would, in turn, contain around 3,100 tonnes of Nd/Pr.

Rainbow expects Phalaborwa's beneficiation costs to be significantly lower than those of a conventional REE mining project.

George Bennett, Rainbow's CEO, said: "We are delighted by the initial results… which… reaffirm our confidence in the considerable potential of the project and support our expectation that it will represent a significant source of NdPr for Rainbow. Sasol's processing flow sheet demonstrates the viability of the project, which is further validated by the proven ability to extract REEs from the gypsum, as displayed by the successful operation of its pilot plant."

Pilot plant results suggest that the Phalaborwa project could deliver a high value product at low processing opex and capex, according to Bennett. "The value of the mixed rare earth carbonate will not only be higher than a traditional rare earth mineral concentrate, due to the chemical form… in the stacks, but also [because] of [its] underlying value, which at 30 percent NdPr, compares very favourably with other rare earth projects globally," he said.

CaMona project

The recently completed German-Brazilian CaMona project investigated the industrial-scale extraction of REEs from phosphogypsum waste generated by the phosphate fertilizer industry in Brazil's Catalão region. The project targeted the recovery of rare earth monazite concentrates from phosphogypsum using a cost-effective physical separation process. Its ultimate aim was to produce a rare earth concentrate from a continuously operated pilot plant and further process this – via chemical leaching and digestion – into highly pure and marketable rare earth products.

The €1.2 million, three-year, German government-funded project was coordinated by rare earths exploration company Ceritech. Partners included Brazilian phosphate producer CMOC and three German and Brazilian universities. The project first received funding at the start of 2018 and ended in June 2020. Preliminary results published last year concluded that industrial REE recovery from Brazilian phosphogypsum looked feasible, although further optimisation and scale-up of the process was still necessary.

Florida start-up recovers REEs from phosphoric acid

In 2019, Precision Periodic, an incubator company based at the University of Central Florida, successfully extracted and separated REEs from phosphoric acid using a reusable nano-filtration system called *Thor*. According to the company, the *Thor* filter can be reused for thousands of cycles and is highly scalable for all size applications.

In an extraction project for the Florida Industrial and Phosphate Research Institute, *Thor* captured 40-60 percent of the REEs and radioactive elements from wet-process phosphoric acid in a five-minute single pass-through. The innovative filter can handle up to 9,000 gallons an hour, allowing it to hold and recover around 0.5-1.2 kg of REEs, precious metals, or heavy metals.

"The successful test projects proved that the Thor nano-filtration technology could be a game-changer for US production of its own rare earth elements supply," said Brian Andrew, CEO of Precision Periodic. "The phosphoric acid contains 150 ppm of total rare earths. Based on our extraction capabilities, we could extract 75 grams of total rare earths out of every 1,000 litres of phosphoric acid from a phosphate mine. This equates to one Florida phosphate mine being able to produce 230 tonnes of total rare earths per year – which would supply an estimated 25 percent of annual US military needs."

Uranium

Interest in uranium recovery from phosphates is on the rise again – thanks to increased environmental awareness, energy security and rising uranium prices. Phosphate fertilizer producers could provide more than 15 percent of the world's non-military uranium requirements, according to some estimates[4].

On a national basis, it has also been calculated that uranium as a by-product of phosphate production could meet 8-9 percent of Argentina's demand, two percent of EU requirements and 10 percent of US needs. Amounts recovered could even exceed current domestic uranium production in some instances. The US phosphate industry, for example, could potentially provide 5.5 million pounds (2,495 tonnes) of uranium (U_3O_8), versus US domestic production of 4.9 million pounds (2,223 tonnes) in 2014[4].

Commercial techniques to recover uranium from phosphoric acid are well-known (see K-Technologies box) and were used on an industrial scale in the United States – and to a lesser extent elsewhere – up until the late 1990s, when plummeting uranium prices made recovery uneconomic for fertilizer producers[4].

Prayon's fluoride recovery technology

Prayon's **Thomas Henry** and **Hadrien Leruth** provide an overview of fluorine recovery at phosphoric acid plants – and explain how the many technical challenges can be overcome.

For phosphoric acid producers, fluorine is often considered as a bulky by-product to be neutralised and discharged along with the gypsum. This chemical element is often regarded as an obstacle to meeting ambitious P_2O_5 production objectives, whereas it should be the focal point of a lot more attention, both for environmental and economic reasons.

Fluorine, bonded to apatite, usually occurs as 10 weight percent of the P_2O_5 content of sedimentary rocks and 2.5-5 weight percent of igneous rocks. It reacts with either soluble silica to produce fluorosilicic acid (H_2SiF_6) or alumina to produce soluble AlF_3 or AlF_6^{3-} during the weak phosphoric acid production stage (28-42% P_2O_5). Some of the fluorine dissolved in the phosphoric acid acidifies the plant's off-gases through the formation of volatile SiF_4 or HF, while another fraction precipitates as fluosilicates, being discharged with the gypsum cake. At the phosphoric acid concentration stage (48%-60% P_2O_5), almost all the remaining liquid fluorine present in the acid is released as SiF_4 and/or HF in the evaporated water.

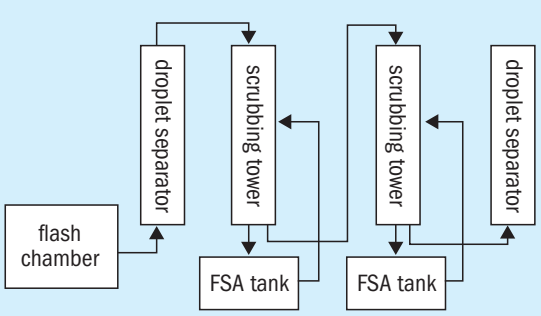
Therefore, all the untreated gaseous effluent from phosphoric acid plants can represent a significant source of atmospheric pollution. This is as hazardous for the people working in the plant as it is for the nearby environment.

The technical challenge presented by fluorine recovery from those gaseous effluents lies in the important formation of solid silica. This is generated from gaseous silicon tetrafluoride when it is adsorbed in water to form fluorosilicic acid:

$$3SiF_4(gas) + 2H_2O\ (liquid) \rightarrow 2H_2SiF_6(liquid) + \underset{\downarrow}{SiO_2}(solid)$$

This reaction shows that an efficient fluorine recovery system results in high silica precipitation. However, the solid silica forms hard scaling in tanks and piping, creating some difficulties in the recovery system. Over the years, Prayon has adapted the design of its fluorine absorption system to meet the needs of producers and achieve the desired recovery performance, meet environmental objectives, and tackle silica scale formation.

Fig. 1: **Prayon's fluorine recovery process during phosphoric acid concentration to 48-60% P_2O_5**



Source: Prayon

Prayon's vacuum fluorine recovery and atmospheric gas cleaning systems both avoid the use of easily clogged packed bed towers and instead use simple but robust void towers equipped with high-efficiency sprayers and droplet separators. Prayon's sprayers are especially designed without inserts to maximise the liquid-gas contact surface and simultaneously avoid clogging thanks to their large free passageways.

At the phosphoric acid concentration stage, the operating principle is as follows (Figure 1): the fluorinated gas to be cleaned flows through one or several absorption stages where the gaseous fluorine is absorbed in a fluorosilicic acid solution of decreasing concentration. If required, a final wash stage with pure water is carried out.

The operation of each absorption stage in batch mode is preferred to maximise the fluorine recovery. Firstly, the fluorosilicic acid tank is filled with pure water with a high capacity for fluorine absorption. Over time, fluorine slowly accumulates in the loop to reach the required fluorosilicic acid grade. Finally, the concentrated liquor is emptied to the storage area and the cycle starts again.

The design of the fluorine absorption tower (Figure 2) is focussed on two targets:

- **Highest fluorine recovery** (gaseous + liquid) to limit the fluorine conveyed to the next stage
- **Self-cleaning of the piping** with a mechanical washing provided by efficient sprayers implemented at the right locations.

IMAGE: PRAYON

Fig. 2: Atmospheric gas cleaning tower. This system achieves under 5 ppm of fluorine in the waste gas.

Any remaining fluorosilicic acid droplets escaping the absorption tower are separated by passing the gas flow through Prayon separators (Figure 3) – *Praysep* – where, just as in a regular cyclone, droplets are separated using centrifugal forces. However, the special feature of this proprietary equipment is a static impeller that creates a vortex in the gas flow without the need for a change of direction. This feature greatly improves the compactness of the system and reduces its pressure drop to a few millimetres of water column.

In summary, production teams at phosphate plants find Prayon's fluorine recovery system a comfortable solution that is easy to operate. At the same time, it avoids fluorine being released at the stack, or being recycled back to the plant where it results in scaling and presents a solids handling and removal challenge. Finally, producers simultaneously save money on maintenance and increase their revenues, especially if the fluorosilicic acid generated is sold for the manufacture of hydrofluoric acid or aluminium fluoride. ■

IMAGE: PRAYON

Fig. 3: Praysep droplet separator by Prayon.

In the US, current costs for uranium recovery from phosphoric acid using industrially proven solvent-extraction technology are within the range $44-61 per pound ($U_3O_8$). This is on the verge of being economically profitable, given that US nuclear reactor operators purchase uranium from foreign suppliers at an average cost of $38.81 per pound[4].

Ion exchange technology for uranium recovery from phosphoric acid, although as yet unproven at commercial scale, could drive down costs further. Pilot-plant scale ion exchange trials in the US by the Australian company PhosEnergy have reported costs of $33-54 per pound. Even greater cost savings could eventually be realised if uranium was leached directly from beneficiated phosphate rock prior to digestion. This would have the added benefit of making both the final fertilizer product and the phosphogypsum waste virtually uranium-free[4].

Fluorosilicic acid

Hexafluorosilicic acid (H_2SiF_6), commonly known as fluorosilicic acid or fluosilicic acid (FSA), is generated as a by-product of phosphoric acid production. This originates from the natural levels of fluorine present in sedimentary (0.10-0.14 kg F per kg P_2O_5) and igneous (0.06-0.08 kg F per kg P_2O_5) phosphate rock.

Production of phosphoric acid (H_3PO_4) and phosphate fertilizers creates silicon tetrafluoride (SiF_4) as a toxic off-gas. Currently, this problem is mainly resolved by absorbing SiF_4 in water to form fluorosilicic acid (FSA) and then storing it in ponds, neutralising it or disposing into the sea.

World phosphoric acid production, and by association FSA, is on the rise. Assuming phosphoric acid contains three percent fluorine on average, around 1.4 million tonnes of by-product FSA was produced globally in 2019, according to some estimates, being roughly distributed regionally as follows[5]:

- 560,000 tonnes in East Asia
- 230,000 tonnes in Africa
- 225,0000 tonnes in North America
- 130,000 tonnes in East Europe and Central Asia
- 100,000 tonnes in West Asia.

Use of by-product FSA remains comparatively low, however, and most FSA produced by the phosphate industry, in general, continues to be either neutralised, ponded or discharged to the sea. Nevertheless, around 200,000 tonnes (fluorspar equivalent) is consumed annually in aluminium fluoride (AlF_3) manufacture, meeting some 11 percent of global industry's fluoride needs. Water fluoridation and fluoride salt manufacture consume a further 200,000 t/a of by-product FSA. Some FSA is also used during phosphoric acid production as a sulphuric acid substitute, reducing the latter's usage by about five percent[5].

Currently, FSA generation is produced by at least 30 companies worldwide. Yet only one-third of these business obtain their FSA as a phosphate industry by-product, with the majority preferring to make FSA from fluorspar. Phosphate-derived FSA is, however, a negative cost raw material – as it must be neutralised and disposed of at extra cost if it cannot be used[5].

Another factor that has limited the widespread use of FSA as a source of fluorine has been its high capital and processing costs, together with logistical constraints, although these have been reduced by the technology advances made by Buss ChemTech and others (see companion feature on p50). A further complication is that HF plants must be configured to use either fluorspar *or* FSA, not both, as the associated chemical processing systems are unable to accept variations in feedstock quality[5].

More positively, the Chinese government has acted to encourage the use of by-product FSA in Guizhou, Hubei and Yunnan, the country's the three main phosphate provinces. As a consequence, several FSA-consuming anhydrous hydrogen fluoride (AHF) plants have been set up by Guizhou Wengfu Lantian Fluorine Chemical, a subsidiary of Wengfu Group. Other Chinese HF producers, such as Do-Fluoride, are investigating whether producing HF from FSA looks economically feasible. Wengfu is also reported to be planning a joint venture to produce AHF from FSA in Morocco[5].

In the USA, an estimated 40,000 tonnes of FSA – equivalent to about 64,000 tonnes of pure fluorspar – was recovered from five phosphoric acid plants during 2019. This was mostly used in water fluoridation. North America's first industrial-scale FSA-to-HF plant is currently under construction (see Arkema-Nutrien box). ■

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Converting fluorosilicic acid into value-added hydrogen fluoride

Buss ChemTech AG offers the international phosphate industry a robust solution to create added-value products from fluorosilicic acid (FSA). **Thomas Dahlke**, the head of the company's process engineering department, and **Emre Sen**, sales manager for fluorine technologies, explain how this can be done in a sustainable manner.

Sustainability is becoming ever more important across all industries – with the phosphate industry being no exception. Because of this, value creation needs to be built around a comprehensive sustainability strategy embracing ecological, technological, social and economic aspects.

One route to perfecting sustainability involves the conversion of low-value co-products into value-added products, without any compromise to the four aspects mentioned above.

One of the most promising phosphate industry co-products, from both a value-added and sustainability point of view, is fluorosilicic acid (FSA).

Shift away from limited, traditional FSA markets

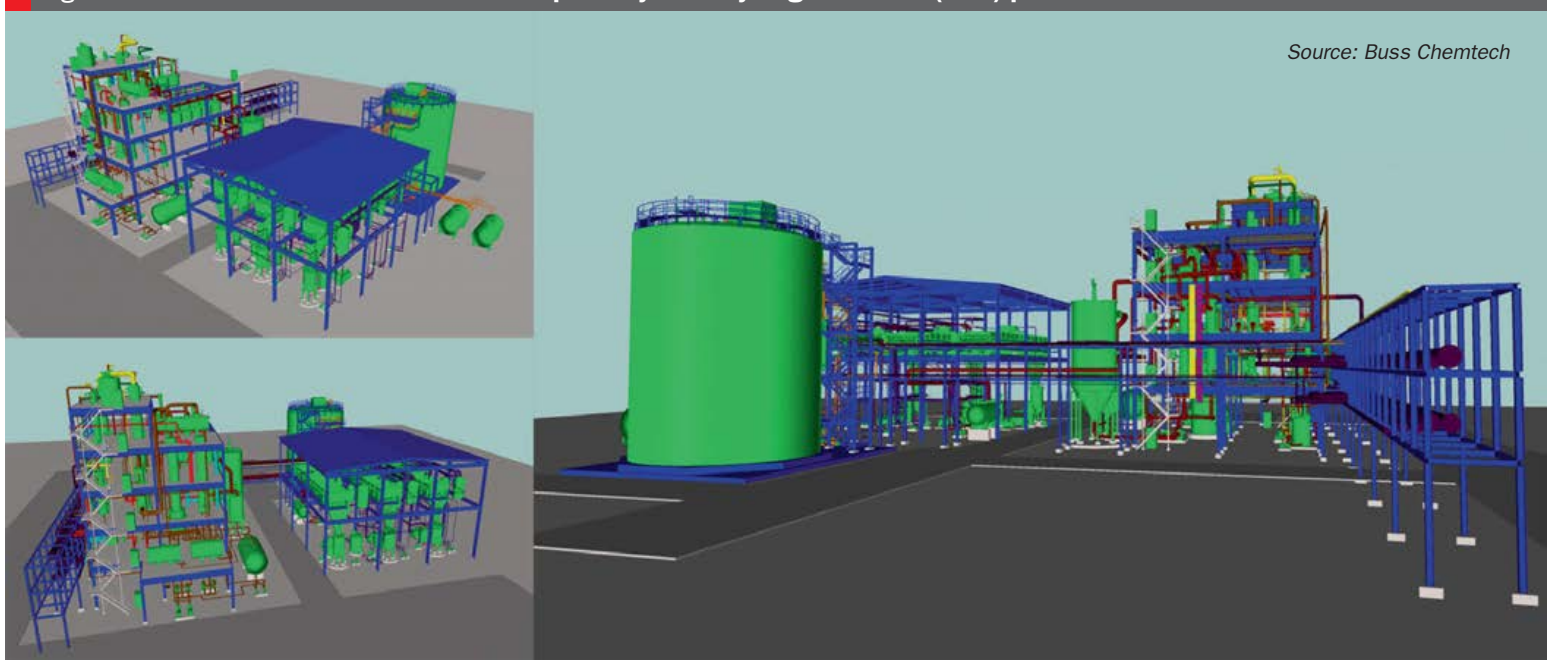
The consumption of FSA in conventional end-uses is very low compared to overall production capacity. The three traditional markets for FSA are small and/or in decline:

- The main end-use for FSA – **low bulk density aluminium fluoride** (LBD AlF_3) – is limited and ever shrinking.
- The market for **water fluoridation**, another key application, is also limited, as well as being controversial due to increasing public health awareness.
- The other principal application**, fluoride salt manufacture**, again, has very limited market size.

Fortunately, these market obstacles can be overcome. Buss ChemTech AG (BCT) offers the international phosphate industry a robust solution to create added-value products from FSA in a sustainable manner. For phosphoric acid producers, BCT's technology opens the door to the manufacture of **anhydrous hydrogen fluoride (AHF)** from FSA – bringing with it new higher value markets such as organic and inorganic fluorochemicals or high bulk density aluminium fluoride (HBD AlF_3) (Figure 1).

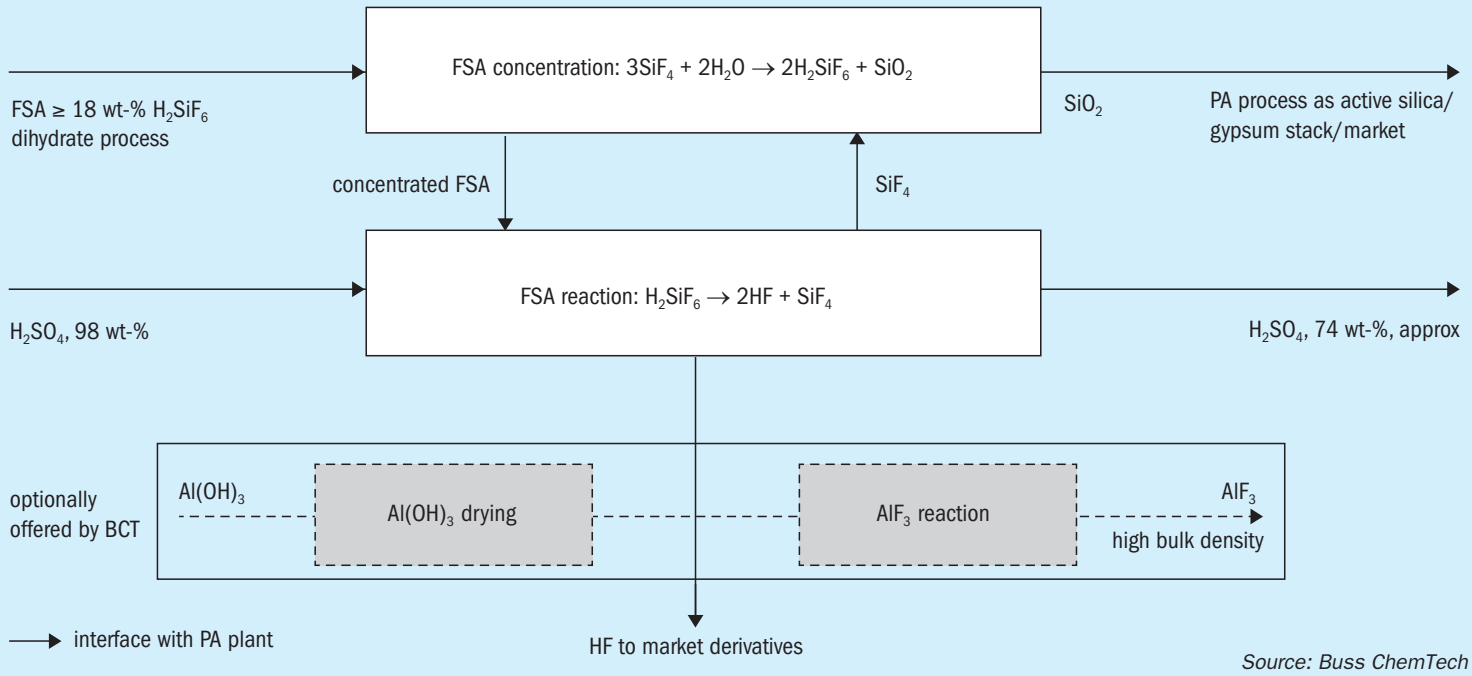
Diversification into such revenue streams, given the competitive challenges faced by the phosphate industry, improves not only the bottom-line but also balances and protects producers from

Fig. 1: **Three dimensional model of an example anhydrous hydrogen fluoride (AHF) plant**



Source: Buss Chemtech

Fig. 2: **Diagram of FSA to HF conversion process with optional AlF_3 production**



Source: Buss ChemTech

market volatility in their core business. To summarise, BCT's anhydrous hydrogen fluoride technology allows phosphoric acid manufacturers, who operate in a highly price sensitive industry, to generate a high value-added co-product for the first time.

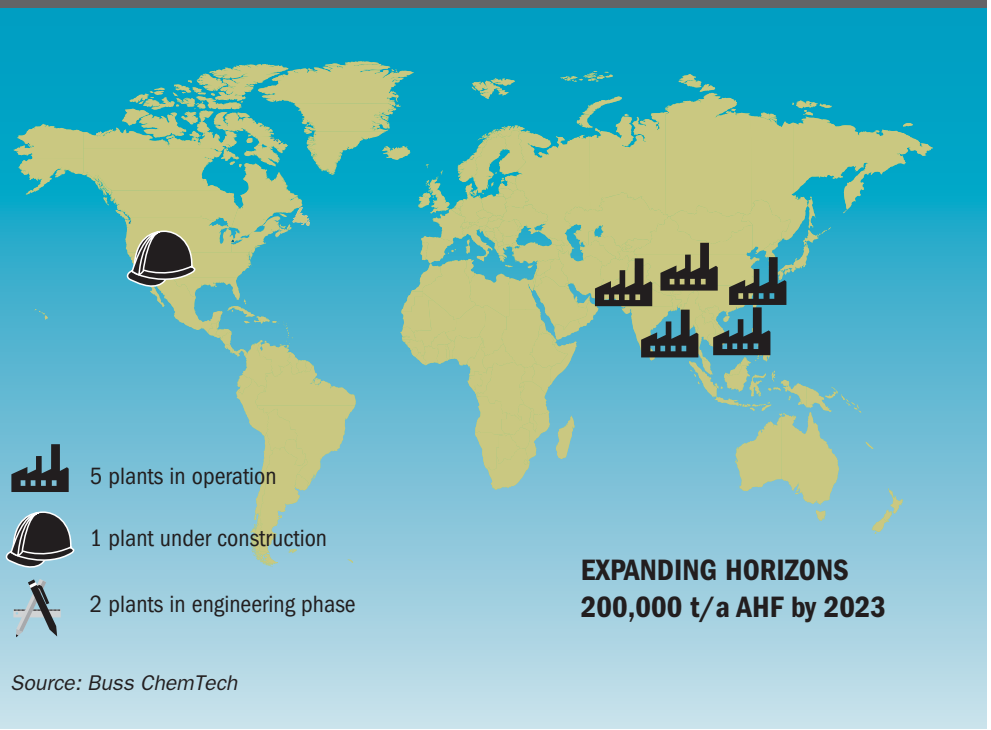
The anhydrous hydrogen fluoride (AHF) process

On arrival at the AHF plant, the FSA initially undergoes a concentration step. The absorption of SiF_4 is used to raise the FSA concentration from approximately 18-24 weight percent to levels above 45 weight percent. Silica is also precipitated and filtered from the concentrated acid solution at this stage.

The concentrated FSA is then pumped to a reactor where it is contacted with sulphuric acid. As a consequence, HF and SiF_4 form and are separated. Following on from this, the crude HF is condensed and purified, while the SiF_4 is routed back to the initial concentration step to concentrate the FSA. The diluted sulphuric acid generated is stripped of residual HF within a stripping column, using steam and air, before being recycled back to the phosphoric acid plant.

The AHF production plant has to be attached to and integrated with the phosphoric acid plant to close the sulphuric acid and water process loops (Figure 2).

Fig. 3: **Current status of FSA-to-HF technology projects globally**



Source: Buss ChemTech

Commercial installations

BCT first commercialised FSA-to-HF conversion technology in the early 2000s. The company subsequently signed a contract with Chinese phosphate producer **Wengfu (Group) Co Ltd** to supply the first industrial plant in February 2006. Project engineering began in mid-2006 and was followed by two years of construction which ended with the commissioning of the AHF plant in mid-2008.

Regular communication between Wengfu and BCT, following on from this successful first AHF project, ensured that new developments in process design, construction materials and plant operations continued to be implemented. Currently, Wengfu operates five BCT-constructed AHF plants, with a sixth under-construction plant due to commence operation in late 2022 (Figure 3).

BCT signed the first AHF project contract outside China with PCS Phosphate Company, a PotashCorp subsidiary, in 2017. This US-based project has continued in phases after Agrium and PotashCorp merged in 2018 to form Nutrien, with Arkema also participating as the HF consuming partner. The project, located at Nutrien's Aurora site in North Carolina, is

Fig. 4: **Gulf Fluor AHF and HBD AlF_3 plant**

PHOTO: BUSS CHEMTECH

now nearing completion and is expected to be commissioned in coming months.

BCT also signed a contract with another renowned fertilizer company in 2020. This project is expected to be commissioned by mid-2023. Combined, the total global capacity for all the FSA-to-HF technology projects mentioned above will have reached more than 200,000 t/a of AHF by 2023.

Comparison with the fluorspar (CaF_2) route

Traditionally, HF has been produced by reacting fluorspar (CaF_2) with sulphuric acid. Indeed, since the 1960s, Buss ChemTech has completed more than 30 plants globally based on its proprietary technology for the CaF_2 route.

The FSA process, meanwhile, also needs sulphuric acid, but only as a dehydration medium, meaning it can be sent back to the phosphoric acid plant. This makes the overall economics of the process more attractive in terms of operational expenditure (opex).

The payback period for a traditional HF plant may exceed 10 years at current CaF_2 price levels. This, however, can be reduced to just 3-4 years by switching to the FSA route. While the investment costs (capex) are similar for both process routes, operation and maintenance are simpler for the FSA process

Importantly, FSA-to-HF technology – by valorising a co-product – also checks all the boxes for sustainability. Moreover, it also adds indirect value, both for environmental protection and to the economy, by substituting for large amounts of CaF_2 which would otherwise have been mined.

HF and its derivatives

HF is widely consumed by many industries and BCT technology offers a high purity product suitable for a wide variety of applications. BCT's technology portfolio also covers the following HF derivatives:

- High bulk density (HBD) aluminium fluoride (AlF_3) – see Figure 4
- Lithium fluoride (LiF)
- Lithium hexafluorophosphate ($LiPF_6$).

HBD AlF_3 is used in primary aluminium production. It reduces energy consumption by lowering the bath operating temperature, as well as acting to replace fluorine losses and maintain the cryolite (Na_3AlF_6) ratio.

In contrast, LiF is most widely used as a flux in the production of ceramics, such as enamels, glasses and glazes. Similarly, it is also used in brazing and welding fluxes and molten salt chemistry in metallurgy.

Consumption as a raw material for $LiPF_6$ production is another area of use. $LiPF_6$ is used as an electrolyte ingredient in lithium-ion batteries. The demand for $LiPF_6$ has increased tremendously in the past ten years due to the shift towards electric and hybrid electric vehicle manufacturing.

About Buss ChemTech AG

BCT is a well-established technology provider located in Pratteln, Switzerland. The company has a long history in the field of fluorine chemistry. This is in addition to capabilities in various gas-liquid reaction technologies and phosgeneation technology. When these are combined with the competencies in fertilizer technologies of its parent company Desmet Ballestra – including phosphoric acid, sulphuric acid, nitric acid and complex fertilizers – BCT can offer a comprehensive solution for the whole phosphate value chain. ■

Developing the Woodsmith mine

Aerial view of Anglo American's Woodsmith mine site in the UK, June 2021.

PHOTO: ANGLO AMERICAN

Anglo American is developing the Woodsmith project in northeast England. This will access the world's largest known deposit of polyhalite, a natural mineral fertilizer containing potassium, sulphur, magnesium and calcium – four of the six nutrients that every plant needs to grow.

PHOTO: ANGLO AMERICAN

Service shaft wheels, Woodsmith mine.

Woodsmith mine project

Anglo American gained control of the UK-based Woodsmith project in March 2020 through the cash purchase of Sirius Minerals for $496 million (£405 million). Once developed, the Woodsmith project will mine the world's largest known source of high-grade polyhalite.

The under-construction Woodsmith mine is located around five kilometres south of Whitby, a small fishing port on England's North Sea coast. The mine will access and extract polyhalite from a deeply buried underground ore deposit – containing 290 million tonnes of permitted reserves – via two 1.6-kilometre-deep shafts. Unusually, the ore extracted at the mine will then be transported to the port of Teesside through a 37-kilometre-long underground tunnel on a conveyor belt system. This mineral transport system (MTS) is designed to minimise the project's surface environmental impact.

On arrival at Teesside, polyhalite ore will be granulated at a materials handling facility to produce a premium-quality, low-carbon fertilizer certified for organic use. This product, known as *POLY4*, will be exported from the company's dedicated port facility to a network of overseas customers.

Once complete, the Woodsmith mine is expected to produce up to 10 million t/a

of *POLY4*. The timeline for the project's development is, however, currently under review.

Project progress

Anglo American provided a progress update on the Woodsmith mine project at the end of July, as part of its interim results announcement to the London Stock Exchange. Project development has continued apace in 2021, according to Anglo American, with capital expenditure of $279 million invested during the first half of the year.

The westwards excavation of the MTS conveyor tunnel from Wilton passed the 15-kilometre mark at the end of June, some distance beyond the intermediate shaft location at Lockwood Beck. The sinking of the intermediate shaft at Lockwood Beck is also now complete, having reached the target depth of 383 metres, allowing shaft lining to now commence. At the main Woodsmith mine head, boring of the service shaft has started, with Anglo American also reporting good progress on installation of production shaft infrastructure.

Expected capital expenditure on the Woodsmith project for 2021 is unchanged at around $0.5 billion. Investment is expected to increase further once a detailed review of the project's development plan is completed. This review will optimise the project as well as ensure it is properly aligned with Anglo American's technical and other standards.

The outcome of the review – together with finalisation of the mine's design and project timings – is expected by the end of the year. It will also include the final capital and schedule estimates for the project. Anglo American has already indicated that investment in additional ventilation is likely to be brought forward to increase early production flexibility. The review is also scrutinising the detailed scheduling of the two main shaft installations.

Marketing update

An impressive range of supply agreements for the polyhalite product *POLY4* – with well-established trading companies and fertilizer producers such as Archer Daniels Midland Company, BayWa AG, Cibra, IFFCO and Wilmar Group – are already in place globally. The pricing of many of these agreements is benchmarked against the market prices of the underlying key nutrients within *POLY4*.

PHOTO: ANGLO AMERICAN

The Woodsmith Mine: moving towards a cleaner, greener and more sustainable future

In an exclusive interview, **Dr Alexander Schmitt**, Chief Marketing Officer at Anglo American Crop Nutrients talks to *Fertilizer International* about the latest developments at the under-construction Woodsmith mine in the UK and the company's plans for its polyhalite product *POLY4*.

Anglo American purchased Sirius Minerals for $496 million in March last year. Could you explain a little more about the rationale behind the purchase of Sirius and the timing of Anglo's re-entry into the fertilizer market?

Anglo American's strategy is to own and operate a diversified portfolio of high quality and long life assets producing future-enabling metals and minerals that are essential to decarbonisation and meet consumer demand trends. Our products are helping the world move towards a cleaner, greener and more sustainable future. The Woodsmith project fits perfectly with that strategy.

The world needs to grow more food, more sustainably, from less land to meet the needs of its expanding population – 60 percent more food by 2050. Finding more effective, efficient and environmentally friendly fertilizers will be a crucial way of doing that and *POLY4* ticks all those boxes: it delivers higher crop yields while also improving farming's impact on the environment, not least by having a very low carbon footprint – 85 percent lower than most chemical fertilizers in fact.

Finally, the Woodsmith project embodies Anglo American's purpose: that is, to reimagine mining to improve people's lives. It is an opportunity to showcase how Anglo American is working to make a cleaner, greener and more sustainable future a reality, through the creation of an ultra-low environmental impact mine and product, with benefits for local communities, customers and the world at large.

In weighing up the purchase, how important to Anglo American were factors such as the scale of the polyhalite resource and the fact that the project had already entered the construction phase?

The size and quality of the deposit and the sustainable mine design fits perfectly with Anglo American's goal of securing access to the best resources and operating these assets more effectively and more efficiently than our competitors. We expect to be extracting polyhalite for the long term, generating almost no waste product, and shipping it from a port less than 30 miles away, and with a product that meets today's and future needs of farmers and food consumers – that sort of asset doesn't come along very often.

The fact that the project was already established, with a clear design and pathway to production was obviously an attraction also, helping to reduce some risks that can affect greenfield development projects.

There's also the human element here. Is it true to say that Anglo American has placed great value on the professional competencies of existing staff, and on the leadership and successful track record of the original Sirius management team – given that this has remained largely intact?

The human element is hugely important to me personally and Anglo American as a whole. I am proud to now be part of that Anglo American Crop Nutrients leadership team and, yes, my colleagues who were here during the Sirius ownership deserve great credit for what they achieved: identifying, securing and developing an asset like this took remarkable vision, innovation, perseverance and determination.

For me in my role as heading our sales & marketing team, the most important element to maintain was the customer relationships. Before this role, I was part of Anglo American's marketing business leadership team, helping to transform businesses and teams to understand and fulfil customer needs through our offerings. So, I really under-

Woodsmith mine construction has progressed well, despite the unprecedented challenge of the Covid-19 pandemic.

PHOTO: ANGLO AMERICAN

stand and value the importance of human relationships and trust in making business happen – the team must have been doing something right to have secured a peak of over 10 million tonnes a year of orders for a relatively new product that is not yet widely available.

Now it's important to build on that strong foundation with Anglo American's industry-leading operational and marketing expertise: we can introduce a number of our *FutureSmart Mining*™ technologies to the project and provide the global reach to further develop markets for *POLY4*, thereby providing additional reassurance to our customers.

How is the Woodsmith mine project progressing? Construction during a pandemic must have thrown up many challenges.

Covid-19 has thrown up challenges for everyone across the globe and we're no different. Despite this, progress has been good. Excavation of the conveyor tunnel had passed 15 kilometres at the end of June, beyond the intermediate shaft location at Lockwood Beck.

At Lockwood Beck, shaft sinking is complete, having reached the target depth of 383 metres, and shaft lining is under way. At the mine head, shaft boring has started in the services shaft, while good progress is also being made on the production shaft infrastructure. We're all incredibly proud of how the whole team has pulled together to progress the project in such unprecedented circumstances.

Expected capital expenditure in 2021 is unchanged at circa $0.5 billion, while the detailed technical review of the project's development plan is completed, with the objectives of optimising the project and aligning it with Anglo American's technical and other standards. The review and subsequent finalisation of design and timing are expected to be complete by the end of the year, including final capital and schedule estimates.

Anglo American has a disciplined approach to capital allocation so that we can deliver consistent returns for shareholders, and this year's capital allocation shows the strength of commitment from the Group to the project. With our Quellaveco copper mine in Peru – one of the company's other major development projects – due to come online in 2022, the timing is perfect for Woodsmith as its capital requirements increase over the next few years.

> **"Our products are helping the world move towards a cleaner, greener and more sustainable future. The Woodsmith project fits perfectly with that strategy.**

Looking further ahead, when is the outcome of the ongoing technical review of the project's development plan due – and what are the main objectives behind that?

The technical review is an assessment to ensure the development proceeds and is delivered according to Anglo American's exacting safety, environmental and technical standards. We expect to complete this work later this year and be in a position to set out the final development budget and schedule in February 2022.

We know our customers are eager to start using *POLY4* and we want to make sure we can deliver it as quickly, safely and as reliably as possible for many years to come. We're looking at this as a long-term investment that can produce healthy margins for Anglo American for several decades – so it's important to spend some time now getting the engineering and development plan right.

Your role, Alex, encompasses the marketing of Anglo American's polyhalite product *POLY4*. How have sales and marketing activities progressed over the last 18 months under Anglo American ownership?

For sure it's been a key feature, and an essential one for our customer support activities. At the start of the project, long before Anglo American became involved, the objective was to prove the concept and demonstrate the effectiveness of *POLY4* as a crop nutrition product.

The team achieved that and more: we consistently demonstrated the real world contribution to better farm yields, crop quality and various other needs of farmers like disease resistance and soil quality. The offtake agreements are a testament to the strength of that marketing, plus the agronomic work, and the confidence that our customers have in the product.

Now the research has moved on into full-scale commercial trials: we're up to around 550 on-farm commercial demonstrations, adding to the 600 research trials we've already done. The aim is to assess how *POLY4* fits best in customer portfolios and where it can achieve most value for farmers, so that we can market it effectively.

In South America, for example, it will find a role as a substitute feedstock for major blends, replacing some – but not all – potassium, sulphur and calcium inputs, while increasing the overall nutrient content of that blend (with MgO and micronutrients) and reducing its chloride content. Our 2020 commercial trials on Brazilian soybeans have shown that *POLY4* inclusion in a typical 0:18:18 blend can give a four percent yield improvement over standard practice.

In Europe, it will generate most interest as an environmentally friendly and organically-certified straight or NPK feedstock to aid more sustainable farming practices. The EU has set some ambitious environmental targets for farmers: a 50 percent reduction in nutrient losses while maintaining soil fertility; 25 percent of farmland to be organic by 2030; reductions in nitrogen and phosphorous fertilizer use, etc.

POLY4 can help because it increases overall nutrient use efficiency with more balanced nutrition. It improves soil health, crop quality and weather resilience – and has a very low carbon footprint.

Farmers are trying to improve the productivity and sustainability of their land. So they will use *POLY4* as part of a high-performance package combined with other traditional fertilizer products, as a way of providing their crops with a broader range of efficient nutrients than they are currently able to easily and affordably access. Our marketing is about working with our customers to get that message down to the farmgate, so that farmers understand it as a solution to their needs.■

Innovative mine design

The Woodsmith mine's innovative design – by allowing most operations to take place unobserved underground – was key to the project gaining planning consent in 2015 (*Fertilizer International* 481, p56). To accomplish this, the mine incorporates very large diameter foreshafts near to the surface. These cavernous structures are designed to house and conceal the mine's bulky winding gear and associated equipment. Narrower diameter vertical production and service shafts lead off from these large near-surface chambers. These, in turn, connect to the horizontal mineral transport system (MTS) tunnel (Figure 1).

Initially, the production and the service shafts extend from surface level to a depth of 60 metres as 36 metre diameter chambers. From that depth, they extend downwards as nine metre diameter shafts to the polyhalite seam 1.5 kilometre below ground.

A third shallower MTS shaft is being sunk at the Woodsmith site to enable a tunnel boring machine (TBM) to be lowered and launched. This will be used to drive one section of the 37-kilometre-long MTS tunnel northwards from the Woodsmith site towards the Lockwood Beck intermediate shaft (Figure 1). The MTS will be used for horizontal transport of polyhalite ore from the mine to Teesside. It intersects and connects to the production and service shafts at a depth of 360 metres.

The project is using a variety of rock boring and shaft sinking techniques. Notably, the Woodsmith mine features the deepest diaphragm walls ever constructed in the UK – down to 120 metres in the case of the service and production shafts. The project will also be the first in the UK to use a Herrenknecht vertical shaft sinking machine (VSM)[1].

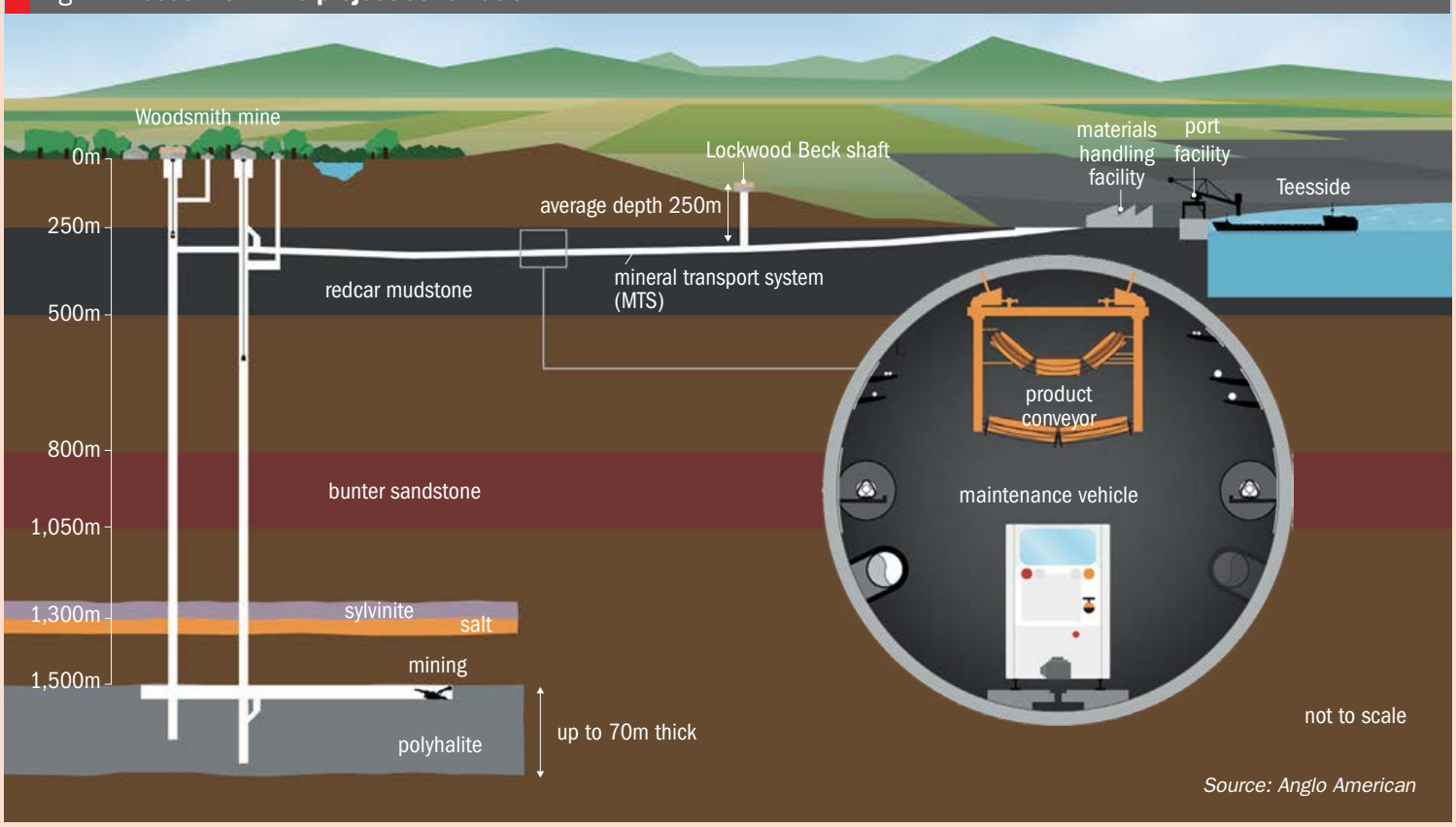
Bauer began the diaphragm walling in 2018. The scope of its work included the initial 120-metre-deep section of the production shaft, together with completion of the diaphragm walling on the near-surface sections of all three mine shafts. Similarly, contractor Careys extended the initial 120-metre-deep section of the service shaft, this time using conventional sinking segmental lining coupled to a slipform secondary lining[1].

The production and service shafts will now be taken to their full 1.5-kilometre depths using two Herrenknecht shaft boring roadheaders. These were delivered on site in 2020 and the first machine was launched this summer. Careys, meanwhile, extended the MTS shaft to a depth of 120 metres using the Herrenknecht VSM. A Galloway frame will now sink the MTS shaft to its full 360 metre depth using a conventional drill and blast method[1].

At the project's Teesside end, tunnelling contractor Strabag is using a Herrenknecht TBM to drive the first section of the MTS tunnel southwards from Wilton to the Lockwood Beck intermediate shaft. This TBM began work in April 2019 and, subsequently, has advanced well ahead of schedule. Strabag expected to remove a massive 400,000 m^3 of material from the first 12 kilometres of the tunnel drive. Better than expected ground conditions have enabled this TBM to be refurbished and reused to complete the second 12-kilometre tunnel drive. This approach has cut project costs by reducing the size of the cavern needed at Lockwood Beck and using the infrastructure already installed at Wilton[1].

The Lockwood Beck intermediate shaft is located around 32 kilometres east of the main Woodsmith mine site. It is constructed within a secant piled wall to a depth of 20 metres. A grout curtain installed by Bachy Soletanche leads on from this to a depth of 160 metres. Strabag excavated the shaft to its full 380 metre depth in August this year using a blind boring method.

Fig. 1: **Woodsmith mine project schematic**



Currently, the project's marketing activities are concentrating on the development and implementation of detailed regional-level sales and marketing strategies. To further promote *POLY4* to end-users, additional support is also being provided to help customers with their own market development activities.

The number of commercial-scale on-farm demonstrations has accelerated, with around 550 either in progress currently or complete. These demonstrations continue to validate the product's agronomic efficacy and the potential improvements in crop yield and/or quality it can deliver to farmers (*Fertilizer International* 502, p46).

Additional studies have also shown the ability of *POLY4* to enhance soil health by increasing resilience to compaction, erosion and run-off. This is addition to improvements in nutrient availability to crops, with a corresponding reduction in excess nutrients entering watercourses. *POLY4* is certified for organic use and, according to Anglo American, generates up to 85 percent less carbon emissions thanks to a production method that generates little to no waste.

Delivering on jobs

In its latest update, Anglo American revealed that 1,300 people are now employed full time in the construction of the Woodsmith mine, up from 1,000 at the end of last year. The company is also set to hire more than a dozen local apprentices to add to the 14 already employed on the project. Hundreds more contractors and local companies are also beneficiaries of the project's supply chain expenditure.

Commenting in July on project progress, Chris Fraser, CEO of Anglo American's Crop Nutrients business, said: "The first half of the year hasn't been without its difficulties for everyone, not least because of the ongoing restrictions that we've been working with during the pandemic. But I am incredibly proud that the whole team has pulled together and that we're continuing to provide important opportunities for people in the region."

He added: "We're determined to provide as many jobs for local people as we can and build a long-term local workforce – our apprenticeship programme is testament to that."

So far this year, Anglo America has provided £150,000 to support local organisations in North Yorkshire and Teesside. The money forms part of a £300,000 regional social & economic development plan. This is designed to help increase employment opportunities and raise aspirations in the region. Additionally, the project's charitable foundation has donated more than £236,000 to good causes. This includes more than £125,000 in Covid-19 recovery funding, as well as significant donations to food banks and other emergency food supplies during the pandemic.

"We continue to identify ways in which we can help and support people, business and organisations in the areas around our operations," said Chris Fraser. "Anglo American is committed to the area for the long term and is determined to make a positive impact on the health and wellbeing of our communities, as well as the local environment." ■

Reference

1. Smith, C., 2020. Sensitive engineering for North Yorkshire fertiliser mine. *New Civil Engineer*, June 2020.

Editor:
SIMON INGLETHORPE
simon.inglethorpe@bcinsight.com

Publishing Director:
TINA FIRMAN
tina.firman@bcinsight.com

Subscription rates:
GBP 300; USD 550; EUR 450

Subscription claims:
Claims for non receipt of issue must be made within 3 months of the issue publication date.

Sales/Marketing/Subscriptions:
MARLENE VAZ
Tel: +44 (0)20 7793 2569
Fax: +44 (0)20 7793 2577
marlene.vaz@bcinsight.com
Cheques payable to BCInsight Ltd

Advertising enquiries:
TINA FIRMAN
tina.firman@bcinsight.com
Tel: +44 (0)20 7793 2567

Previous articles from *Fertilizer International* and *PK Insight* from 1997 to the present are available digitally in PDF format. To make a purchase, or for a list of available articles, please see:
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ISSN: 0015-0304

Design and production:
JOHN CREEK, DANI HART

Mixed Sources
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www.fsc.org Cert no. SA-COC-001904
© 1996 Forest Stewardship Council

Printed in England by:
Buxton Press Ltd
Palace Road, Buxton, Derbyshire, SK17 6AE

BCInsight

Published by: BCInsight Ltd
China Works, Unit 102,
100 Black Prince Road,
London SE1 7SJ, UK
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