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From volume to value

> **For commodity fertilizers, this is not the end... but it may be the beginning of the end.**

Something special has happened in 2017. Or rather speciality/ specialty products – choose your spelling – have started to happen.

Just look at the conferences. The theme of the International Fertilizer Association's Strategic Forum in Zurich this November is: "Enhancing Nutrient Use Efficiency – The Role of Specialty Fertilizers." In the US, Green Markets are holding their Specialty Fertilizer Global Summit 2017 in Charlotte, NC, in December. Integer's forthcoming Value Added Fertilizer Summit Asia 2018 is scheduled to return to Singapore in February.

That is evidence of the industry's growing commercial interest in speciality fertilizers. There are clearly sizeable audiences – in the Americas, Europe and Asia – eager for intelligence about their growing prominence.

Adding to the clamour, much of the coverage in our previous September/October issue was devoted to enhanced efficiency fertilizers (EEFs), an important segment of the speciality product market.

EEFs are a niche but fast-growing and high-value group of plant nutrient products. They include slow- and controlled-release and stabilised fertilizers – hence the label SCRSFs, the other widely-used term for these products.

The market for EEFs is potentially large. But growth is being constrained by two factors: availability and affordability. Because of this, many EEFs have traditionally been sold into the turf and ornamental market. In agriculture, their use has largely been restricted to higher-value cash crops such as fruits and vegetables.

Stabilised fertilizers (SFs), however, are increasingly being applied to broad-acre crops. These agricultural staples, grown on a vast scale, are the main market for commodity fertilizers such as urea.

The highly innovative *SUPERU* product from Koch Agronomic Services is one trailblazing example. This stabilised urea fertilizer incorporates both urease and nitrification inhibitors. Targeted at broad-acre crops such as corn and soybean, it protects against all three forms of nitrogen loss – volatilisation, denitrification and leaching.

Koch is also serious about tackling the availability and affordability issue. The company recently increased North American supply by dedicating capacity at its Koch Enid, Oklahoma, plant to *SUPERU* production, as part of a $1.3 billion expansion project.

Earlier this year, Koch also signalled its desire to license *N-TEGRATION*, the proprietary technology used to manufacture *SUPERU*, to third party urea producers. This could be a key breakthrough for EEFs, as making them more available and affordable to broad-acre farmers will require a production roll-out on a much greater scale.

Producing EEFs at scale is certainly key. That is what makes Stamicarbon's recent entry into the controlled-release fertilizer (CRF) market so symbolic. After all, the company has licensed some 250 urea plants around the world, more than half of installed global capacity.

In October, Stamicarbon announced it would start licensing a cost-competitive coating technology to produce CRFs for broad-acre crops. Stamicarbon will license the technology to major urea producers outside North America, in a partnership arrangement with its US developer, Pursell Agri-Tech.

Given its market presence and might, Stamicarbon's entry should provide the production scale needed to achieve cost reductions and improve availability – finally enabling EEFs to penetrate deeply into the broad-acre crop market and displace commodity urea.

Where is all this leading? IFDC president and CEO Amit Roy has long called for a fundamental fertilizer market shift from volume to value. The fertilizer majors are certainly changing their business models, widening their product portfolios, moving inexorably downstream, and making strategic shifts into areas such as digital farming.

The inevitable end-point will be integrated production-distribution-retail businesses offering farmers a complete package of agronomic products and services. That makes the classic model of fertilizer producers as standalone commodity companies look increasingly outmoded, redundant and unviable.

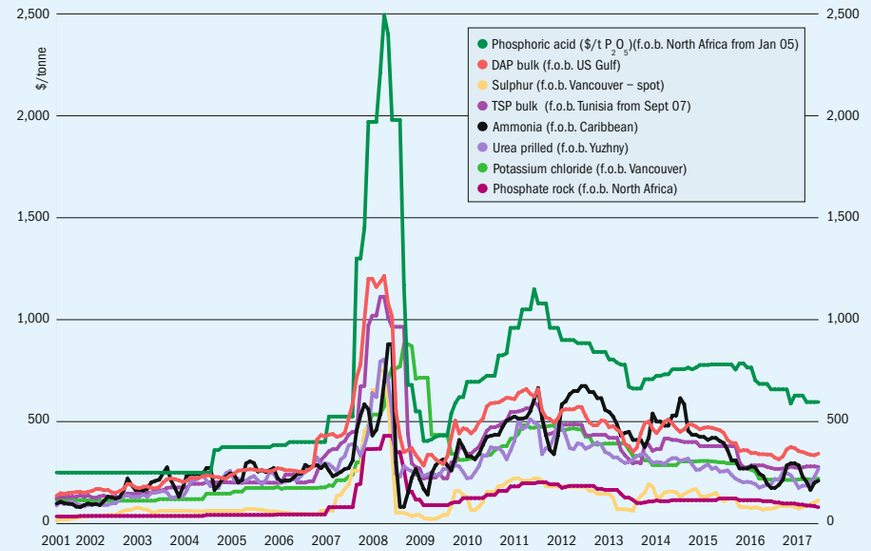
Will 2017 be seen as the year in which speciality products took centre stage and commodity fertilizers – and the commodity fertilizer business model – was ushered to the wings? That may be an overstatement. But 2017 certainly has been a breakthrough year for the speciality market.

For commodity fertilizers, to misquote Churchill, this is not the end. But it may be the beginning of the end, with signs of their gradual eclipse as speciality products increasingly come to the fore. Such a transition, if well-managed, will be good news for the industry and efficient nutrient use globally. Importantly, it will also be good news for farmers, and for the soil, water and air on which we all depend. ■

Simon Inglethorpe, Editor

Market outlook

Historical price trends $/tonne



Source: BCInsight

Market insight courtesy of Integer Research

AMMONIA

September marked a turning point in price sentiment. Prices moved upwards due to stronger demand combined with ammonia export supply interruptions. Ending three consecutive months of price decreases, the Yuzhny Black Sea price broke the $200/t f.o.b. barrier in mid-September, before swiftly moving towards $220/t f.o.b. by September's end. The Tampa contract price also increased by $30/t to $245/t cfr between September and October. LSB Industries' Pryor ammonia plant in the US is expected to be closed for a month for repairs, following a fire on 23 September.

UREA

The market was left reeling from unexpectedly sharp price increases in September. These were prompted by a sequence of Indian import tenders. The first two tenders, both from IPL, coincided with a temporary reduction in global supply in September. This created an explosive month for urea prices, with some producers concluding sales as high as $300/t f.o.b. RCF closed its first urea import tender on 14 October, receiving 17 offers totalling 1.4 million tonnes. It is understood that around 440,000 tonnes was agreed for shipment by 30 November, with a further 60,000 tonnes under discussion at the time of writing. In Russia, TogliattiAzot shut down one of its prilled urea units in October to boost ammonia production.

PHOSPHATE

Global benchmarks found some price support in September, amid tighter supply and rising raw material costs. The US Gulf benchmark edged up $10/t from August levels, after Mosaic revealed that disruption from Hurricane Irma in early September may have lost it up to 400,000 tonnes of DAP/MAP production. Russian producers had little product available for export, focusing instead on domestic and regional commitments. Export availability from Chinese producers was similarly restricted due to their focus on domestic commitments. This resulting lack of availability enabled exporters to raise price expectations for major benchmarks to $360-$365/t f.o.b. in October.

The bulk of September/October demand was concentrated in Asia. India and Pakistan received DAP shipments from the Middle East, North Africa and the US. Mosaic also sold its first volumes from Wa'ad al Shamal to South Asia. After an active August, Brazilian MAP demand slowed through September.

POTASH

Strong MOP demand held up in many major markets in the third quarter. MOP spot markets prices have risen consistently throughout 2017, reaching $280/t cfr in Brazil and $265/t cfr in Southeast Asia in October. The market now appears to be at a crucial juncture, however. Any

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retreat in demand from current levels will coincide with rising production from new supply sources, namely K+S Bethune in Saskatchewan, plus additional new supply from EuroChem in Russia expected in 2017-2018.

PotashCorp has taken measures to alleviate oversupply through its planned shutdowns at Allan and Lanigan for 8-10 weeks in the fourth quarter.

SULPHUR

Recent prices have been surprisingly robust. In September, the Vancouver and Arab Gulf f.o.b. reference prices averaged around $105/t, having traded in the $80-90/t range for many months previously. Prices for sulphur delivered to China averaged $133/t in September. There were also reports of a Middle East cargo being sold for $130-135/t f.o.b. for Chinese delivery mid-October.

Several factors contributed to this price uplift. In China, there has been a rush of activity due to environmental taxes scheduled to be imposed next year. Sulphur availability from Russia has also been squeezed. Harsh weather has reduced sulphur volumes for export by causing earlier-than-usual closures to inland rivers and waterways.

Market price summary $/tonne – Start-November 2017

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phosphoric Acid
f.o.b. Caribbean	270	n.m.	f.o.b. E. Europe 110-120	f.o.b. US Gulf	345-350	n.m.	n.m.
f.o.b. Yuzhny	240-290	268-273	-	f.o.b. N. Africa	355-385	263-280	492-700
f.o.b. Middle East	300-330	231-290**	-	cfr India	380-385	-	567-572*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	209-233	-	cfr US Gulf	55-65	f.o.b. Vancouver	160-180	
f.o.b. Middle East	207-229	-			f.o.b. Arab Gulf	170-180	
f.o.b. Western Europe	-	€420-450			cfr North Africa	98-119	
f.o.b. FSU	192-224				cfr India	180-200+	

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)*

MARKET DRIVERS

- **Ammonia:** Seasonal refill demand in the US should keep prices firm until December. Similarly, recent supply outages looks likely to continue, tightening the supply-demand balance in the fourth quarter. In Saudi Arabia, the absence of the SAFCO IV ammonia/urea plant, which went offline in late September for a scheduled 84-day turnaround, will remove more than 100,000 tonnes of merchant ammonia from the market. Prices are forecast to soften in the first quarter of next year, as planned turnarounds come to an end and seasonal fertilizer demand slows. Prices are expected to remain above $200/t f.o.b., however.
- **Urea:** Following sharp September and October increases, prices are expected to fall from current levels once Indian buying comes to a close. Spring pre-buying next year should stimulate prices somewhat, although regional price benchmarks, in the US for example, will be driven by the timing of new project commissioning. YPFB's Bulo Bulo urea plant in Bolivia moved closer to completion in October. Around 80 percent of the plant's output of 2,100 t/d is destined for export to Brazil, Argentina and Paraguay.
- **Phosphate:** DAP demand East of Suez is likely to soften through the remainder of the year, as is usual seasonally. Chinese availability is expected to remain limited. Producers are committed to the domestic market and unwilling to lower price expectations. Ma'aden will be well positioned to supply the Asian market as it ramps up production at Wa'ad al Shamal. Across the Atlantic, US phosphates demand will have weakened by November. Brazilian buyers will be keen to secure *safrinha* volumes, although we expect the majority of buyers to defer large purchases, choosing to see how prices play-out over the rest of the year.
- **Potash:** We believe the MOP market will loosen slightly in the fourth quarter, based on projected demand and supply. Producers have ramped up production in recent months, and demand from inventory filling is also likely to retreat. However, the outlook for the first half of 2018 suggests the potash market could tighten slightly, with conditions generally supporting buying and application. Southeast Asia is likely to remain a bright spot for demand due to profitable palm oil economics, stable currencies in Malaysia and Indonesia, and generally more favourable planting conditions compared to last year.

  We are awaiting news on the impact of new supply sources from Canada, Russia and Turkmenistan. K+S's Bethune facility in Saskatchewan will have capability to service the US market through Koch, once granulation capacity is installed. EuroChem reports that it is on track to begin producing MOP at Usolskiy before the year's end. Turkmen supply seems to have been undisruptive so far.
- **Sulphur:** Looking ahead, factors which have contributed to the recent price spike are likely to stay in play for the next few months. This means the sulphur market will remain tight in the short term, supporting current elevated prices, possibly slightly higher, although the market situation should unwind in 2018. We expect to see Chinese import demand soften in the first half of 2018. Downstream Chinese sulphur consumers who have run their plants harder in 2017, postponing maintenance and other scheduled stoppages, look likely to turn plants down next year. Similarly, in Russia, sulphur stocks are likely to build, while the winter weather situation makes transportation difficult, although this product will appear next spring. We therefore expect f.o.b. prices to head back below $100/t in the first half of 2018, most likely settling in the price range we saw during the first half of this year.

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CANADA

Regulators clear path for Agrium-PotashCorp merger

China's Ministry of Commerce (MOFCOM) approved PotashCorp and Agrium's proposed 'merger of equals' on the 7 November.

MOFCOM's approval is conditional on PotashCorp's divestment of its minority shareholdings in Arab Potash Company (APC) and Sociedad Quimica y Minera de Chile (SQM) within 18 months, and Israel Chemicals Ltd (ICL) within 9 months, respectively, of the merger's closure.

PotashCorp is believed to have hired Goldman Sachs and Bank of America Merrill Lynch to handle the sale of its 32 percent stake in SQM, according to *Reuters*. The *FT* later reported that Sinochem, China's state chemical group, is one of four potential Chinese bidders for the $4 billion SQM stake.

Chinese business interest is linked to SQM's position as one of the world's largest producers of lithium, a key component in electric car batteries. China is the world's largest electric car market and, says *FT*, is set to dominate global production of lithium-ion batteries. SQM shares have risen in recent times on the back of the soaring lithium market (*Fertilizer International* 478, p18).

China's regulatory approval is also conditional on PotashCorp agreeing to convert its equity in Sinofert Holdings Limited to a passive investment. This is designed to ensure that Canpotex remains a reliable, dedicated potash supplier to China.

PotashCorp's Lanigan mine.

The regulatory approval in China follows unconditional Canadian regulatory clearance for the merger on 11 September. The Canadian Competition Bureau (CCB) issued a 'no-action' letter after concluding that the merger was unlikely to reduce or prevent market competition for potash, phosphate and nitric acid.

Brazil, Canada, China, India and Russia have now all given regulatory clearances for the merger. Critical US regulatory approval remains outstanding, however, although PotashCorp and Agrium still expect the merger to close by the end of 2017.

In an unrelated move, PotashCorp also announced it was temporarily stopping potash production at its Allan and Lanigan mines during the last two months of the year. The shutdown at Allan begins on the 19 November for 10 weeks. Lanigan will then shutdown on 3 December for eight weeks. PotashCorp said in a statement that the measure was due to the company's "strategy of matching supply to market demand" and fully-utilising its lowest cost Rocanville potash mine. ■

UNITED STATES

Agrium divests phosphate and nitric acid assets

Agrium is selling two of its US fertilizer production assets to help ease the closure of its merger with PotashCorp.

The company announced the sale of its Conda, Idaho, phosphate production plant to Itafos for around $100 million on 7 November. The purchase price includes working capital and adjacent phosphate mineral rights.

On the same day, Agrium also announced it was selling its North Bend, Ohio, nitric acid plant to Trammo Nitrogen Products, a wholly-owned Trammo subsidiary company. Both of the production plant sell-offs are in the form of definitive asset purchase agreements.

The Conda sales divests Agrium of its entire super phosphoric acid (SPA) business in North America. Similarly, the sale of North Bend disposes of Agrium's entire US Midwest nitric acid business. Both divestments are intended to address concerns raised by US regulators about Agrium's merger with PotashCorp, which requires US Federal Trade Commission approval.

"The divestment of these assets will help pave the way for our merger with PotashCorp. With Itafos operating the SPA business and Trammo operating the nitric acid business, farmers and industrial customers will be served across the US for many years to come," commented Chuck Magro, Agrium's president and CEO.

Mosaic idles Plant City, Florida

The Mosaic Company is to idle its one million tonne capacity Plant City, Florida, phosphate concentrates plant for at least one year.

The indefinite shutdown of the former CF industries plant is a sign of phosphates industry rationalisation in North America. This is in reaction to the arrival on the market of new low-cost capacity, including Mosaic's Wa'ad Al-Shamal Saudi Arabian joint venture (JV) with Ma'aden and SABIC.

In future, Mosaic says it will be able to supply its Indian phosphate customers more effectively from its Saudi Arabian JV, and will instead focus its US production on the North and South American markets where it has logistical advantages.

The idling of Plant City should improve Mosaic's phosphate margins and lower the company's capital requirements.

Tessenderlo opens Illinois liquid fertilizer plant

Tessenderlo Group opened its new *Thio-Sul* manufacturing plant in East Dubuque, Illinois, in October. This newly-commissioned plant, part of the company's Crop Vitality business unit, creates around 20 new jobs.

Thio-Sul is a liquid fertilizer used for broad-acre crops, as well as arboricultural and vegetable crop cultivation. The East Dubuque plant will allow Crop Vitality to deliver this product to Midwest farmers more efficiently.

Tessenderlo Kerley's CEO Steve Azzarello said: "This facility combines excellence in process technology, manufacturing efficiency, product quality safety and environmental performance. The East Dubuque facility allows us to take thousands of tons of product off long-haul truck and rail routes as well as be more service orientated as product will be available locally."

Rentech Nitrogen Partners, now CVR Partners, leases property at East Dubuque to Crop Vitality, as part of a long-term agreement signed in 2014. Under this deal, CVR also supplies the site with ammonia, a key ingredient in *Thio-Sul* production.

Stamicarbon invests in Pursell Agri-Tech

Stamicarbon has expanded into the controlled-release fertilizer (CRF) market through a 20 percent stake in Pursell Agri-Tech, an Alabama-based start-up company.

Stamicarbon's parent company Maire Tecnimont announced the $5 million purchase of Pursell shares on 3 October.

Pursell Agri-Tech's main expertise is in polymer-coating technology. The Sylacauga headquartered company has developed a cost-competitive coating technology – enabling it to produce CRFs for efficient fertilization of broad-acre crops.

Pursell's innovative technology is capable of delivering a range of CRF products, notably urea, by combining a proprietary polymer with a high-performance coating process. The resulting crop nutrient products are more sustainable, improving crop yields while at the same time reducing potential environmental impacts.

Importantly, Stamicarbon will become the exclusive global licensing partner for Pursell coating technology. It will license the technology to parties outside North America, such as major urea producers, other large fertilizer producers or distributors. Pursell Agri-Tech will retain the right to develop the North American market with selected partners, with Stamicarbon acting as a non-exclusive licensing partner. The two parties will also work closely together to develop other new businesses and technologies through open innovation.

"This… collaboration will combine Stamicarbon's global network and technological capability with Pursell Agri-Tech's leading expertise in coated fertilizers, enabling us to pursue promising initiatives in controlled-release fertilizers worldwide," commented Pierroberto Folgiero, the CEO of Maire Tecnimont.

Nick Adamchak, CEO of Pursell Agri-Tech, added: "Pursell Agri-Tech is delighted to welcome Stamicarbon as a shareholder and to enter into this strategic partnership with them. We're confident it will allow for better fertilizers to become widely available, paving the way for more sustainable

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climate-smart agriculture worldwide. Stamicarbon has a global network in the urea production market, and a proven record of leading through continuous innovation."

Koch expands SUPERU capacity

Koch Agronomic Services has improved the availability of its *SUPERU* fertilizer. The company has increased *SUPERU* production capacity at its Koch Enid, Oklahoma, plant as part of a $1.3 billion expansion project.

SUPERU is a granular urea fertilizer that incorporates urease and nitrification inhibitors. The product offers the highest available concentration of nitrogen – 46 percent – and provides both above- and below-ground protection against all three forms of nitrogen loss – volatilization, denitrification and leaching.

Koch will now produce *SUPERU* fertilizer using proprietary *N-TEGRATION* technology at the Enid plant, as it already does at its urea plant in Manitoba, Canada, and its speciality plant in St. Louis. *N-TEGRATION* allows proprietary Koch additives such as *AGROTAIN* nitrogen stabilizer to be integrated into granular or prilled urea.

"Our increased production capacity allows us to offer retailers and their customers across a broader geography this flexible, easy-to-use fertilizer," says Stan Koster, vice president of Koch Agronomic Services.

SUPERU helps farmers maximise their yield potential and minimise potential environmental impact. Recent field trials on spring wheat in Glyndon, Minnesota, found that *SUPERU* reduced cumulative nitrate leaching, or soil nitrogen loss, by 30 percent. The product significantly reduced all three types of nitrogen loss.

"The weather is something you can't control on the farm. *SUPERU* protects you from volatilization, if you don't get rain, but it also protects from leaching if you get too much rain," says Clark Anderson, who, along with his brother, farms 2,800 acres of corn, soybeans and hay near Princeton, Minnesota.

Yara buys Adapt-N

In a downstream move, Yara International completed its purchase of US-based Agronomic Technology Corp (ATC) on 6 November.

ATC is the owner of *Adapt-N*, a market-leading digital nitrogen fertilizer recommendation tool used by US farmers. Technologies offered by ATC, such as *Adapt-N* and *N-Insight*, allow farmers to optimize fertilizer use on zones in individual field. This improves farm profitability and agricultural sustainability.

The acquisition substantially strengthens Yara's digital farming capabilities. Yara is currently accelerating its investment in digital farming as part of its business strategy.

"ATC will help us implement our farmer-centric strategy and is an important building block in expanding our position in digital farming," said Terje Knutsen, executive vice president, Crop Nutrition, Yara. "It is another important contribution to our mission to responsibly feed the world and protect the planet."

Adapt-N is the final outcome of decades of research which originally began at Cornell University. ATC, which is based in both New York and Silicon Valley, already has a strong commercial presence in US corn, and is expanding to other crops and regions. Yara plans to use its global presence to accelerate this expansion.

"Joining our advanced technology… with a leading crop nutrition company like Yara provides a tremendous opportunity to scale globally, innovate across a wider product portfolio and crop base, and maintain focus on the success and sustainability of all farmers and those who serve them," said Steve Sibulkin, ATC's CEO.

JDCPhosphate secures commercialisation funding

JDCPhosphate has closed an equity financing deal with Stonecutter Phosphate Investors, an affiliate of Stonecutter Capital Management.

JDCPhosphate will use the investment to accelerate the commercialisation of its Improved Hard Process (IHP) technology. The company has been developing a highly-innovative patented IHP process for producing high-quality phosphoric acid from low-quality phosphate rock that eliminates gypsum waste.

JDC will modify its Fort Meade plant by early 2018, enabling it to complete the processing design package for a full-scale commercial IHP plant. Forthcoming trials on various types of phosphate rock will allow potential licensors to validate the process for their raw material sources.

Independent engineering studies will also be conducted ahead of commercial deployment of IHP. JDC was recently granted a US patent covering its proprietary induration process, a core component of the IHP technology.

"We are extremely pleased to have Stonecutter join JDC as a co-investor," said Farouk Chaouni, JDC Phosphate executive chairman. "The company is ready to move forward with commercialisation of IHP on an aggressive timetable. This will enable more sustainable and efficient production of phosphate fertilizers."

Samuel Cole, a principal at Stonecutter, said: "At Stonecutter, we look for companies with strong management teams focused on highly compelling market opportunities. Stonecutter is excited to be able to participate in the JDC story."

MOZAMBIQUE

Yara urea project to cost $2bn

More details about a potential major urea production investment by Yara in Mozambique have emerged at an Olso business summit.

CEO Svein Tore Holsether said it was too early to say if Yara would develop the project alone: "The value of the project, if I use industry benchmarks, will be about $2 billion. We are working on it and time will tell what the structure will be."

He also confirmed that Yara was interested in further expansion into Africa. "Africa is going to be our largest market at some point. I am just looking at the fundamentals – land availability, climate, water – tick all the boxes on that. I do believe the fundamentals are in place," he said.

Discussions about the 1.3 million t/a capacity fertilizer project, originally announced in January, are at an early stage. Budgets and a construction timetable, for example, have yet to be agreed.

If developed, the project would consume around 80-90 million cubic feet of natural gas daily for ammonia and urea production. The ammonia/urea complex would also require a 50 megawatt-capacity power plant.

Mozambique is eager to reduce its reliance on fertilizer imports through substitution with domestically-produced fertilizers manufactured from the country's natural gas resources.

RUSSIA

SNC-Lavalin secures Acron contract

SNC-Lavalin has won an engineering contract from Novgorodskiy GIAP, an Acron subsidiary, for the Dorogobuzh fertilizer project in Russia's Smolensk region.

The contract covers pilot tests and engineering services, including basic engineering packages, and documentation for the construction of a fertilizer complex.

The Dorogobuzh project includes sulphuric acid, phosphoric acid and granulated NPK production units. SNC-Lavalin will also assist with the procurement, construction, commissioning and start-up phases of the project.

PhosAgro and Ma'aden to collaborate

Two leading phosphate producers, Russia's PhosAgro and Saudi Arabia's Ma'aden, have agreed to share production know-how, after signing a landmark memorandum of understanding in October.

"[We have] agreed to share best practices and knowledge related to technical aspects of production, environmental protection, and workplace health and safety," PhosAgro said in a statement.

Precisely what the collaboration will involve is not yet clear.

The memorandum was signed by both companies during a recent official Russian state visit by King Salman bin Abdulaziz Al Saud.

PhosAgro subsidiary NIUIF, Russia's only research and development institute for fertilizers and 'insectofungicides', will be an active participant.

Ma'aden and PhosAgro are both completing major production investments. PhosAgro is due to launch its 760,000 t/a capacity ammonia line and a 500,000 t/a capacity granulated urea plant at PhosAgro-Cherepovets in the near future. Ma'aden is also ramping-up production at its recently-commissioned Wa'ad al-Shamal phosphate fertilizer megaproject, a joint venture with Mosaic and SABIC.

PhosAgro CEO Andrey Guryev said: "This landmark memorandum… is an important achievement for both of our companies and will help, among other things, to ensure greater discipline to secure the stable supply of phosphate-based fertilizers to customers around the world."

Ma'aden president and CEO Khalid bin Saleh Al-Mudaifer said: "We are happy to cooperate with PhosAgro, and look forward to the opportunities that sharing knowledge and best practices can bring both of our companies."

NORWAY

Siwertell secures fertilizer unloader contract

Siwertell has secured a ship unloader contract from Yara International. The new ST 490-M unloader unit will be installed at Yara's Glomfjord site, joining a long-serving, existing Siwertell unloader at the Norwegian fjord-side location.

The new unloader will mainly handle the discharge of phosphate rock from ships of up to 20 000 dwt. The unit has a continuous rated discharge of 600 t/h, with a peak capacity of 700 t/h. The unloader is designed to work in Glomfjord's harsh Arctic climate, and is also equipped with an advanced electrical control system.

The unloader will be erected and commissioned at a southern-European port before being transported to Glomfjord by a heavy-lift vessel. It will incorporate steel structures produced in southern Europe and equipment built in Sweden. Delivery is planned for June 2019.

Yara and Siwertell, part of Cargotec, have enjoyed a long business relationship.

"Yara was one of Siwertell's first customers, taking advantage of our unique screw-type unloading concept in 1979," said Peter Göransson, sales manager, Siwertell. "Its wealth of experience operating a Siwertell unloader, combined with our ongoing support and aftercare were big influences in Yara's decision to once again invest in Siwertell's proven technology."

"Our diverse and lengthy experience with bulk handling systems was also an important factor in winning this contract," he added.

UNITED KINGDOM

New soluble fertilizer plant

Omex Agrifluids says it is "powering ahead" with a new soluble fertilizer plant at its King's Lynn headquarters in Eastern England.

The production capacity expansion should help Omex capitalise on growing fertigation market demand globally, as export director Peter Prentis explains.

"We are in the process of expanding and upgrading our capacity to manufacture fully soluble powder NPK products for the international marketplace," said Prentis. "Our Kings Lynn manufacturing plant will now have its own expanded production site for this increasingly important product range."

Prentis, whose responsibilities include Europe, the Middle East and Asia, added: "Much of our business includes bespoke productions to suit individual country requirements by adapting formulation to meet the needs of local farmers and growers. Demand for high quality top-end soluble powders has been increasing for some time – particularly for companies making large investments in crop irrigation, especially drip irrigation systems, for both outdoor crops and those grown undercover."

FERTILIZER INDUSTRY NEWS

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The Jorf Lasfar Phosphate Hub, Morocco.

ETHIOPIA

OCP confirms $3.7bn investment

OCP Group has confirmed it will be investing billions of dollars in Ethiopia to strengthen its partnership with the country's government.

OCP timed the announcement to coincide with its attendance at Ethiopia's 10th International Trade Fair at the end of October. The Moroccan phosphates giant used the occasion to confirm a total investment of $3.7 billion in the proposed Dire Dawa Fertilizer Complex in Ethiopia.

When complete, Dire Dawa will be the largest fertilizer complex in Africa, second only in size to OCP's Jorf Lasfar complex in Morocco.

Plans for the Ethiopian megaproject were first unveiled in November 2016, when Morocco's King Mohammed VI, OCP and the Ethiopian government signed a strategic partnership to construct a world-class fertilizer plant.

A first phase investment of $2.4 billion will be required for the complex to reach an annual production capacity of 2.5 million tonnes by 2022. Production capacity at the complex will eventually rise to 3.8 million tonnes after a second phase of investment. When this is complete, the complex will comprise of nine production units, increasing its annual fertilizer production by 50 percent.

Production on this scale will meet all of Ethiopia's domestic fertilizer requirements and also create opportunities for export. Dedicated storage capacity will also be constructed at the port of Djibouti to provide the fertilizer complex with necessary raw materials. OCP says the megaproject will create more than 1,200 jobs during construction and more than 500 permanent jobs once operational.

The Dire Dawa complex will be fully-integrated, being designed to take full advantage of complementary natural resources in both countries. Finished fertilizers will be produced by combining Ethiopian potash and natural gas with Moroccan phosphoric acid shipped-in by OCP.

The complex is aiming to provide Ethiopian farmers with a reliable and affordable supply of plant nutrients, and will manufacture customized fertilizer products adapted to the needs of local crops and soils. Ethiopia is completely reliant on imported fertilizers currently. If realised, the OCP-Ethiopian government joint venture will enable the country to become self-sufficient in fertilizers by 2025.

OCP is the biggest private Moroccan investor in Ethiopia, and a long-standing agricultural partner to the country. The company has provided most of Ethiopia's phosphate fertilizer supplies since 2012. More recently, it has also carried out extensive soil fertility mapping in the country, an exercise that has increased Ethiopian crop yields by nearly 37 percent, according to OCP.

East Africa has one of the lowest levels of fertilizer use globally. The region's application rate is just 13 kg/ha, compared to 47 kg/ha in North Africa , more than 300 kg/ha in Asia, and the global average of 98 kg/ha.

Yara signs mining agreement

The future of the Yara Dallol mine in Ethiopia look more certain after Yara International signed a mining agreement with the Ethiopian government on 7 November.

The mining agreement was signed at ceremony in Addis Ababa by Ethiopian mining minister, Ato Motuma Mekasa and Yara's president and CEO, Svein Tore Holsether.

The agreement clears the path for future development of the Yara Dallol potash project, located in the Afar region in the northern part of Ethiopia. The planned solution mine will have an annual SOP (sulphate of potash) production capacity of 600,000 tonnes, equivalent to around ten percent of the global market. SOP is a premium fertilizer targeted at fruit, vegetable and coffee crops.

Yara International owns 51.8 percent of the Yara Dallol project. The other owners are Liberty Metals and Mining Holdings and XLR Capital, with a 25 percent share and 23.2 percent share, respectively.

"We are glad to achieve this key milestone in the Dallol mining project. A mine in the Afar region would contribute significantly to economic development locally and nationally. We recognize and appreciate the efforts made by the Ethiopian government in supporting the project, both by providing necessary infrastructure and through making the mining agreement possible," said Svein Tore Holsether, Yara's president and CEO.

Yara has yet to make a final project investment decision but expects to do so towards the end of 2018. Total capital expenditure has also not been finalized, but should be under $740 million, according to Yara ■

China News Round-up

Courtesy of Kcomber, owner of CCM and Tranalysis

Sinochem-OCP supply deal

China's state chemical group Sinochem has signed an exclusive long-term supply deal with Morocco's OCP Group.

A memorandum of understanding was signed by the two companies in Shanghai on 24 October. This covers the supply to China of around five million tonnes of Moroccan phosphate rock and diammonium phosphate (DAP) between 2017 and 2021. Prices will be determined from market rates.

According to the memo, Sinochem will be the exclusive distribution agent for OCP phosphate rock and DAP, apart from exceptions agreed by both companies. This agreement will be executed by Sinofert on behalf of Sinochem.

Sinofert's president Qin Hengde said high quality Moroccan phosphate rock and DAP can play a very important role in China's agricultural production, food security, product supply, and environmental protection. Mohamed Belhoussian, OCP Group's executive vice president, said that OCP and Sinochem are long-term strategic partners, and emphasised how much OCP valued Sinochem and the Chinese market.

China's phosphate fertilizer prices remain high

Domestic and export prices for China's finished phosphate fertilizers remained high in September. Rising raw material prices appear to be partly behind this.

The market for Chinese diammonium phosphate (DAP) has remained stable, supported by the execution of large Indian and Pakistan orders until October. Producers are also keeping operating rates low in order to push up prices, with added pressure from the Vietnam government's anti-dumping duty on Chinese DAP.

Some signs of price weakening, in contrast, are emerging in the Chinese monoammonium phosphate (MAP) market. This has been spurred by low downstream demand and production limits imposed by a fourth round of environmental inspections in China. Demand for MAP is expected to decline further during the traditional autumn slack season.

Mixed fortunes for elemental phosphorus

Financial results from China's elemental phosphorus (yellow phosphorus) manufacturers for the first half of 2017 have revealed differing fortunes.

Jiangsu Chengxing, a major producer of yellow phosphorus, phosphoric acid and high-grade phosphates, reported a 23 percent fall in profits, and a slight year-on-year decline in sales volumes. One of China's largest fertilizer manufacturers, Liuguo Chemical, cut its year-on-year net losses by 73 percent to $1.29 million.

Two companies, Hubei Yihua and Sichuan Hongda, have both seen enormous rises in net profits. Hubei Yihua reported a 413 percent profit surge, despite a sales decline of 23.7 percent year-on-year. Sales also surged at Sichuan Hongda which reported a 395 percent profit rise.

Yunnan Yuntianhua to acquire Yunnan Tianning

In an assets reorganisation, Yunnan Yuntianhua is to acquire phosphate mining company Yunnan Tianning in a transfer from Yuntianhua Group.

The development should improve Yunnan Yuntianhua's profitability and access to phosphate resources.

The acquisition could reduce Yunnan Yuntianhua's annual phosphorus ore procurement from Yunnan Tianning by $40.97 million. Conversely, Yunnan Tianning's sales could fall by $68.28 million.

Encouragingly, Yunnan Yuntianhua recorded fertiliser sales of $1.17 billion in the first half of 2017, up by 25 percent on the same period last year. This was despite several challenges. Phosphate fertilizer production costs have increased due to the rising price of electricity, coke and sulphur. Competition with lower-cost producers in the international fertilizer market has also intensified, despite a boost from the cancellation of export tariffs.

Yunnan Yuntianhua is, however, committed to improving its competitive position via structural reforms, integrated operations and sales and marketing improvements.

Fertilizer regions face fresh inspections

China's Ministry of Environmental Protection is to launch an air pollution inspection tour in several cities in the industrially-important Beijing-Tianjin-Hebei Region.

The fresh round of inspections are taking place between 1 September 2017 and 29 March 2018. Their purpose is to check and strengthen air pollution measures in these cities.

Unauthorized companies will be targeted and inspections are also expected to focus on the reduction of pollution at industrial sites, measurements supervision and pollutant discharge permits.

The Beijing-Tianjin-Hebei Region is home to many small-sized elemental phosphorus and phosphate fertilizer manufacturers. Environmental actions by inspectors may therefore hinder their operations.

Elemental phosphorus prices remain high

The price of Chinese elemental phosphorus (yellow phosphorus) is expected to remain high this year, subject to fluctuations. Prices are supported by high raw material prices and restrictions on output as a result of environmental inspections (see above).

Prices began to recover mid-August, mainly in the important production regions of Yunnan, Sichuan, Guizhou, and Hubei. Yellow phosphorus prices peaked in April this year only to fall back subsequently.

Current prices are still around $500/t above the 2016 average. High price levels look set to continue. The price of domestic coke, a key feedstock, is rising in China. Downstream demand for yellow phosphorus is also growing. ■

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People

EuroChem Group has appointed **Dmitry Strashnov** as its chief operating officer, a new role created at its corporate headquarters in Zug, Switzerland. His responsibilities include the day-to-day running of EuroChem's worldwide business and its drive to expand further globally. He will report directly to CEO, Dmitry Strezhnev.

Prior to taking up his new role, Strashnov was CEO of Russian Post from 2013 to 2017. Before that, he was CEO and president of the Russian subsidiary of Tele2. Previously, he also served as CEO of Philips Consumer Electronics in Russia.

"At an exciting time of growth for EuroChem, we were looking for someone who would significantly strengthen our management team and we are delighted to have Dmitry Strashnov join as chief operating officer," said Dmitry Strezhnev. "His extensive experience and successful track record will enable him to make an important and positive impact on our company."

Dmitry Strashnov said in reply: "I am thrilled to be joining EuroChem at this important time in the company's development. I look forward to supporting EuroChem's further growth and global expansion."

Jack Cohn, senior vice president at Savage Services Corporation, is the new chairman of The Sulphur Institute (TSI). He takes over from Mike Lumley, former vice president of Shell Sulphur Solutions. It is the second time Cohn has assumed the role.

Rob McBride, TSI's president and CEO thanked Mike Lumley for his tenure and welcomed back Jack Cohn as chair: "We appreciate Mike's leadership and the direction he provided the Institute while serving as vice chairman and chairman over the last 18 months. We welcome Jack, who is no stranger to TSI; the staff looks forward to working with him as chairman of the board."

Cohn previously served as TSI's chairman from 2012 to 2013. "It is an honour to once again serve the sulphur industry as TSI's Chairman," said Cohn. Cohn will continue to spearhead existing TSI initiatives. These include plans to demonstrate its value to members within and outside North America, developing its offering for European members and expanding into Central Asia, the Middle East and North Africa.

Compass Minerals has strengthened its plant nutrition team through several appointments. The company has announced: **Sean Knapp** as vice president of North America; **Ron Restum** as strategic account director; and **Cole Hansen** as marketing and product strategy director. All three will support the company's specialty plant nutrition products, including *Wolf Trax DDP Nutrients* and *Protassium+*.

"Sean, Ron and Cole add tremendous talent to our team," said Brad Griffith, senior vice president, plant nutrition. "They bring more than 70 years of combined agricultural experience to our growing specialty plant nutrition business."

Knapp will oversee North American business strategy. He joins Compass Minerals after nearly 20-years at Syngenta, where he held leadership roles in their vegetable seeds, crop protection and customer programs divisions. Restum, who has worked at Koch Agronomic Services and Agrium previously, will manage and build key customer accounts. Hansen will be responsible for the commercialisation of the plant nutrition portfolio. He worked for Dow AgroSciences – primarily in the seed division – prior to joining Compass Minerals.

JDCPhosphate has announced the appointment of **Timothy Cotton** as CEO. He is a member of the company's board of directors and a principal of Agrifos Group, one of JDC's largest shareholders. **David Blake** has been named chief operating officer. **Tip Fowler** has been named director of business development.

Susan Menzel joined CF Industries as senior vice president, human resources at the start of October. Menzel will be responsible for human resources strategy and management for the company. She will serve as a member of the senior leadership team, reporting to Tony Will, CF's president and CEO.

Menzel holds a bachelor's degree in business administration and economics from Augustana College. She brings to the company 30 years of human resources management experience and leadership, most recently as executive vice president, human resources for CNO Financial Group.

"Sue's proven track record of providing strategic business and human capital leadership, along with her experience partnering with senior executives and boards of directors to improve talent management and maximize employee engagement, will serve CF and our employees well," said Will, welcoming Menzel to the role. "We look forward to having her help us drive continuous improvement both within the HR function and across the whole company.

Calendar 2018

JANUARY

22-24
Fertilizer Latino Americano,
SAO PAULO, Brazil
Contact: Argus Media
Tel: +44 (0) 20 7780 4340
Email: fertconferences@argusmedia.com

31-2 February
23rd AFA Annual Fertilizer Forum & Exhibition, CAIRO, Egypt
Contact: Arab Fertilizer Association
Tel: +20 2 23054464
Email: afa@arabfertilizer.org

FEBRUARY

26-March 1
Nitrogen+Syngas 2018,
GOTHENBURG, Sweden
Contact: CRU Events
Chancery House, 53-64 Chancery Lane,
London, WC2A 1QS, UK
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

MARCH

6-9
IFA Production and International Trade Meeting, BUENOS ARIES, Argentina
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

12-14
Phosphates 2018,
MARRAKECH, Morocco
Contact: CRU Events
Chancery House, 53-64 Chancery Lane,
London, WC2A 1QS, UK
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

APRIL

9-12
IFA Global Technical Symposium,
MADRID, Spain
Contact: IFA Conference Service
28 rue Marbeuf, 75008 Paris, France
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

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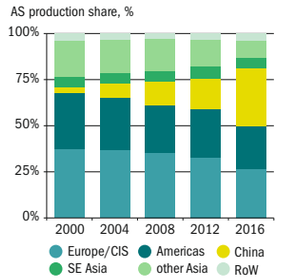
PICTURE THIS...

Ammonium sulphate market

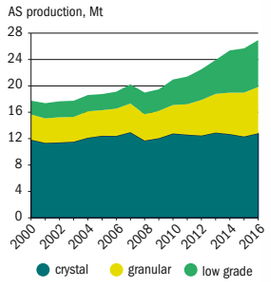
In a global nitrogen market that remains dominated by urea, it is easy to dismiss ammonium sulphate (AS) as a minor, niche product. That view underestimates ammonium sulphate's importance as an established and widely-used fertilizer in countries such as the United States, Canada, Brazil, Mexico, Indonesia, Vietnam, Malaysia and Turkey. For crop growers in these countries, ammonium sulphate is valued as a low-cost source of nitrogen and sulphur. World production continues to rise and is currently heading towards 28 million tonnes per annum. This growth is linked to rising 'involuntary' production in China – where ammonium sulphate it generated as a by-product of coke oven gas (COG) and caprolactam manufacture. Chinese product has entered the export market in ever larger volumes since 2010, being increasingly destined for Brazil and South East Asian markets. Brazil alone consumes 1.5-2.0 million tonnes of ammonium sulphate annually, and is showing an increased preference for granular over crystalline product. Involuntary supply from China should continue to grow strongly over the next five years, as will ammonium sulphate demand globally, particularly in South and Central America and Southeast Asia.

Data sources: CRU/IFA

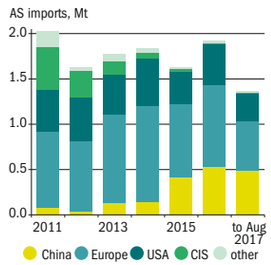
CHINA DRIVING...



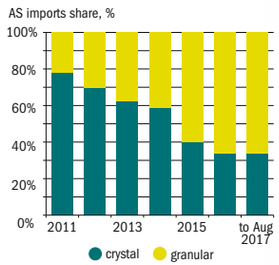
GLOBAL PRODUCTION GROWTH



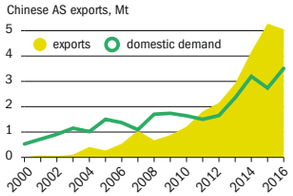
BRAZIL: A MAJOR MARKET...



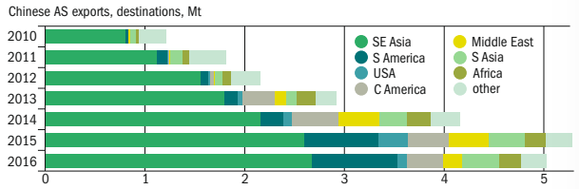
WITH A PREFERENCE FOR GRANULES



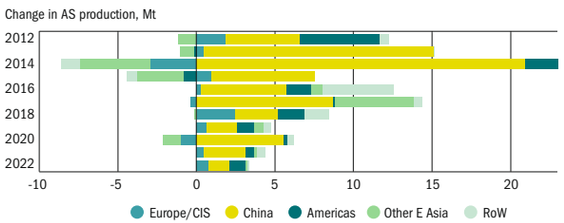
GROWING CHINESE EXPORTS...



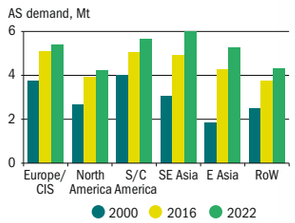
TARGET BRAZIL AND SOUTH EAST ASIA



GROWING CHINESE SUPPLY...



AS DEMAND RISES FURTHER



Value Added Fertilizer Summit Asia 2018

Delegates interact at VAFSA 2017.

PHOTO: INTEGER

Integer Research's director of fertilizers, **Oliver Hatfield**, reports on the state of the speciality fertilizer market ahead of Integer's second Value Added Fertilizer Summit Asia in Singapore next February.

Those of you who've been regularly attending fertilizer industry conferences over the last few years will have noticed the increasing number of presentations devoted to products referred to as premium, value-added or speciality fertilizers.

This is a sign that the value-added fertilizer business has become the industry zeitgeist – and a signal that what was once niche now appears to be moving into the mainstream.

But for an audience familiar with commodity fertilizers, the value-added end of the business can seem impenetrable. While commodity fertilizers are reasonably easy to figure out, with just a few nutrient categories, each containing a handful of homogenous products, the speciality business is more opaque and difficult to grasp. Speciality product categories are numerous. To add to their complexity, even products in a single category can have a diverse set of characteristics.

The International Fertilizer Association's Strategic Forum in Zurich, Switzerland, this November has a speciality fertilizer theme, reflecting the shift in industry interests, and has a particular focus on improving fertilizer use efficiency. We at Integer Research have also embraced this industry shift, primarily through our Value Added Fertilizer Summit Asia 2017. The first Summit was held in Singapore in February – and will be return to the city again in February next year.

At a cursory level, the demand for commodity and speciality fertilizers appears to be driven by the same macro drivers – more nutrients are needed to improve crop productivity on increasingly scare land resources, in response to higher crop demand from a rising and increasingly wealthy population. But as we drill down further, we find that what truly drives the value-added fertilizer market is, in fact, distinctly different.

Broad acre crops

Commodity fertilizers like urea, DAP and MOP are relatively unsophisticated and of lower value. These products are generally used by farmers to grow 'broad acre' crops at the low value end of the spectrum, such as grains and oilseeds. They are applied in straight, blended or compound form in various ways, from hand broadcasting to mechanised spreaders. The degree of application precision, being a function of farming sophistication, is highly variable. This lack of precision, in turn, contributes to nutrient losses – which can be substantial.

Farmers also have little incentive to apply fertilizers efficiently where these are available at low cost. The fact that commodity fertilizers are subsidised in many countries, to make them more affordable, is a further disincentive for farmers to behave efficiently. The focus on affordability in countries with subsidy schemes also means that the nutrient applications are

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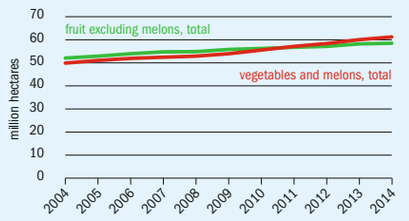
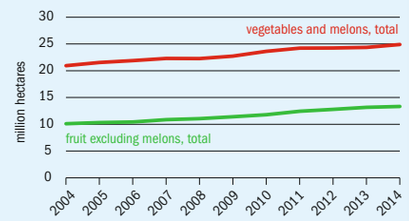
Fig. 1: **World harvested area of fruits and vegetables, 2004-2014**



Source: FAO

Fig. 2: **Harvested area of fruits and vegetables in China, 2004-2014**



Source: FAO

often completely skewed and imbalanced. The irrigation of broad acre crop is also often left to the weather, although increasing and competing demand for water has seen investment in irrigation increase.

Rising fruit and vegetable cultivation

The target crops for value-added fertilizers, in contrast, tend to have significantly higher financial worth. They include fruits and vegetables with a significantly higher market price than broad acre crops, allowing farmers to invest in greenhouses and polytunnels as the norm. Since improving yield and quality delivers higher rewards for these crops, there is also a greater incentive for ensuring the full range of nutrients are available at both the right time and at the right rate. Such behaviour requires more sophisticated, higher value fertilizer products. Similarly, proper management of fruit and vegetable water demand also requires increasingly sophisticated irrigation systems.

> **"The target crops for value-added fertilizers tend to have significantly higher financial worth.**

The agricultural importance of higher value crops requiring speciality products is clearly increasing. During the decade between 2004 and 2014, the global area harvested to fruits and vegetables increased by around 18 million hectares, as shown in Figure 1.

Geographically, the development of value added fertilizers, and much of market growth, has traditionally taken place in mature and highly-developed regions and countries like the US, Japan and Europe. Many of the current leading valued-added fertilizer producers became established by supplying high value agriculture in these economies.

However, the value-added market is rapidly changing, with the balance now shifting towards Asia. The rate of change is again highlighted by crop data. Looking at China, for example, the land area dedicated to fruits and vegetables increased by a total of seven million hectares between 2004 to 2014 (Figure 2), representing about 40 percent of the global increase over this same period.

Likewise, the harvested area of fruits and vegetables in India has increased by more than a half over the last decade, from around 10 million hectares to almost 16 million hectares (Figure 3). Combined, the rise in the harvested area for fruits and vegetables in India and China made up more than 70 percent of the global increase between 2004 and 2014.

China leads the way

In little more than a decade, China has become the world's biggest market for slow release and controlled release fertilizers (SRFs and CRFs), with annual consumption now close to three million tonnes. This development has prompted the emergence of major Chinese speciality fertilizer producers like Kingenta, the dominant supplier of enhanced efficiency fertilizers (EEFs) to the Chinese market.

Kingenta should continue to benefit from – and drive further – Chinese market expansion. Kingenta plans to set up hundreds of new crop production service centres across China over the next five years, in a project backed by a $200 million finance package secured from the International Finance Corporation (IFC) In July 2017.

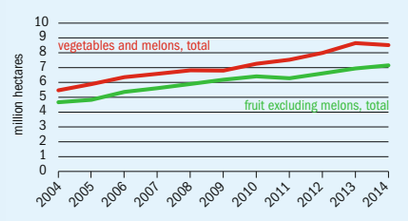
The new centres should boost Chinese crop production by capturing nutrient use efficiency gains delivered through the greater use Kingenta's speciality fertilizer products. Such aims tie in neatly with the Chinese government's target of zero growth in fertilizer use by 2020, while at the same time continuing to raise crop production and yields. Kingenta is also increasing its international influence, having acquired several European speciality companies in 2016.

India's vast potential

India looks like becoming the next big market for value-added fertilizer products. There appear to be an enormous potential to improve the country's crop productivity. Indian yields for grains and cereals are below developed country levels, and the levels of its main Asian economic rival, China. These yield gaps could be partly closed by adopting a more sophisticated approach to using commodity fertilizer products, and a greater focus on balanced nutrient use. But a rapid increase in the embryonic market for premium fertilizer products also looks likely.

To boost use efficiency, the Indian government recently made the neem coating of urea mandatory. Although the efficacy of neem is modest and dismissed in some quarters, it widespread adoption is a sign of the country's general direction of travel. The Indian market for water soluble fertilizers is still relatively small, at around 200,000 tonnes annually. But major investments in improved crop irrigation are being made, including drip irrigation which often goes hand in hand with the use of water soluble fertilizers. Many farms in India which have recently invested in drip irrigation equipment don't yet have fertigation systems – but, again, the direction of travel is clear. The Indian area under drip irrigation has increased tenfold in recent times from around 350,000 hectares to 3.5 million hectares in 2015.

Fig. 3: **Harvested area of fruits and vegetables in India, 2004-2014**



Source: FAO

India has not emulated China on the production side, with no big players in premium fertilizers yet emerging. India does, however, possess large producers of advanced agriculture systems. Jain, for example, a specialist producer of irrigation systems, has seen its revenues grow from $700 million in 2010 to $1.1 billion 2017. Almost half of Jain's revenues are also now generated outside India.

Value Added Fertilizer Summit Asia 2018

Not only do we offer considerable expertise in fertilizer market analysis at Integer, we also provide insightful conferences where there are knowledge gaps, such as the Asian market for value-added fertilizers. In February this year, we held the highly successful Value Added Fertilizer Summit Asia 2017 (VAFSA 2017) conference in Singapore. This focused on how to improve margins by adopting new technologies, solutions and application methods.

The summit included presentations from the Asian region and global market leaders in the value-added business, like Kingenta and BASF. Also participating were companies with a strong commodity fertilizer heritage and pedigree who nevertheless are quickly adapting and taking advantage of the growth in premium fertilizer markets, namely Yara, Coromandel, Tessenderlo and EuroChem.

Interest in the first Summit was overwhelming and a date of 6-7 February 2018 has now been set for the repeat VAFSA event in Singapore. Next year's VAFSA programme is looking even more informative and comprehensive. Once again, we will be covering the markets for EEFs, micronutrients and water soluble fertilizers. We are also pleased to announce the extension of the Summit's coverage to include expert speakers on the biostimulants market, a segment with enormous growth opportunities. We look forward to welcoming you and a growing number of your industry peers at VAFSA 2018!

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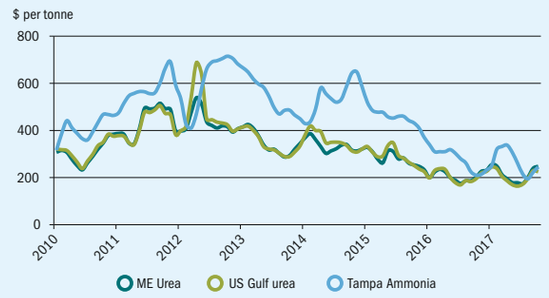
New supply reshapes the market

A wave of new capacity is reshaping global nitrogen markets and trade dynamics, explains **Doug Hoadley**, CRU's head of nitrogen, and one of the industry's most experienced analysts. A tighter global market is ultimately expected as Chinese exports diminish.

Fig. 1: **Ammonia and urea price benchmarks, 2010 onwards**



Source: CRU

Prices drifting lower

The global nitrogen market has become over supplied over the last two years, pushing prices to the market floor. Leading benchmarks have drifted downwards, depressed by new supply (Figure 1).

Between 2013 and 2015, urea prices ranged from $300 to $400 per tonne, resulting in good cash margins for most producers. But urea prices drifted lower during 2016, falling below $200 in mid-2016 to hit the floor price set by marginal producers, namely anthracite coal-based Chinese exporters. The pressure on prices came from new, large capacity coming on-stream outside China. As Chinese coal prices recovered in late 2016 and early 2017, urea prices followed suit, rising briefly before once again setting new lows in mid-2017.

Nitrogen demand growth slows

Before discussing world supply, let's first examine faltering demand. Global nitrogen demand is forecast to grow 1.5 percent year-on-year in 2017. This is somewhat below the modest growth rate of nearly two percent per annum over the previous five years. Looking ahead, over the medium term, world nitrogen consumption is expected to grow at just one percent annually through to 2022.

East Asia accounts for 30 percent of world demand, followed closely by South Asia with 20 percent. Within these regions, China and India are the key nitrogen markets and together account for about 45 percent of global nitrogen demand.

Although total nitrogen demand will show modest growth in 2017, global urea demand is expected to fall by 0.3 percent year-on-year. However, lower urea demand in China and little growth in India, the two largest consumers of urea, will be partially offset by growth in the Americas and Southeast Asia.

Looking ahead, global urea demand is forecast to increase by less than two percent per annum between 2017 and 2021. This growth rate is inflated, however, by technical urea demand, which is expected to grow by over three percent annually. This contrasts with forecast growth in urea fertilizer demand of close to one percent per annum.

Demand outlook for China

China's urea demand is forecast to decline this year by around eight percent. Modest total urea demand growth is expected from 2018 onwards, despite a modest decline in demand from fertilizers over our medium term forecast period, due to stronger industrial demand growth.

Forecast demand for industrial urea, which accounts for 30 percent of total urea consumption in China, has been reduced for 2017, following a new round of environmental inspections in late August across eight provinces. (A sign that the Chinese government is taking environmental protection more seriously.) Growth in industrial urea demand then returns for the remainder of the outlook period.

Agricultural consumption of urea in China will continue to be pressured in the medium term, driven by falling application rates, declining corn area and a market shift towards bulk blended fertilizers.

Demand in other key regions

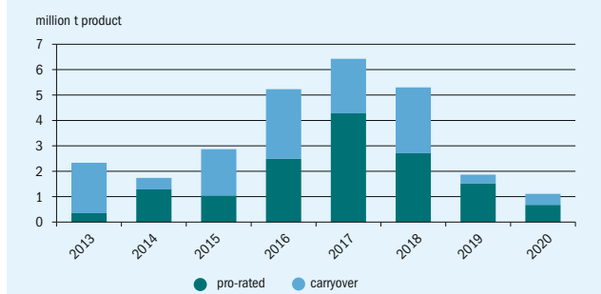
Although remaining pressured, urea consumption in India is still expected to increase by one percent in 2017. Imports remain weak and, together with proposals to cut urea bag-weights by 10 percent, have underpinned negative market sentiment. More positively, however, stocks are low, and good cropping conditions are expected in the upcoming Rabi season, providing some upside for urea demand in 2017. India's urea demand growth from 2017 to 2022 is forecast to average around 1.5 percent per annum.

Urea demand in Brazil is forecast to increase 14 percent year-on-year in 2017. Record *Safrinha* planting in the year's first half has been a key driver of demand.

Underpinned by Indonesia in particular, Southeast Asia is forecast to show strong demand growth, with increasing local capacity and fertilizer subsidies supporting demand. Corn area in Southeast Asia has been growing in recent years due to increasing demand from the animal feed sector. Demand for animal protein in the region has moved upwards in tandem with rises in per capita GDP.

Indonesia and the Philippines have witnessed the strongest growth in corn area. Indonesia's corn area has grown annually at three percent between 2015 and 2017, and by six percent annually in the Philippines during the same period.

Fig. 2: **Global ammonia capacity growth, ex-China, 2013-2020**



Source: CRU

Increases in capacity peak this year and next

CRU's estimate of new global ammonia plant capacity, excluding China, is shown in Figure 2. Growth in annual capacity is split into two categories, pro-rated and carryover. Pro-rated capacity is effective first year capacity based on the start-up date. Any remaining capacity (full annual capacity minus pro-rated capacity) is then added the following year as carryover. Note: because these estimates do not include any capacity closures, actual capacity will be lower if plants close. Indeed, we do expect some plant closures globally, especially in China.

The forecast shows that new ammonia capacity will peak in 2017 and remains relatively large in 2018. However, capacity increases taper off in 2019 and 2020 and are below demand growth, spurring an increase in the global operating rate. A similar scenario is forecast for urea capacity, as most of the new ammonia capacity will be dedicated to supplying new urea plants.

By region, North America will account for about half of the ammonia capacity increase in 2017 and about one-quarter of the increase in 2018. This new North American capacity will shift nitrogen trade flows, this year and next. Beyond 2018, we do not expect any growth in North American capacity over the medium term.

In Latin America, the only capacity expansion is the YFPF plant in Bolivia. This will be commissioned in the fourth quarter of 2017 with most of its capacity coming on-stream next year.

No change in European capacity is forecast. Expansions in Russia and Turkmenistan have been included for the CIS region. Most Russian growth occurs in 2016 through to 2018, with Turkmenistan to follow in 2018 and 2019.

In the Middle East, we expect two new plants to come on-stream in Iran, spread out from 2017 to 2020, partly offset by a plant closure in Kuwait in 2018.

India will also have two new plants coming on-stream. This includes the Matix plant at the end of 2017, as it finally gets feedstock for its delayed commissioning. Malaysia and Indonesia will also add new plants in 2017 and 2018.

Growth in Chinese urea capacity will slow over the forecast period. China's urea capacity is even expected to decline in 2017 as closures outweigh capacity additions. Two ammonia/urea projects are expected to come on-stream in 2017, five plants will follow in 2018, and three plants in 2019. Only one plant is expected to come on-stream in 2020.

We expect there to be numerous closures of uneconomic Chinese plants over the medium term. Indeed, many of these plants are already idle. CRU is currently tracking over 20 idle nitrogen plants with a combined urea capacity of about seven million tonnes.

Global trade shifts, especially for North America

Global urea trade is forecast to decline in 2017 by about five percent, as imports decline for both the US and India – the two largest importers in 2016. US urea imports are expected to drop by more than half from 2015 through 2020 as new capacity comes on-stream. By contrast, Indian imports, which are expected to decline by about 17 percent this year, look set to recover in 2018.

Brazil remains the outlier. Its urea imports will reach record levels throughout the next five years, and is forecast to eventually become the world's second largest importer of urea.

On the export side, China became the largest global exporter in 2013, and continued in this role through to 2016. Global trade will be balanced this year, however, by a forecast 44 percent decline in Chinese exports.

The largest increase in urea exports over the last two years has been by Russian and Middle Eastern producers (Figure 3). Iran, in particular, increased its exports in 2017, a trend that is expected to continue in 2018 and 2019 as new capacity comes on-line.

Ammonia imports will decline in the US as more ammonia capacity comes on-stream to satisfy domestic needs. This puts pressure on Trinidadian export volumes, and we expect these to lose some market share in the medium term. Simultaneously, as new merchant ammonia capacity comes on-stream in Indonesia, we see that country tripling its market share by the end of the forecast period, from a 2014 baseline. Strong ammonia export growth is also forecast for Russia, with shipments projected to grow by over 10 percent by 2022. This is linked to new export-oriented capacity coming on-stream.

NITROGEN OUTLOOK

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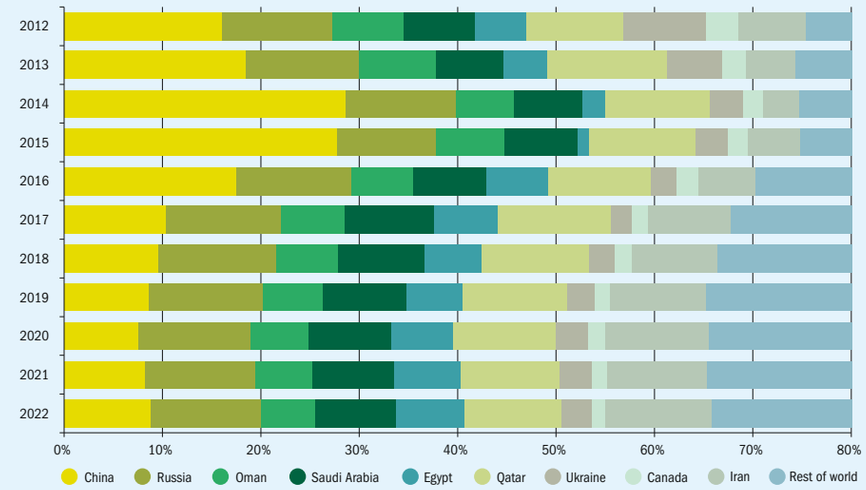
Fig. 3: **Market share of Top 10 Urea Exporters, 2012-2022**

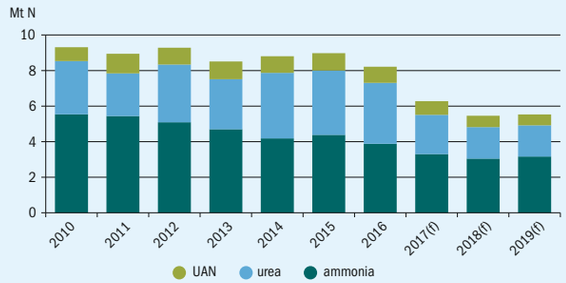


Source: CRU

On the ammonia import side, Indian and Moroccan requirements continue to grow over the forecast period, driven by increasing phosphate fertilizer production in both countries. These two destinations remain the most desirable markets for producers with extra capacity wishing to target the merchant ammonia market.

The largest shift in nitrogen imports will be in the US (Figure 4). We are already seeing the impact of this from new capacity which has already come on-line. The US imported about nine million tonnes of ammonia, urea and UAN in 2015. Imports then declined by eight percent in 2016 as the first wave of new plants came on-stream. US imports are currently expected to fall by another 25 percent in 2017. Although the decline in imports will slow, they will still fall by over 10 percent in 2018, with total US ammonia, urea and UAN imports expected to be below 5.5 million tonnes N, a total decline of about 40 percent in three years. US imports are expected to stabilise by 2019.

Fig. 4: **United States nitrogen imports, 2010-2019**



Source: TFI, CRU

Costs increases in China support prices

The EIA has lowered its natural gas price forecast, due to lower US industrial consumption and exports, with Henry Hub now expected to average $3.03/MMBtu in 2017. CRU forecasts US gas prices to remain subdued over the medium term, averaging below $3.25/MMBtu through 2022. The average cost of urea produced in the US is estimated at around $140 per tonne – among the most competitive in the world. Still, most urea producers in the Middle East are at or below this cost on a delivered basis to the US Gulf, so they will continue to export some urea to the US.

Natural gas prices in Europe remain attractive as greater competition between LNG imports and Russian pipeline gas continues. The Russian-German border gas price averaged $4.98/MMBtu in June and the TTF hub spot price averaged $4.87/MMBtu in July.

Given the low oil price environment and the LNG era, Russian gas has taken on a less politicised pricing structure, leaning more toward hub indexation. This resulted in Russian natural gas exports, via Ukraine to Europe, breaking above 5 Bcm in August for the first time in three and half years. Looking ahead, European contract gas prices are expected to continue at a discount to oil indexed prices, averaging around $5.25/MMBtu in 2022 at the German border. As a result, most European producers remain competitive in their home market, especially for AN and CAN, although they are mostly in the third quartile of costs in the world market.

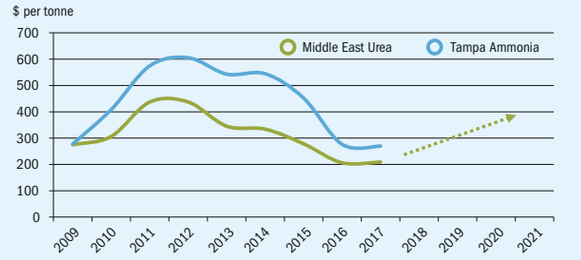
Chinese coal prices have rallied since their fall in the second quarter of 2017, entering the year's third quarter with considerable bullish steam. Lump anthracite prices increased by $24/t in late 2017, nearly 17 percent, while prices of powdered anthracite and thermal coal rose by 34 percent and 11 percent, respectively.

This rally is a direct consequence of developments in the Chinese coal market. The government has increased its focus on improving safety procedures and is ahead of its target to permanently close 150 million tonnes of less efficient coal capacity in 2017. These two factors have limited supply growth and, when combined with higher demand and a stronger renminbi, has supported Chinese prices considerably above the government's 2017 target price of RMB 535/t.

These production issues are temporary and Chinese demand will cool. However, CRU does believe that Chinese coal production will remain constrained by government policy for longer than previously expected, and we have raised our coal price forecasts for 2018 as a result.

Chinese producers remain the marginal urea exporters with costs ranging from $225 to $260 per tonne. Chinese exports have declined as a consequence of the fall in global imports and additions to global export capacity. But Chinese volume is still needed in the global market and helped support global prices towards the end of 2017.

Fig. 5: **Ammonia and urea price forecasts, 2009-2021**



Source: TFI, CRU

Rising operating rates support price recovery

The ammonia market is expected to remain oversupplied in 2018, as new merchant ammonia comes on-line. But some relief should be found beyond 2019, when we expect to see a pickup in downstream demand and a slowing of capacity additions. CRU does not project any significant merchant ammonia capacity additions between 2019 and 2022. As a result, the global ammonia operating rate bottoms in 2018 and then recovers from 2019 through 2022. This is expected to support higher prices over the 2019 to 2022 period (Figure 5).

The urea price outlook for 2018 is generally more positive than 2017. Oil and gas prices are expected to average higher and the urea market is expected to recover on the back of improved supply fundamentals. Price recovery is expected towards the latter years of the forecast period with recovery underpinned by cost inflation (led by oil and coal) and improving supply and demand fundamentals (Figure 5).

We expect a rebound in Indian urea demand and imports in 2019 to lend some price support. In China, anthracite prices are forecast to increase by above $15/t in 2020, as the Chinese economy recovers. This will raise Chinese urea export costs to around $280-$290 per tonne, supporting higher prices.

Reduced Chinese capacity and environmental curtailments by provincial governments will prevent a large rebound in exports, however, even with rising prices. This feeds into our outlook as a tighter market with China expected to play a less important role in the urea export market. ■

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Record-breaking Brazil

Brazil is the world's fourth largest consumer of crop nutrients, reflecting its status as an agricultural powerhouse, regionally and globally. Brazil's fertilizer consumption is on track to reach record levels in 2017, reports **Cleber Vieira** of Agroconsult, although margins for the country's main crops look set to tighten.

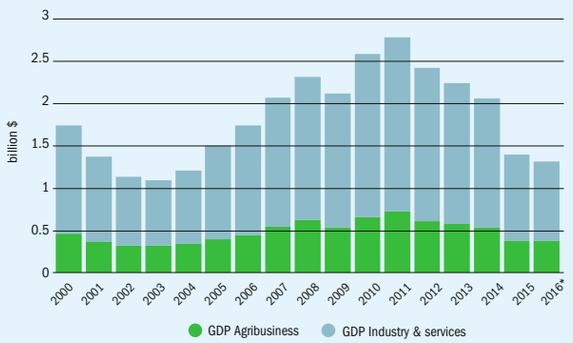
Agribusiness is a vital, vibrant industry in Brazil. The sector contributes substantially to the country's economic development by fostering domestic production, generating trade surpluses, increasing currency reserves and improving the country's risk rating.

Agribusiness accounted for 29 percent of Brazilian GDP in 2016 (Figure 1). Brazilian agriculture has also maintained Brazil's trade balance almost singlehandedly in recent years. Indeed, growing agricultural surpluses over the last decade have countered the trade deficit shown by Brazil's industry and service sectors (Figure 2). Agribusiness generated a trade surplus of $71 billion in 2016, for example, compared with a $24 billion industry/services deficit that year. Agribusiness also generates some 46 percent of the country's total exports currently.

Underpinning the agribusiness sector's strong economic performance is the fact that Brazil is one of the world's largest agricultural producers, especially in meat, soybeans, sugar, ethanol, orange juice, coffee and cotton. Brazilian agricultural output has grown consistently, partly due to major productivity gains. These have been achieved by the adoption of new technologies, some of which have also brought about more intensive fertilizer usage.

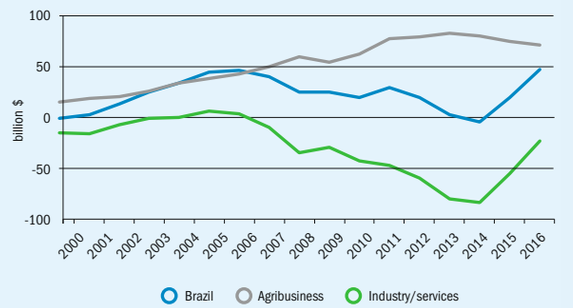
Significant growth in Brazilian grain production has been delivered by both yield increases and land expansion, especially for the 2nd crop. The planted area in Brazil grew at an annual rate of 2.2 percent from 2000 to 2017. A similar agricultural expansion is expected in coming years, albeit at a lower pace of 1.8 percent year-on-year. Although Brazilian agriculture is expected to add 11.5 million ha to the area under agriculture from 2017 to 2021, production increases will mainly be achieved through yield improvements.

Fig. 1: **Brazilian agribusiness GDP, 2010-2016, vs industry and service sectors (US dollars billion)**



Source: CEPEA-USP

Fig. 2: **Brazil's agribusiness trade balance, 2000-2016, vs industry and service sectors (US dollars billion)**



Source: Agroconsult

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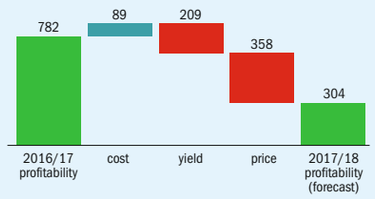
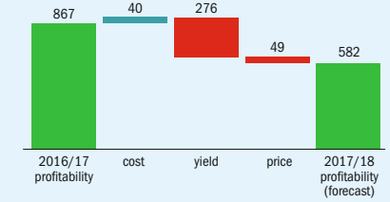
Fig. 3: **Soybean: effects of costs, yield and price on profitability Mato Grosso state, 2017/18 forecast vs 2016/17 season (BRL/ha)**



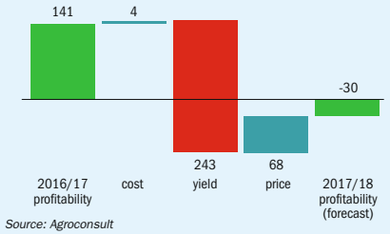
Source: Agroconsult

Fig. 4: **Soybean: effects of costs, yield and price on profitability in north of Paraná state, 2017/18 forecast vs 2016/17 season (BRL/ha)**



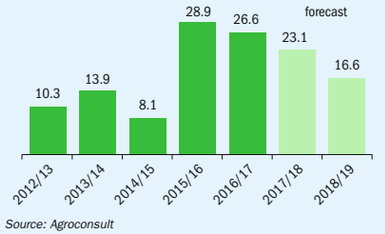
Source: Agroconsult

Fig. 5: **2nd crop corn: effects of cost, yield and price on profitability, 2017/18 forecast vs 2016/17 season (BRL/ha)**



Source: Agroconsult

Fig. 6: **Sugarcane profit margins (EBIT), 2012/13-2018/19 (BRL/tonne of cane)**



Source: Agroconsult

Brazil is endowed with plentiful resources, holding 13 percent of the world's freshwater, for example. Land and water availability have undoubtedly played an important role in raising Brazil's agricultural output. Yet, despite the availability of an additional 34 million hectares of arable land in Brazil, low soil nutrient levels strongly limit agricultural output. Acid soils with the power to fix phosphorus and a high exchangeable aluminium content are widespread.

Brazil's poor soil conditions make fertilizer applications vitally important to farming sector performance, now and into the future. Indeed, agricultural sector and fertilizer market growth strongly correlate. Any future expansion in crop acreage, and efforts to improve crop yields, will need to be accompanied by increasing nutrient consumption, a clear indication of the potential for fertilizer market growth in Brazil.

Currently, Brazil is the fourth largest consumer of crop nutrients in the world, only being surpassed by China, India and the United States. On a nutrient basis, an estimated 15.3 million tonnes of N, P and K will be delivered to Brazil's farmers this year.

The country's main fertilizer-consuming crops are soybean, sugarcane and corn. Soybean alone accounts for 43 percent of current fertilizer consumption. Summer and winter corn are responsible for another 16 percent, while sugarcane, coffee and cotton combined consume another 23 percent. Although nitrogen is the predominant plant nutrient in many countries across the globe, Brazil consumes larger quantities of phosphorus and potassium, a reflection of the importance of soybean growing, a K- and P-hungry crop that relies less on N fertilization.

Brazil's fertilizer market grew at an annual rate of 4.8 percent over the five years between 2011 and 2016, rising from 28 to 34 million tonnes. Fertilizer deliveries of 34.3 million tonnes are forecast for 2017, Agroconsult estimates, exceeding last year's historical high.

Key fertilizer market drivers in 2018

The Brazilian economy continues to show signs of recovery. The country's central bank is forecasting GDP growth of 0.7 percent in 2017 and 2.2 percent in 2018, thankfully ending the longest recession in Brazilian history.

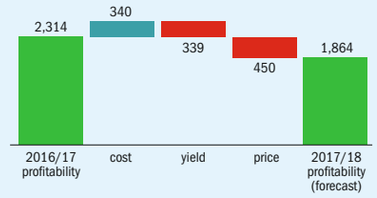
The planted area in Brazil may reach 92 million hectares in the 2017/18 season, taking into account summer and winter crops. Agroconsult estimates that grain production could reach 236 million tonnes.

The 2017/18 planting season began with an expectation of regular weather conditions, although some weather models suggest that the La Niña phenomenon may appear during the summer, potentially posing a risk to crops in southern Brazil.

Prices of all the main agricultural commodities were under pressure as the season began. A sugar price decline is also expected, as the sugar market looks set to move into surplus following three years of production shortfalls.

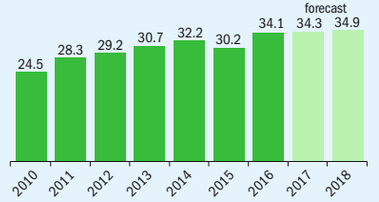
The Brazilian real (BRL) is also predicted to appreciate further against the US dollar. Agroconsult currently expects the BRL/USD exchange rate to move from 3.30 at the end of 2017 to 3.20 by the end of 2018. In the recent past, a strong dollar has often helped improve farm revenues. But this is unlikely to be the case over the next few months.

Fig. 7: **2nd crop cotton: effects of cost, yield and price on profitability, 2017/18 forecast vs 2016/17 season (BRL/ha)**



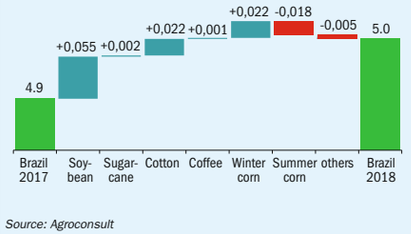
Source: Agroconsult

Fig. 8: **Deliveries of fertilizer products in Brazil, 2010-2018 (million tonnes)**



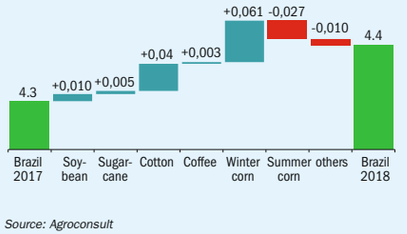
Source: Agroconsult

Fig. 9: **Changes in Brazilian demand for phosphate by crop, 2018 forecast vs 2017 estimate, million tonnes (P_2O_5)**



Source: Agroconsult

Fig. 10: **Changes in Brazilian demand for nitrogen by crop, 2018 forecast vs 2017 estimate, million tonnes (N)**



Source: Agroconsult

2017/18 crop trends

Soybean: Cultivated area is expected to rise by three percent above last season to occupy 35 million hectares. Production is forecast to reach 111.3 million tonnes, 3.5 percent up on the 2016/17 season.

Corrections to the BRL/USD exchange-rate has reduced crop margin projections due to its effect on domestic prices. In Mato Grosso state, for example, profitability looks set to fall sharply from BRL 782/ha in 2016/17 to an estimated to BRL 304/ha in 2017/18 (Figure 3). In Paraná state, profits are also forecast to fall from BRL 867/ha (2016/17) to BRL 582/ha (2017/18), with much of this change expected to come from lower yields (Figure 4).

Summer and winter Corn: The summer corn area is expected to fall this season. We are projecting 4.8 million hectares of planted area in 2017/18, 13 percent down on the previous season. Consequently, production is set to fall to 25 million tonnes, 17 percent down on 2016/17.

High yields last season guaranteed summer corn producers returns of BRL 700-900/ha. We are forecasting a return to trendline yield in 2017/18 and a slight rise in prices.

The good 2016/17 yield was also fundamental to ensuring margins for second crop (winter) corn producers, whereas margins are projected to be close to breakeven in 2017/18. A return to trendline yield in 2017/18 would reduce producer margins by 243 BRL/ha (Figure 5).

Sugarcane: Planted area is expected to rise year-on-year by 1.0 million hectares in the 2018/19 season to 9.8 million hectares. Mills have invested in renewing and expanding their plantations in recent seasons. Sugar cane growers posted healthy profits in 2017/18. Some 57 percent of their investment in 2018/19 will be from profits. Other sources of credit – such as bank loans and government farming credit – remain unchanged.

Under normal weather conditions, we are currently forecasting that 610 million tonnes will be milled in the Central-South region and 50 million tonnes in the North-Northeast during 2018/19.

Changes to the BRL/USD exchange rate have reduced the sugarcane profitability forecast for the 2017/18. We are now forecasting a margin of BRL 23.1/t, around BRL 3.0/t down on 2016/17 and expect margins to drop even further to BRL 16.6/t in 2018/19 in anticipation of lower sugar prices (Figure 6). That looks set to make 2018/19 the least profitable season since 2014/15. Overall returns for sugarcane suppliers are also likely to drop from BRL 900/ha in 2017/18 to BRL 694/ha next season.

Cotton: The estimated 2018 planted cotton area (1.12 million hectares) is a 19 percent increase on last season. Healthy 2017 season results have increased producer optimism. Falling corn and soybean prices are also helping make cotton more competitive.

While healthy yields guaranteed good margins for cotton producers in 2017, we are forecasting a fall in 2018 season producer margins to BRL 1,864/t for second crop cotton. Falls in production costs should be more than offset by yields returning to trend and falling international prices (Figure 7).

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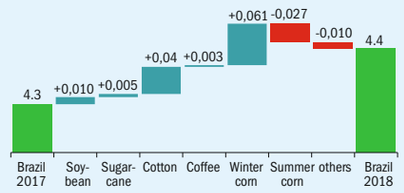
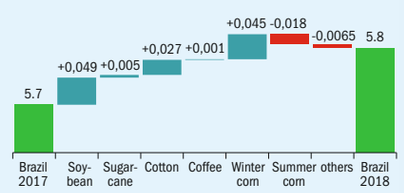
Fig. 11: **Changes in Brazilian demand for potash by crop, 2018 forecast vs 2017 estimate, nutrient tonnes (K_2O)**



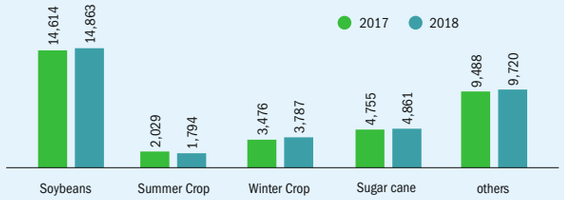
Source: Agroconsult

Fig. 12: **Changes in Brazilian demand for sulphur by crop, 2018 forecast vs 2017 estimate, nutrient tonnes (S)**



Source: Agroconsult

Fig 14: **Fertilizer product deliveries by crop (million tonnes)**



Source: Agroconsult

Table 1: **Brazil's fertilizer demand by product, 2016-2018**

Raw Materials	2016 volume, t	Forecast 2017 volume, t	Forecast 2018 volume, t
Ammmonium Sulphate	1,919,890	1,960,428	1,992,626
Urea	5,223,852	5,230,296	5,314,687
Nitrates	2,181,360	2,260,235	2,287,764
Single Superphosphate (SSP)	4,553,502	4,619,051	4,715,736
Triple Superphosphate (TSP)	1,600,019	1,626,717	1,667,189
Diammonium Phosphate (DAP)	468,872	429,768	438,348
Monoammonium Phosphate (MAP)	4,083,587	4,121,814	4,200,786
SSP + Ammonia	542,060	550,357	567,043
Thermophosphate	68,324	68,630	70,602
Reactive Rock Phosphate	182,875	183,889	186,203
SOP	64,217	62,968	61,940
Potash (MOP)	9,286,472	9,368,668	9,590,283
NPKs	1,004,618	1,012,370	1,011,596
NPs	1,618,595	1,634,341	1,685,838
Micronutrients	309,015	312,377	319,694
Others	976,155	920,349	914,182
TOTAL	**34,083,414**	**34,362,256**	**35,024,517**

Source: Agroconsult

The 2018 fertilizer market

With an eye on main crop figures, continued fertilizer market growth is expected in 2018. More than 600,000 tonnes could be added to the market next year, relative to current demand levels of 34.3 million tonnes. Fertilizer product deliveries are likely to approach 35 million tonnes in 2018, equivalent to 15.8 million tonnes of nutrients, almost two percent up on this year's estimate (Figure 8). Planted area and average application rate will be the two main drivers of fertilizer demand. At overall national level, average application rates for all crops could reach 375 kg/ha.

Forecast changes to nutrient demand (N, P, K and S) by crop for 2018 are shown in Figures 9-12. Demand for sulphur-containing fertilizers is likely to rise in coming seasons, as better sulphur availability has improved soybean yields to 60 bags/ha in some regions, up from 52 bags/ha previously.

A more stable economic and political environment is assumed in 2018, even though it is an electoral year. Exchange rate volatility should also decrease, creating more favourable conditions for farmers to make decisions and plan ahead.

Fertilizer product deliveries by crop (2017 estimate vs 2018 forecast) are shown in Figure 14. Grains will continue to be the most important crop for the fertilizer market. More than two-fifths of Brazil's fertilizers are applied to soybeans, followed in volume terms by corn and sugarcane. Corn, cotton and soybean are generally cropped by similar kinds of farmers, meaning that collective fertilizer-buying decisions can be made for all three crops.

Grain and sugarcane growers usually buy their fertilizers as NPK blends. Countrywide, we estimate that 68 percent of fer-

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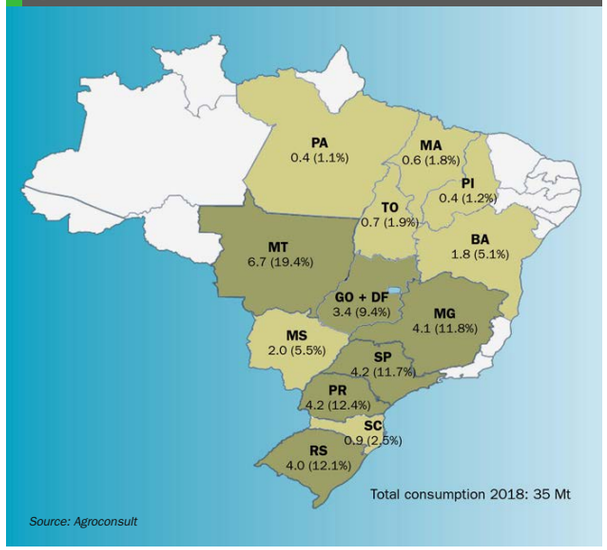
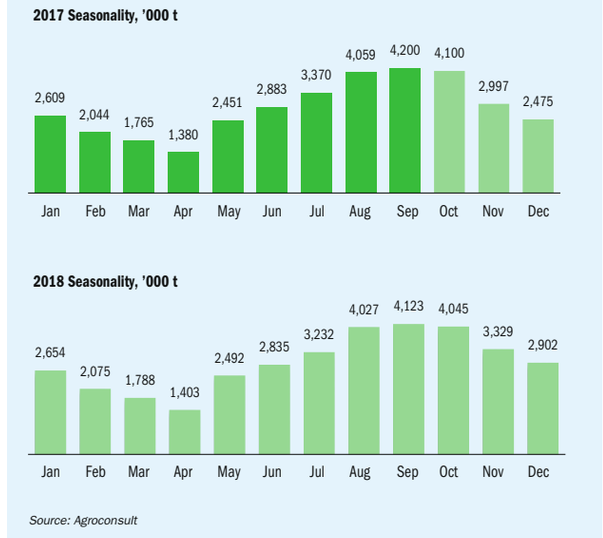
Fig. 15: **Brazilian fertilizer consumption by region, 2018 forecast (million tonnes)**



Source: Agroconsult

Fig. 16: **Monthly variation in fertilizer sales in Brazil, 2017 (top) and 2018 (bottom) ('000 t)**



Source: Agroconsult

tilizers are applied as NPKs. On a product basis, Brazil requires potash (more than nine million tonnes) as well as urea, MAP and SSP (all of them above four million tonnes) in large volumes (Table 1).

Because they are the main fertilizer-consuming crops, regions where grains, sugarcane and coffee are cultivated on a large-scale are also the regions where fertilizer demand is highest. Consequently, Brazilian fertilizer demand is concentrated in the central and southern regions. The six largest consumer states (Mato Grosso, São Paulo, Paraná, Minas Gerais, Rio Grande do Sul and Goiás) represent more than 75 percent of domestic demand (Figure 15).

Although Brazilian fertilizer consumption has grown into a 35 million tonne market, few investments have been made to increase national production. Domestic supply, limited by the existing capacity of Brazil's fertilizer producers, has been static for many years, with demand growth instead being met through imports. Import reliance will only increase, given that significant expansion in Brazilian fertilizer production is unlikely to happen. With current stock levels above five million tonnes, Brazil will need to import more than 25 million tonnes in the coming year, creating major logical challenges, especially at ports.

Fertilizer sales in Brazil are also characterised by strong seasonality (Figures 16). Sales tend to be concentrated in the year's second half to coincide with the planting calendar for Brazil's main crops between September and December.

For 2018, we expect the Brazilian fertilizer market to be sluggish, moving very slowly during the first half of the year, only to accelerate from July onwards. Although fertilizer sales always vary naturally with the seasons, fertilizer purchases and demand levels also depend on:

- Crop price and crop margins
- Fertilizer prices
- Barter ratio
- Cropped area

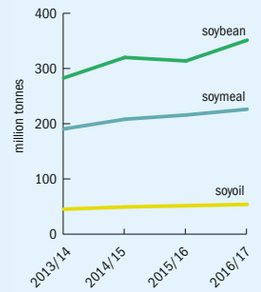
The main other factors that can influence fertilizer market conditions in Brazil include:

- **Farm economics:** those farmers able to pay in cash at times of lower fertilizer demand can obtain lower prices
- **Agricultural credit:** availability may influence fertilizer purchases
- **Market price expectations:** these can influence fertilizer buying decisions, based on whether prices are expected to rise or fall during the year ■

Fertilizers for soybean

Around 350 million tonnes of soybean are grown globally every year and processed to yield oil and meal, a major source of animal protein. Its cultivation in countries such as Brazil requires large applications of potash and phosphate. The nutrient needs of this major oilseed crop are reviewed.

Fig. 1: **World soybean, meal and oil production, 2013/14-2016/17**



Source: USDA

PHOTO: NNATTALII/SHUTTERSTOCK.COM

Soybean (*Glycine max.*) is a bushy, green legume species native to East Asia. Now widely grown in the Americas, it produces an edible bean prized as a source of high-protein meal and oil.

The pod-producing plant is related to clover, peas and alfalfa. It is typically planted in the late spring, each plant producing up to 80 pods in the summer on flowering. Individual pods contains 2-4 pea-sized beans which are rich in commercially-valuable protein and oil.

World production and consumption of soybean oil is second only to palm oil (*Fertilizer International* 479, p14). Soybean meal is also the world's largest protein source for farm animals, being a major feed ingredient for chickens, pigs and cattle.

Soybean was one of the first crops to be cultivated agriculturally, having originally been grown for food in China nearly 6,000 years ago. In recent decades, soybean growing, processing and trading has turned into a multibillion dollar global industry – and a cornerstone of world farming and agricultural trade, because of the millions of livestock it feeds across the planet.

Global soybean production grew almost ten-fold during the 50-year period between 1960 and 2010. World production has expanded by a further 25 percent in the last four years, increasing from 283 million tonnes in 2013/14 to reach 351 million tonnes in 2016/17 (Figure 1). Approximately 75 percent of that total is ultimately destined for animal feed.

Soybean can be successfully grown in tropical, subtropical and temperate climates. Global production is concentrated in seven main growing countries, the US,

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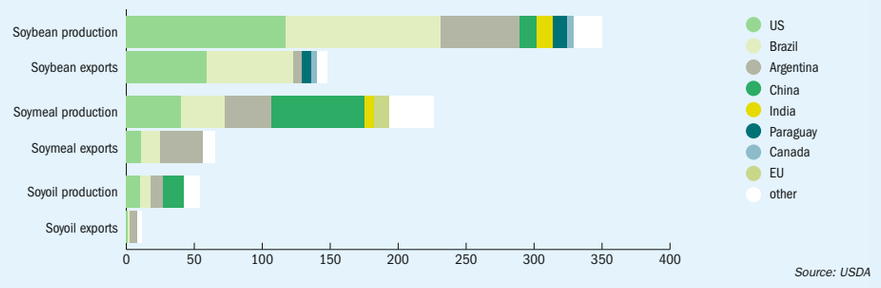
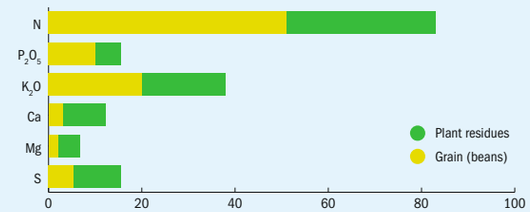
Fig. 2: **World soybean, meal and oil production and exports, by country, 2016/17 (milion tonnes)**



Source: USDA

Fig. 3: **Typical soybean macro nutrient removal rates, Brazil (kg/t)**



Source: Yara

Brazil, Argentina, China, India, Paraguay and Canada (Figure 2). Of these, three countries in the Americas, the US, Brazil and Argentina, collectively account for more than 80 percent of global output. Furthermore, the US and Brazil also dominate the soybean export market, being responsible for over four-fifths of world trade. Argentina has adopted a different approach, choosing to process much of its domestic soybean harvest at home, and export soybean meal and oil in large tonnages instead.

China is the world's biggest soybean importer by a large margin, and the main destination of Brazilian exports. Thanks to its importance to global agriculture, this trading route even has a name: the Brazil-China soybean pipeline. The 92.5 million tonnes of soybeans imported into China in 2016/17 represents more than 60 percent of global trade in this commodity. By processing these imports, China has also become the world's largest soybean meal and oil producer (Figure 2).

The EU is the biggest importing region for soybean meal globally (19.0 million tonnes in 2016/17), and also imports large tonnages of soybeans (13.2 million tonnes). Southeast Asian countries (Vietnam, Indonesia Thailand and the Philippines) collectively imported a further 14.6 million tonnes of soybean meal in 2016/17. Mexico, South Korea and Japan are also major meal-importing countries.

Nutrient uptake and removal

Soybeans are known for their efficient use of residual soil nutrients, although modern, high-yielding varieties require more careful nutrient management and higher nutrient inputs.

Proper and well planned crop nutrition is known to be one of most effective ways of influencing both soybean yield and quality. Fertilizer management, and the alleviation of soil acidity, for example, generally have a commercially valuable and positive effect on the oil and protein levels of soybeans.

Maintaining soil fertility also protects soybean plants from environmental stresses such as weather, disease and nematodes.

In soybean production, soil pH has been singled out for its influence on soil fertility and plant growth. Soybeans thrive at soil pH between 6.0 and 6.8, and both nutrient uptake and yield are maximised at this pH range.

Soybean plants remove nutrients from the soil in large quantities from emergence until the point of maximum accumulation is reached at the pod-filling stage around 75 days later. After this point, plants mobilise their accumulated internal stores of nutrients from vegetative parts to the grain.

Nutrient uptake is highest at 45 days after plant emergence during the start of soybean flowering. Soybean plants will have taken up around half of their total nutrient requirement at this point. The following 30-day interval between flowering and pod-filling is the critical period for soybean crop quality and yield. Several factors such as drought, nutrient deficiency, pest attacks and diseases may dramatically reduce yields during this stage in the plant's growth

Nitrogen fixing ability

Soyabean is a nitrogen-fixing crop with an ability to fix as much as 175 kilograms of nitrogen per hectare. It therefore requires little, if any, mineral nitrogen, although minor application to seedbeds is commonly advised. High soil nitrogen levels may even be counterproductive as they can cause excess vegetative growth, reduce nitrogen fixation, increase disease pressure and delay plant maturity.

Soybean plants are able to satisfy their

Soybean nutrition from Compass Minerals

The popular *Wolf Trax™ DDP® Nutrients* line manufactured by Compass Minerals incorporates *EvenCoat™* technology to coat every NPK granule in a fertilizer blend with micronutrients. The line also features the patented *PlantActiv™* formulation which improves plant nutrient uptake by resisting soil tie-up (*Fertilizer International* 478, p 24).

Indiana field study

In 2007, a field study to evaluate the performance of *Wolf Trax Mn DDP* in soybeans was conducted by Purdue University in Indiana. This showed that, for soybeans prone to manganese deficiencies, a soil application of *Mn DDP* with starter fertilizer can be a highly beneficial addition to current grower practice. *Mn DDP* increased yield by 5.3 bushels per acre [0.36 t/ha] versus the starter on its own. Combining this approach with a foliar application of Mn with glyphosate provided a further yield benefit of 3.6 bu/ac [0.24 t/ha].

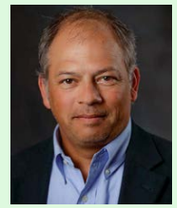
Recent Brazil field studies

Many soils in Brazil are micronutrient deficient. Multisite field studies in 2015 evaluated the performance of *Wolf Trax DDP* as part of an early-season fertilization programme for soybean in Brazil. These compared the use of *WolfTrax DDP*s in a granular fertilizer blend versus oil-based liquid micronutrient coatings. Consistent yield improvements were obtained for individual *DDP* products, but the best yields were achieved when all of the required micronutrients (B, Mn, Cu, Zn) were supplied by applying four *DDP* products together. Application of *Wolf Trax DDP*s increased soybean yield by up to 3.5 bu/ac [0.24 kg/ha] relative to the control.

Further comprehensive field studies were performed in eight different locations in Brazil's Cerrado region in 2016/17. These evaluated the performance of *Wolf Trax DDP*s as part of an early season fertilizer programme for soybean, drybean and corn production. The application of *Wolf Trax DDP*s consistently increased soybean yields by as much as 3.2 bu/ac [0.22 t/ha], versus an approach using granular micronutrients. In addition, *DDP* products also achieved higher yields than an approach based on the use of granular oxysulphate, despite being applied at considerably lower application rates.

New *ProAcqua™* line launches in North America

Compass Minerals Plant Nutrition is currently in the process of rolling out a new foliar Mn product as a part of its new *ProAcqua* line. This is the first line of Produquimica products being launched by Compass in North America. This same product line has already achieved significant success in soybean growing in Brazil.



"All of the Produquimica products are used on soybean production. A soybean record of 133 bu/ac [8.9 t/h] was achieved with an integrated programme using all of their products from seed treatment all the way until harvest. Based on sound agronomic support and collaboration with growers, a programme was designed to maximize soybean yield potential with minimal environmental impact," comments Vatren Jurin, Senior Product Manager, Compass Minerals Plant Nutrition (pictured).

"Our new *ProAcqua* line of Manganese and Zinc is the perfect in-season foliar application and has been attributed to a nine percent increase in yield in Brazil," says Karin Nicolajsen, Agronomist, Compass Minerals Plant Nutrition.

Complementary soil and foliar micronutrient lines

The *ProAcqua* range also complements the company's existing *DDP* products, as Karin Nicolajsen explains: "For example, in the Purdue study, the best yields were achieved when we applied *Mn DDP* and a foliar Mn in season. With our new *ProAcqua* line, we now offer a foliar Mn EDTA which can be applied in season to maximize yields in soybean fields that are prone to Mn deficiency."

Compass Minerals officially launched *ProAcqua* in North America on 9 November.

"It's important to have the right micronutrient programme in place to achieve optimal yields and mitigate stress throughout the growing season. We offer innovative product lines, ranging from granular fertilizer applications in the spring to foliar applications in season to meet critical plant nutrition needs," concludes Karin Nicolajsen. ■

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large nitrogen requirement (Figure 3) by fixing the majority of this from the air. They do this via nodules formed on their root system by *Rhizobium* bacteria. Soybean seeds require inoculation with this bacterium to promote nodule formation and, as a consequence, ensure good nitrogen supply.

High potassium requirement

Soybeans also require large amounts of potassium (Figure 3), especially during the period of rapid vegetative growth. Potassium has a major effect on both yield and quality of the crop and is therefore essential for healthy, high-yielding plants. For certain soils, potassium application rate has been shown to correlate with both yield and seed oil content.

As well as being vital for vegetative growth and pod and seed formation, potassium also:

- Reduces pre-harvest pod shedding
- Improves seed quality by keeping the numbers of shrivelled, shrunken, mouldy and off-colour beans to a minimum
- Promotes root nodulation and nitrogen fixation from *Rhizobium* bacteria
- Improves transpiration by reducing water loss from the leaf
- Helps minimise the effects of frost in prone areas

Phosphorus: good for roots, yield and quality

As with many crops, phosphorus availability is important for good root development and crop establishment. Under certain soil conditions, applications rates have been shown to correlate with yield, seed oil content and seed protein content. Phosphorus is involved in:

- The development of roots
- The production of root nodes and hence nitrogen fixation ability
- The movement and uptake of other nutrients
- Plant growth and maturation
- Seed numbers, seed size and seed germination

Phosphorus, together with potassium, can also limit damage from several plant diseases.

Other nutrients such as magnesium, sulphur and iron are also required during photosynthesis and maintain good growth.

Calcium has a direct influence on crop yield. It strengthens cell walls and is involved in pollen tube growth and pollen germination. It is also an essential nutrient for flower impregnation, flower bud fixation and pod formation. Deficiency causes the shedding of flowers and pods.

Sulphur helps optimise yield and quality and is involved in the formation of nitrogen-fixing nodules on soybean roots. Sulphur availability is directly linked to the quality of harvested seeds, as it promotes oil formation and helps makes oil easier to extract.

Yield limiting micronutrients

As growers aim for ever higher soybean harvests, the likelihood of nutrient deficiencies holding-back yield improvements also increases. Micronutrients, particularly zinc, boron and manganese, can be yield-limiting. Iron, manganese and chlorine removal rates for soybean are notably high (Figure 4).

Boron is required for pollen tube growth and pollen germination, and also ensures good fruit set. Boron-deficient plants show poor pod fill and as a consequence produce small, poor-quality seeds. The element also promotes nitrogen-fixation and counteracts aluminium toxicity. Foliar applications of boron and manganese help to ensure consistently high yields, especially for intensive cultivation in poor soil conditions. Manganese is involved in chlorophyll formation and can helps increase seed protein content. It also improves disease tolerance. Zinc enhances photosynthesis.

Fertilizer manufacturer recommendations for soybean, and a selection of recommended fertilizer products currently on the market, are reviewed below.

Balanced nutrient mix from Mosaic

Nutrient management for soybean firstly requires soil testing of macro-nutrient and micronutrient levels. Soil pH is also an important consideration because of its influence on nutrient availability, as The Mosaic Company notes:

"As soil pH increases, the availability of phosphorus (P), zinc (Zn) and iron (Fe) decreases. Although variety selection can help manage iron deficiency in soybeans, fertilizer application is still needed to address the P and Zn deficiencies prevalent in high-pH soils."

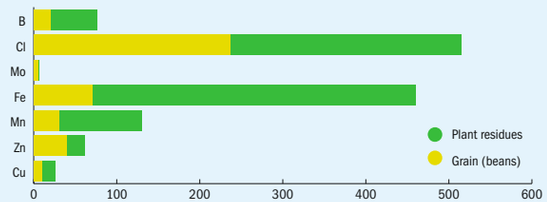
One of the main formulations offered by Mosaic for soybean is zinc-fortified *MicroEssentials SZ* (12-40-0-10S-1Zn). This combines 12 percent nitrogen, 40 percent phosphorus and 10 percent sulphur with one percent zinc (*Fertilizer International* 478, p 24). With a balanced mix of nutrients in every granule, *MicroEssentials SZ* is able to maximize soybean yields, according to Mosaic, by counteracting the influence of pH on P and Zn availability.

In 2014, Mosaic also launched a new micronutrient product, *Aspire*, a boron-enhanced potash fertilizer (*Fertilizer International* 478, p24). This first-of-its-kind premium potash fertilizer (0-0-58-0.5B) combines potassium chloride (58% K_2O) with boron (0.5%). This is uniformly distributed within granules using proprietary *Nutriform* technology. *Aspire* is marketed for soybean and other crops including corn, alfalfa and cotton.

Traditionally, in corn-soybean crop rotation systems, enough nutrients are provided at the start of the corn crop to cover both its needs and the needs of the subsequent soybean crop. But a series of University of Illinois trials commissioned by Mosaic suggest this approach may cause soil nutrient mining and leave insufficient nutrients for the soybeans.

The trials examined how potassium, and the phosphorus and micronutrients in *MicroEssentials SZ*, can help maximize soybean yield.

Fig. 4: **Typical soybean micronutrient removal rates, Brazil (g/t)**



Source: Yara

"We think that growers are not adequately fertilizing phosphorus because they don't know how much the corn is removing, and they're not actually fertilizing their soybeans," says Dr Fred Below, a lead scientists on the Illinois trials. "That's what we've demonstrated in our trials over the past few years.

He continues: "This leads [on] to the idea of balanced crop nutrition. For some reason, when the potassium is adequate, the plant seems to use the phosphorus better – it can squeeze another bushel or two out of it."

Mosaic's trials show that nutrient removal rates for soybean, especially for potassium, can be as high if not higher than for a standard corn crop.

"Compare a 60-bushel soybean crop [4 t/ha] to a 230-bushel corn crop [15.5 t/ha]: That corn crop is going to remove about 80 pounds of P_2O_5 [36 kilos], while the soybean crop is going to remove about 40 pounds [18 kilos]," comments Dr Matt Clover, former research manager at Mosaic. "But when we look at potassium, that 230-bushel corn crop is going to remove about 58 pounds of K_2O [26 kilos], and that soybean crop is actually going to remove about 75 pounds of K_2O [34 kilos]."

Manganese is one of the most common micronutrient deficiencies in soybean, and a particular problem in high-pH soils. Soil alkalinity, in turn, may be caused by calcium, magnesium and iron soil imbalances. Manganese deficiency is most acute in high organic matter soils during cool spring months when soils are waterlogged, and symptoms often disappear as soils dry-out and soil temperature rises. Mosaic suggests several ways of correcting manganese deficiencies:

- Keep soil pH below 6.5 if liming is causing the deficiency
- Mix a soluble form such as manganese sulphate ($MnSO_4$) with the starter fertilizer and apply in bands, as a high-phosphorus starter fertilizer helps move manganese into the plant.
- Correct field deficiency symptoms with foliar application

Foliar recommendations from Haifa

The foliar application of potassium nitrate by soybean growers is becoming more common, according to Haifa Group. The company has conducted numerous trials in Argentina and Brazil from the late 1990s onwards. These have examined soybean's response to foliar fertilization using *Haifa Bonus*, a water soluble potassium nitrate product enriched with monoammonium phosphate (MAP). Based on these trial results, Haifa's agronomic team has concluded that foliar fertilization offers the following benefits:

- Soybean responds well to foliar application of potassium nitrate and NPK fertilizers
- Yields up to 15 percent higher
- At least five percent more pods per plant
- Average grain weight up to five percent heavier
- Higher response shown when nutrient levels are not optimal
- Low yield cultivars also show better response
- Soybean plants are healthier, more resistant to pests and diseases, and are less prone to stress during drought

Haifa recommends two foliar applications of *Haifa Bonus* (13-2-44) as part of a soybean fertilization programme:

- First spray application at the last vegetative stage before flowering (V3 stage): 3.0 percent dilution to give 3 kg/ha application rate at 100 l/ha

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- Second spray application when pods in the 'third superior' part of the main stem are 0.5-1.5 cm size (R3 stage): 5.0 percent dilution to give 5 kg/ha application rate at 100 l/ha

Yara's soybean fertilizer programme

Yara International offers five *YaraVita* brand fertilizer products for soybeans:

- *Agripotash*: a highly concentrated liquid potassium fertilizer designed for foliar application
- *Hydrophos*: a concentrated, fast-acting liquid phosphorus fertilizer designed to boost crops during periods of rapid growth or to help crops overcome adverse climatic conditions
- *Glytrel MnP*: a glyphosate-compatible foliar fertilizer for soybean crops, containing both phosphorus and manganese
- *Glytrel ZnP*: a unique glyphosate-compatible foliar fertilizer, containing both phosphorus and zinc
- *Procote Zn*: liquid suspension coating for prilled or granular fertilizers that ensures an even supply of zinc to each prill or granule

Yara advises application of foliar products, as necessary, based on leaf tissue analysis. The company makes soybean recommendations at two different growth stages. The following application rates are suggested when plants are 5-10 centimetres tall:

- 3-5 l/ha of *Hydrophos*
- 1-2 l/ha of both *Glytrel MnP* and *Glytrel ZnP*

And also when plants are 10-15 centimetres tall:

- 3 l/ha of *Agripotash*
- Further 3-5 l/ha of *Hydrophos*
- Further 1-2 l/ha of both *Glytrel MnP* and *Glytrel ZnP*

Procote Zn can also be applied as a starter to soybean seedlings.

In 2015, Yara also launched the speciality product *Absoluto* for soybean crops in Brazil. *Absoluto* combines nitrogen, potassium, calcium and micronutrients in the same granule, together with a high concentration of phosphorus and readily-available soluble sulphur. The product is designed to "challenge the current limits of crop productivity to offer even more yields, operational efficiency, and safety", according to the company.

Yara believes there is plenty of scope for improving the productivity of new soybean varieties in Brazil. "A big slice of this increment comes from the better management and nutritional efficiency of our crops, which can be reached using innovative products and high technology such as *Absoluto*," comments Maicon Cossa, commercial director at Yara.

K+S recommends K, Mg and S

K+S offers a number of products which cater for the potassium, magnesium, sulphur and micronutrient requirements of soybean. One such product is *Korn-Kali*, a combined potash and magnesium fertiliser. This contains 40 percent K_2O in the form of potassium chloride (KCl, muriate of potash, MOP) and six percent MgO in the form of magnesium sulphate ($MgSO_4$, kieserite). K+S also suggests applying magnesium to soybean as *ESTA Kieserite* ($MgSO_4$) to ensure the plant's high sulphur requirement is satisfied, especially on tropical soils with poor organic matter content.

Two micronutrient-enriched $MgSO_4$ products from K+S are also suitable for quick-acting foliar application on soybean: *EPSO Microtop* contains boron and manganese while *EPSO Combitop* combines manganese and zinc. Their foliar application is recommended for heavily-weathered soils prone to micronutrient deficiency, or when boron and manganese deficiency results from heavy liming of soil.

The potassium and magnesium requirements of soybean vary with soil conditions but can require surprising high applications, according to K+S's fertilizer advisory service.

Soybean plants typically take up 30 kg K_2O and 7 kg MgO from the soil for each tonne of grain produced. Of this amount, the harvested grain removes 15-20 kg K_2O and 4-5 kg MgO. K+S calculates that balancing soybean nutrient removal requires 37.5-50 kg of *Korn-Kali*, or 15.4-19.2 kg *ESTA Kieserite* combined with 25-33 kg of MOP.

Potassium and magnesium applications to soybean can simply be adjusted to balance nutrient removal with soil nutrient supply, under no-till conditions and when nutrient losses are negligible. However, to sustain high yields and to maintain soil fertility under humid conditions with soils prone to leaching, K+S recommends the application of:

- 90-120 kg K_2O, equivalent to 150-200 kg MOP or 225-300 kg *Korn-Kali*, and
- 20-25 kg MgO, equivalent to 77-96 kg *ESTA Kieserite*

Even higher applications may be necessary for heavily-depleted soils and soils which fix potassium – because of clay content, for example. Under these conditions, K+S recommends applications of:

- Up to 180 kg K_2O, equivalent to 300 kg MOP or 450 kg *Korn-Kali*, and
- 50 kg MgO, equivalent to 192 kg *ESTA Kieserite*

Polyhalite, the new entrant

In February 2016, Sirius Minerals released results of four Brazilian agronomic trials on soybean for its *POLY4* polyhalite product (*Fertilizer International* 474, p44). The company concluded that the presence of *POLY4* in fertilizer blends provides soybean crops with a balanced, efficient supply of nutrients. The main results were as follows:

- In greenhouse trials, *POLY4* blends increased soybean nitrogen fixation and potassium and sulphur uptake
- The presence of Mg and micronutrients in *POLY4* also helped improve above ground soybean biomass in greenhouse trials
- In field trials, using *POLY4* as part of pre-planting starter blend (2:28:6+7S) improved soil nutrient status (K, Ca, Mg and S) after cropping
- Compared to an MOP-based blend, pre-planting with the *POLY4* starter blend obtained the maximum yield of 4.4 t/ha using 66 percent less K_2O, delivering a potential nutrient input saving of $27/ha

In trial results released in June, ICL reported significant increases in soybean yield and profit in Brazil using its *Polysulphate* polyhalite product. Working in conjunction with Fertipar Bandeirantes, a field trial was performed in Piraju, a major soybean producing area in the south eastern region of Sao Paulo, Brazil. The region's growers are interested in boosting soybean productivity and farm profits as the crop's yield potential is not always reached.

Fabio Vale of the International Potash Institute (IPI) coordinated the field trial. This compared a fertilizer blend incorporating *Polysulphate* with a local, high-quality blended fertilizer. Root development was deeper and more vigorous with *Polysulphate*. The *Polysulphate* blend also increased soybean yield by 18 percent. Advantageously, the *Polysulphate* blend, because it was no more costly yet still increased yield, also delivered a 20 percent increase in profits. ■

Sulphuric acid upgrades: cutting costs, raising output

Maximising profitability has always been of paramount importance to sulphuric acid plant operators. Equipment upgrades are generally the most cost effective option for operators seeking to improve profitability and their competitive position. Replacing aging equipment with the latest technology helps to reduce operational expenditure and plant downtime, while increasing production capacity and energy efficiency.

Sulphuric acid plant design and technology are constantly evolving. Because of this, upgrades to sulphuric acid plants eventually become necessary to ensure they continue to remain economically viable. Replacing old equipment with the latest technology helps keep operating costs and profits competitive with the newest plants entering service. Historically-low price levels for sulphuric acid, commodity chemicals and metals also provide another strong incentive to raise output and improve energy efficiency by upgrading plant equipment.

Even the best designed sulphuric acid plants eventually need upgrading. Typically, upgrading is also a more affordable and timely option for plant owners, compared to financing and building a completely new plant. Plant modernisation projects can usually be delivered more quickly and at a fraction of the cost of a full plant replacement. Consequently, overall loan costs, loan repayments and the cashflow of sulphuric acid upgrade projects are generally more attractive than those of new build projects.

Plant 'upgrades' are used interchangeably or synonymously with other engineering terms. They are commonly called revamps or retrofits, for example, or debottlenecks if they increase plant capacity. Around ten sulphuric acid revamp projects are underway globally, according to the latest sulphuric acid project listing from *Sulphur* magazine (Table 1). Leading providers of sulphuric acid plant upgrades include Chemetics, MECS, NORAM and Outotec.

NORAM's strategy

NORAM has extensive expertise and experience in installing new equipment at existing acid plants. The Canadian company has successfully carried out more than 250 sulphuric acid plant debottlenecking studies worldwide, and specialises in engineering strategies for upgrading plants. NORAM recently published an overview of its approach to sulphuric acid plant modernisation, including case study results for 11 recent upgrade projects[1].

NORAM offers the following proprietary sulphuric acid technologies:

- Cellchem and sulphur burners
- Brick-lined and conventional *NORAM SX* alloy towers
- Stainless steel converters
- *SMART* acid distributors
- HP packing
- RF radial flow and SF split flow gas heat exchangers
- *NORAM SX* and anodically protected acid coolers

These technologies help make NORAM the natural partner for plant owners in upgrade and debottlenecking projects. The main drivers for plant upgrades identified by NORAM include the need to:

- Replace end-of life equipment
- Comply with more stringent environmental regulations
- Meet new energy recovery targets
- Increase gas handling or acid production capacities

Additionally, acid plant equipment may need to be upgraded or replaced because of their age and mechanical condition – or when they are found to be the source of a plant bottleneck.

Replacing end-of-life equipment

Certain equipment items may require replacement due to their poor mechanical condition. Commonly replaced items of equipment include:

- **Catalytic converters:** 20 to 40 years life expectancy
- **Acid towers:** 20 to 30+ years life expectancy
- **Gas-to-gas heat exchangers:** 5 to 20 years life expectancy
- **Acid coolers:** 5 to 30+ years life expectancy
- **Piping:** 5 to 20 years life expectancy

In sulphuric acid plants, equipment usually deteriorates as a result of corrosion or because of design and installation issues. Although temporary repairs can sometimes extend the life of major equipment, replacement is ultimately necessary. A range of factors need to be considered when deciding if a major piece of equipment should be replaced:

- The probability of failure
- Potential lost production
- The time required for engineering, fabrication and installation
- The total replacement cost

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Table 1: **Sulphuric acid upgrade projects, April 2017 snapshot**

COMPANY	SITE	APPLICATION	CAPACITY	LICENSOR	CONTRACTOR	TYPE OF PROJECT	START-UP DATE
Nyrstar	Port Pirie	Smelter off-gas	n.a.	Outotec	Outotec	Revamp	2017
BRAZIL							
Nitro Quimica	Sao Paolo	Sulphur burning	900 t/d	Chemetics	Chemetics	Revamp	2018
Paranapanema	Camacari	Smelter off-gas	3,144 t/d	Chemetics	Chemetics	Revamp	2016
CANADA							
Glencore	n.a.	Smelter off-gas	n.a.	Chemetics	Chemetics	Revamp	2018
Vale	Sudbury	Smelter off-gas	n.a.	Chemetics	Chemetics	Revamp	2017
CHILE							
Codelco	Potrerillos	Smelter off-gas	n.a.	Outotec	Outotec	Revamp	2018
NETHERLANDS							
Nyrstar	Budel	Smelter off-gas	n.a.	Chemetics	Chemetics	Revamp	2017
NEW ZEALAND							
Balance	n.a.	Sulphur burning	625 t/d	Chemetics	Chemetics	Revamp	2017
PERU							
SPCC	n.a.	Smelter off-gas	n.a.	Chemetics	Chemetics	Revamp	2016
RUSSIA							
Ural Mining	Svyatogot	Smelter off-gas	n.a.	Outotec	Outotec	Revamp	2018

Source: Sulphur magazine's annual survey of recent and planned projects. Sulphur 369, p30.

A simple cost evaluation is often the best way to decide if replacement is warranted or not. This compares the estimated costs of not replacing the equipment with the costs of a replacement project.

The potential costs of not replacing the equipment (cost A) include:

- Cost of temporary repairs
- Increased maintenance costs
- Daily costs of lost production from a possible plant shut-down, weighted to the probability of equipment failure
- Time required to repair or replace equipment after a catastrophic failure

Whereas the costs of replacing the equipment (cost B) include:

- Cost of basic engineering
- Cost of detailed engineering
- Equipment fabrication cost
- Shipping costs
- Foundation costs, if required
- Erection and installation costs

As might be expected, equipment replacement projects are generally recommended when 'cost A' is greater than 'cost B'[1]. However, other considerations also need to be factored in, such as:

- Service life of existing equipment
- Plant turnaround schedule
- Space constraints
- Risk and safety factors

The life expectancy of equipment strongly depends on the quality of the design and fabrication as well as plant operation.

New energy recovery targets

Many sulphuric acid plants, particularly sulphur-burning plants, recover energy via a steam system. Opportunities for improving energy integration and recovery can be identified using plant-wide simulations. These can scope the potential for reducing the plant's electrical power consumption and increasing its steam and electricity production.

For example, the electrical consumption of the plant's main blower can be reduced by installing low pressure drop equipment such as NORAM's RF (radial flow) gas-to-gas heat exchangers, and by replacing fouled equipment and catalysts. NORAM's HP packing also reduces pressure drop and increases tower capacity.

Many metallurgical and acid regeneration plants end up losing energy that could be captured from process gas because they employ SO_3 coolers which vent hot air to the environment. However, this lost energy can be recovered by incorporating new SO_3 cooler designs which recover process heat and use this to produce hot air. The hot air obtained can increase energy production by feeding combustion furnaces or be used to produce steam. Energy can also be recovered during sulphuric acid cooling using a water heater for the boiler feed or a heat recovery system.

Increasing production capacity

Sulphuric acid plants are assets with both fixed and variable operating costs. Upgrades that increase production capacity are typically financially advantageous for plant owners. This is because improvements in plant capacity deliver a proportional gain in profits for a relatively small increase in variable costs.

For metallurgical plants capturing smelter off-gas, reasons for increasing capacity include:

- Newly purchased or modified smelting equipment with a higher ore throughput
- A rise in gas throughput
- The transfer of gas loads from other plants

Increases in acid plant capacity can be realised either by increasing gas concentration or by increasing gas flow. Although some acid plants operate near to the practical limit of SO_2 concentration (12-13%), other plants may benefit from an increase in SO_2 concentration. This often requires an upgrade which can increase the conversion capacity of the catalytic converter without raising environmental emissions. Solutions often involve replacing equipment that cause process bottlenecks or using an improved catalyst or low pressure drop equipment.

Upgrade objectives

The project execution strategy for a sulphuric acid plant upgrade will need to satisfy a range of requirements. In NORAM's view, the following objectives are desirable when installing new equipment as a part of the upgrade:

- **Reduce SO_2 emissions to the environment:** usually requires catalytic converter replacement
- **Cut the energy consumption of the main blower** by using lower pressure drop equipment
- **Fabricate using better-than-existing materials**
- **Incorporate safer and more ergonomic equipment**
- **Reduce downtime and cut maintenance requirements** by using more mechanically robust and reliable equipment
- **Eliminate gas leaks**
- **Maintain dimensional limits**
- **Minimise ducting and piping changes** by matching specific tie-points
- **Re-use existing foundations** when possible
- **Fabricate equipment in shop** as much as possible
- **Ship equipment to site in one piece**, if possible

Upgrade projects may last several years. It may be possible to achieve design objectives in one single stage. But, in practice, it is often easier to upgrade plants in multiple stages, both to reduce upfront capital investment and minimise disruption to plant turnaround schedules.

Deciding where to locate replacement equipment is a key determinants of overall project cost. The re-use of existing foundations, piping, ducting and rotating equipment can also significantly reduce the total project cost.

Custom revamps from Outotec

Outotec's knowledge of sulphuric acid technology is built on more than 90 years of engineering experience and the completion of more than 650 plants globally. Valuably, the company also possesses considerable expertise in associated upstream metallurgical smelting and roasting technologies.

According to Outotec, the main drivers for sulphuric acid plant revamps and upgrades (Figure 1) include[2]:

- Lowering environmental emissions
- Increasing production capacity and reducing operational expenditure
- Replacing damaged equipment
- Reducing unplanned downtime
- Responding to ore feedstock changes at metallurgical acid plants
- Decoupling connected operations
- The generation of additional products, e.g. oleum, SO_3, liquid SO_2, ultrapure acid, heat, electrical energy etc.

The company offers a wide range of custom equipment and process solutions for acid plant revamps including:

- Brick-lined and *SX* alloy cooling towers
- *SX* alloy piping

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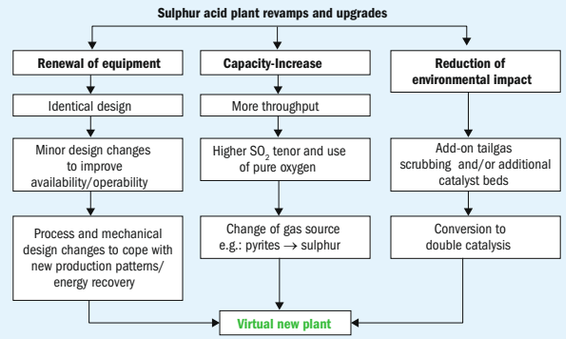
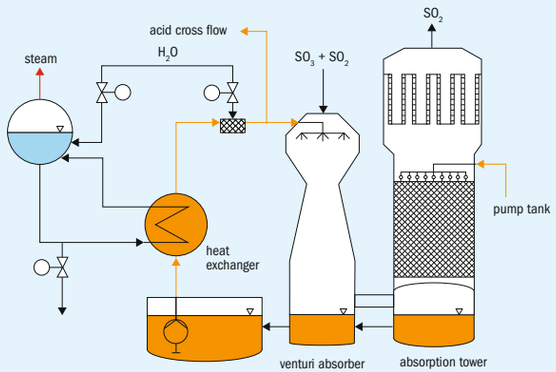
Fig. 1: **Main drivers for revamps and upgrades**



Source: Albrecht (2016)

Fig. 2: **HEROS™ plant configuration**



Source: Outotec

Table 2: **Design basis for a financial efficiency calculation**

Plant capacity	4,500 t/d H_2SO_4 (as 100 wt-%)
Plant location	Europe
Plant type	Sulphur burning, 3+1
Utility concept	"Over the fence" – purchase of electricity, cooling water, demin water and LP steam. Sale of HP and LP steam.
Financial concept	Plant cost fully financed by a commercial loan: interest rate 6%, depreciation based on a 20 year period.

Source: Outotec

- Stainless steel catalytic converters
- *LURO2* sulphur burner
- *CORD* heat exchanger
- *HEROS* and *LUREC* process technologies
- *Peracidox* off-gas scrubber
- *FiDiTM* irrigation systems

Equipment replacement and capacity increases

Equipment replacement provides an opportunity to remove bottlenecks and improve overall plant performance. Outotec's latest catalytic converter, for example, offers the following design advantages:

- Symmetrical welded stainless steel design
- Radial gas distribution with low pressure drop
- Eliminates converter hot gas nozzles
- Reduces gas ducts, expansion joints and duct support
- Minimises heat loss and reduces insulation
- High heat capacity, allowing longer 'hot' shutdowns
- Good accessibility for inspection and maintenance

In one recent revamp, Outotec demolished and replaced a 30 year-old catalytic converter within 23 days during an annual maintenance shutdown. The converter's brickwork had deteriorated and SO_2 emissions had increased due to gas slippage between brickwork and shell. The installation of a new stainless steel converter and internal heat exchanger as part of the revamp increased acid plant capacity from 1,700 t/d to 2,200 t/d.

In one notable revamp, Outotec installed a new, prefabricated brick-lined drying tower and a new, prefabricated converter for Aurubis AG (Norddeutsche Affinerie) during a six week shutdown period at its Hamburg complex in Germany. The old drying tower was removed and various items of equipment were replaced, increasing the capacity of the three parallel sulphuric acid plants at the site. In another revamp, Outotec also replaced a converter for Aventis (Höchst AG) during a 17 day shutdown period at its Frankfurt site in Germany. The company also demolished a tower for Evonik (Degussa Röhm GmbH) at Worms in Germany and replaced it with a prefabricated unit within five days.

Outotec's *LUREC* process is an effective plant debottlenecking solution able to lower operating costs and reduce plant emissions. The technology can be installed without interfering with existing plant operations. *LUREC* is a suitable add-on unit in situations where strong gases (30-60%-vol. SO_2) from smelter processes are available. Processing highly concentrated gases has the following key benefits:

- Smaller equipment: reduced investment cost
- Lower gas flow: less energy demand
- Higher SO_2-content: higher energy recovery potential

Improving reliability

Equipment replacement offers a golden opportunity to improve reliability, availability and ease of maintenance. Outotec, for example, replaced a gas-gas heat exchanger for Boliden Rönnskär in Sweden with its patented *CORD* design. Delivered within 6 months, the new heat exchanger offered the following design improvements:

- Vertical section in carbon steel
- Horizontal section in stainless steel
- Much less corrosion and blocking
- Significantly extended lifetime

Improving energy efficiency

Energy efficiency improvement projects are strategically important and can lead to valuable opex savings for sulphuric acid plant operators. A significant amount of energy is wasted as cooling water in sulphuric acid plants. This can be addressed by implementing a heat recovery process such as *HEROS* to improve overall plant energy efficiency[3].

A typical *HEROS* system includes a venturi absorber, a second stage absorption tower and a pump tank (Figure 2). The latter is connected to a heat exchanger which generates low pressure steam by cooling hot, highly concentrated sulphuric acid.

The system can be retrofitted at an existing metallurgical or sulphur burning plant. Valuably, it should be possible to construct, check and pre-commission the *HEROS* system while the existing plant is fully operating. This reduces the shutdown time needed for the tie-in to a bare minimum.

Energy and financial efficiency

Calculations by Outotec suggest that energy recovery retrofits at sulphuric acid plants can combine large energy efficiency improvements with a quick return on investment. An absolute increase in thermal efficiency of 21 percent is typically achieved by installing a heat recovery system in the intermediate absorption section of an acid plant, for example, leading to an overall plant efficiency of 79 percent.

Outotec has also estimated the financial efficiency of the *HEROS* system for a typical set of plant design parameters (Table 2). With an annual return on investment of 0.44, the installation project breaks even in 2.4 years in this example.

Chemetics: converter revamp projects

Sulphuric acid plant operators will always be strongly motivated to adopt technology and equipment that:

- Offers compliance with or exceeds statutory environmental regulations
- Is cost competitive, low maintenance and highly reliable
- Improves energy use and efficiency
- Designed to allow simple installations or retrofits

The design of Chemetics sulphuric acid equipment has been continuously improved during 40+ years of plant experience. This has helped eliminate, as far as possible, recurrent maintenance problems associated with traditional acid plant designs. The range of speciality proprietary equipment offered by Chemetics, for both new sulphuric acid plants and retrofit applications[4], is an important aspect of the company's business.

Converters are the largest items of process equipment in sulphuric acid plants and the focal point of production. Chemetics has completed 14 retrofit projects involving converter replacement during the last 20 years (Table 3). Delivery of such replacement projects usually focusses on:

- Space constraints
- New foundation vs existing foundation
- Improving technology
- Fabrication strategy, e.g. modular approach
- Increasing capacity
- Replace aging equipment
- Preheater evaluation
- New ducting
- Catalyst
- Shutdown time for tie-in

Modular converters

Converter vessels contains a series of catalyst beds which convert sulphur dioxide to sulphur trioxide. Most modern double absorption processes require four or more catalyst beds. Gases flow through these beds in series with intermediate cooling in between.

Chemetics introduced the first all stainless steel converter in 1980. Prior to this, vessels were traditionally manufactured from brick-lined carbon steel and cast iron. Although many hundreds of these conventional units are still installed and operating around the world, most have caused their

Table 3: **Converter replacement projects: Chemetics retrofit references for last 20 years***

Startup	Country	Beds	SS converter	Internal heat exchangers	New foundation	Modular
2015	Confidential	4	Yes	Yes (2)	Yes	Yes
2014	Canada	4	Yes	Yes (2)	Yes	Yes
2014	Brazil	4	Yes	Yes (2)	Yes	No
2013	USA	4	Yes	Yes (1)	Yes	Yes
2012	Canada	4	Yes	Yes (1)	Yes	Yes
2010	UK	4	Yes	No	Yes	No
2006	USA	4	Yes	Yes (1)	Yes	No
2006	Canada	4	Yes	No	Yes	No
2000	Sweden	5	Yes	Yes (1)	Yes	No
1999	RSA	4	Yes	No	No	No
1999	Netherlands	1	Yes	Yes (1)	Yes	No
1995	USA	4	Yes	Yes	No	No

Source: Chemetics (2015) **Total replacement projects as of 2015.*

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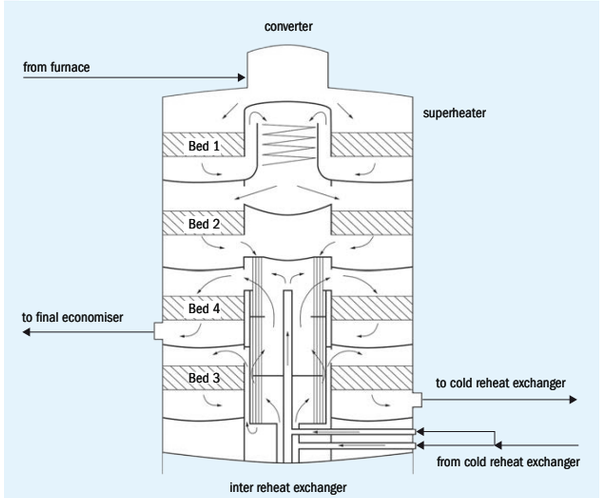
Fig. 3: **Chemetics converter with internal superheater and gas exchanger**



Source: Chemetics

owners significant operating and maintenance problems.

The latest converter design from Chemetics can incorporate an internal gas exchanger and superheater inside the vessel core. This innovation, by avoiding hot gas ducting between beds 1 and 2, eliminates a recurring maintenance problem found on many plants caused by very high gas and metal temperatures (Figure 3).

Converters that are too large to be shipped fully-fabricated have traditionally been built on-site using a 'stick built' or 'knock down' construction methods. Plates are cut, bevelled and rolled remotely in a shop before being welded together piece-by-piece on site. Building or retrofitting a large, new converter in this way can take four to six months, with 50+ personnel working on site in two shifts, six days a week. Lengthy on-site fabrication carries with it substantial risks, due to weather conditions and the availability of skilled welders and fitters local to the plant site.

To minimise field construction, Chemetics has supplied nearly all of its stainless steel converters in modular form since the 2000s. Such converters are shipped as prefabricated modules for subsequent on-site assembly. This method greatly reduces construction time from the conventional 4-6 months to 8-10 weeks. Prefabrication also improves overall construction quality, since the majority of the welding and fitting is completed off-site under ideal conditions in a shop (Figures 4 and 5).

Drawing on its considerable experience, Chemetics says converter replacement projects can provide sulphuric plant operators with the following options and solutions:

- New stainless steel converter built on new foundation
- Incorporate internal exchangers where space is limited and to avoid ducting costs
- Allows installation while plant is in operation
- Tie-in period can coincide with a maintenance shutdown (<30 days)
- Use the project as an opportunity to replace other aging equipment
- Capacity increase common, but only if existing equipment can cope
- A modular approach reduces construction costs and increases fabrication quality
- Catalyst emissions guarantee ■

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PHOTO: CHEMETICS

Fig. 4: Prefabricated converter modules.

PHOTO: CHEMETICS

Fig. 5: Converter modules assembly in-field.

MECS CASE STUDY

Cutting emissions, increasing fertilizer production

This case study describes how LLC IG Phosphorit is set to raise the output at its sulphuric acid production plant located in Kingisepp, Russia to over one million t/a with the help of MECS[5].

In 2001, when LLC Industrial Group Phosphorit (IG Phosphorit) became part of the Mineral and Chemical Company, EuroChem (MCC EuroChem), the group began carrying out a large-scale reconstruction of the industrial processes at its plant in Kingisepp near St. Petersburg (Russia). The main driving force for the reconstruction was a projected increase in mineral fertiliser production capacity along with a simultaneous reduction in industrial emission levels. Between 2001 and 2005, production capacity for sulphuric acid at IG Phosphorit's sulphuric acid plant (SAP) increased from 450,000 to 700,0000 t/a. MECS began working with IG Phosphorit in 2005, supplying the Kingisepp site with highly efficient Brink® mist eliminators for its drying and absorption towers, which helped to solve the problem of acid mist and droplet carry-over. During 2007-2008, IG Phosphorit launched a gradual systemic revamp programme for the SAP based on MECS know-how, in order to achieve a final sulphuric acid performance capacity of 1 million t/a.

A few years later the goal was within reach. As Mr Sergey Sheibak, Technical Director of the IG Phosphorit plant, said: "In 2015 MECS specialists conducted a technical audit to evaluate opportunities to further enhance the performance of the SAP by at least 10%. Their report clearly showed the presence of hidden production increase reserves. We should be able to reach an output of 1,122,000 tonnes of sulphuric acid per year and, at the same time, reduce the number of equipment units to generate steam from five to three. These three pieces of steam generating equipment should allow us to reduce the pressure drop across the plant from 1,800 to 800 mm water column, which would give us the opportunity to improve performance while maintaining the existing emissions."

Apart from supplying equipment, MECS carried out engineering studies (ducting, steel structure, 3D model), provided process design and supported IG Phosphorit with advisory services for site installation, commissioning and start-up. SNC Lavalin was tasked with detail design and project execution.

Thierry Marin, managing director MECS explains: "One of the key requirements from IG Phosphorit was to help the group to comply with the new MCC EuroChem sustainability goals. The first goal focused on energy recovery, and the introduction of a new MECS® Heat Recovery System (*HRS*™) helped the site recover 20% additional energy that previously had been wasted. The second aspect of the sustainability goals concerned the SO_2 emissions. To address that, we developed and improved the conversion rate of the IG Phosphorit plant in Kingisepp. This represents a real step change for the site."

Efficiency improvements on all fronts

Mr Sheibak provides more detail of the long-standing project: "We initially replaced the converter, the sulphur burner and the gas-gas heat exchangers. To enhance the functionality of the sulphuric acid plant operation, a new stainless steel converter was installed. This has allowed us to save almost a day of production time, which was previously lost as a result of plant shutdowns for repair and time needed to put the plant back into operation".

The deputy head of the sulphuric acid production plant, M. Aleksandr Smirnov, sums up the revamp since 2008: "I was given an outstanding opportunity to participate in all stages of the revamp over the last 10 years. During this period, the plant underwent repeated reconstruction followed by an increase in production capacity from 450,000 tonnes of sulphuric acid per year (the initial capacity of the plant) to 700,000 tonnes. MECS has played a big role in our project and helped us to increase our production rate even further from 700,000 to one million tonnes."

The sulphuric acid plant revamp continued in 2010. IG Phosphorit replaced two absorption towers: a drying tower and final tower, with all tower internals coming from MECS including the acid distributors and support grids. Next, IG Phosphorit decided to replace the interpass absorbing tower, called the "A1", and install a new tower with an *HRS*™ designed by MECS. Mr Valery Degtyarev, head of the sulphuric acid plant, points out: "The resulting efficiency gains were impressive." He says: "With the start-up of the *HRS*™ system, we have received an additional 70 tonnes of steam at 10 bar and were able to solve a number of problems. We no longer use boilers to produce steam at 10 bar and do not burn natural gas for this. Steam obtained through the *HRS*™ allows us to meet the needs of the site, avoiding the use of additional resources and extra costs for the purchase of natural gas."

Mr Smirnov explains further: "With the launch of the *HRS*™ system in 2012, the heat from absorption, in the form of medium-temperature steam, is sufficient to cover the needs of the entire plant. The steam is also used by our structural subdivisions."

All the high-pressure steam produced by the waste heat boiler installed after the sulphur furnace is used to generate electricity, and this allows IG Phosphorit to export an average 2.5 MW of power to the external network.

Maxim Petrov, director of maintenance and repairs at the Kingisepp site, is happy that the boiler system has also been updated: "For over 10 years we had a system consisting of two boilers made in Poland and the Ukraine, but this did not provide the HP steam performance we wanted. So we replaced both boilers with a single boiler supplied by MECS and manufactured by Thermal Systems (India) that offers a capacity of 150 ton/h.

The boiler was commissioned in October 2016 according to plan and is much easier to operate than our previous two boilers. With the support of MECS specialists, it was then directly brought up to design capacity and has to date operated at design load."

Lowering emissions and saving time

The benefits of the revamp that IG Phosphorit has undertaken are not limited to high performance and efficiency. Changes in technology and equipment also led to a reduction in emissions. Mr Sheibak points out: "We are working at a capacity of 2,940 t/d without exceeding the permissible emissions limit. With the standard rate of emissions limited to 0.05 g/m³, we are currently working at an emission level of 0.017 g/m³."

"In accordance with the feasibility study carried out in 2015/2016 by MECS," he continues, "it seems possible to increase the production rate of the SAP to 1.122 million tonnes of sulphuric acid per year (3,300 t/d), while reducing SO_2 emissions from the current value of 417 ppmv to 132 ppmv (conversion rate of 99.9%). This modification should be carried out in the next few years."

Mr Sheibak concludes: "Our cooperation with MECS will continue, and we will realise the hidden production reserves identified during the audit in 2015/2016."

As Mr. Marin says: "The aim of MECS from the outset was to enable IG Phosphorit to realise its target production capacity efficiently, reduce emissions and recover energy in a sustainable manner. This the project has now achieved." ■

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Young professionals

The International Fertilizer Association (IFA) is helping to fully develop the career potential of younger employees through the recently-launched Young Professionals initiative. This is providing a new generation of industry professionals with access to mentoring and career development advice. It also gives individuals a chance to network with their peers, as well as subsidising attendance and participation at international conferences.

To support IFA's new initiative, *Fertilizer International* magazine is running a series of profiles featuring industry young professionals. These highlight the wide range of attractive and rewarding career options available to young people in the fertilizer sector. In this issue, Mathias Schroeder, who manages EuroChem Agro Asia in Singapore, talks to us about his career. ■

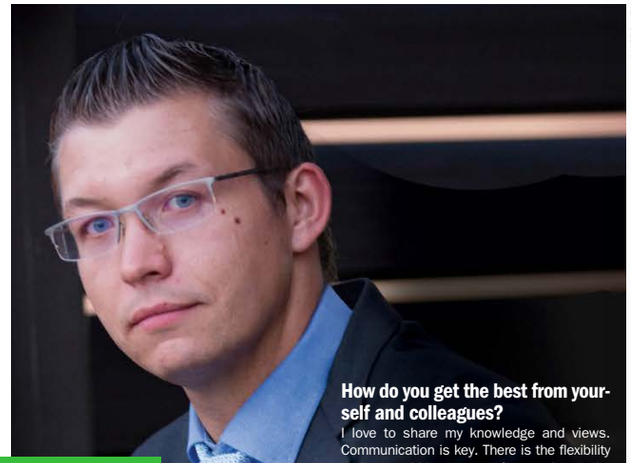

PHOTO: IFA

Mathias Schroeder, 32 Managing Director

How did your career in the industry start?
Agriculture is the way of my heart. I grew up in a village of just 140 people in the far north-east of Germany. My father worked, and still works, in the dairy industry. I sat on a combine harvester for the first time at the age of six!

After graduating in 2008, I became a sales manager in Germany for fertiva, the former nitrogen subsidiary of K+S. Unusually, I actually began working for fertiva in 2005 as part of my degree course at the Cooperative State University in Mannheim, Germany. You could say I've been with the same company for 12 years – it's just changed names and the corporate structure is different.

How do you get the best from yourself and colleagues?
I love to share my knowledge and views. Communication is key. There is the flexibility and trust within my team for people to take responsibility for projects and tasks. Understanding *when* to ask for advice is an essential part of learning too. Encouraging my team to ask questions and share ideas is equally important, so my door is always open.

Has mentoring been important to you?
Yes, it has been most important. My first boss was known as the 'fertilizer gentleman'. He was a clear thinker, very calm and patient. I learnt a lot from him. Although he is now retired I'm proud to say we are still in contact.

What achievements are you most proud of?
Growing the business to where it is today. I moved to Singapore in 2011 as Asia-Pacific director of K+S Nitrogen. I subsequently incorporated EuroChem Agro Asia after the sale of the company in 2012. As managing director in Singapore, I then became EuroChem's head of sales and marketing for Asia. We've since gone from being a 'one man show' to a team of 14 in Asia-Pacific. I also take great pride in making my family proud.

What do you find most rewarding about your job?
Getting deals done on a daily basis gets me motivated. What I also really enjoy is communicating with people from different countries and different cultural backgrounds. That is interesting, challenging and really educational. Inspiring people and leading them towards success is also highly rewarding for me.

What hurdles have you had to overcome?
Age can be a hurdle – if it's linked to inexperience and not a person's achievements and their skills set. To overcome this, I have needed to show my knowledge and 12 years of practical fertilizer industry experience, as well as my dedication and willingness to learn. Attitudes are changing with younger people in executive roles. In today's business, younger and more dynamic leaders are definitely on the rise.

Will your job and the industry change in future?
Change is part of the game in every industry in this day and age. Some of the biggest mergers in the world are happening in agriculture. The global fertilizer trade is changing, with new products emerging. Nutrient use efficiency and sustainability will define the way forward.

Would you recommend a career in the sector to others?
Absolutely. It is a privilege to be part of an industry that helps feed the world's population. My advice to anyone joining the industry? First and foremost, 'get your hands dirty' and learn the basics. Be dedicated, be motivated and have a positive work ethic. Strengthening your knowledge, relationships and networks is of the utmost importance. For me, the fertilizer industry has never been more exciting.

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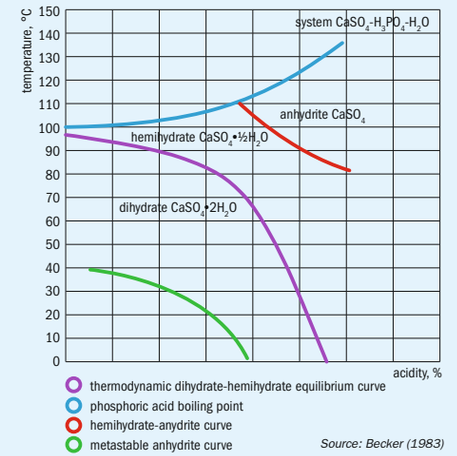
Phos acid process choices

Most of the world's phosphoric acid is produced by the wet process via the dihydrate or hemihydrate route. **Hadrien Leruth** of Prayon Technologies outlines the range of process options for new and converted phosphoric acid plants and their relative merits and demerits.

Fig. 1: **The calcium sulphate crystallisation system in phosphoric acid production**



Source: Becker (1983)

The wet process route is the most economical and widely-adopted commercial production method for phosphoric acid globally. Phosphate rock is attacked with sulphuric acid, producing phosphoric acid and a solid calcium sulphate by-product. These are subsequently separated by filtration.

Table 1: **Phosphoric acid production routes**

	Dihydrate route*	**Hemihydrate route***
Single crystallisation	Dihydrate (DH)	Hemihydrate (HH)
Double crystallisation + one filtration	Di Attack – Hemi Filtration (DA-HF)	Hemi Recrystallisation (HRC/Nissan H)
Double crystallisation + two filtrations	Dihydrate – Hemihydrate (DHH/CPP)	Hemihydrate – Dihydrate (HDH)

** Route is called as per the first crystallisation.* *Source: Prayon*

Dihydrate versus hemihydrate

The crystalline structure and degree of hydration of the by-product have a critical influence on the production process and vary according to reactions conditions. Two process variables, acidity and temperature, determine whether calcium sulphate crystallises in dihydrate (DH, $CaSO_4 \cdot 2H_2O$) or hemihydrate (HH, $CaSO_4 \cdot \frac{1}{2}H_2O$) form (Figure 1).

Six process routes for phosphoric acid production have been developed, based on whether DH or HH crystals are first crystallised, and the number of crystallisation and filtration steps involved (Table 1). For example, DH crystals can be converted into HH crystals by double crystallisation. With a single filtration step this is called the DA-HF process. If instead there are two filtration steps, one after each crystallisation, the route is known as the Central-Prayon Process (CPP).

Prayon has developed production technologies for every process route in Table 1, with the exception of HRC, also known as the Nissan H process. In Prayon's view, process selection, and the relative merits and drawbacks of each process route, can be weighed-up using 10 main criteria (Figure 2) and their sensitivity to process instability:

- Phosphate requirement
- Sulphuric acid quality and quantity
- Steam consumption
- Water consumption
- Power consumption
- Additive use
- Phosphoric acid quality
- Quality of gypsum
- Operational skills required
- Investment cost

These are discussed in turn below. Although some of these criteria are generally more significant than others when it comes to process selection, their relative importance will also vary from project to project.

Phosphate requirement

Single crystallisation processes (DH, HH) are tolerant of impurities and will generally work with almost all types of commercially available phosphate rock. Double crystallisation processes, in contrast, are more sensitive to phosphate rock impurities and can be more difficult to manage as a consequence. This is because some impurities can shift reaction boundary conditions between hemihydrate and dihydrate. A high aluminium content, for example, shifts hemihydrate conversion to a much higher temperature and acidity. Similarly, some elements like lanthanides or strontium can dramatically reduce the conversion of hemihydrate to dihydrate.

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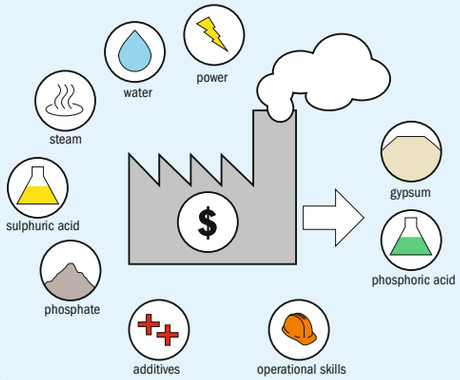
Fig. 2: **Phos acid process selection criteria**



Source: Prayon

The particle size of the phosphate rock concentrate delivered to the acidulation plant can also influence process choice. The grinding requirements for each process are not the same, being stricter for the DH process (all the particles under 500 µm) than for HH process (all under 1 mm).

Moisture levels are also an important consideration:

- DH process: can accept wet rock, or even a rock slurry
- HH process: moist rock results in a fall in plant performance
- DA-HF process: tolerant of rock moisture levels of up to 14 percent
- CPP process: also accepts up to 14 percent rock moisture (if P_2O_5 content kept close to 32-33 percent) as higher levels reduce the P_2O_5 content of the phosphoric acid product

Phosphate consumption, and therefore plant efficiency, varies between process routes. Processes can be ranked from highest to lowest efficiency as follows:

- CPP and HDH (most efficient)
- DA-HF
- DH
- HH (least efficient)

Sulphuric acid quality and quantity

The quality of sulphuric acid used in phos acid production usually depends on local availability. Economics may dictate the use of diluted acid produced as a by-product from a nearby metallurgical plant, for example. Such a decision could affect the choice of process. This is because the water brought-in by diluted sulphuric acid may upset the overall water balance, possibly disqualifying some processes, especially HH.

For a given phosphate rock, the sulphuric acid consumption is linked to two variables: firstly, the SO_3/P_2O_5 ratio in the acid leaving the filter and, secondly, losses in the filter cake. The CPP process has the lowest specific consumption of sulphuric acid due to a very low SO_3/P_2O_5 ratio and high efficiency. All other processes have roughly similar specific consumptions. The HH process typically has a SO_3 acid content of 1.5% for a P_2O_5 content of 39-40%. This ratio is much more favourable than for a DH process (2% for 28% P_2O_5), although greater co-crystallised losses in the HH process offset this advantage.

Steam, water and power consumption

At most phosphate complexes, steam from on-site sulphuric acid production generates electricity in a turbine to concentrate the phosphoric acid produced. Steam produced is also generally sufficient to cover the steam needs of the plant. However, when sulphuric acid plant steam is not available on site, steam is produced using a boiler instead. This can be expensive and favours high strength phos acid processes like HH or HDH process which enjoy a competitive advantage.

Fresh water consumption is also an important factor when the quantity of available water is limited. The DH process is less favoured in these situations as it consumes more water than other process routes.

In the phosphoric acid process, only the process energy directly associated with reaction, filtration and concentration is relevant, in terms of power consumption, as the energy consumed by grinding is part of the beneficiation step. Power is mainly consumed by agitators, blowers and fans, none of which have a particularly high or significant demand.

Additives use

Defoamers sometimes needs to be added to the reaction tank to remove a layer of foam generated by organic matter. The HH process generally requires more defoamer because its higher temperature promotes foam formation. Other additives are also needed to prevent the filter scaling associated with HH cake.

Quality of phosphoric acid

HH and HDH processes typically produce higher quality phos acid containing less aluminium and iron. This is an important process advantage, if the phosphate concentrate is relatively impure, or when a better quality acid is required for downstream production, e.g. for super phosphoric acid (SPA) or dicalcium phosphate (DCP) manufacture.

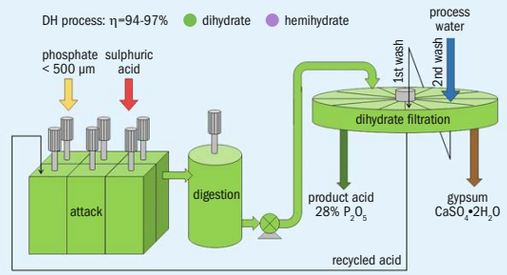
Quality of gypsum

In phos acid production, 4-5 tonnes of gypsum are generated for each tonne of P_2O_5 produced, and this needs to be stored or stacked. The quality of this gypsum by-product is of increasing concern in the industry, as it may limit the ability to find a suitable market use. Low P_2O_5 content is critical for gypsum in the plaster and cement market, favouring high grade processes like CPP or HDH.

Operational skills required

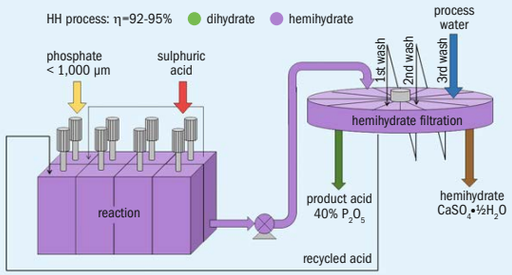
The lack of trained workers locally can be an important factor, especially for double crystallisation or HH processes.

Fig. 3: **The DH process**



Source: Prayon

Fig. 4: **The HH process**



Source: Prayon

Sensitivity to process instability

Process instability is undesirable as it can make calcium sulphate cake less easy to filter and increase P_2O_5 losses. Such losses can be high for HH, the process with the strongest phos acid concentration, greatly reducing overall performance.

Investment cost

Investment cost is an important factor. But it is generally more critical to purchase the process route that suits project circumstances the best, and enables the successful operation of the whole fertilizer complex, rather than opt for the phos acid unit with the cheapest investment cost. The malfunctioning of a low-cost, undersized or inflexible process can make an integrated complex uneconomic.

The key characteristics together with the main operational advantages and drawbacks of the process routes offered by Prayon are summarised below.

The DH process

The DH process (Figure 3) is by far the most widely used in the world and will be used as a benchmark for comparison with other processes. The DH process is very versatile and has been successfully operated with a very wide variety of rock types. Its efficiency can vary from 94 percent to more than 97 percent, depending on rock type. Rock can be fed to the process either dry or moist, or even in the form of a slurry with a solids content of about 65 percent.

DH can also contribute to overall plant profitability by accepting dilute sulphuric acid. This allows low-grade sulphuric acid sources to be used, including some kinds of waste sulphuric acid.

The P_2O_5 content of phosphoric acid within the reactor is the lowest (about 28% P_2O_5) out of all the processes. It also requires a fairly high level of steam to concentrate the acid. On the other hand, when slurry filtration is disturbed (e.g. after a long shut-down), less acid is lost in the gypsum cake due to its lower concentration.

Operators of average skill can also successfully operate the DH process.

The specific water consumption of DH is higher than for the other processes, due to the lower P_2O_5 content of the acid leaving the filter, and the form of calcium sulphate. Although this slightly affects operating costs, it should be possible to run the DH process as a zero effluent plant. The washing water or the cooling tower bleed can be easily recycled back to the process.

Gypsum can be stacked dry or wet and used in downstream applications after suitable post treatment.

Valuably, the equipment used in the DH process can be designed for easy conversion to high-strength process routes, like the DA-HF or the CPP process, in future.

The HH process

The main advantages of the HH process (Figure 4) are its slightly lower investment cost and a lower utility consumption compared to the DH process. The size of the concentration unit can be smaller, the acid produced being more concentrated than for a DH process, about 40-42 percent P_2O_5 versus 28 percent P_2O_5. This reduces the Capex of an HH process plant by 10-50 percent, relative to DH.

The phosphate grain size can be coarser (1mm instead of 0.5 mm) than for a DH process. This can allow the installation of a costly and energy consuming mill to be avoided.

The water consumption of HH is lower than the DH process due to the higher P_2O_5 content of the product acid and lower calcium sulphate crystal water. This is a definite advantage when water availability is limited. On the downside, water recycling possibilities are limited. An effluent neutralisation unit is usually required, and this partially counteracts the Capex advantage of the HH process. The efficiency of the HH process is also lower than for DH (about 2 percent less). Taking into account

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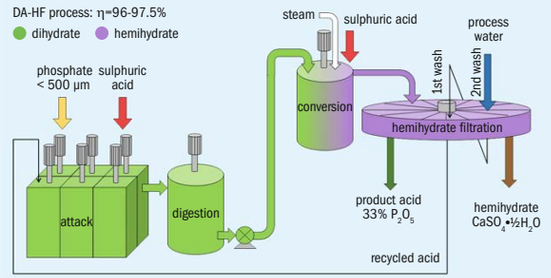
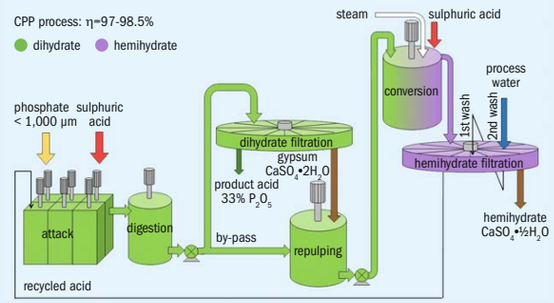
Fig. 5: **The DA-HF process**



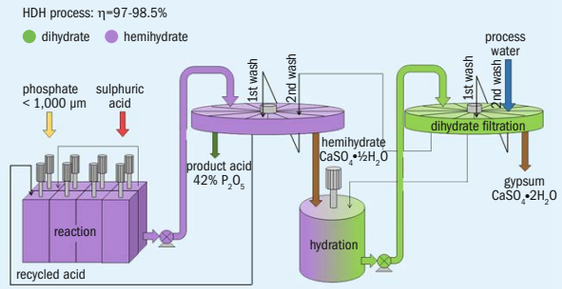
Source: Prayon

Fig. 6: **The CPP process**



Source: Prayon

Fig. 7: **The HDH process**



Source: Prayon

the need to beneficiate phosphate rock, this can be a significant cost.

The sulphate content of HH product acid is in the order of 1.5 percent, for a P_2O_5 content of 40 percent, suggesting that specific sulphuric acid consumption is low. In reality, however, consumption is much higher than expected due to low overall efficiency, with major lattice and soluble losses. Concentrated sulphuric acid should be used in order to ensure sufficient wash water on the filter.

The filter design needs to limit scaling in pipes due to the presence of HH. This involves incorporating steam injection points and sometimes using specific rehydration inhibitors.

The P_2O_5 content of HH gypsum is too high for use in plaster or cement applications, limiting its use to other markets such as agriculture.

The DA-HF process

The DA-HF process (Figure 5) is an extension of a DH process: the digestion volume being transformed into a conversion volume with the conversion of dihydrate gypsum into hemihydrate. This delivers an efficiency gain of about 1.5-2 percent compared to the DH process. The phosphoric acid produced is also more concentrated (32-33%). Specific sulphuric acid consumption is also similar or slightly better than a DH plant. Water consumption is lower than for a DH process, as hemihydrate gypsum is produced,

Moist phosphate rock with a water content of up to 4-12 percent can be used.

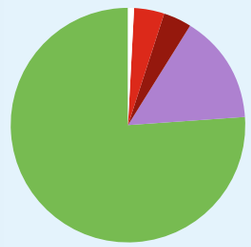
These performance advantages are partly counteracted by the slightly higher investment cost, about 10 percent higher than for a DH plant. Extra operational care is also necessary due to the presence of hemihydrate on the filter.

Valuably, operational flexibility means a plant can be operated under the DH or the DA-HF process. A DH plant can even be designed for ease of future conversion to DA-HF.

The CPP process

The CPP process, with its double crystallisation and two filtration steps (Figure 6), provides the best operational efficiency: 98-99 percent can be achieved. This not only reduces phosphate rock consumption, it also generates less calcium sulphate to manage.

Fig. 8: **Global phosphoric acid production by process route, excluding China**



76% Dihydrate (DH)
15% Hemihydrate (HH)
4% Hemihydrate-dihydrate (HDH)
4% Hemi Recrystallisation (HRC)
1% Dihydrate-hemihydrate (DHH/CPP)

2015 world total: 56,308 kt P_2O_5

Source: IFA/Prayon database

The P_2O_5 content in the gypsum is also low enough for usage in cement or plaster applications. Moreover, low P_2O_5 content, as long as the calcium sulphate is neutralised, strongly reduces the environmental impact of stacking. In Belgium, the performance of the CPP process, and the local conditions, allows Prayon to stack any unsold gypsum (just 10 percent of the total volume produced) without an expensive cap or liner.

The hemihydrate leaving the filter can be directly used as a construction material after drying.

To ensure dihydrate to hemihydrate crystal conversion, temperature and acidity are increased by steam and sulphuric acid injection into the conversion tank.

CPP has the lowest specific sulphuric acid consumption of all processes. It produces phosphoric acid with a sulphate content of about one percent for a P_2O_5 content of 32-33 percent. Unlike the cake losses in the HH process, the efficiency of CPP is very high.

Capex for CPP is higher than for a DH process, about 20 percent more, due to the larger number of equipment items required. This extra cost is largely compensated for by revenues from the commercial sale of gypsum.

Table 2: **Global phosphoric acid production, excluding China: capacity of 'classical' single crystal process vs double crystal process routes**

Process	Capacity (kt P_2O_5)	Proportion (%)
One crystal 'classical'	32,825	91.5
Two crystals	2,972	8.3

Source: IFA, Prayon data base

Prayon has now developed a 'convertible' DH process. This has all the up-to-date features of the latest Mark IV dihydrate technology, and its layout is designed for ease of transformation into a CPP process.

The HDH process

The HDH process (Figure 7), because it incorporates double crystallisation and two filtration steps, matches the efficiency of CPP, with 98-99 percent efficiency expected. The process has a low phosphate requirement.

The rehydration of hemihydrate cake to dihydrate can be a more difficult step for some phosphates containing particular impurities. The water consumption is higher than the HH process, as two molecules of water are required to form gypsum, but lower than the DH process as the acid produced is more concentrated. The electricity consumption is higher than DH due to the energy requirements of agitators in the rehydration section.

Although the P_2O_5 content in the gypsum is very low, overall water content is too high to meet plaster and cement specifications, meaning drying is necessary to make that gypsum industrially-usable.

Discussion

Over three quarters of global phos acid production (excluding China) is currently produced by the DH route (Figure 8). 'Classical' single crystallisation routes are also still employed much more frequently in production than double crystallisation routes (Table 2). This is somewhat surprising given that, in terms of P_2O_5 efficiency, double crystallisation routes (HDH and CPP) are significantly more efficient (Table 3).

Raw material costs are critical to the economics of phos acid production, accounting for around 86-88% of the merchant grade acid (MGA) price (Table 4). Integrated production is highly advantageous given that phosphate rocks costs alone can account for 67-69% of the MGA price.

Selecting the right phosphoric acid process route is clearly a complex task that requires the consideration of a wide range of parameters and criteria. However, skilled and experienced process engineers can help phos acid plant operators chose the correct production route for their project by evaluating the criteria described above on a case-by-case basis. ■

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2. Smith, P., 1988. Phosphoric Acid – Wet Process: What Process? International Fertiliser Society, *Proceedings 269*.

Table 3: **Comparison of phosphoric acid process efficiency**

Process	P_2O_5 eficiency (%)
HH	92-95%
DH	94-96%
HRC	96-97%
DA-HF	96-97%
HDH	> 98%
DHH-CPP	> 98%

Source: Prayon

Table 4: **Phosphoric acid production costs, example breakdown ($/t P_2O_5)**

Process	DH: 95%	HH: 93%
Phosphate rock	320.7	327.6
Sulphuric Acid	87.0	88.9
Total cost	407.7	416.5
MGA price N Africa	475	475

Source: Prayon

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Russia invests in Syrian phosphate project

Russian company OAO Stroytransgaz plans to start mining phosphate from deposits near Palmyra, following the city's recapture by the Syrian army. In an exclusive report, our Russian correspondent **Eugene Gerden** reveals Russia's plans for phosphate production in Syria.

Russian billionaire businessman Gennady Timchenko wants to mine phosphate in Syria on a large-scale for the export market. His ambitious plan to mine Syrian phosphate rock on a massive scale – and manufacture fertilizers from these – has been confirmed by the Russian government's press service and Timchenko's personal spokesman. The businessman is said to be close to the Russian President, Vladimir Putin.

An agreement between Timchenko and the Syrian government to mine phosphate from deposits at Sharqiyah and Khunayfis, close to the historic city of Palmyra, dates back to 2016. But its implementation has only become possible since the expulsion of Islamic State forces from the region. Developing two phosphate rock mines in this eastern part of Syria will have two objectives: supplying the export market and meeting the production needs of a local fertilizer manufacturing plant.

Syria's news agency reported that the country's General Fertilizer Company (GFC) had resumed urea and calcium ammonium nitrate (CAN) production at its Homs fertilizer plant in July, during a visit by the Syrian Prime Minister Imad Khamis.

Experienced Syrian contractor

The $350 million project to develop mines at both Sharqiyah and Khunayfis is reportedly well advanced. The mines will be built by OAO Stroytransgaz, a Russian construction company owned by Timchenko, with construction scheduled to officially begin before the end of 2017. Timchenko will provide the majority of the investment required, supplemented by loan finance from Russian state-owned banks.

Stroytransgaz, also known as STG Group, has been operating in Syria since 2000. The company completed the construction of a gas processing plant for the Syrian Gas Company in 2009 and was also the contractor for the country's 319 kilometre-long Arab Gas Pipeline. These assets could be used to supply the fertilizer projects being planned.

The Syrian government has already signed a contract with Stroytransgaz to develop both the Sharqiyah and Khunayfis phosphate deposits, according to a spokesman for Syria's Geology and Mineral Resources Directorate. He also confirmed that the company has received all the permissions it needs to proceed with and implement the project. According to reports, Stroytransgaz already has the equipment in place to develop the mines, much of this having been shipped into Syria on Russian warships.

Targeting phosphate exports

An ambitious annual phosphate rock production target of 3.5 million tonnes has been set initially for both mine projects, with the possibility of further expansion subsequently. Most of this volume will be exported, according to Timchenko's spokesman, although rock production will be partly dedicated to local fertilizer manufacture at a plant near Homs.

"[Mine] products will be partly processed into phosphate fertilizers at a plant in the Syrian city of Homs," Timchenko's spokesman confirmed. "Stroytransgaz is ready to invest an additional $100 million in the extension of a railway line from the east of Homs to the [phosphate mine] fields to ensure regular raw material deliveries to meet the plant's needs."

Fertilizer production at the Homs plant was suspended in May 2015, after it fell into the hands of Islamic State. The group's subsequent expulsion from the city and the surrounding region in May means the re-opening of the plant is now a possibility. The scale of future production following the resumption of operations has not been disclosed. However, the reopened fertilizer plant will be one of the largest in the entire Middle East, according to sources close to Timchenko, and will specialise in the manufacture of finished phosphates.

Once the mines are open, Timchenko plans to regularly export deliveries of Syrian phosphate rock to Russia and the EU. These will target the large-scale requirements of fertilizer manufacturers in both regions. Phosphate rock will be exported through the Syrian port of Tartus, using a safe transport route secured by Russian troops.

Syria was one of the world's top five phosphate rock exporting countries, before the recent civil war caused the suspension of phosphate mining in the country.

Russia favoured over Iran

The Syrian government has changed its development plans for the Ash Sharqiyah mine in recent months. The contract for the mine was originally expected to go to its strategic ally Iran. Indeed, the Syrian government signed a memorandum of cooperation with Iran to develop the Ash Sharqiyah mine in January. However, a final agreement between the two countries failed to materialise.

Stroytransgaz plans to increase annual phosphate rock production in Syria to 10 million tonnes over the medium-term, some 5-6 million tonnes of which will be earmarked for export. Production on this scale will require the development of other Syrian phosphate mine sites, particularly Aeolulun located near Latakia, Syria's principal port.

Meanwhile, the implementation of the existing Stroytransgaz phosphate mining project in Syria may require more funding than has been allocated, according to Sergey Shirokov, a mining expert at Moscow Mining State University. Shirokov linked the extra expenditure to the unusual geochemical properties of Syrian phosphate ore. The country's phosphate rock may require washing to remove excess chlorine, in his view.

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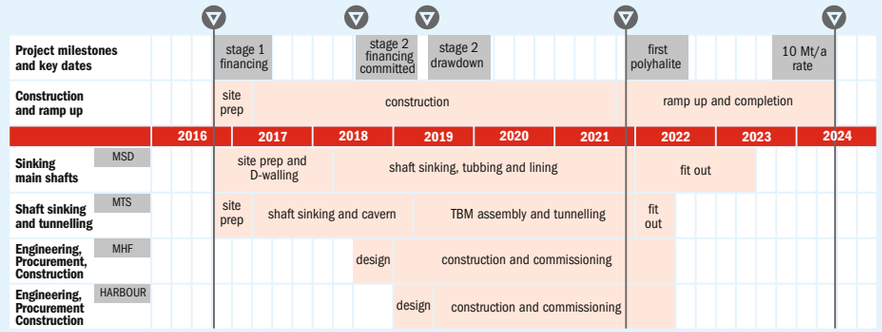
Sinking the Woodsmith Mine

PHOTO: SIRIUS MINERALS

KEY
1. Site offices
2. Service shaft
3. Production shaft
4. Concrete batch plant
5. MTS shaft platform

Fig. 1: Aerial photograph of the Woodsmith Mine site, August 2017

Fig. 2: **Woodsmith Mine project schedule**



Source: Sirius Minerals

In an exclusive series of interviews with the senior management team at Sirius Minerals, we report on progress at the Woodsmith polyhalite mine in North Yorkshire, England, as the project prepares for shaft sinking.

No one could accuse Sirius Minerals of lacking ambition. The company is aiming to create a new ten million tonne capacity polyhalite mine in the UK over the next five years at a cost of $2.9 billion – and create more than one thousand jobs in the process.

Even the normally sober *Financial Times* has been struck by the massive scale and economic significance of the enterprise. "[This] vast new fertiliser mine… represents one of Britain's most ambitious industrial investments in decades," the newspaper said in March, adding: "The deep shaft mine would be sunk to a depth of 1,500 metres, the equivalent of five Shard skyscrapers stacked one on top of the other, making it the deepest mine in Britain – and the second-deepest in Europe."

A landmark twelve months

Sirius Minerals has come a long way since it secured planning permission in 2015 (*Fertilizer International* 468, p18), followed up by the unveiling of a definitive feasibility study in early 2016. The last twelve months, in particular, have been a make-or-break period for Sirius Minerals and the future of its North Yorkshire Polyhalite project.

In February, in a sign of growing confidence, the mine site was renamed the Woodsmith Mine after Peter Woods and Frederick Smith, the original geologists who worked on the project. Yet, as recently as last autumn, the future of the mine remained far from certain. There was the not-so-small matter of raising the $1.2 billion of finance needed to start construction for one thing.

The project's breakthrough moment came in October last year when Sirius secured a commitment for $300 million from Gina Rinehart, Australia's richest woman, through her company Hancock Prospecting. Rinehart's cornerstone investment undoubtedly helped Sirius secure the rest of the initial finance it was seeking.

Rinehart unequivocally endorsed the Woodsmith Mine and the *POLY4* polyhalite product it will yield: "This project delivers a new and natural product that is relevant to Hancock's focus on agriculture, and after years of field tests and across many crop types, demonstrated improved yields."

In November, following Rinehart's participation and strong backing, successfully raised a further £370 million in equity and $400 million from a convertible bond. These amounts, together with Hancock Prospecting's pledge, provided Sirius with all the finance needed for shaft sinking.

Challenges remain, however, and Sirius Minerals still needs to borrow up to $3 billion of 'Stage 2' finance if it is to complete the mine and enter production in late 2021.

Construction well underway

The Woodsmith Mine is being built on high, windswept land overlooking the English coastal town of Whitby and the North Sea beyond. With $1.2 billion of initial 'Stage 1' finance in place, Sirius had gained the impetus and all the investment it needed to enter construction this year.

Sirius Minerals certainly has been hard at work at the mine site in recent months preparing for the start of shaft sinking, the results of this being clearly visible (Figure 1). Site clearance, screening and fencing, drainage management, putting up site offices and constructing platforms for shaft sinking have been the immediate priorities.

Following the completion of enabling and preparatory work, the site now boasts a new access road, site offices and a concrete batch plant. The production shaft and service shaft areas have also been prepared (Figure 1).

Sirius formally awarded shaft sinking work to contractor AMC in July. It has also entered into an agreement with the Hochtief Murphy Joint Venture (HMJV) for early work on the mineral transport system (MTS), in advance of a formal design and build contract.

The Woodsmith Mine site was a hive of activity during our visit in mid-September, with over 100 people engaged in construction work. Impressively, more than one million man hours have already been logged since construction began 12 months ago.

As of the end of September, construction of the pad for the MTS shaft was in progress and the site's concrete batch plant had been commissioned (Figure 1). A further borehole at the production shaft has been successfully sunk to a depth of 950 metres and tests on the core samples collected have been completed. The bentonite plant, rig workshop and welfare facilities are also now constructed.

Shaft sinking kicked off this year with an initial diaphragm-walling (D-Walling) phase. D-Walling is highly symbolic, as it marks the start of sub-surface mine construction. It is also a necessary first step prior to the start of the main shaft sinking phase in 2018.

D-Walling equipment has been assembled on site in parallel with the construction of guide walls for the service shaft. Both the service shaft and production shaft require wide foreshafts, of 35 metres and 32m diameter, respectively, down to a depth of 60 metres. Once the foreshafts have been constructed, D-Walling rigs will then complete the main service and production shafts to a depth of 120 metres below the surface. This will allow formal shaft excavation to begin.

One team, one job, one building

Graham Clarke, the operations director at Sirius Minerals, briefed us on construction progress:

"At its peak, there'll be around 1,500 workers across our sites working in shifts on the shaft sinking, tunnelling and other works. There's 230 workers active on site at the moment. With drilling, concreting, site preparation work, there's a range of different contractors present.

"The contractors are starting to integrate very well. That's necessary if we're going to do this in the time we've said while keeping people safe."

Clarke emphasised the need for integrated team working, an ethos that comes all the way down from CEO Chris Fraser. Staff numbers are rising fast. The company's new Scarborough headquarters, Resolution House, currently home to a team of 100, is expected to accommodate 160 people by the year's end.

"Integrated project working is vitally important for safety," stresses Clarke. "There's 30-35 AMC staff at Resolution House and a dozen others from HMJV. Our new office has given us the ability to have contractors and ourselves under one roof. First and foremost, from a health & safety point of view, it's one team, doing one job in the same building."

The project has a tight five year construction schedule (Figure 2). Clarke explains the significance of the start of D-walling work:

"The D-walling contractor Bauer have now mobilised from Germany and are

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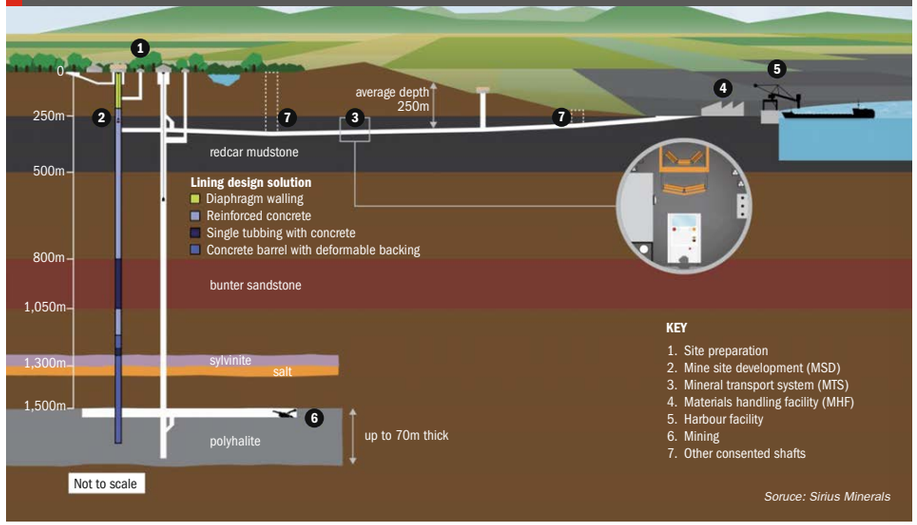
Fig. 3: **Woodsmith Mine schematic**



focused on the job in hand. In D-Walling – diaphragm walling – they cut a hole and start filling it with bentonite, a clay which keeps the hole open and stops the wall falling in until the reinforced concrete is put in."

"For the service shaft, a guide wall has been excavated so we can maintain the exact circumference. The diameter is around 30-35 metres for the top 60 metres. This foreshaft, as we call it, is much larger, allowing us to sit the winders in there, ready for shaft sinking. For that, we're going with tried and tested drilling and blasting."

Something to shout about

There is a real and justifiable sense of achievement and increasing optimism at Sirius Minerals, following the securing of Stage 1 finance last year and the start of construction. The project's solid fundamentals have helped when it comes to raising finance, as Thomas Staley, the company's chief financial officer, explains:

"We have a very large, very high grade, high value fertilizer resource that is located very close to a deep sea port. That makes this resource a world-class asset.

"The ability to produce from such a high-value asset in a simple way – making our product with minimal processing – on such a large scale with access to the seaborne market. That is absolutely invaluable and the fundamental cornerstone of our asset and the company."

While other potash projects have failed to progress in recent years, Sirius appears to have discovered a winning formula.

"When you compare our success to others, the long mine life, the quality of the product, the very low cost of production and the ease of access to the global market – those factors should absolutely not be underestimated," comments Staley.

The project's UK location has also helped in his view.

"Being located in the UK helps tremendously as you can capture the attention of British investors. That's really important as investment comes down to risk appetite and risk perception. People are much more comfortable with investments in their own backyard."

A diligent team effort

Financing is only part of the picture though, says Staley.

"It's simplistic to sit here and think the financing team did a great job. But it's just the icing on the cake. The financing is actually the culmination of all the hard work, diligence and effort put in by the whole team, all of the company's employees, over a five-year period.

"If you want to get people serious about investing one billion dollars you have to address all the key aspects of project development. That's about approving the resource, securing the licence to develop your project, and demonstrating that people actually want to buy the product. You also have to give investors comfort that you can build the project – and know how much that will cost and how long it will take."

Tearing up the textbook

The project's Stage 1 finance includes £370 million in equity, a $400 million convertible bond and a strategic investment of $300 million by Hancock Prospecting. But completing the project will also require further borrowing of up to $3 billion. Thomas Staley elaborates further:

"Projects are generally financed using a mix of equity and some debt. The textbook for project financing is to raise all the money you need at the beginning. That was never going to work for our project because of its size in dollar terms – and also because it takes five years to build.

"Instead, we decided to stagger our financing, putting Stage 1 financing in initially, then deferring Stage 2 financing until more offtake agreements are in place and procurement is complete."

This second tranche of financing (Stage 2) is due to be secured in late 2018. It will be 100 percent debt finance provided through a mixture of banks (including JP Morgan, Lloyds Bank, EDC, Societe Generale, ING, RBS) and a Treasury (UK government) guarantee. Sirius Minerals hopes to have the remaining finance in place by late 2018, enabling access to and drawdown of funds in 2019. Thomas Staley explains the thinking:

"Our project will be approximately 60 percent debt to 40 percent equity. That's a very conservative and appropriate debt level for a project with a cost structure that is fundamentally extremely strong.

"The project is capable of generating at least one billion dollars EBITDA [earnings] annually. For the sake of simplicity, let's say we have three billion dollars of debt. Then we can pay back that debt in four or five years from an asset with a life of 100 years plus."

Notionally, the Stage 1 finance is dedicated to the shaft sinking, while Stage 2 finance is earmarked for the tunnelling of the mineral transport system (MTS), the materials handling facility (MHF) and the port (Figure 3).

"That initial finance will fund us through the first two and half years of construction," comments Staley. "The key point is we won't actually commit to the tunnel, the handling facility and the port until we're certain that we have the commitment from the lenders to pay for these."

Sirius Minerals is always exploring ways to help de-risk the construction process.

"The first thing people on the street will tell you is the costs and schedule of major projects always overrun. The reality of projects is that things do not go to plan. If you are not constantly seeking out opportunities to improve every aspect of the project then your risk is only to the downside," says Staley.

He adds: "We have a very different mentality. We love to do things faster and better. But the focus on continuous improvement is actually more about delivering the achievements [on schedule] as we have set out."

Marketing goes global

Chief marketing officer J.T. Starzecki is another longstanding senior manager at Sirius Minerals. Over time, J.T. and his sales and marketing team have successfully built a multimillion tonne market for the company's *POLY4* polyhalite product.

Sales achievements have been impressive. To date, Sirius has secured a total of 8.9 million tonnes p.a. of customer buying commitments, including 4.4 million p.a. of firm take-or-pay offtake agreements. These totals include the 750,000 p.a. offtake deal recently agreed with Wilmar Group, the Southeast Asian agribusiness multinational.

Global expansion is a sales and marketing priority currently, as Starzecki explains:

"We're adding sales and marketing people across the globe, including regional heads in Latin America, Europe, Africa and Southeast Asia. We're also expanding the agronomy trial programme to underpin those commercial efforts. So in 2018 you'll see expansion of our Southeast Asian programme, plus we'll be expanding into more countries in Africa, expanding

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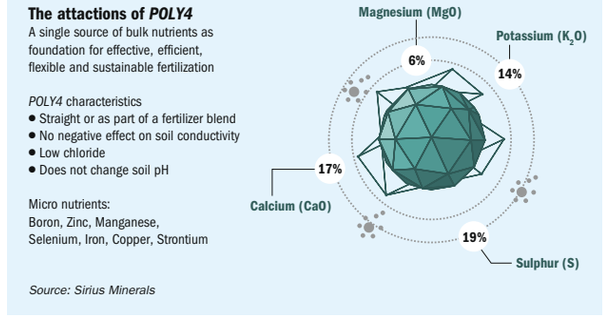
Fig 4: **Nutrient composition of *POLY4* polyhalite product**



Source: Sirius Minerals

from Brazil into all of Latin America, and expanding into Central America to increase our presence there."

Further offtakes

Offtake agreements, such as the recently announced one with Wilmar Group, help underpin the final tranche of debt financing that Sirius hopes to complete next year, says Starzecki.

"We are negotiating some significant offtake agreements in new regions. We're trying to find a happy medium and have enough tonnes under contract to assist Stage 2 finance, but we won't commit more than we need to.

"Although right now we have an entry point price strategy, we believe very firmly that the product will ultimately sell at a premium. But it will take time to build that market. [Increasingly] we will shift our marketing efforts down into the regions and, with our customers, deploy a strategy to educate farmers."

POLY4, a bulk speciality

Starzecki speaks eloquently and enthusiastically about *POLY4* and its agronomic attributes (Figure 4), whether used straight or as part of a blend.

"In the low-chloride, high-value market, we can compete as a straight fertilizer in those regions that recognise its value. In bulk blending, *POLY4* brings four macronutrients [K + S + Mg + Ca] into a six macronutrient NPK blend.

"In all cases, we're performing better [agronomically] than MOP in NPK blends – and in most cases the same as, or better than, SOP. Bringing *POLY4* into an NPK blend gives a broader spectrum of nutrients. We're eliminating chloride from the system and supplying a better suite of nutrients, and in the right quantities for complete take-up by crops."

As a high-volume yet speciality product, Starzecki thinks *POLY4* will be a game-changing fertilizer when it enters the market.

"With *POLY4* you've got a bulk speciality. It emulates the properties of all speciality fertilizers but we can produce it at scale. It's going to open up a lot of markets because our cost of production is in the bottom quartile of the cost curve. Now, all of a sudden, farmers – who couldn't before – can afford low-chloride forms of potassium."

> **"*POLY4* emulates the properties of all speciality fertilizers but we can produce it at scale. It's going to open up a lot of markets**

Summing up, Starzecki is keen to emphasise the four cornerstone properties of *POLY4*, as well as it soil reconstruction abilities.

"We do now talk in terms of the four cornerstones, *POLY4* being an efficient, effective, flexible and sustainable fertilizer. We've also spent a lot of time focussing on its soil reconstruction properties.

"What we've been able to show is that polyhalite leave soils in much better condition at the end of a 3-4 year cropping cycle because of the nutrients it delivers. That ultimately means that farmers are getting greater rewards from the nutrients they're paying to put into the field."

What matters to farmers

When it comes to inputs such as fertilizers, what farmers really care about is their return on investment, says Robert Meakin, the R&D director at Sirius Minerals.

"One of the things we've looked at recently is return on investment. What you find with *POLY4* is that it's a very effective product financially, in terms of margin over capital expense. That's what matters to farmers. It's all about what margin they can create, and whether they can reinvest that to generate higher margins in subsequent years."

To date, some 235 agronomic trials have been carried out in 17 countries on 29 different crops as part of the company's R&D programme. As well as being broad ranging, Sirius Minerals has a meticulous and thorough reputation when it comes to agronomic research.

"We reference standard agricultural practice in every trial we do," explains Meakin. "We'll see what influence changing fertilizer policy has on economics, crop performance, residues, crop quality, crop yield etc."

Broad benefits

Polyhalite's broad spectrum composition provides multiple dividends, especially in terms of nutrient use efficiency and crop yield, says Meakin.

"Depending on where you are in the world, up to 50% of the yield gap could be exclusively due to poor fertilization. [Providing] a broader nutrients spectrum improves nutrient use efficiency, which in turn fuels improvements in crop yield."

This behaviour, according to Meakin, also explains the typical yield response seen time and again in so many of *POLY4*'s crop trial results.

"You see this standard curve with *POLY4*. It reaches the same yield earlier and the maximum yield is elevated. It is not potassium that is limiting crop yield. Instead, this is a classical example of how applying a broader spectrum of nutrients drives and elevates your yield – as with *POLY4* you've taken away the limits to growth."

There's a growing realisation that micronutrients are also becoming yield limiting, says Meakin, a situation which also plays to *POLY4*'s compositional strengths.

"The penny's dropping that secondary and micronutrients are becoming yield limiting. Around the world we've now got down to magnesium, sulphur, boron, zinc, molybdenum, manganese. Those are the key micronutrients. Fertilizer manufacturers are now trying to include these specifically to give their products an edge.

"One of the beauties of *POLY4* is that we don't beneficiate, we don't purify, so you get more than it says on the label. You get these extra micronutrients – boron, zinc, manganese, molybdenum, iron and copper. They're variable but commonly present in hundreds of parts per million. That will maintain soil status although [admittedly] it won't cure chronic deficiency."

Meakin confirms that *POLY4* will mainly be applied to crops as part of NPK blends.

"We foresee that 80 percent of the product is going to go to blenders. So making NPKs is much more important [than straight application]. You can transform a basic NPK to an NPK plus Mg plus Ca plus S by incorporating *POLY4*, and you can drop the chloride content.

"That has great value to growers. On-farm storage and access to this new kind of blend provides flexibility in terms of timing and the crops it can be applied on. It's also of great value to distributors because it gives them more flexibility by widening their customer base."

Mirroring the sales and marketing strategy, Meakin confirms that the company's agronomic research is set to expand into new regions globally.

"Our focus is very much on where the market is, who the offtake partners are, and their crop base. Expansion into South-east Asia is imminent, now that we have a head of agronomy in the region. We're very active and expanding our trial base there – in Myanmar, Malaysia, Indonesia, Thailand and Vietnam.

"Expansion into Africa is also under discussion. We've always been here in the European market too. We've done lots on cereals, potatoes and canola [in this region]. We've also done quite a lot of work on wheat and will progress into barley in Europe."

Confident, not complacent

Operations director Graham Clarke, one of the company's original stalwarts and a key team member, sums up the current upbeat mood at Sirius Minerals.

"We've done three things people said we couldn't do. We've got the planning approval, we've sold the product and we've raised the money to build it. A lot of people told us we weren't going to do any of those things.

"I've believed in polyhalite for a long time. I was the first to start mining it at Cleveland Potash. Fundamentally it's a great product. The project is also a fantastic one with a team of people who believe in it completely – and I think you need both to carry it off successfully."

Clarke is particularly complimentary about the calibre of his colleagues and the company's leadership.

"It's Chris Fraser's commitment and unerring belief that has got us where we are. We're all backing ourselves – backing ourselves as a team – and we're backing Chris. It's also important that we've managed to have a lot of fun and enjoy the project – you really can't ask for much more than that." ■

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