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Fertilizer Focus

Soil integrity for the future

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Fertilizer Focus
Argus Media group
Lacon House, 84 Theobalds Road,
London, WC1X 8NL

Email: fertilizer@argusmedia.com
www.argusmedia.com/fertilizer

The European liquid sulphur market

Written by

Maria Mosquera, *Editor, Sulphur Products,* and **Jasmine Antunes,** *Senior Reporter,* ***Argus Media, UK***

The European liquid sulphur market has seen structural change in recent years, with a chronic shortfall in supply making the region reliant on imports.

Over the past two years sulphur output from European refineries has dropped as a result of poor refining margins, and competition from imports from modern mega-refineries out of region. Additionally, sanctions on Russian crude oil imports to European refineries have turned the crude slate in the region sweeter. Tightening environmental regulations have also turned refiners to convert to bio-refineries or to produce greener fuels that require lower sulphur content feedstocks, with a knock-on impact on reduced sulphur output.

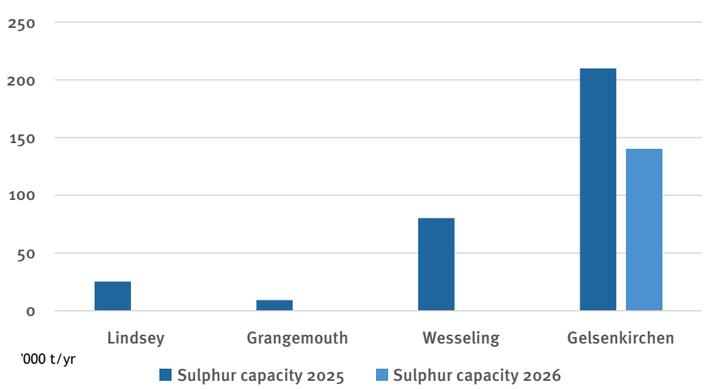
Over the past two years sulphur output from European refineries has dropped

Refinery closures still coming

Refinery closures and sweeter feedstocks continue to crimp European sulphur production.

Crude oil imports to the UK and Germany fell by 15,000 b/d and 35,000 b/d, respectively, due to permanent closures of refineries — Petroineos' 150,000 b/d Grangemouth in Scotland, Shell's 147,000 b/d Wesseling in Germany, and a capacity cut at BP's 257,000 b/d Gelsenkirchen.

Figure 1. Europe's lost refining capacity 2025-2026



An unplanned closure of the 25,000t/yr sulphur capacity Lindsey in the UK due to insolvency will further reduce sulphur output.

These come in addition to the refinery capacity lost in France in 2021 of around 42,000t/yr with the closure of the TotalEnergies Grandpuits refinery, and in Rotterdam BP's refinery lost 26,000t/yr sulphur capacity in 2022 through a part closure.

Cheaper light and medium sweet crudes made up more than half of Rotterdam's imports in July, while the share of medium sour crudes dropped from roughly a third in July last year to less than 18% in July. Similarly, the share of light sweet and sour crude imports in France rose from 57% in July last year to 73% in July this year, while imports of medium sours dropped by nine percentage points.

Regular imports...at a cost

The European market has increasingly turned to imported liquid sulphur quantities, but these come at a substantial cost as a result of the significant costs of logistics in transporting a liquid product that requires heating across long distances. The need for dedicated

The European market has increasingly turned to imported liquid sulphur

transport modes mean backhaul opportunities to reduce costs are not an option.

The spot price for liquid sulphur imported to Europe in early August 2025 was at USD330-476/t delivered. Imports come in as trucked liquid sulphur from origins including east Europe, Mediterranean and the UK, as well as via tanker vessel deliveries from the US Gulf, the UK and the Mediterranean. A shipment was also brought in from as far as from the UAE. Delivered pricing are much higher compared with local cfr prices, with the cost of logistics for imports adding substantially to the final price, making product imports unworkable for many European chemical companies facing subdued downstream markets.

Local pricing structures changing

Local prices from the region's refineries have historically been negotiated on a quarterly basis, with liquid sulphur not easily transported over long distances, and contract supply ensuring smooth management of tank space for both producers and consumers.

Planned remelting projects are expected to tie the region's pricing more directly to global solid market prices. Quarterly contract prices negotiated between suppliers and buyers in the region have broadly tracked the weekly global spot markets. With at least two new European sulphur remelting projects at planning stages, within three years the region would be tied more closely to global solid sulphur market prices,

Figure 2. Benelux contract against global prices 5 years

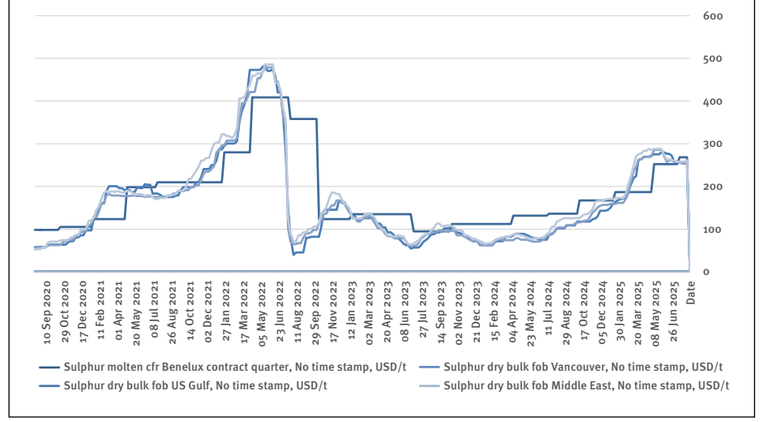
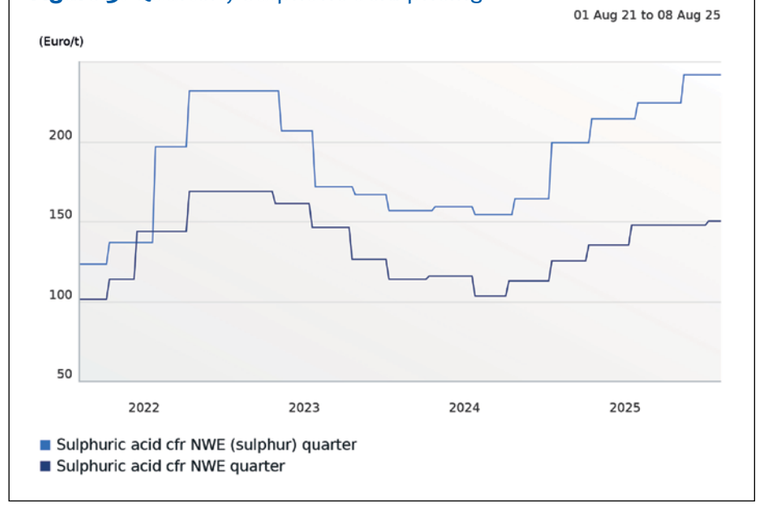


Figure 3. Quarterly sulphuric acid pricing



as more solid sulphur melting capacity will open the way for more imports. The region's suppliers are expected to align regional prices to the new developments, though will likely continue to be prices below imported tonnes to keep tanks from filling up.

Sulphuric acid production has dropped

Sulphuric acid production from the region's sulphur burners has dropped as a result of lower availability of liquid sulphur. This has driven some usual consumers of burnt acid to switch to smelter acid instead.

The quarterly contract price for sulphur-burnt acid settled at a rollover at EUR218-265/t for the third quarter, on the back of higher availability of sulphuric acid in the domestic market.

Similarly, the contract range for smelter-based acid settled at EUR141-181/t cfr, at a rollover to a slight increase of EUR5/t on the previous quarter. The gap between the two forms of sulphuric acid has grown as sulphur prices have risen. ■

Building momentum

The Chemicals Omnibus and Europe's fertilizing products sector

Written by

Jessica Fitch, *Senior Consultant,* ***Prospero & Partners, Belgium***

The European Commission's Chemicals Omnibus proposal, published in July 2025 under its simplification and competitiveness agenda, represents a substantial opportunity for Europe's fertilizing products industry. It is not a sweeping reform, but it directly addresses friction points that have slowed innovation and increased compliance costs. If adopted, the Omnibus will:

- Open a predictable EU market pathway for microbial biostimulants
- Restore proportionate REACH requirements for all EU fertilizing products
- Ease Classification, Labelling and Packaging (CLP) obligations that generate unnecessary waste and costs

Together, these measures could unlock stalled investment, reduce administrative burden, and strengthen Europe's circular bioeconomy – to the benefit of competitiveness, farmers, and the environment.

Next steps: Why vigilance matters

The Chemicals Omnibus marks a turning point – but nothing is final yet. The proposal now moves through the ordinary legislative procedure, with committee assignment in the European Parliament expected after the summer break. In the Council, Denmark holds the rotating Presidency, and discussions should begin in the coming months. What happens next will depend on how the co-legislators respond – and whether the fertilizing products sector remains engaged, aligned, and ready to contribute. The gains on the table today could still be lost without sustained attention and constructive input from industry.

Fitting the pieces together: The Chemicals Omnibus could help fix regulatory misalignments in EU fertilizing rules

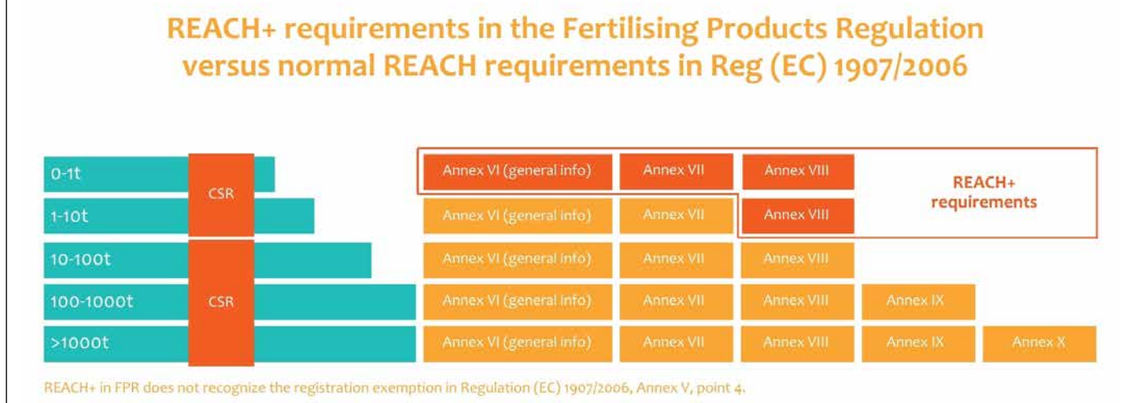
A market pathway for microbial plant biostimulants

For years, Europe's microbial biostimulant innovators have faced a regulatory bottleneck. The EU Fertilising Products Regulation (FPR) currently recognises only four microbial groups, and while a one-off procedure is underway to add new ones, it has proved inefficient, slow, with uncertain outcomes, and not something that could or should be repeated.

According to a survey of European Biostimulant Industry Council (EBIC) members, this has stranded over EUR100 mn in private investment and denied farmers access to microbial solutions that enhance nutrient uptake, improve soil function, and build crop resilience under climate stress.

The Chemicals Omnibus creates a criteria-based mechanism under CMC

Figure 1. REACH+ burden: Additional REACH registration steps are required under FPR – even when the substance is already compliant and poses no new risk



7 that finally makes market access predictable and science-driven:

- The European Commission will set the safety and efficacy criteria and define the methodology
- Products containing a new microbial strain will undergo conformity assessment by an accredited notified body
- Robust safety checks are maintained at every step, while unlocking a continuous route to the EU single market

For manufacturers, this means previously blocked innovation can reach the market, and investments in bio-based technologies can deliver returns. For farmers, it means new, high-performing tools for more resilient and sustainable production.

Restoring proportionate REACH requirements

Under the FPR today, substances manufactured in quantities under 10 t per year and used in CE-marked fertilizing products face extended REACH obligations, requiring extra data generation and registration even when the substance already meets the REACH requirements for its tonnage band, or it is approved for use in food or feed.

These additional requirements drive up costs to a point that is not economically viable, especially for technical additives that may be present in the final product in quantities as low as <0.5% concentration w/w, with no additional safety benefit.

Because these additional requirements affect substances that are produced at low tonnages, they weigh most heavily on innovative and bio-based products – including plant biostimulants (PBs) and organic based fertilizers (OBFs) – which often rely on a diverse mix of specialised inputs and in which some active components may be applied at very low rates per hectare. However, even inorganic fertilizers produced in large quantities are not immune. For example, a food-grade stabiliser or dye may face full REACH registration costs solely because the product is CE marked, not due to any new safety concern.

EBIC analysis shows that for one such additive used at <0.5% concentration, unit costs could rise 40–500%, potentially requiring a retail price increase of 25% to maintain viability.

The Chemicals Omnibus removes these disproportionate registration extensions, restoring proportionate and standard REACH requirements:

- Workers, farmers, and consumers remain fully protected under the world's most robust chemicals framework
- Redundant administrative burdens are eliminated
- Manufacturers gain a simpler, fairer, and more predictable regulatory environment

For companies, this means lower costs, shorter timelines, and renewed confidence to invest in sustainable, differentiated solutions.

CLP: Small fixes that reduce waste

Recent CLP amendments created practical headaches for fertilizing product manufacturers:

- Rigid label formatting rules
- Six-month deadlines for label updates
- Extensive hazard info for advertising and distance sales

These would have led to label reprints, increased packaging waste, and unnecessary compliance costs – all without demonstrable safety benefits in the fertilizing products context. Manufacturers also face overlapping labelling obligations under CLP, packaging waste rules, and digital labelling for fertilizing products.

As European Consortium of the Organic-Based Fertilizer Industry (ECOFI) and others have noted, multilingual packaging is often the only viable solution to comply with labelling requirements across Member States – yet it complicates compliance, especially given new packaging waste limits and digital labelling rules. The lack of coordination between frameworks has created an increasingly complex labelling environment, where the accumulation of obligations increases costs and risks unintended waste. The Chemicals Omnibus introduces pragmatic fixes:

- Non-critical formatting rules are removed, keeping only legibility requirements
- Label updates will be required "without undue delay" rather than every six months
- Advertising and distance-selling obligations are simplified, especially for small packs

For manufacturers, this means lower packaging and printing costs, less waste, and clearer labelling requirements – with all safety-critical elements retained.

A new dawn: Smarter EU rules can unlock environmentally responsible technologies – without compromising safety

Beyond the Omnibus: Unlocking the next wave of circular innovation

While the Chemicals Omnibus is an important step, further changes are needed to fully realise the FPR's potential as a fit for purpose, innovation friendly regulation under the EU's New Legislative Framework.

ECOFI, with the support of EBIC and other partners, has called for a criteria based pathway to introduce new component materials into the FPR.

Today, many safe, circular, and bio-based materials – from treated oilseed cakes to innovative organic residues – remain excluded from CE marked fertilizers because the FPR relies on static Component Material Categories (CMCs). This slows the uptake of circular solutions, blocks investment in new products and limits the EU's ability to close nutrient loops and strengthen strategic autonomy.

A criteria based mechanism for new materials – similar in principle to the newly introduced microbial pathway – would provide predictability and speed for innovators, maintain robust safety through clear criteria and conformity assessment and support the EU's circular bioeconomy by bringing safe secondary materials to market.

This reform will need to be addressed in the upcoming FPR evaluation and future legislative updates. The Chemicals Omnibus lays the foundation, but completing the job is essential for Europe's fertilizer sector to remain competitive, circular, and resilient.

Why engagement is essential

The Chemicals Omnibus is now moving through Parliament and Council, and its benefits for every EU fertilizing products manufacturer will only materialise if the industry remains engaged and aligned.

- If you produce microbial biostimulants, this is your market breakthrough
- If you produce OBFs or circular fertilizers, this reduces costly regulatory friction
- If you produce inorganic fertilizers, you have more freedom to formulate optimized products
- If you want to shape what comes next – from non microbial criteria-based pathways to alignment with the Animal By-Products Regulation and a truly circular, innovation ready FPR – now is the time to be involved

Through European associations such as EBIC, ECOFI Fertilizers Europe, working alongside other key industry stakeholders, the sector is making regulation work for innovation and competitiveness. Joining and engaging through these associations ensures companies stay ahead of change, help unlock the next wave of improvements, and strengthen the future of European agriculture. ■

About Prospero
Prospero & Partners empowers clients in agrifood and the bioeconomy to unlock market access and transform innovation into business success. Since 1999, we have been delivering unrivalled sector expertise for our clients to cultivate change and harvest value.

www.prospero.ag

Why granulated fertilizer is better for agriculture

Written by

Alberto Militare, *Sales Manager, Granulation and dry Mortars,* ***LB Technology, Italy***

Granulation is a technological process in which the particles of a homogeneous powder are adhered to each other for the formation of granules. Granules are smooth and compact, making them easier to transport, dose, and manage overall. They prevent the dispersion of fine dust and the segregation of different components.

Why do we granulate? We granulate because:

- Fine dust is a nuisance
- Granules are easy to handle
- Granules guarantee a constancy of the composition of the mixture of components

In the agriculture sector, granulation is used for the production of granules and/or microgranules of fertilizers rich in nutrient components for the soil. We can divide the granulation process into two large families: Dry granulation and wet granulation.

Dry granulation

Dry granulation is a process in which no liquid component is used in the formation of granules. This is done for compounds that are extremely sensitive to moisture and heat and when it is not necessary to obtain a granule of 'spheroidal' shape. Therefore, it is possible to use a much cheaper process than wet granulation. Since no liquid is used, the process requires compaction and densification of the finely pulverized compound to convert it into granules. It is a highly sustainable process from an economic and environmental point of view.

For effective use, microgranules can applied together with the seed

In dry granulation, granules are produced by compacting the powder to form briquettes, which are then broken down and screened. Depending on the type of material, proper compaction may require a certain moisture content or the use of binders. Granules are formed under high pressure, which causes the powder particles to aggregate into a solid mass.

Wet granulation

In wet granulation, granules are formed by adding a granulation liquid (binder) to the powder. This process produces microgranules with sizes ranging from 0.5-1.2 mm, commonly used as microfertilizers in agriculture.

Granulation increases the initial particle size by adding water and/or binding additives, in either liquid or solid form, starting from MAP or DAP. This method can produce macrogranules ranging from 2.0-5.0 mm in size.

Plant nutrition

Fertilizers are essential to agriculture, providing a combination of key nutrients such as nitrogen, phosphorus, and potassium. Like other minerals, fertilizers undergo several processing steps before reaching their final usable form.

Granulation is a key stage in this value chain, increasing particle size, minimizing losses, and improving the precision of field applications.

Fertilizers serve plants in the same way food nourishes humans and animals. To grow, plants must absorb nutrients from the soil; however, over time, soils become depleted, making nutrient uptake increasingly difficult. Fertilizers restore soil fertility by supplying the right blend of primary nutrients (nitrogen, phosphorus, and potassium) and secondary nutrients (such as calcium, magnesium, and sulphur).

Sowing with seeders is suitable only for mineral fertilizers, ensuring even distribution and effective plant nutrition.

Dry granulation plant by LB Technology

(top) Dry granules; *(bottom)* Briquettes from dry compaction

Advantages of granulation

The microgranular shape, combined with the type of machine used for distribution, ensures that the 4R principle is met: The Right source, at the Right rate, at the Right time, in the Right place. The advantages of microgranules and the rules of 4Rs, as well as using the right technology (+1) are the following:

Added value of microgranules:
Microgranules, and their optimal use in the agri-food sector, address a key current need: precision agriculture, also known as precision nutrition.

This technology enables the targeted application of a fundamental resource – fertilizers – to efficiently produce food and agricultural commodities.

Through the technological process, farmers can apply the exact quantity of fertilizer at the most effective moment, such as during sowing. This precision offers intertwined advantages:

Optimizing nutrient availability for the crop and reducing waste and environmental impact.

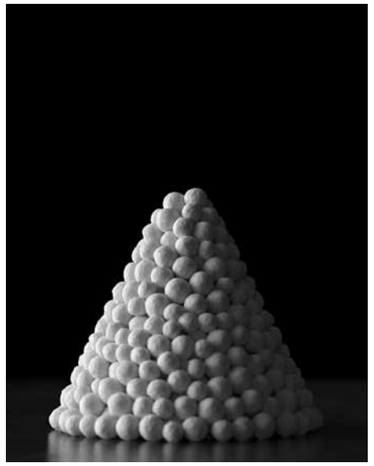
Historically, granulation was developed to deliver the right amount of nutrients at the right time, aligned with the crop's phenological stage – such as when a seed is about to germinate in the soil. The microgranule production process emerged specifically to meet this need.

Efficiency in the use of nutrients:
The current needs, combined with historical developments, are driving the adoption of microgranules. This approach enables accurate and efficient application of fertilizers in the field, following the 4R rule:

- Right source › balanced composition of nutrients
- Right rate › right quantity of fertilizer
- Right time › locate it at a particular time
- Right place › such as sowing
- (+1) Right technology (to produce and apply granules)

The right dosage, at the right time, using the right technology – this is what the most advanced *Made in Italy* solutions offer to operators in the fertilizer sector.

Granule size plays a crucial role, as it ensures the plant receives the optimal amount of nutrients without hindering its growth. Microgranules provide



Wet granules

fully available and easily accessible nutrients for young plants.

For effective use, microgranules should be applied together with the seed, passing through the seeder's distribution system to place them precisely in the soil.

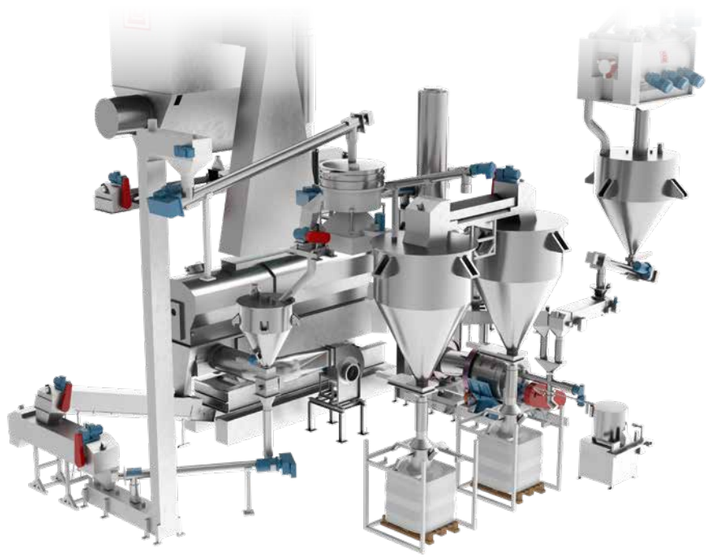
Within the agricultural supply chain, it is essential to provide the most suitable and sustainable technical solutions to nourish plants – and, indirectly, to sustain human life.

Right technology (+1)

Microgranulation technology supports the growing demand for higher agricultural productivity, as the use of microgranules is a key factor in helping farmers increase yields per hectare. Microgranules enable the precise application of the exact amount of nutrients plants need, exactly when they need them, minimizing waste. This approach prevents both nutrient losses and the risks associated with overfeeding or under nourishing plants.

It is essential to provide equipment and solutions for both dry and wet granulation processes – covering the production of microgranules as well as macrogranules.

Wet granulation process by LB Technology



In soil fertilization, microgranules offer significant advantages, both in terms of fertilizer effectiveness and environmental sustainability.

Microgranulation fertilizers technology in Turkey

The first two production lines of a fertilizer granulation plant are successfully operating in Turkey. Their combined annual output ranges from 15,000-16,000 t of microgranules, with particle sizes between 0.5-1.2 mm.

The system incorporates high-quality Made in Italy technology, enabling automatic quality control of the finished product and fully automated adjustments to dosages and formulas – without the need for operator intervention.

In addition to the production lines, the plant features a state-of-the-art analysis, research, and control laboratory equipped with high-value instruments. The laboratory is staffed by over 10 specialists.

Construction of a third line is scheduled to begin in October this year, with production expected to start by the end of 2025. This expansion will increase capacity by an additional 8,000 t per year.

Granulation technology for animal feed

In addition, a major American group has signed an agreement for the supply of a microgranulation line dedicated to animal feed additives. The line will feature the latest Made in Italy granulator and a fluid bed dryer, with a production capacity of approximately 2 t/hour of microgranules up to 2 mm in size.

Designed with a strong focus on environmental responsibility, the system will ensure minimal atmospheric emissions through advanced, eco-friendly filtration technologies.

The new plant is scheduled to begin operations in early 2026. ■

MARKET NEWS ›

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EUROPE

Anglo, Teck merger committed to UK polyhalite project

UK-South African mining firm Anglo American will merge with Canadian metals producer Teck Resources to become the Anglo Teck Group, creating a consolidated critical minerals company, which will be headquartered in Canada.

Anglo American will exchange existing Teck shares for 1.3301 Anglo American shares. It will also issue a USD4.5bn dividend to existing Anglo American shareholders ahead of the merger.

Anglo American said that Anglo Teck will remain committed to the development of Anglo's Woodsmith polyhalite fertilizer project in North Yorkshire but highlights that progression will depend on the project meeting a stringent investment criteria.

Polyhalite is a naturally occurring mineral, containing one macronutrient — potassium — and three secondary nutrients — sulphur, magnesium and calcium — along with trace amounts of micronutrients. Israeli fertilizer firm ICL has produced polyhalite from the same deposit that Anglo American plans to mine since 2011, selling it under the brand name Polysulphate.

Anglo American had initially targeted commercial output in 2027. But the company said in May 2024 that it would slow investment in the UK mine by injecting USD200mn in 2025 and nothing in 2026 to support its balance sheet by deleveraging.

Anglo American acquired the Woodsmith project from UK-based Sirius Minerals in early 2020. Under previous guidance from former owner Sirius, the mine was expected to begin producing polyhalite by the end of 2021.

Ukraine partly lifts fertilizer import ban, allows NPKs

Ukrainian authorities have partially lifted a ban on the shipment of ammonia-based fertilizers to the country's ports, allowing the resumption of NPK imports, but not ammonium nitrate (AN).

NPKs with a nitrogen content of 21% or lower, and at least 5% phosphorus and potassium, will now be permitted to arrive at Ukrainian ports, according to the country's largest farmers' union, the All-Ukrainian Agrarian Council.

AN remains banned, although there are reportedly plans to establish a safe passage for the product through ports on the Danube delta.

Ukraine's naval forces in July enforced a ban on shipments of ammonia and AN, citing safety concerns. Ammonia and AN pose the risk of explosions and many countries impose strict guidelines on their storage and transportation.

But the union urged Ukraine's authorities to unblock shipments of UAN, amsul, urea, NPKs, superphosphates and potash to the country's ports. Ukraine depends on imports of these fertilizer grades, without which crop yields could suffer and the country may face a "food crisis", the union said.

Ukraine to sell 2mn t/yr Odessa port fertilizer plant

The Ukrainian government has said that it will sell its dormant 2mn t/yr OPZ fertilizer plant at Odessa port.

The state-owned facility, known as Odessa Port Plant or OPZ, has a prilled urea production capacity of 860,000 t/yr, and ammonia capacity of 1.1mn t/yr. But fertilizer output ceased at the country's single largest gas consumer in 2022 after high gas prices made production financially unviable.

The government is now looking to sell the plant to the private sector, and will take bids in an open electronic auction beginning at 4.5bn hryvnia (USD109mn), according to a Telegram post by prime minister Yulia Svyrydenko.

The government in the past has tried repeatedly to privatise OPZ. Authorities made efforts in 2016 to sell the plant, but a deal was never reached. A year before this, Ukraine's prosecutor general launched a criminal investigation into allegations that hundreds of millions of dollars had been siphoned off by management through the plant. The Ukrainian government last said in 2021 that it intended to privatise OPZ, with the sale originally planned for 2022.

NORTH AMERICA

Nutrien to sell 50% stake in Argentina's Profertil

North American fertilizer major Nutrien has agreed to sell its 50% stake in Argentinian nitrogen producer Profertil to agribusiness Adecoagro and the country's ACA co-operative.

Profertil is Argentina's only urea producer currently operating, running a granular urea facility in Bahia Blanca with capacity of 1.32mn t/yr, located near the southern tip of Buenos Aires province. The site has integrated ammonia capacity of just under 800,000 t/yr. Nutrien's stake in Profertil is expected to be around USD600mn on a pre-tax basis, Nutrien said, with the deal set to close before the end of this year. Profertil's other shareholder, Argentinian state-owned energy firm YPF, has a 90-day right of first refusal to buy Nutrien's stake on the same terms and conditions, according to Nutrien.

Profertil operates a sizeable distribution network at major ports in Argentina, in addition to operating the Bahia Blanca nitrogen complex, with warehouses in Puerto General San Martin, San Nicolas, Necochea and Loma Paraguaya. The firm is accordingly a large importer of other finished fertilizers, such as DAP, MAP, MOP and others. Profertil has storage capacity for 150,000t of urea and 20,000t of ammonia at its Bahia Blanca site, according to its website.

SOUTH AMERICA

Brazil's Heringer chooses new CEO, CFO

Brazilian fertilizer producer Heringer shuffled its board of directors, including replacing its chief executive and chief financial officer.

The firm replaced chief executive and board vice-chairman Rodrigo Horta Dias — who had taken the post in July — with Sergio Castanheiro, who previously headed Russian fertilizer company Eurochem's distribution division and Norwegian fertilizer producer Yara's industrial operations in Brazil.

Former Rabobank Brasil executive director Gustavo Barreiro replaced Fausto Goveia as chief financial officer.

Castanheiro and Barreiro are expected to remain in office until 2027, when Heringer's next general management election takes place.

Andrey Serebrennikov and Nikolay Vasilchikov replaced Aleksandr Benke and Rafael Cesar as board members. The latter will be the board's chairman.

Commercial director Anton Slavnov and operations director Maicon Cossa also left their positions. Both will remain vacant.

Heringer has been a part of Eurochem since March 2022, when the Russian firm acquired a 51.48% stake at Heringer. In June 2023, Eurochem acquired an additional 28.5% of shares in a tender offer to buy up to all common shares, with 20% of shares still outstanding.

Heringer's second-quarter sales fell by 23% from a year earlier, it said in August. It also reported a BRL29mn (USD5.4mn) loss, down a loss of BRL343mn a year earlier.

Brazil's Unigel names new chief executive

Brazil's petrochemical group Unigel has tapped Helena Valente as its chief executive to substitute Dario Gaeta, effective immediately.

The new chief executive will also keep acting as the chief financial and investor relations officer until further notice, Unigel said.

Unigel filed for extrajudicial reorganization in February 2024 and completed the process in early 2025.

The company is focusing on its styrene supply chain and sulphuric acid project, it said when it announced the completion of the extrajudicial plan earlier this year. Unigel also issued a new credit line of USD100mn, of which 30% will be used to complete the sulphuric acid unit in northeastern Bahia state's Camacari industrial complex, which is in the final stage of construction.

Unigel will leave the fertilizer market. Brazil's state controlled Petrobras will take back control of two fertilizer plants from Unigel, which have been idle since March 2024. That marks the company's return to the fertilizer market.

The plants, that operate as Fabricas de Fertilizantes Nitrogenados (Fafens), are in Camacari and in Laranjeiras, in Sergipe state, respectively. They have a combined capacity of 900,000 metric tonnes (t)/yr of ammonia and 1.1mn t/yr of urea.

AFRICA

Nigeria's Dangote to build urea plant in Ethiopia

Nigeria's Dangote Group and the government of Ethiopia have signed an agreement to build a 3mn t/year urea plant in Gode, Ethiopia — a first for the country.

Dangote will have a 60% share in the factory while the government of Ethiopia will hold the balance through Ethiopian Investment Holdings.

No date has been set for the start of construction. The companies expect the cost to be around USD2.5bn, and construction to take 40 months.

Ethiopia currently consumes around 750,000t/year of urea, importing this through large tenders. There will likely be a significant surplus for export as a result.

Natural gas feedstock will be sourced from the nearby Calub and Hilala gas fields. In years past OCP was connected with the possible development of an NP/NPK plant sourcing gas from the same fields.

ASIA

Japan's Ube moves up Thai chemical output termination

Japanese petrochemical company Ube has decided to move up its plan to terminate part of its chemical productions in Thailand by one year to March 2026, the company announced.

Ube in January announced a plan to end its cyclohexanone, caprolactam, and ammonium sulphate production in Thailand and reduce its two manufacturing lines for nylon polymer in the country to one line by March 2027.

The Thailand site has a production capacity of 130,000 t/yr for caprolactam and 540,000 t/yr for ammonium sulphate, a company spokesperson told Argus. The closure of one line cuts the nylon polymer production capacity from 75,000 t/yr to 25,000 t/yr, he added.

The business environment has become weaker than expected, mainly in the Asian market, because of oversupply from Chinese companies, and recovery will be difficult, Ube said in January. The situation has persisted, Ube said, which has prompted the company to seek an earlier optimisation timeline.

The timeline of its plan to stop producing ammonia in Japan by March 2028 remains unchanged from January, as well as ending the production of caprolactam, cyclohexanone and nylon polymer in Japan by March 2027. The Japan site has a production capacity of 380,000 t/yr for ammonia and 50,000 t/yr for caprolactam, the company spokesperson said.

Ube also has a production site for caprolactam in Spain. The Spain site will continue manufacturing caprolactam and nylon polymer, as the European market environment is stable compared with the Asian market. But the company will stop producing cyclohexanone in Spain as well, it also announced in January.

Asian Chemical Group buys Uzbek potash producer

Asian Chemical Group (ACG), an Uzbekistan-based joint venture, has acquired all the shares of Uzbek state-owned Dekhanabad Potash Plant, leaving the MOP producer under private ownership.

The transaction was published on Uzbekistan's Unified Corporate Information Portal, but the details were not disclosed.

ACG was registered in November 2024 as a joint venture between OV Industrial Investments and New Industrial Technologies, companies with links to Russia and China.

Dekhanabad has an MOP capacity of 400,000 t/yr, with plans to increase this to 600,000 t/yr.

Japan's Itochu signs deal for Egypt ammonia bunkering

Japanese trading house Itochu has signed an agreement to develop ammonia bunkering hubs in Egypt, marking its latest move to become a key supplier of ammonia to the shipping sector.

Itochu struck a deal with Cairo-based Orascom Construction to design, develop and operate integrated facilities for supplying ships with ammonia as marine fuel, according to the Suez Canal Economic Zone authority. The hubs will be located at the zone's ports of Ain Sokhna and East Port Said.

The agreement follows a series of recent steps by Itochu to expand its ammonia bunkering footprint.

In August, the firm signed a deal with Mitsui OSK Lines (Mol) to demonstrate ship-to-ship ammonia bunkering in Singapore using a dedicated bunkering vessel and dual-fuel Capesize bulkers. Trials are planned for the second half of 2027. Mol said it intends to co-own three ammonia dual-fuel Capesize bulkers with Belgium-based oil tanker firm CMB.Tech, with delivery scheduled for 2026–27 from Chinese shipbuilder Qingdao Beihai.

Itochu has also recently signed a deal to co-develop a 300,000 t/yr renewable ammonia project in India with engineering firm L&T, aiming to export the output to Singapore for bunkering operations.

The company previously said it plans to commercialise ammonia bunkering in Singapore first before expanding to Spain, Egypt and Japan. Itochu had initially aimed to begin trials in Singapore in 2026, but postponed the timeline, citing expectations of significant demand growth only after 2028.

Other Japanese firms and government bodies also discussed ammonia and hydrogen prospects with Egyptian partners during an investment forum.

The Tokyo Metropolitan Government signed a deal with the Suez Canal Economic Zone authority to co-operate on green hydrogen for ship bunkering, focusing on knowledge exchange, demand stimulation and promotion of clean energy applications.

Japanese trading firm Sumitomo took part in discussions on renewable hydrogen production for export, ship bunkering, green steel and potential involvement in infrastructure such as desalination and "hydrogen service corridors", according to the Suez Canal Economic Zone authority.

Many developers have announced plans to produce renewable hydrogen and derivatives in the economic zone, including for maritime use. But public updates have been limited and most initiatives remain in early development stages.

Russia leans off MAP to prioritise DAP exports

The share of Russian MAP rail movements destined for exports has fallen on the year as demand from Brazil has declined.

Russian MAP railings to the domestic market, sea ports and neighbouring countries in the first eight months of the year came to 2.46mn t — of which 73.6% went to sea ports. This lags behind January-August 2024 when 2.94mn t was transported by rail — of which 76.9% went to sea ports. The focus on production has shifted more in DAP's favour on stronger global demand as MAP interest has tapered off.

Brazil is Russia's key outlet for MAP, and the global MAP benchmark market. But it has reduced its appetite for the product this year because of affordability issues, instead choosing to focus on NPs, SSP and TSP. Brazilian imports of Russian MAP totalled 867,000t in January-August 2025, down from 1mn t in the same period last year, according to line-up data.

Russian MAP exports could remain limited as Brazilian importers keep shunning MAP despite the import window closing soon.

The lack of interest in MAP compared with DAP has driven prices apart, encouraging flexible producers to focus more on the latter. Russian DAP fob prices have consistently remained above their MAP equivalent since mid-June, now at a USD31/t premium to the MAP assessment on a midpoint basis.

The reduced focus on MAP shipments has led to a boost in DAP deliveries.

January-August Russian DAP rail movements to the domestic market, sea ports and neighbouring countries totalled 1.54mn t — of which 96.8% went to sea ports. Rail movements totalled 1.05mn t in the first eight months of last year — of which 91.4% went to sea ports.

The increase in rail deliveries to sea ports this year is linked to a surge in Russian DAP exports to India in particular. India imported 437,000t of Russian DAP in the first eight months of the year, compared with the January-August average of 310,000t in 2022-24, line-up data show.

The Indian government has been covering DAP importers for their losses because of an urgent need for the country to rebuild depleted stocks.

Ethiopia's return to importing DAP at the end of 2024 added a significant new outlet for Russian cargoes this year. Ethiopian Agricultural Businesses (EABC) awarded 1.1mn t in various tenders since this time last year. It received 120,000t from Russia up to July this year, according to GTT data. And EABC is back in the market for 549,000t of DAP to be shipped over October-February for the 2025-26 season.

Russia has capitalised on the strong DAP demand in Africa and Asia to shift exports away from MAP and will also look to shift exports away from Europe, where duties on Russian phosphates are now EUR45/t as of July.

But curtailments at Phosagro's 700,000 t/yr Cherepovets production facility in September-October are expected to cut DAP output by 90,000t during the maintenance period, restricting export capacity for the fourth quarter.

AUSTRALASIA

Australia's PRL restarts Ardmore phosphate mine

The 635,000 t/yr Ardmore phosphate mine has resumed operations after Australian phosphate producer PRL Group satisfied all conditions for the takeover of local miner Centrex and its subsidiary Agriflex.

Operations at the Ardmore mine have restarted and customer shipments of phosphate product will begin before the end of 2025.

Centrex entered voluntary administration in March and PRL began a 45-day due diligence period on a potential takeover in April.

PRL has satisfied or waived all conditions for the acquisition. This included reaching a rail haulage agreement with rail operator Aurizon.

PRL will rebrand Centrex as PRL Ardmore when it completes the transaction in five days.

"Based on the work undertaken, while significant challenges remain, the Board is positive on the future

growth prospects for PRL Ardmore," PRL Global Chairman David Somerville said.

Centrex shipped a record high of around 30,000t of phosphate rock to New Zealand in December 2024 and mined over 180,000t in July-September 2024.

Australia's BCI to start building SOP plant in 2026

Australian mining company BCI Minerals' will begin construction of a potassium sulphate (SOP) pilot plant located in the Pilbara region of Western Australia in early 2026.

The plant is part of BCI's Mardie salt and potash project. Construction will take 12 months, after which the pilot plant will run for one year. The SOP pilot plant will allow for end-to-end testing to de-risk the production process and will contribute to the end design of the final commercial plant, BCI said. BCI did not disclose the capacity of the plant.

A final investment decision is expected after the one-year trial, two years from the start of construction, BCI said.

BCI expects the Mardie salt and potash project to produce 140,000 t/yr of SOP once it is fully operational as a full-scale plant.

BCI has delayed the construction of a potassium salt crystalliser to be in line with the SOP plant's construction and operation timeline.

The 5.35mn t/yr Mardie salt operation received all necessary approvals to transition to full-scale operations in April. The project's construction was 69% complete as of the end of the financial year to 30 June.

The company is on track for its first salt export by the end of 2026. BCI came to its third binding offtake agreement in the last 12 months, bringing the total contracted volumes to 62% of the forecast salt production in the first three years.

Australian potash producer SO_4 achieved its first SOP export this month from its 200,000 t/yr Lake Way project. This is currently the only potash production in the country. ■

Price watch

*These market insights are provided by **Argus Fertilizer Analytics team***

AMMONIA

Oversupply expected for 2026

Not for the first time this year, production constraints are driving global price sentiment and causing prices to firm, even during a period of seasonal inactivity in the ammonia market. Reduced operating rates in the Middle East, southeast Asia, Trinidad and north Africa during July limited merchant availability, which was made even worse by an explosion at Eurochem's Ust-Luga terminal that stopped any seaborne Russian trade recently.

To the east of Suez, Saudi Arabia's Ma'aden has restarted a unit which was offline for nearly two months, and plans to export 175,000t in August, up from 150,000t in July. Iranian exports have resumed, with cargoes reaching India after regulatory delays. Production is normalising, but weak fertilizer demand given the offseason in India means prices have only given a muted upwards response.

India's ammonia imports are likely to rise towards the end of the third quarter, as early buying begins in anticipation of the rabi crop season during the fourth quarter. Most buyers have secured August cargoes, but some residual demand remains. DAP stockpiles may soften downstream ammonia demand, but steady domestic DAP output and seasonal recovery will sustain baseline requirements. Prices will likely move gradually, as improving supply conditions limit upwards pressure.

As has been a consistent trend since Russia's invasion of Ukraine in 2022, markets to the west of Suez remain significantly tighter. Constrained spot availability and production issues in Algeria, Egypt and Trinidad are supporting European and Moroccan prices, and these factors, combined with US duties on Trinidadian imports, contributed to a USD 70/t rise in the Tampa price settlement for August.

The recent rise in ammonia prices means European producers remain cost-competitive, but import demand will grow stronger into the fourth quarter as the fertilizer demand season approaches, and colder weather will drive up TTF natural gas prices.

No exports were possible from Ust-Luga during July after an explosion during ship loading on 6 July, but vessel tracking suggests the terminal is once again operational. Additionally, Eurochem has completed construction of a rail expansion to the Port Favor terminal at Ust-Luga, allowing exports from plants further within Russia which have lacked access to the seaborne market for over three years.

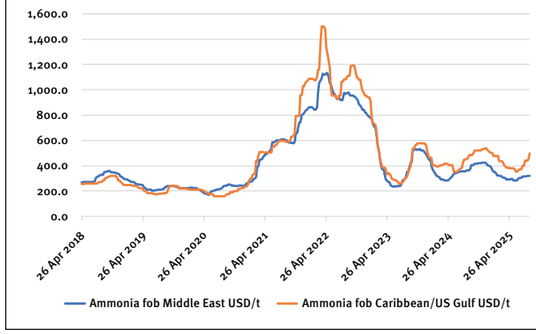
Moving into the fourth quarter, the supply-side issues currently being faced by the global market should have mostly been resolved. Trinidad's gas issues, while severe when they occur, rarely last more than 2–3 months, meaning by October production rates should have recovered in time for the peak US fertilizer season. And Gulf Coast Ammonia's 1.3mn t/yr plant is expected to be up and running now.

This added supply, helped by strong Russian exports to end the year, will add significant length to west-of-Suez markets. As a result, we expect that the recent price uptick in the Tampa contract will not be repeated — increasing demand will still pull prices up towards the end of the year, but not to the extent seen recently.

In the Middle East and Asia, the relative calmness will persist, with only gradual price firming expected over the second half of the year. Once India's rabi demand recedes, there will be only minimal support for prices from east Asian buyers, meaning we expect softening from December and throughout the first half of 2026.

Over 2.4mn t/yr of merchant capacity will be added in the US by the end of the year, and these tonnes will cause prices at all our forecast west-of-Suez benchmarks to be lower in 2026 than this year. East-of-Suez markets will be somewhat insulated from this new supply given the logistical challenges still facing the market, with most ammonia unable to pass through the Red Sea, so prices in these regions will follow a similar pattern to this year.

Ammonia historical pricing



PHOSPHATES

Market awaits news on extra Chinese quotas

The phosphate market is divided when it comes to its core, traditional ammoniated products. Prices, forecasts and fundamentals are diverging, DAP vs MAP.

The MAP market is seemingly behaving in accordance with traditional cyclical market drivers. As we draw ever closer to the start of the key September application season in Brazil, the world's largest MAP importer, demand is waning and price resistance is building. This is particularly the case as it is estimated that only 5–7% of P_2O_5 import demand for the season is unmet, with plenty of product available in the system and farmers having only about 20% of P_2O_5 demand left to secure for the fast-approaching soyabean season.

As a result, our forecast is starting to soften across August and into September, with softening then becoming the dominant trend until the second quarter, when buyers will next be in the market in earnest for tonnes to cover the safra season.

It could be argued that fundamentals are not 100% in line with traditional drivers as superphosphates continue to play a key role in the Brazilian supply picture, with Brazil's July imports reaching a record high. But superphosphates have been a big part of Brazil's supply mix for the past 3–5 years, so it seems they are now here to stay and one of the market's fundamental drivers. And because Brazil is such a seasonal market when it comes to its P_2O_5 needs, they also cannot avoid being driven by cyclical demand, with downwards pressure on TSP and SSP prices likely to be seen for much of the rest of 2025 and into early 2026, with Brazil's lower levels of demand.

As alluded to at the top of this summary, DAP is a very different market as the key word when it comes to our price forecast is firm. The two main drivers of this are India and Europe, but there are some nuances that will be highlighted.

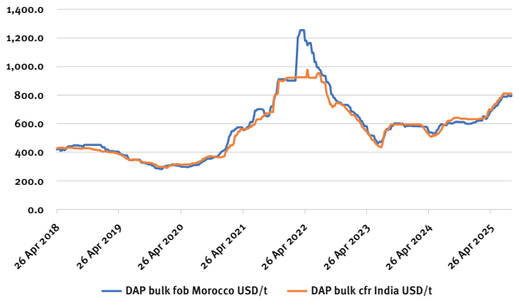
As discussed elsewhere in this outlook, and in many before, India is in a difficult position when it comes to DAP as there are low inventories, and rebuilding them is proving difficult because of domestic pricing mechanisms, as well as availability restrictions from key supplier China. As a result, India is buying tonnes at elevated volumes out of season and usual buying windows, and this is expected to continue across much of this outlook horizon, keeping prices in the USD800s/t cfr India, with softening marginal. But there are two nuanced factors that put this forecast at risk.

One is the Bangladesh private-sector tender. It is oversubscribed, and there are the usual expectations that the entire tender volume will not be awarded. This could result in cargoes being left without a home and added pressure on prices as India is rapidly becoming the only DAP market with any notable buying interest.

The other factor is TSP. India has about 250,000t of the product in stock, all from OCP and part of recent supply deals. If DAP prices rise notably further, and the new nutrient-based subsidy for DAP in India for the six-month period from September is not workable against international prices, then P_2O_5 consumers could well turn to absorbing the TSP stocks available out of a lack of viable alternatives and curb import demand for DAP as the P_2O_5 supply method for a period.

Europe is the other firm driver. The tariffs placed on imports of Russian and Belarusian fertilizers leave European DAP importers in a difficult position, particularly as the traditional import window starts in November, which is fast approaching. It is the lack of supply options to Europe that is driving the notable support across our Morocco DAP fob assessment in late 2025 and nearly the entire first half of 2026. Because of this, if smaller, less competitive importers wish to pick up DAP tonnes in the November–April Europe window, they will have to pay up to match the premium market's prices.

Phosphates historical pricing



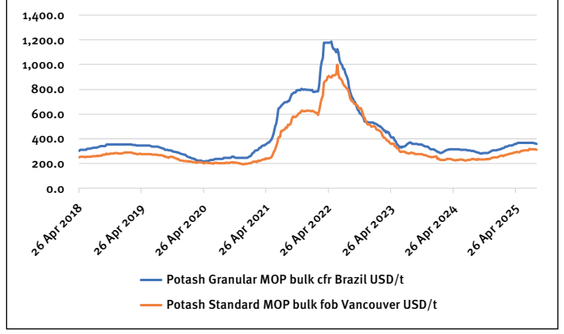
POTASH

Market awaits Bangladesh sMOP awards

Major MOP markets remain relatively calm and prices are largely stable. In the east, suppliers are still awaiting awards under Bangladesh's private-sector tender to buy 250,000t of standard MOP. Meanwhile, the West remains in a seasonal slumber, which is placing some downwards pressure on pricing.

In project news, China's QSHL has pulled out of its planned acquisition of Highfield Resources. The acquisition would have included a 1.3mn t/yr MOP mine in Spain and a 2.8mn t/yr MOP mine in Canada. Meanwhile, BHP has confirmed its decision to delay the production start date of the second stage of its Jansen MOP project by two years, from 2029 to 2031.

Potash historical pricing



Indian inventory stood at around 850,000t of MOP on 1 August, down by 17% from 1.03mn t on 1 July and almost 30% lower than 1.2mn t on 1 June. The August figure was also down by around 250,000t, or 22%, compared with a year earlier.

Meanwhile, in Australia, SO_4 exported its first commercial SOP volumes in July from its 200,000 t/yr Lake Way project in Western Australia. SO_4 has sold more than 1,800t of SOP so far, most of which was exported. It expects to sell another 2,000t in the next month. Its exports went to Mexico, Peru, Spain, Ecuador and Chile.

Demand from the key markets, particularly in the West, should rise towards the end of the third quarter, which will support prices. But affordability remains a concern for blenders and end-users as crop prices remain relatively weak.

SULPHUR

Chinese exports of DAP/MAP to rise in the fourth quarter

We expect a slight uptick in global sulphur pricing across September, with Middle East spot pricing increasing by USD3/t fob to USD270/t fob at the high end, before stabilising and softening into the fourth quarter before buying for fertilizer application season in April 2026 resumes and import demand lifts pricing ideas.

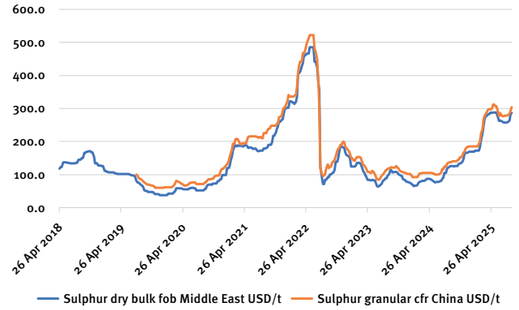
In July, there was slack in the market because of a surplus, with ample available tonnes causing softening and buyers largely covered. These tonnes were sold to east Africa, aligning the global trade balance and lifting pricing as demand from Chinese fertilizer producers and Indonesian nickel producers rose.

The incremental increase expected in pricing is largely driven by the market competition generated as Indonesian demand picked up in August, lifting pricing out of the Middle East. This also encouraged Chinese buyers to put out higher bids to secure tonnes ahead of the domestic fertilizer application season, combined with an increase in fertilizer export quotas. Further exports from Chinese fertilizer producers are expected to support raw material demand in the coming weeks, and Indonesian nickel producers are willing to pay a premium for Middle Eastern tonnes because of affordable netbacks, so we expect the price rise to continue through to September before demand is met and pricing stabilises.

Demand from Brazilian fertilizer producers is also up, with importers seeking a wider spread of tonnes to ensure security of supply amid tariff uncertainty from the US, particularly from the Middle East. The loss of Kashagan block product, combined with some supply-side issues in the Middle East and refinery closures in the US, will curb sulphur availability across the fourth quarter. The refinery maintenance in Kuwait, and halting of crushing block product in Saudi, will contribute to tightening the sulphur balance towards the end of the year, keeping pricing from dropping below the USD230s/t fob at the low end.

Despite the current uplift in pricing, overall market sentiment across our forecast period is stable-to-soft, with largely muted demand from key end-users bringing down pricing ideas into the fourth quarter and through 2026. Demand from OCP is covered with contracted tonnes, and the producer is taking sulphuric acid until the end of the third quarter because of operational issues at burners, leaving north African demand subdued. Tunisian demand is low because of technical issues, and other key fertilizer producers are covered for tonnes. Black Sea delays because of logistics have also meant regular offtakers such as Egypt are remaining quiet in the market rather than seeking alternative tonnes. There is also a lack of

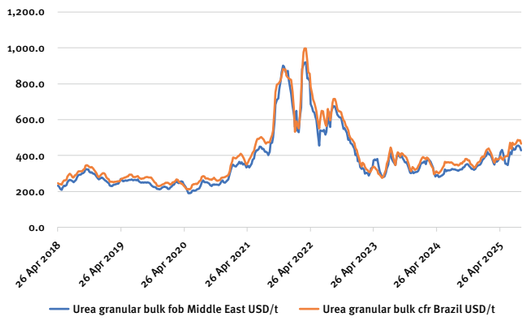
Sulphur historical pricing



spot demand from South Africa because of healthy port stocks. Port stocks in China remain stable, so consumers are unlikely to continue accepting higher offers after this initial rise.

Overall market sentiment is stable, with pricing adjusting to the peak earlier in the year and market participants unwilling to accept tonnes above the USD300s/t cfr as they have the option to adjust to unworkable netbacks, draw on port stocks, or undergo maintenances at operating plants instead of accepting elevated pricing. Thus we expect pricing to remain stable-to-soft, dropping across the fourth quarter and first quarter of 2026, before adjusting to seasonal trends through next year.

Urea historical pricing



NITROGEN/UREA

US demand supporting market

An Indian tender on in early August saw prices rise by USD35–37/t from the July inquiry to USD530–532/t cfr, with trading firms going long in Indonesia, Nigeria and the Middle East in anticipation. The high price reflects India's need to secure 2mn t to be shipped by 22 September — a relatively short period for such a large quantity. This will cut supply to other markets and oblige buyers elsewhere to either pay higher also or defer buying into the fourth quarter. India will likely issue further urea buy tenders ahead of the rabi season (October–March), with the country expected to still need 5mn t of imported urea.

Low affordability will push some demand normally covered in the second half of the year into the first quarter, as buyers opt to wait rather than accept high prices now. Urea prices in the US Gulf are nearly 50% higher than a year earlier, at around USD460/st fob Nola, in the low season.

The US is expected to be a strong driver of demand in the first quarter, owing to reduced production and imports in the third quarter before rivers close in October. Turnarounds at four plants will cut North American production by over 400,000t in the third quarter. Uncertainty created by President Donald Trump's tariff threats has reduced urea imports in July–August and will raise import demand in the first quarter.

The situation is different in Europe. August is a quiet month for sales and the reaction of buyers to high prices will not be tested until September. It is likely that the imbalance between high urea prices and low wheat prices will lead some buyers to defer making purchases until late in the fourth quarter or into the first quarter, in the hope prices will fall. Import buying is expected to peak in the fourth quarter this year because of the introduction of the EU's Carbon Border Adjustment Mechanism (CBAM) from January. This will add several dollars to the cost of each tonne of urea, although no one knows yet exactly how much the new tax will raise prices. Buyers are likely to take product early rather than wait to find out — current predictions suggest the CBAM could add USD26–28/t to the cost of ammonia.

In the meantime, global prices are expected to remain elevated for supplies from firms able to sell to India, at USD480–510/t fob Middle East. India's August tender may well mark a price peak — India has shown it will buy whatever quantity of urea it can, but the surprise announcement on 6 August that some Chinese urea could be sold for shipment to India has taken some of the heat out of the market. India should benefit from increased competition to sell later in the year.

Chinese suppliers have struggled to use up their export quotas for prilled urea, with prices lodged in the low-USD400s/t fob as a result. But prices could rise to USD470–490/t fob now that some exports could be sold to India. Initial reports are that 300,000t will be approved for sale to India, but this remains to be confirmed, as do indications that a third round of 2025 export quotas could be issued for September–October.

Iranian urea has been selling at USD420–430/t fob. Russian urea prices have not been affected by an additional EUR40/t (USD47/t) duty imposed in the EU, as suppliers are able to sell into India and ship urea duty-free to the US and Latin America.

Prices may plateau or ease slightly for October — which is within the window for Chinese exports — but the demand outlook for November is very strong, with a substantial supply deficit forecast globally. This strength is expected to be maintained into the first quarter, and a significant correction in prices is not expected until the second quarter.

Urea capacity additions are limited in the short term. Apart from one world-scale plant in Iran due on stream this year, another major increase in export supply is unlikely before 2028. ■

Special focus

FERTILIZER SUSTAINABILITY ›

Strengthening the fertilizer industry with decarbonization solutions

Written by

Stephen Bell, Ph.D., *Sustainability Analyst,* ***International Fertilizer Association***

While fertilizers are widely recognized for their critical role in contributing around half of world food production, the manufacturing of fertilizers, ammonia in particular, is energy- and carbon emission-intensive by nature. Fertilizers are a hard-to-abate sector. However, the global fertilizer industry is committed to playing its part in achieving the goals of the Paris Agreement. The industry recognizes that an efficient transition to economy-wide, net-zero emissions is the only way to limit global warming. Several companies have already committed to net-zero; others are developing a strategy towards that objective.

Fertilizer production emissions mostly come from ammonia production

The fertilizer industry's greenhouse gas (GHG) emissions span from production to use. At a macro level, fertilizer production emissions mostly come from ammonia production, which accounts for 1.3% of global energy sector emissions, including energy-related and industrial process emissions (note: around 30% of ammonia is produced for uses other than fertilizer). Fertilizer application emissions occur primarily from nitrogen (N) fertilizer use and the subsequent GHGs released through various direct and indirect pathways, such as nitrification, denitrification, volatilization and leaching. In total, N fertilizer production and use emissions account for around 2.5% of global GHG emissions (note: this excludes manure), one third of which is linked to production and the rest from use.

Fortunately, there are multiple decarbonization levers being developed for the fertilizer industry to help reduce some of these emissions while ensuring stable, strong, and sustainable agrifood systems. Each lever, or intervention, is unique and varies in how they reduce and how much they reduce GHG emissions. They also differ in their regional technoeconomic feasibility, social acceptability in local farming contexts, market and logistical readiness, and in how much they might impact global food production if scaled-up. One of the International Fertilizer Association's (IFA) central roles is supporting the world's fertilizer industry find new ways to meet the dual challenge of feeding the world and doing it sustainably. This is an exciting and critical moment in which the fertilizer industry is proactively engaged, inspired by the FAO's 2023 publication: 'Achieving SDG 2 without breaching the 1.5 °C threshold: A global roadmap'.

A new chapter in fertilizer industry decarbonization

IFA has supported the development of several resources in recent years to address decarbonization. For the International Energy Agency's (IEA) Ammonia Technology Roadmap (ATR) published in 2021, IFA worked closely with the IEA by providing relevant data, expert feedback, and facilitating stakeholder engagement. The ATR used scenario analysis to explore three possible futures for ammonia production emissions. Ammonia accounts for around 2% of total final energy consumption, with around 70% of the ammonia produced being used for fertilizers specifically. The ATR was published in 2021 and sponsored by the European Bank of Reconstruction and Development (EBRD). Following this global study, IFA supported the development of national strategies for decarbonizing N fertilizer production in Egypt and Turkey, in partnership with EBRD and local governments. Then in 2022, IFA and Systemiq published a report called Reducing Emissions from Fertilizer Use. The report provided recommendations to fertilizer companies, farmers, their advisers and policy makers on how to cut up to 70% of GHG emissions while continuing to support food production. It included an analysis of six cropping systems and the opportunities for emissions reductions in these systems across five regions of the world, including cost saving opportunities for farmers.

In January 2024, IFA's Fertilizer Industry Ambition Statement was published with the overarching aim to improve food and nutrition security by enhancing crop yield and the nutritional quality of plants, supporting healthy soils and preventing deforestation. Our specific decarbonization aim is to reduce the industry's direct GHG emissions associated with N fertilizer production by an average of 70% by 2050 (using the official IEA's Sustainable Development Scenario and a 2019 baseline). The actions IFA is promoting to achieve this include developing and implementing scientifically validated low-carbon pathways, using Best Available Technologies, using renewable energy with water electrolysis to produce hydrogen feedstock, and using Carbon Capture, Use and Storage. For the use phase of fertilizers, IFA's report Reducing Emissions from Fertilizer Use highlighted that a realistic ambition would be to improve average global nitrogen use efficiency (NUE) in crop production from around 50% currently to 70% by 2040. IFA will continue to contribute to public and private efforts to support investments which benefit IFA members in decarbonizing fertilizer production and use.

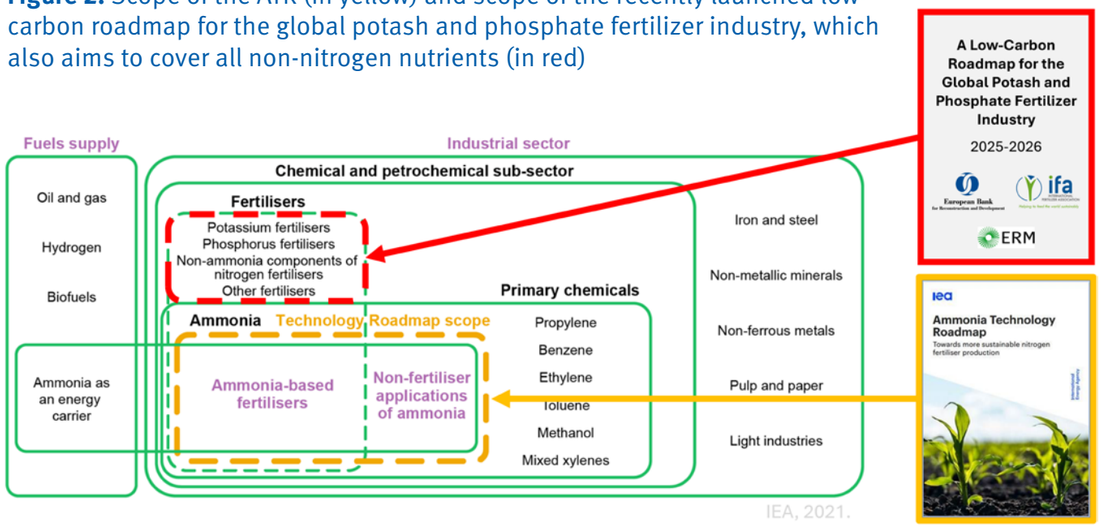
IFA recognizes the need for developing affordable, accessible, and proven technologies that allow companies of all sizes to work towards these ambitions. Fostering an informed policy environment is critical, with the accompanying legislation and financial instruments that support innovation and investment in fertilizer industry low-emission technologies. Therefore, at IFA's Strategic Forum in November 2024, IFA's Board of Directors approved the launch of the Fertilizer Industry Decarbonization Initiative (FIDI), representing a new chapter in how our industry is demonstrating leadership and ensuring long-term business sustainability. Through FIDI, IFA continues to support members to implement flexible, feasible, and effective decarbonization strategies (see figure 1).

Figure 1. IFA's Fertilizer Industry Decarbonization Initiative conceptual framework and phased approach

Filling the gaps to unlock industry-wide decarbonization

As a multi-year initiative, FIDI is being executed in phases, with the scope and scale of future workstreams being developed with continuous IFA member guidance. All decarbonization related projects, services, and tools developed at IFA are open to all IFA members, and participation is voluntary. In the first and current phase of FIDI, we have identified two strategic projects to develop which will create multiple opportunities for the sector. The first project is being fully sponsored by EBRD and will develop the first global low-carbon roadmap for potash and phosphate fertilizers. Launched in August 2025 and following the successful model of the multi-stakeholder ATR project, this roadmap is being led by ERM and supported by Systemiq. It will define a sustainable low-carbon future of the global potash and phosphate fertilizer industry to 2050 to contribute to the Paris Agreement goals while ensuring food security. The roadmap

Figure 2. Scope of the ATR (in yellow) and scope of the recently launched low-carbon roadmap for the global potash and phosphate fertilizer industry, which also aims to cover all non-nitrogen nutrients (in red)



will also allow IFA to ensure that all fertilizer producers, including those who may have not directly benefited from the outcomes of the ATR (see product scope in figure 2), have the same opportunities to explore, plan, and justify credible decarbonization strategies during the production phase.

There are several different GHG emissions sources in the potash and phosphate fertilizer supply chains, necessitating several different mitigation solutions. The project will explore factors such as source mineralogy, mining and processing methods, transportation, by-products/waste (e.g. phosphogypsum), and even emissions from the use of blended and compound fertilizer containing N. As one of the most engaged global industry associations, IFA has involved the world's largest potash and phosphate producers to ensure that the final outcomes are not only technically robust but also workable. Through our Decarbonization Working Group, IFA members are invited to provide expert advice and case studies, undertake peer review of deliverables, and participate in stakeholder engagement activities. This project, which will be able to leverage global supply and consumption data from IFA, follows our May 2025 publication From Waste to Inventory. Phosphogypsum – The Business Case. As the third instalment in IFA's series of reports on phosphogypsum management and utilization, it includes contributions from 28 leading companies and organizations across 18 countries and representing over 85% of global phosphogypsum output (an estimated 245 million tonnes annually). Phosphogypsum has several potential uses as a by-product, including as an alternative raw material for decarbonizing cement production in China, and as the basis for carbon-credit generating projects through landscape restoration and carbon sequestration in Canada.

The second project which could complete the first phase of FIDI is still under discussion amongst IFA members in the Decarbonization Working Group. However, the goal is clear: to develop resources to support a Paris Agreement aligned pathway for mitigating nitrous oxide (N_2O) emissions from fertilizer use. IFA members require guidance on what an ambitious, but also workable, mitigation pathway for fertilizer N_2O in-field emissions looks like considering anticipated changes in global food demand. Nitrogen fertilizer application in agriculture is one of the principal anthropogenic sources of N_2O emissions. All major N fertilizer products, whether applied as anhydrous ammonia, urea, urea ammonium nitrate, ammonium sulphate, ammonium phosphate, ammonium nitrate, or calcium nitrate, promote various microbial processes in soils that lead to N_2O emissions. In our 2022 report 'Reducing Emissions from Fertilizer Use', we estimated that from the 108 mn t of N fertilizer applied to farmland in 2019, there was around 634 mn t of CO_2-equivalent emitted as direct and indirect N_2O emissions. Following the success of that report, we aim to delve deeper into specific emissions reductions measures and how fertilizer companies can quantify their impacts for sustainability reporting. In fact, the lack of an internationally accepted approach is one of the central challenges identified by IFA members in setting science-based GHG emissions reductions targets. The Science Based Targets Initiative (SBTi), for example, has recently recognized the "...importance of establishing a specific pathway for setting targets on N_2O emissions from the use of fertilizers in the field".

In order to design effective N_2O emissions reductions strategies, set achievable science-based targets, and make credible decarbonization claims, fertilizer producers require a comprehensive assessment of the measures they can implement, their respective mitigation potentials, and their technological, logistical, and market readiness. Accurately measuring N_2O emissions from fertilizer application is challenging and expensive, and it can be even more difficult to attribute emissions reductions to a specific mitigation measure implemented in the field. Companies engaging with farmers to improve NUE will reduce surpluses but not entirely eliminate N_2O emissions. Technological solutions such as controlled-release fertilizers and stabilized N fertilizers with inhibitors can further reduce direct and indirect N_2O emissions. With our 2022 report Reducing Emissions from Fertilizer Use as our launch pad, IFA is exploring how to serve members even further by defining and assessing mitigation measures by key factors (i.e., product, crop, site-specific conditions, data availability and gaps, etc.) and exploring mitigation scenarios for N_2O emissions intensity reductions while ensuring critical Sustainable Development Goals are maintained (i.e., biodiversity protection, food security, and land use optimization over agricultural expansion, etc.). Once again, the fertilizer industry is taking a leading role in addressing complex challenges of the global agricultural production system. In addition to technical resources like new roadmaps, models, and mitigation calculators, IFA is working to foster an enabling system involving stakeholder engagement, collaboration within the agrifood sector, public-private partnerships, and market mechanisms to drive demand for the N_2O mitigation measures IFA members choose to implement.

There is no one-size-fits-all approach that can be applied

We need everything, everywhere, all at once

Under the guidance of our members, IFA is also preparing for future phases of FIDI by assessing the feasibility of additional strategic projects which support IFA members. There are several areas of work to be done, from new fertilizer product carbon footprint resources, improved emissions accounting methodologies relevant for fertilizers, and better guidance on how fertilizer producers can make credible decarbonization claims for Scope 3 reporting. IFA's Decarbonization Working Group is working to co-create new solutions with external stakeholders and the wider agrifood sector, all the while with an eye on long-term IFA member needs and market demands for greater product differentiation and emissions reductions visibility.

Engaging the full fertilizer supply chain to promote viable and resilient decarbonization projects will certainly be among the fertilizer industry decarbonization gamechangers in the coming years. IFA's project with Proba and STX on enhanced efficiency fertilizers to reduce Scope 3 emissions associated with fertilizer use represents an ambitious first attempt at achieving this from the ground up. Launched in October 2024 and sponsored by IFA members who will participate in the pilot testing, this project is an industry programme which not only quantifies the emissions reduction impacts of urease and nitrification inhibitors, but establishes how our industry can work together with other agrifood stakeholders by using income from the voluntary carbon market to incentivize broader adoption of these inhibitors. The programme aims to create a powerful mechanism to share costs and de-risk the adoption of inhibitors across the fertilizer supply chain, using insetting strategies to drive both innovation and sustainability.

The fertilizer industry has the potential to be a global leader in showcasing sector-wide transformation through its ambition to sustainably feed the world. In April 2025, IFA explored the synergies of sustainability and innovation in our Cultivating Tomorrow Conference. By showcasing pioneering start-ups and emerging innovations, this new IFA conference is designed to bridge the sustainability gap, with a range of sessions covering climate change, biodiversity, novel fertilizers, generative AI, safety innovation and the circular economy. Following the conference, IFA's new Innovation Hub launched a dynamic 12-month start-up competition and business development programme: "The Cultivate Challenge". The challenge is designed to identify and accelerate global entrepreneurial talent working on the highest priority topics for the global fertilizer industry. In the first edition of The Cultivate Challenge, one of the three core themes is dedicated to halving the energy intensity of ammonia production.

All in all, we at IFA continue to see many opportunities along the long road towards decarbonization in the fertilizer sector. Reducing N fertilizer production emissions remains the most active space, with the increasing share of new technologies coming online addressing the energy-intensive process of producing ammonia. There is no one-size-fits-all approach that can be applied to every company. For decarbonizing the industry as a whole, we need everything, everywhere, all at once. And we need the expertise and ideas of all industry stakeholders, from the world's largest producers to the innovative start-ups now showcased on IFA's Innovation Hub. The business case for making reduced emission fertilizers is growing. Our job is to make sure we do not lose any of the momentum and public interest in implementing verified solutions, while ensuring the pipeline of research, testing, and investment in new solutions continues to expand. ■

CASE STUDY: Greener SOP production

New European SOP producer offers a sustainable method with a circular perspective

Written by

Anders Antonsson, *Communications Manager,* ***Cinis Fertilizer AB, Sweden*** and
Marine Beurskens, *Director of Marketing,* ***Van Iperen International, the Netherlands***

Sweden's Cinis Fertilizer was established with a vision to address the environmental challenges posed by industrial waste and the carbon-intensive production of traditional fertilizers. By producing potassium sulphate (SOP) in a fossil fuel-free production process, Cinis addresses critical environmental challenges while contributing to economic growth and food security.

Jakob Liedberg,
CEO, Cinis Fertilizer

Just over a year in production, and having shipped more than 40,000 t of premium and fully water-soluble potassium sulphate, Cinis has proven itself as the new partner inspiring other players looking for viable participation in the circular economy.

The market for potassium sulphate is large, global, and non-cyclical with significant demand for sustainable solutions supported by several global megatrends. These include a growing global population which increases demand for food, less arable land per capita, climate change, changing eating habits and improved diet due to reduced poverty. By providing a sustainable alternative to current fossil-based fertilizers, Cinis aims to bring its solutions for agricultural sustainability, in line with the global targets of reducing agriculture's climate footprint.

Robust business model

Cinis Fertilizer AB, is a green-tech company founded in 2018 by chemical engineers Jakob Liedberg and Roger Johansson, with the mission to produce the world's most sustainable mineral fertilizer and thus contribute to a more sustainable, circular and fossil-free agriculture. By leveraging the Glaserite process – a well-established production method from the 1950s – using half the energy of conventional SOP production methods, Cinis is now producing a fertilizer with a near-zero carbon footprint from their production process.

Cinis' first production facility is strategically located in Örnsköldsvik, in the northern parts of Sweden, to take advantage of fossil free energy, easy access to the port of Köpmanholmen, and proximity to the pulp industry and other industries with waste streams suitable for the company's proprietary process to produce high quality potassium sulphate.

Jakob Liedberg, CEO of Cinis Fertilizer, commented: "Just like EVs are phasing out gasoline cars we want to phase out incumbent chemical processing of fertilizers and in the future also challenge existing supply chain models with much more circularity and energy efficiency in mind. We have to rethink how we produce chemicals and how we source input materials to increase circularity while maintaining our competitiveness – that means using what we wasted yesterday as a resource today and spending less energy doing it."

The production plant in September 2023

Construction and development

The listing of Cinis on Nasdaq First North Growth Market in November 2020 provided the financial funds required for the construction of the company's Örnsköldsvik facility. Cinis have never received any grants or government loans, 100% of the financing of the project was gained on a commercial basis through banks and investors.

The location was selected to capitalize on the region's industrial ecosystem and access to port infrastructure for cost-efficient logistics. The project was supported by the Örnsköldsvik municipality, which saw the plant as a catalyst for local economic growth and environmental innovation. On 13 February 2023, a ceremonial groundbreaking marked the start of construction and production started less than 15 months later.

The Örnsköldsvik plant is designed to produce 100,000 t of fossil fuel-free and circular potassium sulphate annually. The Glaserite process, powered by fossil-free electricity, converts industrial waste streams into water-soluble SOP and sodium chloride (NaCl) as a by-product. The process is designed to minimize environmental impact by producing no hazardous by-products and using 50% less energy compared to incumbent ways that produce SOP fertilizer.

"Just over a year after the inauguration of Cinis Fertilizers' unique facility in Köpmanholmen, we are approaching stable production. Our business model has been challenged, but we have managed to find alternatives. It has been intensive work with several unexpected events, but we are convinced that we now have a stable operation that is an important part of Sweden's and Europe's ambition to increase its resilience in responsible food production."

Jakob Liedberg, CEO, Cinis Fertilizer AB

The plant employs approximately 35 staff, with 24 working in six-shift rotations. The facility's design integrates seamlessly with the local environment, resembling a modern barn rather than a traditional industrial structure, aligning with the municipality's aesthetic and environmental standards. Mandatory statutory surveys of noise levels and air emissions have been carried out by a third party, proving that Cinis' operations are carried out and more than meet the requirements set by the environmental permit for low noise and air emissions.

Lessons learned

Cinis' first plant has now been in operation for over a year. The project has been implemented over a short time and has quickly become an important part in the work to reduce fossil fuel dependence in food production. The choice of manufacturing process means that the company has unique expertise in the Glaserite-method and how the technical equipment should be upgraded to function optimally.

The first year also brought higher-than-expected costs due to reliance on market-purchased sodium sulphate and cost inflation. The main factor being the bankruptcy of Northvolt in

March 2025. Northvolt was designated to supply sodium sulphate generated from precursor cathode active material (pCAM) production at its battery manufacturing plant in Skellefteå, Sweden.

However, the Örnsköldsvik facility is located close to more established industries, including the pulp and paper manufacturers in both Sweden and Finland. Cinis sees potential in connecting residual products from the traditional industry with the circular industry and will pursue ideas to make this a win-win situation for all stakeholders.

And there is a solid interest from current and scheduled battery material producers across the globe in finding a sustainable solution for their waste streams, especially what to do with sodium sulphate in the effluent, and at the same time to improve their competitiveness in the pCAM market. Partnering up with Cinis will enable and ensure a smoother environmental permitting process by addressing a waste issue from the start.

Cinis Fertilizers production plant in Köpmanholmen, Örnsköldsvik. The plant started operations in March 2024 and was officially inaugurated in June 2024

Partnerships for the green transition

Following the bankruptcy of the key designated supplier of sodium sulphate in March 2025, Cinis has signed agreements with several partners to replace the volumes. The main volumes are sourced from European suppliers, complemented by waste streams via recycling companies. The other key raw material, potassium chloride (MOP) is sourced from K+S, a major European supplier.

To reach customers on the global market, Cinis signed a sales and distribution agreement with Dutch company Van Iperen International relating to sales of water-soluble potassium sulphate. Van Iperen is a global operator active on the wholesale market for Specialty Fertilizers and Biostimulants. SOP from Cinis, branded GreenSwitch SOP, is used in nutrient solutions for fertigation and foliar application for vegetables, house plants, fruit trees and berries, grown in fields and/or greenhouses.

Jakob Liedberg said: “We have an alignment of interest with Van Iperen. We both want to drive change and enable farmers to reduce their carbon footprint and increase the market share of fertilizers produced or derived in a sustainable way. We also want to bring a product to the market with the same or better quality compared with products produced with fossil-based chemical processing.”

Future prospects

In parallel with the ramp-up of the production at its Örnsköldsvik plant, Cinis continues to work on initiatives to improve profitability, such as optimizing logistics and measures to reduce the costs of input materials, MOP and sodium sulphate, and increasing the selling price. This, together with production increases, will lead to stable profitability.

A capital raising was finalized during the spring of 2025, providing Cinis with a stable financial basis to bring the company to profitability and be able to parry unexpected events. Several well-known investors participated, including Van Iperen and Adam Nawrocki. Mr. Nawrocki has over 30 years of experience in developing and leading companies in fertilizer production. As a major shareholder and member of the Cinis Fertilizer Board of Directors, Adam will be a key in the development of Cinis’ expansion.

Globally, major industrial investments are being made where this production model and the resulting products fit very well for those industries that take responsibility for their entire production chain. The company has several ongoing discussions with large industrial partners about the supply of sodium sulphate to potential future production facilities. The players include leading battery manufacturers, chemical industries, and pulp mills across the globe and in different markets.

Cinis has set a precedent for sustainable industrial practices, demonstrating its knowledge to upcycle and produce high-value SOP demanded by farmers wanting to reduce their CO_2 footprint. The strong local support, strategic partnerships, and alignment with global sustainability trends position Cinis as a leader in the green transition of agriculture and circular economy. ■

Soil integrity over input intensity

Microbially-fermented humic substances from lignite/leonardite for sustainable intensification

Written by

Will Li, *VP & Strategy Director,* ***Hebei Monband Water Soluble Fertilizer, China***

By mid-century, mainstream FAO scenarios project that global agricultural output must increase by roughly 50% compared with a 2012 baseline, despite the fact that up to 40% of the world's land is already degraded. Meeting this challenge requires improving nutrient-use efficiency and restoring soils, rather than relying on indiscriminate fertilizer escalation. Humic substances (HS)—particularly humic acid (HA)—represent one of the few levers that can simultaneously enhance fertilizer efficiency and strengthen soil function.

The operational implication is clear: future gains must come from more output per unit of input and land, with soil regeneration embedded in production systems.

This article explores the role of microbially fermented humic substances produced from lignite or leonardite as a lower-impact, process-driven alternative to conventional alkaline extraction, without changing the underlying mineral feedstock base.

Why humic substances matter

Humic substances-operationally, humic acid, fulvic acid (FA) and humin-support sustainable intensification through three fronts:

- Nutrient efficiency: Via physicochemical effects (chelation, buffering, higher cation-exchange capacity), rhizosphere interactions, and signalling (e.g. H^+-ATPase activation), HS improve nutrient acquisition and utilization. Across multiple crops and regions, recent syntheses report average gains on the order of +12% yield, +27% nutrient-use efficiency (NUE), and +17% nitrogen (N) uptake, with strongest responses in pH 6-8 soils and under N-deficit conditions.
- Phosphorus availability: Co-formulating or co-applying HS with phosphorus (P) fertilizers can mitigate fixation and improve plant acquisition, leading to yield gains in cereals-an important sustainability benefit given finite phosphate rock and the environmental costs of P losses.
- Soil function and resilience: By promoting aggregation, structure and water retention, HS improve infiltration, aeration and root exploration, supporting both yield stability and climate resilience.

In terms of the 'deployment guardrail', HS performance is context-dependent (soil pH, organic carbon, texture, climate, fertilizer regime). Sustainable adoption requires integration into nutrient and soil-management plans rather than positioning HS as a universal stand-alone solution.

(left) Humic substances support soil function and resilience

How humic acid is made today and the sustainability trade-offs

Industrial humic acid (HA) supply is predominantly produced through alkaline extraction of lignite or leonardite using strong alkalis such as NaOH or KOH, often with oxidative aids, followed by acidification, precipitation, and drying. This route is entrenched, scalable, and consistent with established analytical conventions such as the IHSS isolation procedures. However, alkaline extraction generally requires substantial reagent consumption and produces saline or alkaline wastewaters, while product functionality can vary depending on deposit chemistry and extraction conditions. Although process-intensification research aims to reduce these burdens, the fundamental trade-offs remain, which drives interest in lower-impact alternatives. Reliable public data on global market shares by production route are not available, yet it is technically accurate to state that alkaline extraction from lignite or leonardite remains the predominant industrial method. In some markets, micronized leonardite is also sold as a soil amendment, representing a physical form distinct from standardized HA obtained through chemical extraction.

Microbial fermentation on lignite/leonardite: a process-driven alternative

Microbially mediated humification can be applied to the same mineral feedstocks (lignite or leonardite). By using selected microbial consortia and controlled process conditions—such as benign co-substrates for C/N balancing, moisture and aeration management, temperature regulation, and residence time—the raw material is bio-oxidized and humified, liberating and activating humic fractions without relying on conventional strong-alkali extraction. Why this advances sustainability with the same feedstock:

Reagents and effluents: Reducing or eliminating strong alkalis and oxidants lowers caustic consumption, neutralization salts, and wastewater salinity/alkalinity, leading to a cleaner effluent profile compared to conventional extraction. The degree of improvement is process-specific and ideally supported by plant data or life cycle assessment.

Functional performance: Biologically mediated humification often produces humic substances (HS) or humic-like substances (HLS) with a rich diversity of functional groups and strong biostimulant activity. While solubility and molecular-size distributions may differ from chemically extracted humic acids, agronomic relevance is ultimately determined by nitrogen use efficiency, apparent phosphorus recovery, and yield response, rather than a single assay.

Sustainable intensification is an engineering challenge

Energy and carbon intensity: Avoiding harsh extraction and neutralization steps can reduce energy requirements; however, overall carbon intensity depends on the site's energy mix and heat integration. The advantage comes from process design rather than switching feedstocks.

Quality assurance: Quality control should focus on functionally relevant metrics such as active acidity, carboxyl and phenolic group densities, spectroscopic fingerprints, and E4/E6 ratios, as well as batch-level variability—not just the percentage of humic acid on the label. IHSS methods remain valuable for comparative analytics even when production pathways differ.

Products derived from biological routes are most accurately described as humic substances (HS) or humic-like substances (HLS). For procurement and auditing, the decisive factors are verifiable field outcomes and documented reductions in chemical use and effluent generation.

Supply chain and farm application

The implementation playbook for supply chains and farms begins with targeting the most likely responders, focusing on soils with a pH of 6–8, low to moderate organic carbon, and systems aiming for nitrogen rate optimization, since responses are

Excavator in a lignite quarry

strongest where mineral nitrogen is not saturating.

Integration with nutrients is critical: for nitrogen, biostimulants should be co-applied at planting or side-dressed under nitrogen-deficient conditions, while tracking partial factor productivity of nitrogen (kg grain per kg N) and agronomic efficiency to translate effects into return on investment. For phosphorus, humic acid–enhanced or humic-complexed sources should be deployed in phosphorus-fixing soils, with careful monitoring of apparent phosphorus recovery and labile phosphorus pools.

Quality and traceability must also be specified: for alkaline-extracted products, suppliers should disclose reagent consumption and wastewater treatment practices, while microbial-derived products require feedstock traceability and functional characterization using methods such as FTIR, NMR, active acidity, and group density measurements; in both cases, independent batch-level quality control should be mandatory.

Quality and traceability must also be specified

Finally, it is essential to measure the outcomes buyers value most by documenting nitrogen saved per tonne of grain, percentage reductions in phosphorus use at equal yields, improvements in aggregate stability or water infiltration, and, where available, life cycle assessment indicators that capture reductions in chemical inputs and effluents. These metrics provide the foundation for credible sustainability claims in audits and buyer scorecards.

Soil integrity

Sustainable intensification is fundamentally an engineering challenge that bridges agronomy, chemistry, and microbial process design. Humic substances occupy a unique intersection where nitrogen use efficiency, soil restoration, and process footprint can improve simultaneously. Alkaline extraction will remain important in regions with abundant mineral feedstocks and strong environmental controls. However, as supply chains account for carbon and wastewater costs and buyers demand traceable, lower-impact inputs, microbially fermented humic substances derived from lignite or leonardite offer a credible, process-driven alternative that maintains agronomic performance while enhancing sustainability profiles. The practical path forward is to focus on areas where responses are most likely, establish standardized, function-relevant quality metrics, and measure outcomes that matter to both farmers and auditors—transforming mid-century targets into near-term, verifiable gains in soil integrity and food security. ■

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stefan.worsley@argusmedia.com
+44 (0) 7711 564 219

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argus
argusmedia.com

Fertilizer Focus
Argus
Lacon House, 84 Theobald's Road,
London, WC1X 8NL
Tel: +44 (0)20 7780 4340
Email: fertilizer@argusmedia.com
www.argusmedia.com/fertilizer

Publisher:
Adrian Binks

Editor:
Stefan Worsley
stefan.worsley@argusmedia.com

Contributors:
Meena Chauhan, Timothy Evans,
Owen Gooch, Claira Lloyd and Jake Preston

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