1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Number 412

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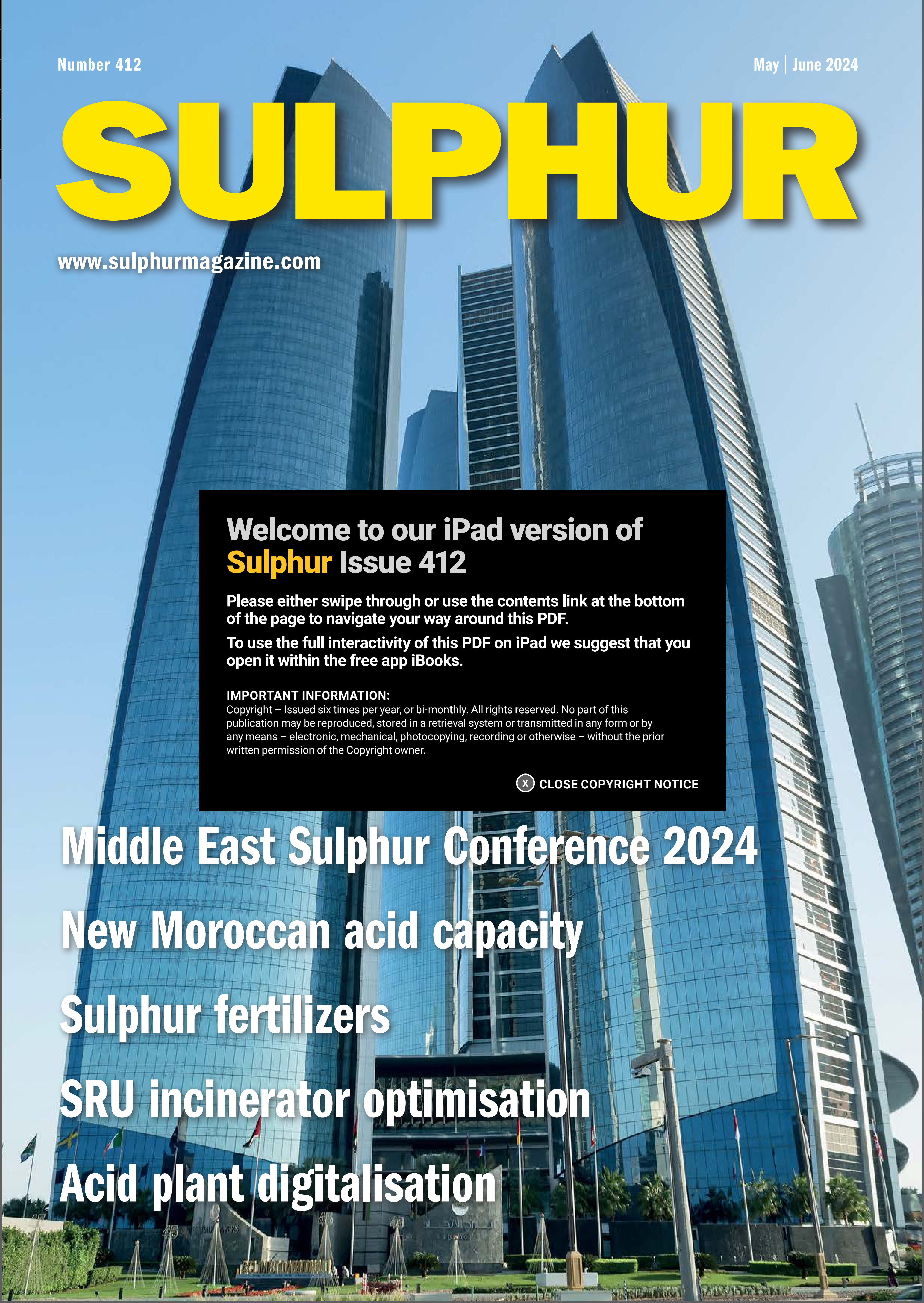

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Middle East Sulphur Conference 2024

New Moroccan acid capacity

Sulphur fertilizers

SRU incinerator optimisation

Acid plant digitalisation

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

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NUMBER 412 MAY | JUNE 2024

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CONTENTS

REGULARS

Morocco

New sulphuric acid plants to drive sulphur imports

Digitalisation

How digitalisation is impacting the sulphuric acid industry

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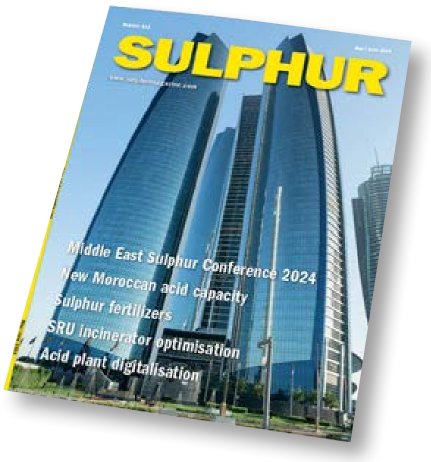
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Major miners



At the end of April, Australian mining giant BHP made waves in the business world by offering US$39 billion to take over its London-based rival Anglo-American, creating the world's largest diversified mining company. For its part, Anglo's board announced that it was rejecting the offer, saying that it was "opportunistic" and that it "significantly undervalued" their company. A revised bid was said to be in preparation at time of writing.

The rationale for the proposed merger is scale. In mining, size matters. Were the deal to go ahead, it would create the world's largest copper producer, the world's largest coal exporter, and the world's second largest iron ore exporter, surpassing Rio Tinto. Of these, the copper combination is one of the most compelling. BHP was the world's second largest copper producer in 2023, just behind Chile's Codelco, with an output of 1.36 million t/a. Adding Anglo-American's assets to this would see that rise to 1.9 million t/a according to CRU production estimates, 35% larger than Codelco, and representing around 10% of global copper production at a time when a tight market is forecast in the coming years.

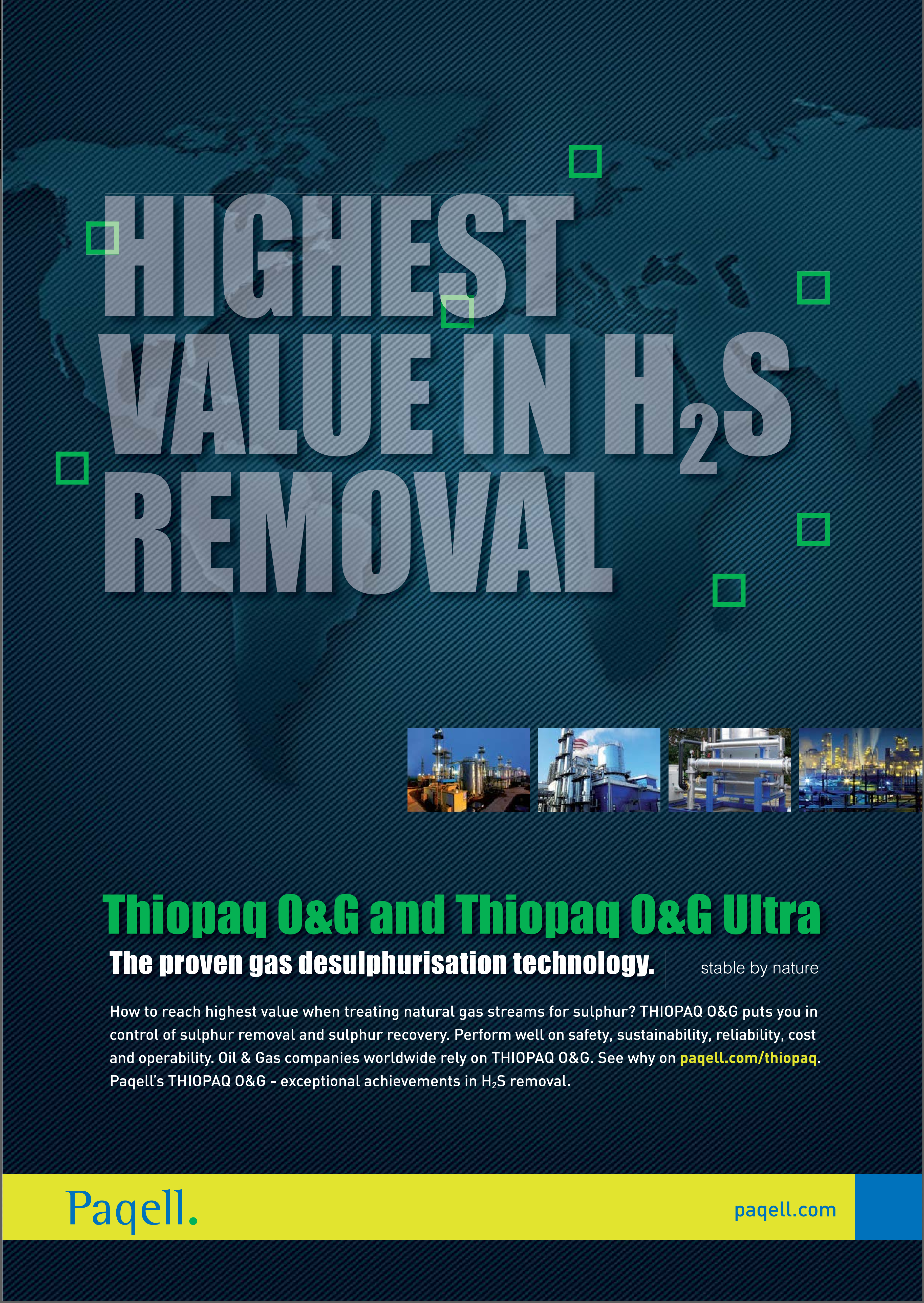
> **"It is easier to grow by buying existing copper mines..."**

Both companies' portfolios are weighted heavily towards operations in Latin America, most notably in Chile and Anglo American also operates the Quellaveco mine in Peru. BHP is the manager of the world's largest copper producing mines, Escondida, while Anglo American holds a 44% stake in the Collahuasi joint venture, the world's third largest copper mine by copper units and second largest by contained copper resources. From a cost standpoint, CRU assess Anglo to be more competitively positioned, in the first quartile, on an All-in Sustaining Cost basis, while BHP sits just above the median, in the third quartile. It is possible that BHP has decided that it is easier to grow by buying existing copper mines rather than developing new ones in the current climate.

There is also the possibility of the combined company becoming a giant in the potash sector by the end of decade. While neither company currently produces potash, both have ambitious plans to build large scale capacity. The Jansen project in Saskatchewan, Canada will be the centrepiece of BHP's potash portfolio, with a planned total capacity of 8.5 million t/a by 2029, making it the largest MOP (potassium chloride) mine in the world. Meanwhile, Anglo-American is constructing the world's largest polyhalite mine at Woodsmith, in the north of England, which it bought from Sirius Minerals in 2020. This mine, with operation planned to begin in 2027, is designed to have a capacity of 13 million t/a of polyhalite ore, although the low potash grade would make this only 1.8 million t/a of K_2O, compared to 5.1 million t/a for Jansen. BHP has described the combined companies' copper and potash assets as "future-facing commodities".

We are currently only at the start of what could be a long process, however. Many people must be convinced, from Anglo-American's shareholders to various regulatory bodies around the world, and it is likely that there would be divestments as part of the deal. Indeed, BHP's proposal was itself conditional on Anglo selling off its South African assets; Anglo-American Platinum (Amplats) and Kumba Iron Ore. But it is potentially the biggest deal that the mining industry has seen for some time, and one with significant knock on effects in the metals and fertilizer sectors.

Richard Hands, Editor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Price Trends

SULPHUR

Sulphur benchmarks firmed around the globe in April. Although availability remains ample, downstream production is expected to rise in the weeks ahead and further upside for prices is expected, at least in the short term. Prices increased the Middle East, Indonesia, India, Brazil, and the Mediterranean. The Middle East spot price was assessed up an average $3/t at $83-88/t f.o.b. The previous low end of the range was no longer considered achievable. The price has climbed 27% since mid-February this year. The benchmark is down 53% from early December 2022, but had climbed 47% from the end of July 2023 to its mid-October average of $110/t f.o.b. before declines set in once again. Chinese buyers returned to the international spot market in late April following weeks of inactivity, lifting c.fr prices.

High stocks in China continued to allowed buyers there to avoid higher offers, with the spot c.fr unchanged at $102-107/t for several weeks before moving up to $107-112/t c.fr for crushed lump and granular cargoes, the highest level since mid-November. The price is 79% lower than in mid-June 2022, but is up 29% from mid-July 2023. It had fallen 29% between mid-October 2023 and the end of January 2024. Chinese sulphur production growth has been the underlying driver of declining import dependence, with supply increasing from 5.6 million t/a in 2016 to 7.5 million t/a in 2020. Chinese sulphur production climbed to 9.44 million t/a in 2022, according to CRU data, up 5.6% year on year from 2021's 8.9 million t/a and up 23% on 2020. Further growth in production is likely to keep Chinese imports below previous highs. China's bans on fertilizer exports have also limited demand for sulphur.

Sulphur port inventories in China decreased to around 2.93 million tonnes in total. The total remains well above the 2022 average of 1.44 million tonnes and the 2023 average of 2.07 million tonnes, as stocks climbed by over 1 million tonnes between mid-June and the end of October in 2023 and have further increased by around 400,000 tonnes since the end of 2023. Chinese buyers are comfortable at a price around $108/t f.o.b., according to local importers. The price remains assessed at $102-107/t c.fr. Domestic phosphate prices, international prices and operating rates all decreased, with the declines having a negative impact on sulphur market sentiment.

Spot prices for sulphur cargoes to Brazil were assessed higher at $115-118/t c.fr. Mosaic reported two 35,000 tonne April cargoes at $115/t c.fr. The origin of the material was not confirmed but supply is building in the US Gulf with refineries coming off turnarounds there. Another purchase by Mosaic at $118/t c.fr was later confirmed. Previous Mosaic buying in March was at $111/t c.fr. Brazil's imports of sulphur for March 2024 decreased 30% year on year to 178,658 tonnes, according to data via Global Trade Tracker (GTT). March imports from the US were down 7% to 80,046 t. Total imports in the first three months of the year were down 18% to 556,772 t, with the US, Saudi Arabia and Russia dominating supply. Imported material from the US in the first quarter reached 320,000 t. Imports from Saudi Arabia in March were up 13% at 43,197 t, with Russian imports in March up nearly sevenfold year on year at 27,500 t. The UAE supplied just 150 tonnes to Brazil in March, down from 73,895 t in the same month a year earlier. The volume from Kazakhstan increased 58% to 26,840 t from 16,948 t. Kuwait was down to nothing from 31,509 t and no tonnes arrived from Qatar in March.

Contract prices for supply of liquid sulphur in northwest Europe in the second quarter of 2024 have been published at wide ranges following a chaotic round of settlements. The price range for Q1 was published at $103.50-123.50/t c.fr Benelux for barge/railcar, with the truckload range at $123.50-153.50/t NW Europe, after settlements were reported at rollovers from 2023 Q4. Some prices were agreed at increases of $10/t from Q1 by one major supplier, sources reported, though the majority were finalised at increases of $30/t by two other major suppliers. Quarterly settlements are usually agreed at consistent deltas across buyers and sellers. The price range for Q2 is published at $113.50-153.50/t c.fr Benelux for barge/railcar, with the truckload range at $133.50-183.50/t CPT NW Europe. Global prices weakened during Q4 and remained soft in early 2024, but tight availability in Europe meant that buyers were unable to achieve a decrease on Q1 contract prices despite price decreases elsewhere for Q1.

The Middle East spot sulphur price was assessed higher at 85-90/t f.o.b., with the previous low end of $78/t no longer deemed achievable. The price has climbed 30% since mid-February this year. With the Middle East celebrating Eid, confirmation of new business was lacking. A sales tender from Muntajat was indicated awarded around $88/t f.o.b. Recent sales of Middle East sulphur to Brazil around $110-111/t c.fr would likely net back in the upper $70s/t f.o.b. Qatar's Muntajat, the UAE's ADNOC, and Kuwait's KPC all posted official monthly contract prices for April at $83-85/t f.o.b., up from $78/t f.o.b. for March and $69/t f.o.b. for February. Indian sulphur prices were assessed higher at $105-108/t c.fr, Based on higher values from the Middle East. An importer on the east coast recently bought 38,000-39,000 t sulphur ex-Qatar at $105-108/t c.fr, local sources report. Demand remains relatively lacklustre due to temporary phosphate shutdowns, with restarts anticipated in the coming month.

Morocco's OCP imported 1.08 million tonnes of sulphur in the first two months of 2024, up 13% year on year, according to data via Global Trade Tracker (GTT). Kazakhstan was the number one source of sulphur for the period with 568,240 t, up 272%. This was followed by the UAE with 255,669 t, down 43%. OCP and Adnoc have a long-term sulphur supply agreement. Supply from Saudi Arabia was down 21% at 139,269 t. Imports from Qatar and Kuwait climbed from nothing to 50,492 t and 42,000 t, respectively. Morocco's imports for 2023 climbed 3% year on year to 6.45 million t/a after imports for 2022 decreased 7% year on year to 6.27 million t/a, representing the lowest annual imports since 2018. Morocco's annual imports for 2021 were down 7% year on year to 6.72 million t/a after imports for 2020 increased 8% year on year to a new record of 7.24 million t/a. Imports are expected to increase further over the coming years as sulphur burner capacity increases and downstream fertilizer production ramps up.

SULPHURIC ACID

Sulphuric acid spot market activity was scarce in late April, while some market participants voiced more bearish sentiment on Asia/Pacific markets, though Europe/Atlantic markets remained well-supported. Spot prices for sulphuric acid exports from China were assessed steady at $20-35/t f.o.b., though some traders expected prices to decrease amid limited opportunities for higher FOBs. The average price of $27.50/t f.o.b. is up from -$5/t f.o.b. in early August 2023 but is well below its 2022 peak of $150/t f.o.b. in mid-June. It has fallen from $42.50/t f.o.b. in October 2023. One deal was reported in mid-January for February loading around $15/t f.o.b., while another source said two sales were subsequently concluded around $10/t f.o.b. More recently, a sale had been concluded last month in the mid-$20s/t f.o.b., followed by another deal early this month in the low $30s/t f.o.b., according to sources.

Some sources said pressure was building on China producers as phosphate markets were weakening and downstream production was being cut, while some smelter maintenances were coming to an end. Given current c.fr prices in key import destinations along with current freight rates, netbacks above the $10s/t f.o.b. appear challenging to most destinations aside from North Africa and possibly Saudi Arabia. Traders suggested a lack of available vessels for 30,000 t lots was also limiting any potential for fresh business.

Resistance from producers to lower export prices emerged partly as a result of relatively higher prices available on domestic sales. Domestic acid prices climbed further after Chinese New Year holidays, partly due to expectations of seasonal peak demand for fertilizer in Q2 and the easing of fertilizer export restriction, and partly due to copper smelter maintenance brought forward to March and April due to tighter concentrate supply and lower TC/RCs.

Spot prices for exports from northwest Europe were also assessed steady at $60-75/t f.o.b., leaving the mid-point at its highest level since October. Sentiment was uniformly bullish for these prices, at least for Q2, as tight availability keeps prices supported. Prices are still 76% lower than they were in June 2022, but are up 575% from early August 2023 and have climbed 69% since February this year. Demand from Morocco has been soaking up most available spot export volumes on offer, leaving the market firmer than expected both for European supply and exports from the Far East. Still, export markets such as Brazil and the US Gulf could still provide netbacks to Europe within the published f.o.b. range.

Spot prices for sulphuric acid cargoes to the US Gulf were assessed up at $105-115/t c.fr, up from $100-110/t based on latest indications, though some argued for lower levels. At least one recent deal was concluded around the upper end of the range, though one source argued that this was not representative and said recent deals elsewhere remained below $100/t c.fr. One supplier also indicated the previous range was still representative. Still, current Europe spot f.o.b. prices suggest that anything below the low end of the new range would be unlikely on new spot business. Acid import prices are unattractive compared with sulphur. The Tampa contract for 2024 Q2 was settled up $12/lt, though this still equates to acid prices well below the published v.fr. Domestic acid prices vary greatly by region, but contracts tend to be more linked to sulphur prices. The US Gulf import market for acid in recent years has seen limited spot activity, with volumes mostly on contracts.

Spot prices for full cargoes of acid to India were assessed steady at $65-75/t c.fr, up from $55-60/t, though buyers mostly continued to resist the higher prices. Major end users said they had limited demand for now and were resisting high offers. Traders said offers were mostly from the mid-$70s/t c.fr upwards. There were reports that IFFCO had purchased around $70/t c.fr, but the buyer said it had not bought international spot acid recently. Indian acid demand is decreasing this year due to new domestic supply, while sulphur is a more attractive alternative as last spot deals were concluded below $100/t c.fr India and one tonne of sulphur yields three tonnes of acid as well as energy credits. Sulphur prices have increased, but India buyers could still likely source spot cargoes around $110/t c.fr. Demand from CIL has slowed as it already started new sulphur-burner capacity as of late August 2023. The plant, which was announced in November 2021, is set to increase the company's acid production by around 500,000 t/a and is reportedly running at full capacity. IFFCO in Paradip inaugurated its new acid plant, with capacity around 2,000 t/day, on 20 February. In addition, Adani Group in late March commenced operations at its new smelter with 1.5 million t/a sulphuric acid capacity.

Price Indications

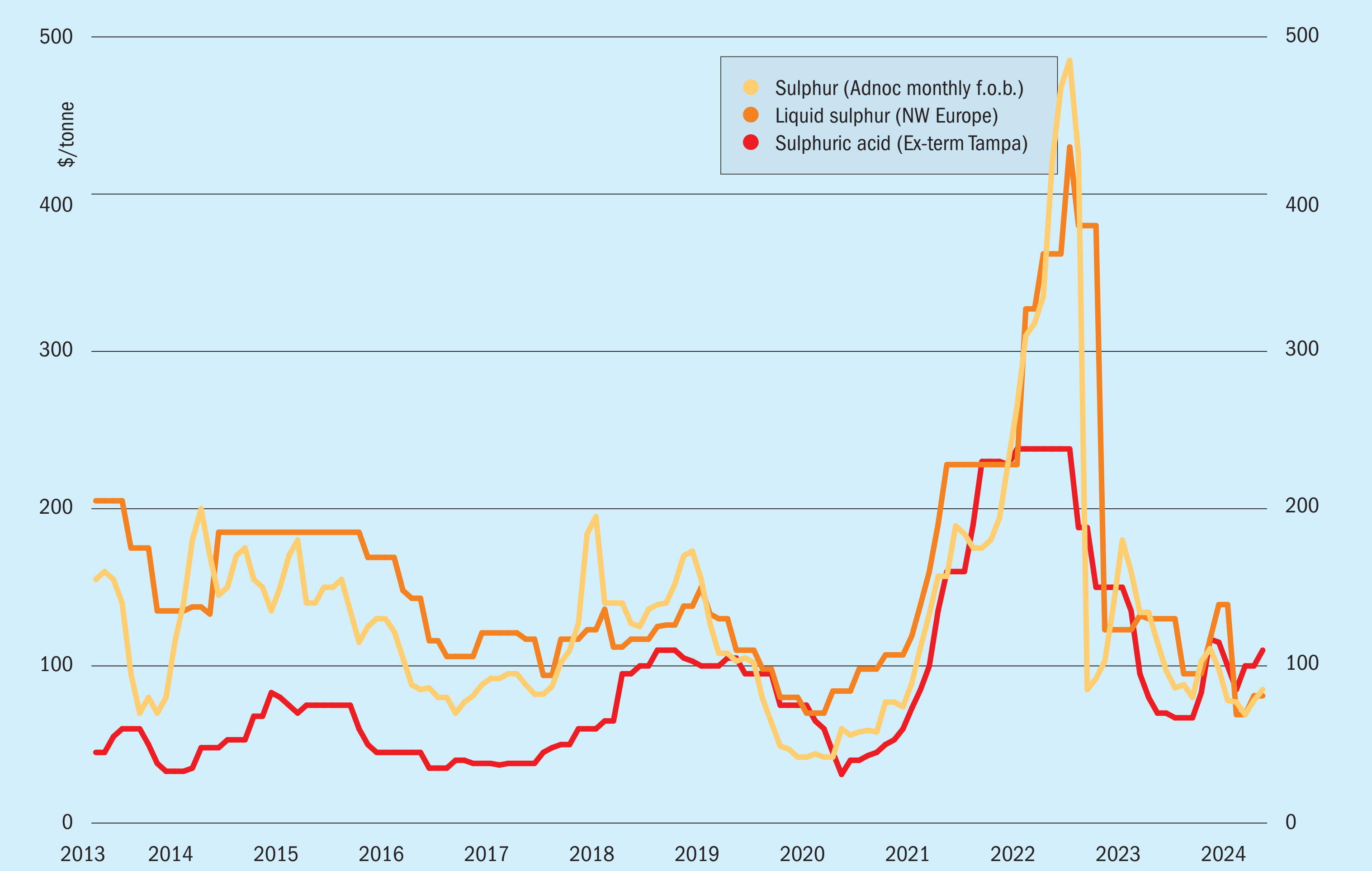
Table 1: **Recent sulphur prices, major markets**

Cash equivalent	December	January	February	March	April
Sulphur, bulk ($/t)					
Adnoc monthly contract	90	77	69	78	85
China c.fr spot	99	90	97	105	110
Liquid sulphur ($/t)					
Tampa f.o.b. contract	102	69	69	81	81
NW Europe c.fr	139	139	139	138	158
Sulphuric acid ($/t)					
US Gulf spot	100	85	100	100	110

Source: various

Market Outlook

Historical price trends $/tonne



Source: BCInsight

SULPHUR

- Downstream phosphate production is expected to climb, with further sulphur price recovery expected. Overall, global demand remains lacklustre as downstream demand has yet to increase substantially in key markets and sulphur availability from most origins is ample.
- Molten sulphur availability in Europe is set to remain tight throughout the year due to decreased European production, despite weakness in the downstream caprolactam sector. Lower production is partly the result of increasingly sweeter crude feedstocks being used by refineries as Red Sea logistics issues and a ban on crude imports from Russia limit the availability of sour inputs. In addition, availability from the Grossenkneten gas fields in Germany is expected to continue decreasing year on year as reserves are depleted.
- Chinese DAP producers attempted to intervene to stem the flow of price declines this week by setting a price floor of \$530/t f.o.b. Still, offers are already indicated at this level, and traders continue to offer short in Indian DAP tenders. Further declines across most markets seem likely in the weeks ahead.
- **Outlook**: the market tone appears to be turning less bullish, with many traders pegging high-end prices lower and most less certain of potential price rises. Some market participants are concerned that weakness in phosphate markets may lead to weaker production and therefore lower demand for sulphur. Phosphate production rates in China have already been cut over the past week.

SULPHURIC ACID

- Global spot sulphuric acid prices are likely to remain relatively firm over the coming weeks. European smelter maintenance, along with strong Moroccan demand, will add support to some benchmarks. Morocco's imports of sulphuric acid for January-February 2024 jumped to 385,260 t from only 63,439 t a year earlier, according to data via Global Trade Tracker (GTT). China was the lead supplier over the two months with 92,549 t, followed by Bulgaria with 75,606 t and Turkey with 58,173 t.
- Downstream production rates remain relatively weak overall and domestic production is increasing in some key import markets. Affordability relative to downstream markets is broadly acceptable, but is the worst it has been for some time and looks particularly bad when compared with upstream sulphur.
- Given current c.fr prices in key import destinations along with current freight rates, netbacks above the \$10s/t f.o.b. on Far East supply appear challenging to most destinations aside from North Africa. Latest business to key import markets such as Indonesia and India net back well below this, while spot demand from Chile is non-existent. There is also little potential for upside in c.fr prices in these markets, as domestic availability in India and Indonesia is growing, while acid affordability is an issue.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

WORLD

Red Sea, Panama cause freight rate hikes

Over the last six months, climate and geopolitical events have disrupted seaborne trade. A record drought in Panama and the unprecedented intensity of attacks on commercial ships by the Houthi rebels in the Red Sea are straining the freight market. Almost 150 ships have been targeted along the latter trade route since the first attack was registered to a non-commercial ship last year.

While vessels in the Panama Canal need to wait for longer to cross it, oil and shipping majors have stopped their vessels from crossing along the Red Sea; and are routing them away from the region. The alternative journey around the Cape of Good Hope in Southern Africa adds around 8.5 days to the journey from East Asia to Europe.

As a result, ship transits through the Panama Canal, Bab el-Mandeb Strait and Suez Canal are falling rapidly, with daily crossings reducing by almost 30%, 65% and 45% from year to date, respectively. With vessel transit along the Panama and Red Sea trade routes amounting to almost 20% of seaborne trade, recent events are already impacting transit volumes and freight costs. The Baltic Dry Index (BDI) has risen more than 30% in March since the Houthi attacks to commercial ships began in November, while the corresponding increase for the Global Container Freight (FBX) has been 143% so far.

As seaborne trade accounts for more than 80% of total global trade, these disruptions have potentially important spillovers to the world economy. In particular, trade in the Red Sea accounts for around 15% of global seaborne trade, and is important for oil and gas, dry bulk and container shipping.

CRU's view is that the nature of current disruptions to the seaborne market is short-term, and trade fundamentals will shape the long-term direction of freight rates. World volume trade growth remains weak and has shown signs of stagnation over the last 12 months. As the weather outlook begins to improve in Panama, subdued trade is expected to weigh down on freight rates. For instance, the Panama Canal Authority has recently softened the restrictions on the number of ships that can cross the Canal, starting in January. Although the BDI fell briefly in January back to October levels, it is trending up again as more bulk carriers have been targeted by the Houthi rebels in the Red Sea.

The situation in the Red Sea remains fluid, but any de-escalation will likely see dry bulk freight rates dropping further and container costs limiting upside movements. However, in a severe downside scenario, we do not rule out renewed pressure on freight rates if the conflict in the Red Sea extends or escalates, leading to higher security risks for shipping majors. An intensification of the Red Sea conflict will result in higher container, dry bulk freight rates and could ultimately lead to higher energy prices.

The global supply chain crisis of 2021-22 saw freight rates soar and queues of ships form offshore major ports. This contributed to the surge in producer prices and consumer price inflation in the US, Europe and other countries. The Global Supply Chain Pressure Index (GSCPI) estimated by the Fed has shown a strong correlation with global PPI inflation over the past few years. Renewed disruptions to supply chains and/or higher energy prices could again cause producer prices to rise which will, in turn, put upward pressure on consumer prices, squeezing consumer real incomes and potentially delaying any easing in monetary policy. This threat is probably greatest for Europe, given the importance of the Red Sea route to West-bound container traffic from East Asia. But higher energy prices would affect most countries. However, a return to the inflation rates of 2021-22 is unlikely in all but a worse-case scenario. ■

INDIA

Investigation into insoluble sulphur imports

The Indian government has launched an antidumping investigation into imports of insoluble sulphur originating in or exported from China and Japan from April 1st 2020 to the end of December 2023. The probe follows a petition by Oriental Carbon and Chemicals Ltd, alleging dumping of the product from the two countries, the directorate general of trade remedies (DGTR) of the Indian commerce ministry said.

In a statement DGTR said: "The applicant has provided prima facie evidence with respect to injury suffered by the domestic industry because of the dumped imports… The volume of the subject imports from the two countries has increased in both absolute and relevant terms… price depression caused by the dumped imports has been preventing domestic industry from increasing its prices to recover the full cost and achieve rate of returns."

Insoluble sulphur is a polymeric form of sulphur which is insoluble in carbon disulphide, and is generally used as a vulcanisation agent in rubber applications, to improve quality, wearability and resistance to fatigue and ageing. Interested parties have 30 days to submit information relating to the investigation.

NETHERLANDS

New venture to decarbonise aviation fuels

Sasol and Topsoe have announced the launch of their joint venture, Zaffra. Based in Amsterdam, the Netherlands, Zaffra is will focus on the development and delivery of Sustainable Aviation Fuel (SAF).

Under the leadership of Jan Toschka, the appointed CEO of Zaffra, the company hopes to make significant contributions to reducing carbon emissions in the aviation industry, by combining Sasol's experience in asset development, plant construction, and robust operating and technology expertise with Topsoe's carbon emission reduction technologies.

Jan Toschka remarked: "Leading Zaffra in this crucial mission is my privilege. The growing demand for SAF will require multiple pathways and Zaffra is in a unique position to become a relevant player in this market. Backed by Sasol and Topsoe's legacies, our offer combines leading technologies with decades of experience in building and running production assets. We recognise the differences in each opportunity. That's why I am convinced there is tremendous growth potential for Zaffra, being agile and creative, whilst recognising it is essential to form partnerships and to collaborate with all stakeholders."

Roeland Baan, CEO of Topsoe, added: "We're very pleased to reach this important milestone with our joint venture with Sasol. With aviation being responsible for 2-3% of global carbon emissions, Zaffra will create significant value for the aviation industry and society by bringing alternative fuels to the market that can help reduce these emissions."

SAUDI ARABIA

Aramco awards Fadhili gas plant expansion contracts

Aramco has awarded engineering, procurement and construction (EPC) contracts worth $7.7 billion for a major expansion of its Fadhili Gas Plant in the Eastern Province of Saudi Arabia. The project is expected to increase the plant's processing capacity from 2.5 to up to 4 billion scf/d. This additional 1.5 billion scf/d of processing capacity is expected to contribute to the company's strategy to raise gas production by more than 60% by 2030, compared to 2021 levels. The Fadhili Gas Plant expansion, which is expected to be completed by November 2027, is also expected to add an additional 2,300 t/d to sulphur production.

Wail Al Jaafari, Aramco Executive Vice President of Technical Services, said: "The award of these contracts reflects Aramco's goal to increase supplies of natural gas, help efforts to reduce greenhouse gas emissions, and free up more crude oil for value-added refining and export. Together with leading international companies, we are advancing our goal to increase gas production. The expansion also supports our ambitions to develop a lower-carbon hydrogen business, while associated liquids from gas are an important feedstock for the petrochemical industry."

The Fadhili gas processing complex, 30 km southwest of the Khursaniyah gas plant, was commissioned in early 2020 and currently has the capacity to process 2.5 billion scf/d of natural gas. It processes sour gas from the offshore Khursaniyah oil field and the offshore Hasbah non-associated gas field.

CHINA

West Sichuan gas field begins operations

China Petroleum & Chemical Corporation (Sinopec) has announced that the West Sichuan gas field has begun operations. The new gas field, with an annual output of 2 billion cubic meters of natural gas and 130,000 t/a of sulphur, will supply gas for southwestern China and regions along the Sichuan-East pipeline.

The West Sichuan Gas Field, designed and built by Sinopec, features integrated gas extraction and desulphurisation processes, ensuring closed-loop desulphurisation and efficient green production. The gas field boasts natural gas sulphur recovery rates of over 99.9% and produces gas that meets national standards while ensuring zero wastewater discharge. Additionally, it implements smart technology to enhance safety, risk control, and operation management, reducing carbon emissions.

CANADA

Study tracks sulpholane presence in ground water

A study by the Universities of Guelph and have identified 'plumes' sulpholane contamination of ground water, particularly in Alberta. Sulpholane is used to remove hydrogen sulphide from sour gas at sites across Alberta. According to a 2008 report by WorleyParsons Komex for Shell Energy Canada, sulpholane was first detected in groundwater in the 1980s and, in 1994, a monitoring program was put in place. A regional sulfolane monitoring program, which began in 1998, detected sulpholane in off-site groundwater near Shell's Waterton facility. By 2007, Shell began actively working to remove sulpholane, building on a pilot project conducted in 2003 and 2004.

Dr. Erica Pensini, associate professor at Guelph's school of engineering, says researchers are tracking how it is spreading in groundwater, work that could help identify risks to supplies of potable water. She says the study suggests that naturally-occurring sulphates react with sulpholane in groundwater and its ability to "mix more thoroughly with water." Research into whether or not it poses a risk to human health is still ongoing, Pensini says, but some companies have already raised concerns. Shell Canada says it is aware of Pensini's research and has been working with the University of Guelph since 2022.

IRAQ

Baker Hughes to collaborate on sour gas flaring reduction

Baker Hughes has signed a memorandum of understanding (MoU) with Iraq's Halfaya Gas Company (HGC) to collaborate on a gas flaring reduction project at the Bin Umar gas processing plant in southeastern Iraq. The MoU signing took place in Washington, DC, in the presence of Mohammed Shia' Al Sudani, prime minister of Iraq, during the his official visit to the United States to strengthen bilateral ties and facilitate new private sector initiatives, including enhancing the resilience and sustainability of Iraq's energy ecosystem.

Baker Hughes and HGC will leverage Baker Hughes' technology and experience in developing and implementing deflaring solutions, including the supply of critical turbomachinery and process equipment, a pre-front end engineering and design (FEED) study of modular gas processing skids, and supporting the project's selected FEED contractor in developing the plant design.

HGC is a special purpose company, owned by Raban Al Safina for Energy Projects (RASEP), established to deliver a new gas processing plant to serve the onshore Bin Umar field. In late 2023, the Iraq Ministry of Oil awarded a build-own-operate-transfer contract to HGC. The field produces 40,000 bbl/d of oil and over 150 million scf/d of associated sour gas, currently flared or used untreated as a fuel gas for a nearby power plant. HGC's Bin Umar gas plant will convert waste gas into treated dry gas, Liquefied Petroleum Gas (LPG) and condensate for domestic use and export.

KAZAKHSATAN

Kazakhstan increases its claims over Kashagan

Kazakhstan has laid additional claims against the international companies operating the Kashagan oil field. The North Caspian Operating Co., the joint venture overseeing the project, is a consortium of major international companies including Eni SpA, Shell Plc, Exxon Mobil Corp., and TotalEnergies SE. Kazakhstan's government was already involved in a $15 billion suit over production costs at the field, which has endured a number of cost overruns, delays and operating issues, but has now added another reported $138 billion claim for lost revenue, calculated by multiplying oil production lost due to delays by current prices.

Discovered in 2000, Kashagan contain between 9 - 13 billion barrels of recoverable oil, according to NCOC, but associated gas is highly sour and must be treated at an onshore processing plant. Coupled with the harsh operating environment, the project has been a technically difficult one. Kashagan currently produces around 400,000 bbl/d of oil, against an originally envisaged output of 1.5 million bbl/d, which may explain where some of the Kazakh numbers of come from.

Sulphuric Acid News

NAMIBIA

Sinomine buys Tsumeb smelter

Dundee Precious Metals says that it has sold the Tsumeb smelter, including all associated assets and liabilities, to China's Sinomine Resources Group for $49 million. Sinomine Resources Group is a Chinese company founded in 1999. Its main business and operations cover four segments: EV-lithium material development and utilisation, rare and light minerals (caesium and rubidium) development and application, geo-tech services and mining property development. Dundee Precious Metals will transfer all assets debt-free and cash-free, subject to normal working capital adjustments. The transaction is subject to customary closing conditions, including approval under the Namibia Competition Act and approvals required from Chinese regulatory authorities for overseas investments, and is expected to close in Q3 2024.

David Rae, Dundee Precious Metals president and CEO, said the sale of the Tsumeb smelter is consistent with the company's strategic objective of focusing on gold mining assets and simplifying their portfolio in the future. "We are extremely proud of the investments that we have made to transform Tsumeb's operational and environmental performance into a specialised custom smelter with a highly skilled workforce," Rae said. He thanked Namibia's government, the Tsumeb community and our employees for their support over the past 13 years. "We will work closely with Sinomine to ensure a smooth transition to support a successful future for the operation and its stakeholders."

Dundee acquired the smelter in 2010 to secure a processing outlet for the complex concentrate produced by the company's Chelopech mine in Bulgaria. With developments in the global smelting market and changes in the quality of the Chelopech concentrate, Dundee Precious Metals can place its Chelopech concentrate at several other third-party facilities, providing secure and reliable processing alternatives at favourable terms.

UZBEKISTAN

Almalyk places new smelter order

JSC Almalyk Mining and Metallurgical company (MMC), Uzbekistan's main copper producer, has signed an agreement with Metso for process technology deliveries for the company's new copper smelter investment in Uzbekistan. The majority of equipment package contracts under the agreement are anticipated to be signed this year. The frame agreement is a continuation of Metso's and Almalyk MMC's contract signed at the end of 2022 for the design and basic engineering work for the copper smelter. The planned production capacity of the new smelter, which will be integrated with the company's existing operations in Almalyk, is 300,000 t/a of copper cathode and 1.8 million t/a of sulphuric acid.

"We are very pleased to be selected as the strategic partner for Almalyk MMC's smelter project," said Piia Karhu, President of Metso's Metals business area. "Metso will provide Almalyk MMC with the most advanced sustainable Planet Positive technology for their copper refining processes," she added.

CHINA

Metso to supply technology for a battery-grade nickel project

Metso has been awarded an order to deliver solvent extraction technology for a nickel plant in China. The company said that the value of the order was in the range of EUR 15-20 million. Metso's scope of delivery consists of the VSF® X solvent extraction process for the production of a battery-grade nickel sulphate solution. In addition, Metso will deliver multiple polishing filters, as well as spare parts and advisory services. Prior to this order, Metso conducted the concept study and process test for the project. Basic engineering for the project is ongoing.

SWEDEN

New duplex tube for acid environments

Alleima has introduces new advanced super-duplex tube tailored for acids. SAF™ 3006 is a high-alloy duplex stainless steel tailored to enhance corrosion resistance in acidic and caustic environments. The new alloy, an upgrade to traditional super-duplex stainless steels, adds to the company's growing duplex portfolio. The main application is heat exchanger tubing exposed to hydrochloric, sulphuric, formic or other acids. Duplex grades, with a 50-50 austenitic-ferritic structure, offer more than twice the strength of standard stainless steels and superior corrosion resistance. The chemical composition involves a high chromium content of 30% and a molybdenum level of 3.2% to maintain good structural stability and balancing of the alloying elements.

"We're thrilled to welcome this new super duplex to our expanding duplex family. It provides that 'missing duplex tool' for customers battling acids in heat exchangers, giving them that extra edge. With the addition of SAF™ 3006, we strengthen our presence in duplex materials tailored for acidic corrosion, where we see strong growth potential. Applications may include caustic evaporators, acid coolers and evaporators," saidEduardo Perea, Market & Product Manager EMEA at Alleima Tube Division.

MOROCCO

OCP joint venture on green fertilizer production

OCP Group has signed a joint venture agreement with green energy, metals and technology company Fortescue Ltd. The 50-50 partnership aims to supply green hydrogen, ammonia, and fertilizers to Morocco, Europe, and international markets. It includes the potential development of manufacturing facilities and an R&D hub to advance the rapidly growing renewable energy industry in Morocco. Fortescue and OCP Group, leaders in iron ore and phosphate respectively, are united in their goal to reach their emissions reductions targets. They share a common vision for the pivotal role of green hydrogen and ammonia in forging a sustainable future globally.

The partners have laid out proposed plans for four cornerstone projects in Morocco: (i) large-scale integrated green ammonia and green fertilizer production capacity, including renewables, energy generation, electrolysis, ammonification and fertilizer production; (ii) manufacturing of green technology and equipment; (iii) a research and technology hub, located alongside Mohammed VI Polytechnic University (UM6P) near Marrakech, to bolster the JV, the ecosystem and other

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

players, with research in renewable energy, green hydrogen and minerals processing; and (iv) collaboration of corporate venture capital funds to drive investment in key technology advancements.

Mostafa Terrab, Chairman and CEO of OCP Group, said: "Our strategic partnership with Fortescue is a testimony to our joint commitment to decarbonisation, driving the development of cutting-edge facilities and delivering competitive renewable energy, products and technology."

Fortescue Energy CEO, Mark Hutchinson added: "OCP and Fortescue are fully aligned on their ambitions. We intend to create in Morocco one of the world's leading integrated renewable energy, manufacturing, and technology enterprises, supplying not only a large and growing domestic market for green products, but also with the potential to supply other countries and continents. This is a very significant moment for Fortescue, OCP Group and Morocco as we help revolutionise the way we power our planet and diversify the world's future energy security, while creating thousands of jobs and industries in Morocco."

GERMANY

New scrubber pilot plant to develop gas cleaning processes

Metso has installed a fully automated multi-purpose scrubber pilot plant at its R&D centre in Frankfurt. The new plant will be used for developing and optimizing gas cleaning processes. The first focus will be on the development of simultaneous scrubbing of SO_2 and NOx at low temperatures.

"This investment will put Metso at the forefront of innovation in the field of emission reduction and allow us to optimize commercial-scale gas cleaning plants. The test facility supports the increasing customer demand for solutions to remove NOx at low temperatures in the presence of SO_2. We are further strengthening these technologies that our customers find extremely valuable," said Leif Skilling, Director, PG Gas Cleaning at Metso.

The pilot plant features modern online sensors for the measurement of an extensive set of gas and liquid properties. The process control system will allow the development of reliable process models for designing industrial-sized plants and will support further process optimization and advanced digitalisation solutions.

RUSSIA

PhosAgro acid output up 5%

In its most recent results, PhosAgro said that production of agrochemicals during 1Q 2024 increased by 6.9% year-on-year to 3.0 million tonnes. This growth was driven mainly by a 9.2% increase in the production of phosphate-based fertilizers and feed phosphates, to 2.26 million tonnes. The production of key feedstocks in 1Q 2024 rose 3.6% year-on-year, mainly due to a 5.4% increase in the production of phosphoric acid and a 4.7% increase in the production of sulphuric acid. Production of phosphoric acid, the main feedstock for making phosphate-based fertilizers, rose to nearly 900,000 tonnes due to earlier upgrades to production units and more efficient equipment utilisation. Sulphuric acid production rose to 2.175 million tonnes. This increase was due to the improved operating efficiency of the sulphuric acid production unit in Cherepovets and the commissioning of a new sulphuric acid production facility in Balakovo in late 2023.

FINLAND

Metso expands solvent extraction range

Metso has expanded its solvent extraction offering with a wider capacity range and improved features. The company is also introducing the VSF® X solvent extraction plant with extended scope. Part of Metso's Planet Positive offering, VSF X allows copper, cobalt, nickel and manganese producers, among others, to purify desired metals from the leach solution in a safe and sustainable manner. The technology can also be used in battery black mass recycling processes.

"Solvent extraction is a crucial step in the production of essential battery metals and is gaining wider ground in hydrometallurgy applications. This is driven by the growing demand for higher purity metals and the increasing use of minerals to empower the energy transition. Our customers are seeking reliable and environmentally sound production processes with lower plant life cycle costs. Metso's VSF® X solvent extraction technology meets these needs and enables an efficient and economical solvent extraction process step for various ore bodies and recycled battery black mass," explains Olli Siltala, Product Manager for the VSF® X solvent extraction plants at Metso.

KAZAKHSTAN

New uranium processing prokect

Inkai, a joint venture by Kazatomprom (60%) and Canadian Cameco (40%), has announced its plan to build a uranium ore processing ('affinage') facility with a capacity of 4,000 t/a U_3O_8. Under the project, the construction of a new affinage facility, a power substation with a diesel generator and the reconstruction of the existing pregnant solution processing plant are expected. The project starts this year and will be completed in 2025. The company plans to build all these new facilities in parallel with uranium production and processing. Once they are ready, these facilities will be integrated into the current utility systems and the power grid.

To produce uranium at the Inkai mine, the joint venture relies on in-situ sulphuric acid leaching that involves leaving the ore where it is in the ground and recovering the minerals from it by dissolving them and pumping the pregnant solution to the surface where the minerals can be recovered. Consequently, there is little surface disturbance and no tailings or waste rock generated. However, Kazatomptom has faced production restrictions in recent months due to shortages of sulphuric acid.

CANADA

Pilot plant for production of merchant grade phosphoric acid

Fox River Resources Corporation says that it has successfully started up a pilot plant for converting phosphate concentrate to high quality merchant grade phosphoric acid (MGA) using the JESA Technologies hemi dihydrate ("HDH") process. Efficiency (P_2O_5 recovery) at the pilot unit is high and above 99%. Sulphuric acid consumption used in the phosphate acidulation process was 2.46 tonnes, basis 100% H_2SO_4 per tonne of P_2O_5. This is lower than most sedimentary deposits and produces an economic advantage due to lower sulphuric acid consumption.

INDIA

Start-up for new copper smelter

Kutch Copper, a subsidiary of Adani Enterprises Ltd, says that it has commissioned the first phase of its new $1.2 billion greenfield copper refinery at

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Mundra in Gujarat. The first phase of the facility that will produce 500,000 t/a of refined copper has started operations and full-scale capacity of 1.0 million t/a is expected by 2029, by which time it will be the world's largest single location custom smelter.

India's per capita copper consumption is estimated around 0.6 kg compared to the global average of 3.2 kg. India's drive towards clean energy systems, increasing penetration of electric vehicles and a host of associated applications are expected to double the domestic copper demand by 2030.

"With Kutch Copper commencing operations, the Adani portfolio of companies is not only entering the metals sector but also driving India's leap towards a sustainable and aatmanirbhar (self-reliant) future," said Gautam Adani, Chairman of the Adani Group. "Our speed of execution in this ambitious, super-sized project underscores our commitment to take India to the forefront of the global copper sector... When (fully) commissioned, our modern smelter will set new benchmarks in copper production, with an enhanced thrust on innovative green technology."

The smelter is also expected to help offset India's imports of sulphuric acid, which currently stand at approximately 2 million t/a. The plant will produce 1.5 million t/a of sulphuric acid, and 250,000 t/a of phosphoric acid.

INDONESIA

Antam to start building new HPAL plant next year

State-controlled mining company Aneka Tambang (Antam) says that it will launch the construction of two nickel processing facilities next year under its partnership with China's Ningbo Contemporary Brunp Lygend Ltd (CBL) as part of Antam's deal with CBL to develop an Indonesian production hub for electric vehicle batteries and ultimately EVs themselves. The companies are conducting feasibility studies for a rotary klin electric furnace (RKEF) plant to process nickel into crude metal and a high-pressure acid leach (HPAL) plant to extract the material used in EV batteries from nickel ores.

UNITED STATES

More efficient lithium extraction

Chemists at the US Department of Energy's Oak Ridge National Laboratory say that they have developed a more efficient way to extract lithium from waste liquids leached from mining sites, oil fields and used batteries. They demonstrated that a common mineral can adsorb at least five times more lithium than can be collected using previously developed adsorbent materials.

"It's a low-cost, high-lithium-uptake process," said Parans Paranthaman, an ORNL Corporate Fellow and National Academy of Inventors Fellow. He led the proof-of-concept experiment with Jayanthi Kumar, an ORNL materials chemist with expertise in the design, synthesis and characterization of layered materials. "The key advantage is that it works in a wider pH range of 5 to 11 compared to other direct lithium extraction methods," Paranthaman said. The acid-free extraction process takes place at 140C, compared to traditional methods that roast mined minerals at 250C with acid or 800 - 1,000 C without acid.

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47 48 49 50 51 52

People

Desmond Long has been appointed as Chief Executive Officer of BASF Shanshan Battery Materials Co., Ltd effective April 1, 2024. In his new role, Desmond will lead the business management of the company.

"BASF Shanshan Battery Materials has established a strong position in the lithium- ion battery materials market as a reliable supplier to our customers, and is poised to further expand our success in the field of battery materials," said Desmond Long. "We are committed to continue the journey of innovative, high-quality and low-carbon footprint products and work tirelessly to further create value for our customers and partners."

BASF Shanshan Battery Materials is a joint venture formed by BASF and Shanshan in 2021 and is majority owned by BASF. It has four sites in Hunan and Ningxia, China, with more than 1,400 employees. BASF Shanshan Battery Materials has a strong position in the battery materials value chain, especially in China.

Long has over 25 years of professional experiences in international business management, sales management, supply chain management, key account management and product marketing in various Asian countries, including China. He has extensive experience in the engineering plastics and performance materials markets especially for automotive, consumer electronics and construction industries. He also holds a bachelor's degree in Business Administration (International Business).

Kuwait Integrated Petroleum Industries Company (KIPIC) said in a post on X, formerly Twitter, that chief executive **Waleed Al Bader**, who had led the company since 2021, is stepping down. There has been no news about a successor at time of writing. Al Bader's was instrumental in the development of the giant Al Zour refinery, which came online in late 2022, leading Kuwait to become a major exporter of refined products, especially very low sulphur fuel oil for shipping. Kuwait's oil exports hit a record high of about 720,000 tonnes (158,000 bbl/d) in February. Al Bader, a veteran of Kuwait's energy sector, had previously also served as chief executive of the Kuwait National Petroleum Company, which he left in 2022.

Gary Stanley, former Director of the Office of Critical Minerals and Metals at the US Department of Commerce, has joins the First Phosphate Advisory Board. Stanley has more than 40 years' experience with the Department of Commerce in Washington, DC, serving under every U.S. President from Ronald Reagan to Joe Biden. During his tenure, he worked with both public and private sector stakeholders to strengthen American supply chains and to enhance US global competitiveness in critical minerals, metals, chemicals, and other materials industries.

Stanley was lead author of the 2019 US Federal Critical Minerals Strategy which became the foundation for the U.S. Government's critical mineral supply chain prerogatives. This initiative also led to the creation of the 2019 USA-Canada Critical Minerals Working Group which has contributed to the advancement of many critical minerals projects involving American and Canadian companies.

"Mr. Stanley shares our vision of deep commitment to a North American battery supply chain and has many years of experience in multilateral cooperation in crucial minerals and battery supply chains," said John Passalacqua, CEO of First Phosphate. "Gary brings a wealth of knowledge and insights and an extensive global network of government, industry, and trade expertise to our team."

"It is a privilege to share in First Phosphate's commitment to the development of a critical piece of the North American lithium iron phosphate ("LFP") battery supply chain," said Mr. Stanley. "Together, Canada and the United States can achieve success in the globally-competitive battery and long-term energy storage sectors. This can be accomplished through respect for environmental standards and with benefit to rural and indigenous communities."

Calendar 2024

MAY

20-23
Middle East Sulphur Conference 2024, ABU DHABI, UAE
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

JUNE

7-8
46th Annual International Phosphate Fertilizer & Sulfuric Acid Technology Conference, CLEARWATER, Florida, USA
Contact: Michelle Navar, AIChE Central Florida Section
Email: vicechair@aiche-cf.org
Web: www.aiche-cf.org

13
European Sulphuric Acid Association Spring Assembly, COPENHAGEN, Denmark.
Contact: Francesca Ortolan, European Sulphuric Acid Association (ESA)
Tel: +32 499 21 12 14
Email: for@cefic.be

SEPTEMBER

1-5
Sulphuric Acid Plants Round Table, PUERTO VARAS, Chile
Contact: Hotlec ltda, San Felipe, Chile
Tel: +56 34 251 5557
Web: https://mesaredondachile.com/en/holtec-round-table-2024-welcome

9-13
31st Annual Brimstone Sulphur Symposium, VAIL, Colorado, USA
Contact: Mike Anderson, Brimstone STS,
Tel: +1 909 597 3249
Email: mike.anderson@brimstone-sts.com

11-12
Oil Sands Conference & Trade Show, CALGARY, Alberta, Canada
Contact: Bruce Carew, EventWorx
Tel: +1 403 971 3227
Email: marketing@eventworx.ca

OCTOBER

15-17
AFPM Annual Summit, NEW ORLEANS, United States
Contact: American Federation of Petroleum Manufacturers
Web: https://summit.afpm.org/about-summit

NOVEMBER

4-6
CRU Sulphur & Sulphuric Acid Conference 2023, BARCELONA, Spain
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

11-14
European Refining Technology Conference, LISBON, Portugal
Contact: World Refining Association
Tel: +44 7384 8056
Web: worldrefiningassociation.com/event-events/ertc

Morocco's new acid capacity

PHOTO: KABELLEGER / DAVID GUBLER, WIKIMEDIA COMMONS

A train carrying phosphate rock from Khourgiba, Morocco

Morocco's OCP is continuing to expand its phosphate fertilizer production capacity. This includes the construction of new sulphur-burning acid capacity to support phosphate production and provide carbon-free power.

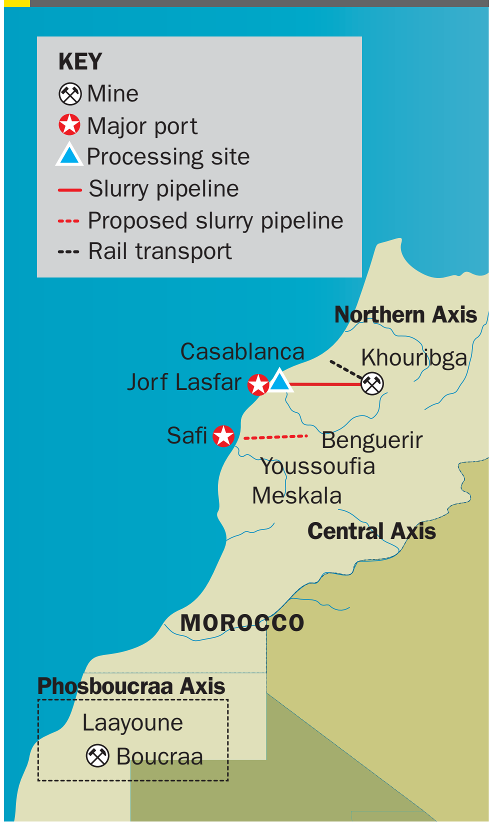
Morocco continues to be the giant of the world's phosphate industry, with around two thirds of the world's proved phosphate reserves (some say as high as 80%) and a major share of its production. All of this is in the hands of state-owned Office Cherefien des Phosphates (OCP), 95% owned by the Moroccan government.

OCP produced just over 30 million t/a of phosphate rock in 2022 (9.3 million t/a P_2O_5), or around 15% of global phosphate rock production, making it the second largest rock producer in the world after China. It also produced 6.3 million t/a (P_2O_5) of phosphoric acid, again just under 15% of the world total. But rock exports were 3.2 million t/a P_2O_5, around 33% of global trade in phosphate rock, and Morocco's share of finished phosphate trade was likewise around 31%.

Most phosphate mining happens in the north of the country, at Khourgiba and Gantour, where most of the country's proved reserves lie (see Figure 1). There is also a smaller mine at Boucraa in Western Sahara. These in turn feed export facilities at Jorf Lasfar (for Khourgiba), Safi (for Gantour) and Laayoune (for Boucraa).

Since 2007, OCP has been in a continuous strategy of expansion, intended to double its phosphate rock production and triple its finished fertilizer production by 2025. The first two phases of this expansion are now complete, and the third phase, now scheduled to be completed in 2027, is under construction. As well as expansions at the mine areas, OCP has instituted beneficiation plants and built two gravity-driven slurry pipelines to take phosphate concentrate from the mines to the coastal processing plants, the largest cluster of which is at the massive Jorf Lasfar Phosphate Hub (JLPH) complex. Jorf Lasfar is the world's largest chemical production site, with a fertilizer production capacity of 11 million t/a and 6 million t/a of phosphoric acid.

Fig. 1: **Major phosphate producing facilities in Morocco**



Strategy

Since 2023, OCP has altered its corporate strategy. While it continues to consolidate its position as a world leader in phosphate production, it has also earmarked $13 billion in investment for the period 2023-2027 to increase its environmental sustainability, with a long-term goal of achieving carbon neutrality by 2040 via investments in innovative green fertilisers and renewable energies. The Green Investment Plan also aims to increase OCP's fertiliser production capacity from the current 12 million t/a to 20 million t/a by 2027. This will involve the expansion of mining capacity, including the opening of a new mine at Meskala, in the Essaouira region, as well as the establishment of a new fertiliser complex in Mzinda. This production unit will process rocks from the Benguérir and Youssoufia mines, as well as from the new Meskala mine.

The company is also increasing its fertiliser and phosphoric acid production capacities at its various sites. By 2027, OCP plans to increase its fertiliser production capacity by 8 million t/a thanks to the addition of three granulation units of 1 million t/a each in Jorf Lasfar and the development of a new chemical complex in Mzinda with a capacity of 4.2 million t/a. The construction of a new chemical complex in Laayoune with a capacity of 1 million t/a is also planned in 2025.

Innovation

OCP is also investing in research and innovation to diversify its products and services and explore new opportunities, particularly in the electric battery market, taking advantage of the high global demand. On the fertilizer side, it has established a strategic alliance with Fertinagro Biotech, SL, a Spanish company specialising in the commercialisation of innovative solutions in plant nutrition. It is also studying innovative options for the monetisation of phosphogypsum such as applications for agriculture and construction materials, offering the company the opportunity to diversify and sustainably manage its waste.

Sulphur fertilizers

As part of its innovation and diversification plan, OCP has also been developing a range of sulphur enhanced fertilizers. In 2016 it signed a deal with Shell to license the latter's Thiogro technology, which was installed at production lines in Jorf Lasfar during 2017. This allows OCP to incorporate micron-sized particles of elemental sulphur into its existing ammonium phosphate, NPKs and current sulphur-enhanced products. These products are nitrophosphate and NPK fertilizers containing from 5-10% sulphur by weight (most are 5-7%). Some also contain other plant micronutrients such as zinc and boron at around 1% levels. Sold in the US under the brand name TerraTek, the fertilizers contain sulphur in both sulphate and elemental sulphur forms. This provides sulphate for immediate plant uptake, as well as micronised elemental sulphur which slowly breaks down and converts in sulphate as soil temperatures, rise, providing sulphur nutrient through a plant's growing cycle.

Africa

OCP's strategy also involves developing agriculture, particularly sustainable agriculture, across the continent of Africa, which has 60% of the world's arable land and which is expected to be the fastest growing area for new fertilizer demand. In February 2016, the company created its OCP Africa division, which aims to provide African farmers with access to adapted and affordable products, services and support, as well as logistical and financial solutions. OCP is increasing its sales on the continent and has committed to invest in new capacities, mainly NPK blending plants, across the region, in Ethiopia, Nigeria, Ghana and Rwanda.

Sustainable production

In addition to committing to achieving carbon neutrality by 2040, OCP has an ambition of achieving 34% water self-sufficiency in 2024 and is also committed to ensuring that 87% of its electricity needs come from renewable or clean sources by 2027. In particular, the company aims to produce 5 GW of clean energy (wind and solar) by 2027 and 13 GW by 2032. This renewable energy capacity will also be used for the production of green ammonia. In this respect, the group aims to reach a production of 1 million t/a of green ammonia by 2027 and 3 million t/a by 2032 at a new site in the south at Tarfava, An electrolyser production plant will support this project, ensuring local industrial integration within the new value chain. A desalination plant with a capacity of 60 million m^3 will supply these industrial facilities and contribute to meeting regional water needs.

As a start to this, under its Green Investment Programme, OCP has secured a 100 million euro loan from the IFC to finance the group's solar projects and build four solar photovoltaic power plants to power the group's facilities in Morocco. The facilities, with a total capacity of 202 megawatts, will be built near the mining towns of Benguérir and Khouribga.

Low carbon energy will also power new seawater desalination plants to meet the industrial production requirements as well as supply drinking water and irrigation to areas bordering OCP sites. Desalination capacity is aimed to reach 560 million m^3 in 2026, with 110 million m^3 up and running by the end of 2023.

Current operations

OCP had a bumper year in 2022, as it benefited from sanctions on Russia and Belarus affecting phosphate customers and high prices for phosphates. The company posted a 48% decline in net profit for the 12 months of 2023, down from $2.78 billion to $1.45 billion, as fertilizer prices declined. However, 4Q 2023 revenues were up 21% as prices rose again. Fertilizers contributed 66% to OCP's total revenues in 2023, the producer said, with TSP volumes increasing substantially to 15% of fertilizer sales, up from 11% in 2022. Phosphoric acid was 8% of revenue by product with phosphate rock at 17% of revenue by product.

In 2024, CRU expects OCP to increase rock exports from levels seen in 2023. Still, these are expected to remain below historical averages as the company continues to negotiate rock sales at high prices. Prices dropped significantly in 2023 Q3, but these have remained largely stable since then. Morocco's 68-72% BPL FOB benchmark price remains at a premium to similar-grade Jordanian rock, and while the gap between prices has started to close compared with that in most of 2022 and 2023, this differential is expected to remain wide when compared with pre-2022 levels.

New capacity

OCP has been building new phosphate capacity at Jorf Lasfar. Two new lines started in 2023, with a third expected to be up and running by the end of 1Q 2024. Each of OCP's three new lines will have a production capacity of 1 million t/a of DAP. Previous expansions have had dedicated phosphoric and sulphuric acid plants integrated into the downstream phosphate production, but for this series of expansions, OCP has debottlenecked phosphoric acid capacity at its legacy phosphoric acid hub, clearing 350,000 t/a P_2O_5, and added two additional 450,000 t/a P_2O_5 lines. There is also additional sulphuric acid production. A tender was awarded in 2019 with Metso for the engineering, procurement, and construction of a new €80 million acid plant based on advanced proprietary technologies such as the HEROS heat recovery system as well as a converter, absorption towers and an acid distribution system

PHOTO: OCP

Phosphate mining

that are made of Edmeston SX stainless steel alloy, and the plant came onstream last year. In 2023 a 2,300 t/d acid plant was also started up at Safi to replace two existing acid plants at the site. Altogether OCP added 2.6 million t/a of new sulphur burning sulphuric acid capacity last year, and another 1.8 million t/a of capacity is expected to start up this year.

In addition to these, OCP also signed a joint venture with EMAPHOS partners Brudenheim and Prayon to build a second purified phosphoric acid plant, with 140,000 t/y P_2O_5 capacity, which was commissioned in 2023. OCP has also announced ambitious plans for a mega-project in Mzinda, aiming for a capacity of up to 4 million t/a of TSP.

Acid supply

As if to illustrate some of the risks involved in relying on overseas acid production, the recent attacks by Houthi rebels on vessels in the Red Sea has led to OCP having to source most of its sulphuric acid requirements from European producers. In January and February 2024 OCP imported 420,000 tonnes of acid via Jorf Lasfar, around 90% of which came from Europe, up from around 50% in December, helping to support acid prices in Europe. At the same time, OCP postponed deliveries of sulphur to Jorf Lasfar in February due to a backlog of up to 40-45 vessels, sources state. OCP has stated that given the difficulties and reduced production levels, it is well covered for sulphur in March. Traders expect shipments to be postponed for up to a month to allow the congestion to ease.

SO_2 reduction

OCP has also been working on reducing sulphur dioxide emissions from its sulphuric acid plant via a process which it calls Sulfacid. The Sulfacid process has been installed at first the Jorf Lasfar and then subsequently Safi sites as a total cost of $58 million, reducing SO_2 emissions by 98%. The system recovers waste gases and converts them into sulphuric acid, which is then fed back into the production process. It incorporates a supplementary gas scrubbing process designed to remove SO_2. The system recovers the gas emitted by the contact unit and converts it into sulphuric acid using a wet catalysis process, and in so doing reduces SO_2 emissions from roughly 600 ppm to less than 15 ppm (i.e. a 98% reduction). It was developed in coordination with a partner company which specialises in waste gas treatment.

OCP is also looking at treating other waste streams, including sulphur ash. Sulphur ash results from the sulphur smelting and filtering facilities at OCP's processing sites. A solution has been found to turn ashes via a hydrometallurgical process into sulphuric acid that can be used at the Safi and Jorf Lasfar processing sites, and industrial tests are ongoing to implement this solution. It is envisaged that around 400 t/d of acid can be produced via this route.

Sulphur demand

At the end of 2017, OCP signed a long-term sulphur supply agreement with the UAE's ADNOC, under which ADNOC will supply OCP with granular sulphur until 2025 on a quarterly contract basis. OCP imported 6.5 million tonnes of sulphur in 2023, and its sulphur consumption is forecast to increase out to 2028, as it expands finished fertilizer capacity at its Jorf Lasfar processing facility. Phosphoric acid production is expected to rise from 6.1 million t/a P_2O_5 in 2023 to 8.8 million t/a P_2O_5 in 2028. Sulphur imports will rise concomitantly as the new sulphuric acid production ramps up, from 6.5 million /a in 2023 to 9.9 million t/a in 2028. OCP has been expanding sulphur import capacity at Jorf Lasfar and installed new melting units to handle the extra volumes anticipated.

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Canada's sulphur exports

Though production, particularly from sour gas in Alberta, has declined, Canada remains the world's second largest exporter of sulphur.

Sulphur stockpile at Port Moody, British Columbia

PHOTO: GUNTER MARX/ALAMY STOCK PHOTO

Canada was the world's fifth largest producer of sulphur in 2023, at 4.52 million t/a. More importantly, it was the second largest exporter, behind only the UAE, with a total of 4.01 million t/a of sulphur exported. While it is not the dominant player that it once was, its exports are comparable to those of Saudi Arabia or Kazakhstan. In spite of falling volumes being recovered from declining sour gas fields, increased recovery from oil sands production have so far by and large balanced this, but falling recovery from oil production may see it slip into third or fourth place in export terms in the next few years. Canada's reservoir of long term sulphur stocks remains a potential wild card for the market however.

Canada's elemental sulphur production has three main components; refining, mainly in the east of the country; sour gas processing, mainly in the provinces of Alberta and British Columbia in western Canada; and production from processing and upgrading of oil sands bitumen, almost exclusively in northern Alberta, as well as some production in British Columbia.

Oil refining

Canada is the world's fourth largest oil producer after the US, Russia and Saudi Arabia, averaging 5.5 million barrels per day in 2022, representing 5.9 % of global oil production, and its reserves, at least if the oil sands patch is included (representing as it does 97% of Canada's oil/oil equivalent reserves), are the third largest in the world at 170 billion barrels, representing 10% of the world's oil reserves. Canadian oil production has been on a steadily rising trend for many years, climbing from 2.1 million bbl/d of production in 2000 to its present figure. Production has risen by 60% since 2010. The country's oil/oil equivalent production is split into two main areas – conventional oil production and oil sands mining and processing. Conventional oil production, including gas condensates, has remained relatively steady over the past two decades at around 1.5 million bbl/d. All of the growth during that time has come from oil sands production, which now represents 65% of Canadian oil production, and most of its exports.

Canadian domestic demand for oil is about 2.4 million bbl/d, mostly (around 1.7 million bbl/d) to feed its refining sector, which provides most of Canada's demand for refined products (the rest is imported from the US, though some product also goes the other way). Consequently, as domestic oil production outstrips demand by over 3 million bbl/d, most of the oil, especially from the oil sands patch, is exported, mainly across the border south to the United States. A total of 4.0 million bbl/d of oil was exported in 2022, but a further 0.5 million bbl/d was imported, mainly into eastern Canada from the north-eastern US, for a net 3.5 million bbl/d of exports. Most of this was diluted bitumen ('dilbit') from the oil sands.

Downstream, Canada's domestic refining capacity is relatively small; there are 16 refineries operational in Canada (including two bitumen refineries), with a total capacity of 1.9 million barrels per day, and an average utilisation of 89% in 2022. Refineries in eastern Canada and Quebec are dependent on imported crudes and tend to process a more diverse crude slate than their counterparts in western Canada and Ontario. Eastern refineries' input is split roughly evenly between conventional, light sweet crude, is medium sulphur, heavy crude oil, and sour and/or heavy crude oil. In western Canada and Ontario, it is around 50% conventional light, sweet crude and 25% synthetic crude oil from bitumen.

Oil sands processing

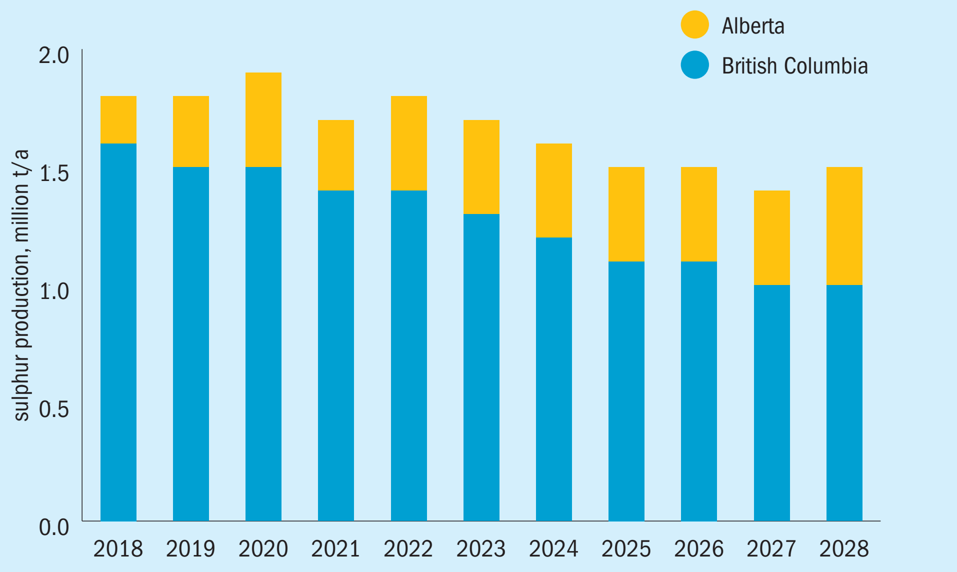
Increasingly, Canada relies upon oil sands bitumen for its oil production. Most of the oil sands mines are in northern Alberta. Mining was originally by open cast recovery of deposits close to the surface, but increasingly extraction relies upon so-called in situ recovery. This involves pumping steam down into underground deposits to soften and melt the bitumen and draw it back out. This method, steam assisted gravity drainage (SAGD), now represents just over 50% of all extraction, and it is likely to become increasingly used, as 80% of all deposits are too deep to be recovered using open pit mining. This causes some controversy, as the energy required to melt and recover in situ deposits, most of that energy coming from burning natural gas, makes oil sands bitumen one of the most carbon intensive forms of oil, roughly 30% more so than US production. This has led to increasing pressure on the industry to reduce its carbon footprint, and carbon capture and storage (CCS) and even nuclear power to generate steam have been suggested as alternatives, and the Federal government is looking at an emissions cap on the industry. There are also carbon taxes within Canada, but as in industry subject to 'carbon leakage' (ie moving to less regulated locations), around 80% of this cost is refunded by the government at present. Nevertheless, it has spurred efficiency improvements from producers.

The largest carbon capture project is a joint venture between the major oil sands producers; Canadian Natural Resources, Cenovus Energy, Imperial Oil, Suncor Energy, ConocoPhillips Canada and MEG Energy. It aims to develop a capture and storage network to carry an estimated 1.1 billion liquid tonnes of CO_2 from more than 20 oil sands facilities to an underground storage hub in northeast Alberta. However, this has faced cost hurdles even with government tax credits modelled on the US Inflation Reduction Act, and while front end engineering and design work is said to be complete, its planned start-up date of 2026 looks very optimistic to say the least.

After mining, the bitumen is either 'upgraded' to produce synthetic crude oil ('syncrude'), or diluted with lighter fractions such as naphtha to produce a 'dilbit' (dilute bitumen) or with syncrude to create a 'synbit'. These are light enough to be pumped, and so can be exported by pipeline or rail. Around 15% is upgraded at present. Oil sands oil production has been rising slowly but steadily, aside from a covid-related dip in 2020. Production is up 10% since 2018, reaching 3.5 million bbl/d in 2023.

As oil sands are sulphur rich (about 4-5% by weight), where this production is processed is of vital importance to the sulphur industry. Most Canadian oil sands production is exported directly to the US, by rail or pipeline, without being upgraded. Bottlenecks in cross-border transit capacity have been exacerbated by long-running disputes over export pipelines like Keystone XL. But these constraints continue to ease. Meanwhile the new Trans-Mountain Pipeline will begin operations on May 1st this year, adding an extra 600,000 bbl/d of export capacity via west coast ports. All of this should see more oil sands bitumen exported over the next few years. In spite of this, domestic sulphur production has been rising as new upgraders come on stream. Oil sands processing in Alberta generated about 2.6 million t/a of sulphur in 2023.

Fig 1: **Canadian sulphur production from sour gas, million t/a**



Source: CRU

Sour gas

North American sour gas production is mainly concentrated in western Canada, in particular the Western Canadian Sedimentary Basin (WCSB), which extends from Saskatchewan across northern Alberta and British Columbia and up into the Northwest Territories. Sour gas exploitation was pioneered in Western Canada, and sulphur production began at Jumping Pound, Alberta in 1951.

Most of Canada's sour gas boom is well and truly over now, with sour gas wells in Alberta declining and most new production coming from unconventional (shale gas) production. However, there is some new production coming from British Columbia. Overall, sulphur recovery from sour gas processing was 1.3 million t/a in Alberta in 2023, and 0.4 million t/a from British Columbia. Over the next few years, output from Alberta is expected to continue to decline to around 1.0 million t/a by 2028, with output from British Columbia increasing slightly to just under 0.5 million t/a.

Sulphur markets

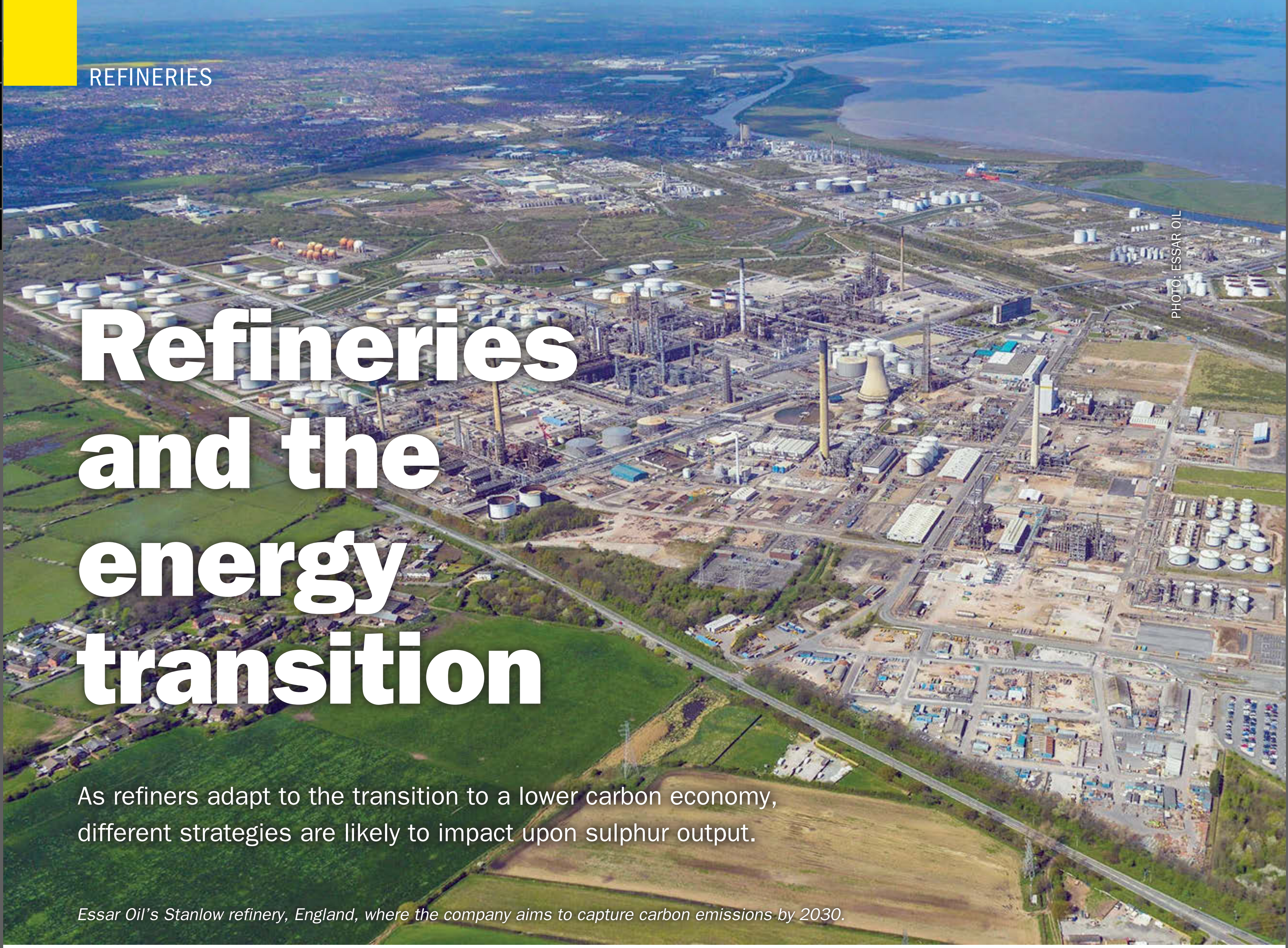
Domestic demand for sulphur in Canada is relatively low, totalling about 630,000 t/a. While the country is a major producer of potash, it has never really developed the phosphate mining industry that its larger neighbour to the south has, and the last phosphoric acid plant closed down in 2019. Sulphur consumption is mainly for industrial uses and some ammonium sulphate production.

Ariane Phosphates has for some years been developing a phosphate mine and beneficiation complex at Lac a Paul in Quebec, which would produce 3 million t/a of phosphate concentrate at capacity. It has also been looking at downstream phosphoric acid production at Belledune in New Brunswick, using sulphuric acid from Glencore's Brunswick lead smelter to process 1.4 million t/a of the phosphate concentrate from the mine. Most recently it has begun a feasibility study into a purified phosphoric acid plant to feed lithium iron phosphate battery production. However, there is as yet no on-stream date for these project.

Exports

Canadian sulphur production was about 4.5 million t/a in 2023, with about 1.7 million t/a coming from sour gas processing and 2.6 million t/a from oil sands upgrading, plus 0.2 million t/a from conventional refining. Canadian domestic consumption runs at about 0.6 million t/a, leading to a surplus of 3.9 million t/a, most of which is exported. In 2023, 4.1 million t/a of sulphur was exported, around 1.3 million t/a was exported south to the US, mainly as molten sulphur, while 2.8 million t/a was exported via Vancouver port. Around 0.2 million t/a of this export was from stock drawdowns, at both oil sands and sour gas producers.

Generally Canada has exported molten sulphur south to the US market for phosphate production, but demand continues to fall, as the US phosphate industry shrinks and new import options like the New Wales sulphur melter put pressure on Canadian supplies. This in turn has pushed Canada towards more sulphur forming projects, allowing for greater flexibility in export. Over the medium term, CRU expects that exports will continue to be in the range 3.8-4.2 million t/a, depending on pricing, stock build and stock draw down.



Refineries and the energy transition

As refiners adapt to the transition to a lower carbon economy, different strategies are likely to impact upon sulphur output.

Essar Oil's Stanlow refinery, England, where the company aims to capture carbon emissions by 2030.

At present oil refining produces 32 million t/a of elemental sulphur, just under half of the total global supply of 67 million t/a. However, the global transition towards a lower carbon economy is leading to much greater uptake of electric and hybrid vehicles, eating into the demand for liquid fuels, which are the main source of demand for refinery products at present.

Demand is unlikely to fall rapidly. Some sectors are hard to electrify, such as aviation fuel or long-haul goods vehicles, both of which use middle distillates. However, demand from passenger cars, which is the largest segment of consumption, is likely to fall faster than these sectors, and overall refinery throughputs are forecast to peak and plateau from around 2025-2035, before beginning to fall thereafter, though some models see throughput falling earlier, from around 2030. But even with flat demand, there will be pressure on refiners to decarbonise their operations to a greater or lesser extent, depending on local regulatory environments, and these will in turn necessitate changes in operations or product mix.

Refinery strategies

Broadly speaking there are four strategies for refiners in dealing with these pressures;

1. Increase energy efficiency. Refining is an energy-intensive activity, and energy requirements have increased over the years to meet demand for cleaner fuels, e.g. in hydroprocessing to remove sulphur. Energy accounts for about 60% of the cash operating costs of EU refineries, a proportion that has doubled over the last 20 years as a result of increasingly stringent product specifications, higher refinery complexity and increasing energy costs. Many refineries already recover most of the heat generated, but most are not able to use low temperature streams such as very low pressure steam or hot condensate. Some efficiency gains can be achieved via cogeneration, but in e.g. Europe most refineries already integrate generation into their operation. Many refineries are looking at switching to renewable energy feeds for electricity, heat and even hydrogen production via electrolysis.
2. Switch to lower carbon products. Most (ca 85%) of the carbon emissions associated with liquid fuels are produced when they are burnt. If the carbon in the fuel comes from a lower carbon source, then it is a more environmentally friendly product. A number of refineries are converting to produce biofuels. In Italy, Eni has converted or is converting its refineries at Porto Marghera, Gela and Livorno, and in the US Phillips 66 is converting its Rodeo refinery to produce biodiesel. The current vogue for sustainable aviation fuels (SAF) is another manifestation of this trend.
3. Capture and store carbon emissions. Where suitable disposal sites are available, capturing and sequestering carbon dioxide is an option some refineries are embracing, such as Essar Oil's Stanlow refinery near Liverpool, United Kingdom. Reducing precombustion emissions entails removal of carbon from the fuel gas system using reforming (steam or autothermal) or gasification technologies. The CO_2 from the reforming processes is

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captured, and the hydrogen is used for downstream fired sources. Oxygen injection is also possible to increase the CO_2 in the stack, thereby improving CO_2 removal. Alternatively, post-combustion capture can be achieved via amine adsorption.

4. Switch to other production. While demand for liquid fuels may peak, demand for other petrochemical products is likely to continue to rise. For this reason, some refiners are looking for opportunities to adjust or modify their production to increase their output of naphtha, propylene, and reformate, where margins tend to be higher than for liquid fuel production.

A combination of these strategies is of course possible, depending in refinery configuration. However, challenges remain, such as cost and pressure on margins and utilisation, or finding ways to minimise the amount of bottoms sent to the bunker fuel pool, demand for which is also shrinking. Residue conversion techniques such as solvent deasphalting may assist with utilising refinery bottoms.

Closures

The alternative of course is closure of assets. Between 2023 to 2028, global refining capacity is expected to grow by 5.1 million barrels/day, based on currently announced capacity, whereas demand is expected to increase somewhere between 0 and 4.6 million bbl/d over the same period. North America and Europe are most susceptible to closures, with Wood Mackenzie forecasting that Europe may lose as much as 5 million bbl/d of capacity by 2050 and North America a similar amount. Asia and the Middle East are the only regions expected to see net capacity gains in the 2030s, with large chemicals integrated sites coming online, with net capacity losses not expected until the 2040s.

Competitiveness will be the key for refiners to survive this environment, requiring both strong margins and low carbon intensity of operation; the former perhaps derived from petrochemicals or renewable fuels, with better margins, the latter from investment in reducing emissions.

Sulphur production

The good news for the sulphur industry is that most of these transition strategies for refiners do not involve a reduction in sulphur production. Greater energy efficiency, a switch to renewable power sources and green hydrogen, or the installation of carbon capture and storage technology will still see the amount of sulphur recovered stay roughly the same. However, conversion to bio-refineries or of course closure will impact upon refinery sulphur output, meaning that refinery sulphur volumes are likely to begin falling in the US and Europe over the next few years. New refinery capacity in Asia will balance this at least as far as the end of the decade, but the current wave of 'mega refineries' in Asia will be over by about 2028, and it remains uncertain how much new capacity will be built beyond that. CRU's current forecasts see overall global refinery sulphur output rising to 35 million t/a by 2026, and remaining roughly constant at that level for at least the next couple of years, but switching away from western markets towards eastern ones.

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Is sulphur nutrient supply meeting crop demand?

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

The sulphur cycle

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

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

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

Falling atmospheric emissions

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

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

Fig 1: **The sulphur cycle**

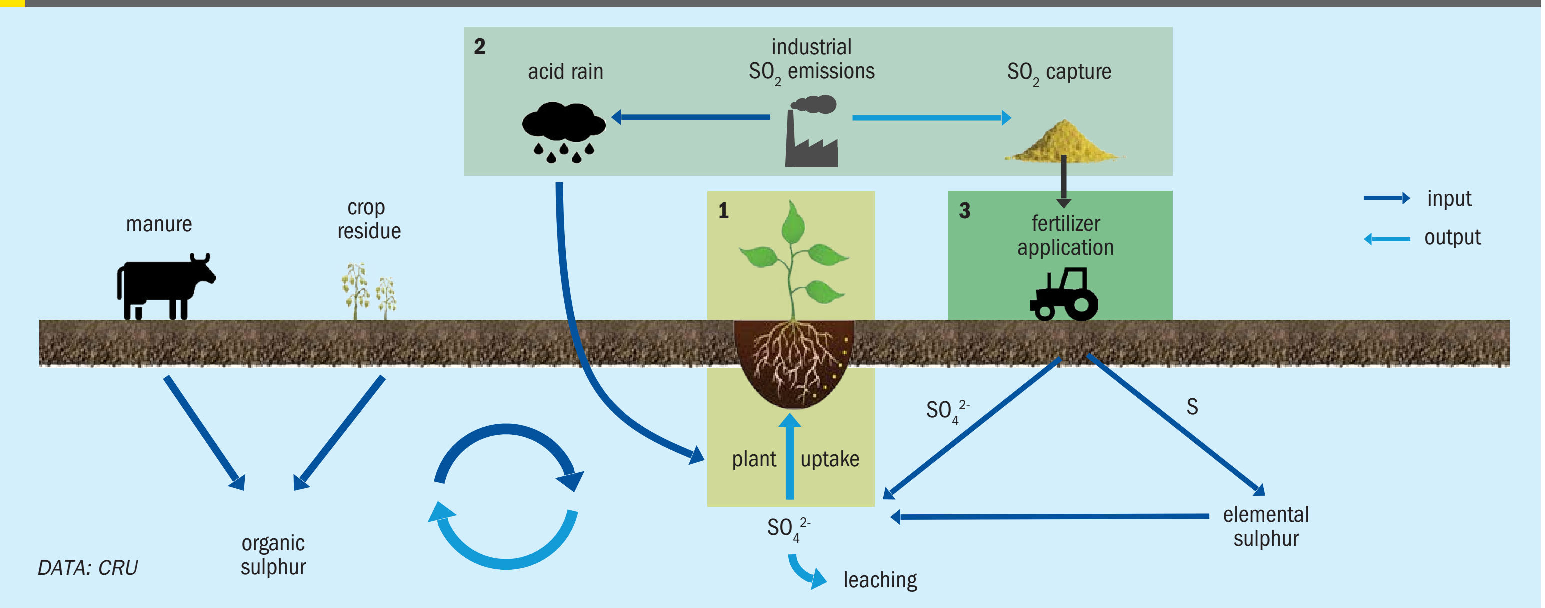

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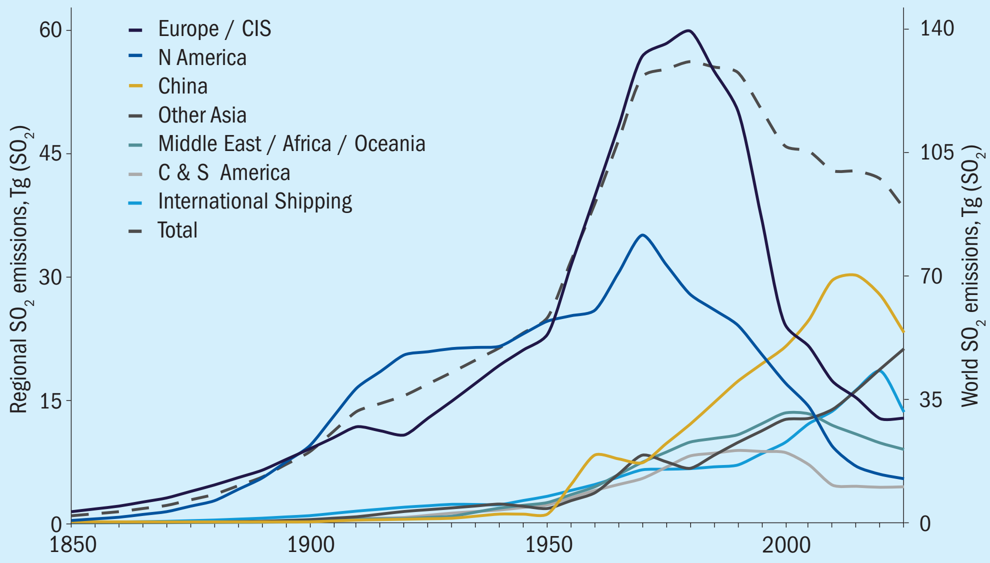
Fig 2: **The decline in global anthropogenic sulphur emissions has reduced sulphur deposition to soils. Emissions have fallen furthest and fastest in North America and Europe.**



Source: CRU, European Geosciences Union, IEA

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

Rising crop areas and yields

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

Increasing consumption of high-analysis fertilizers

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

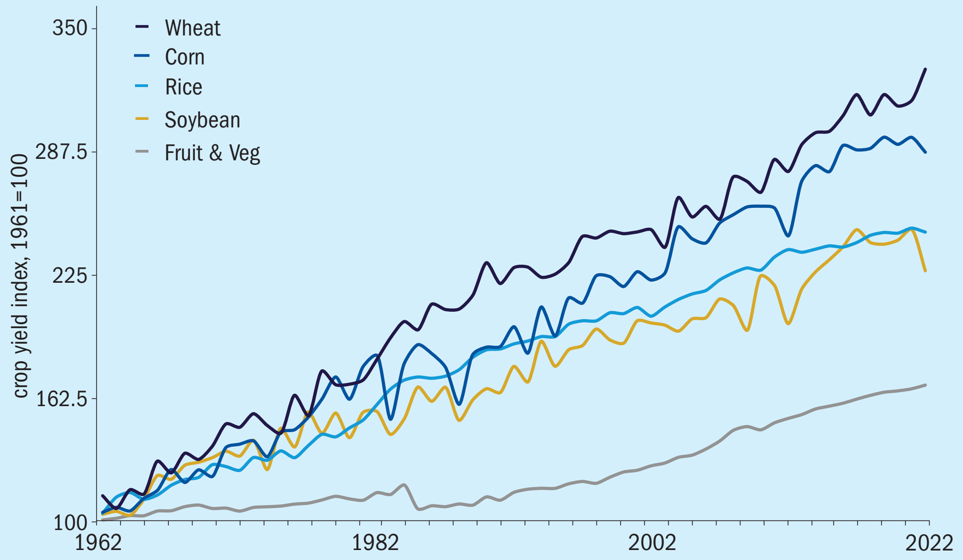
Current market for sulphur fertilizers

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

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

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

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



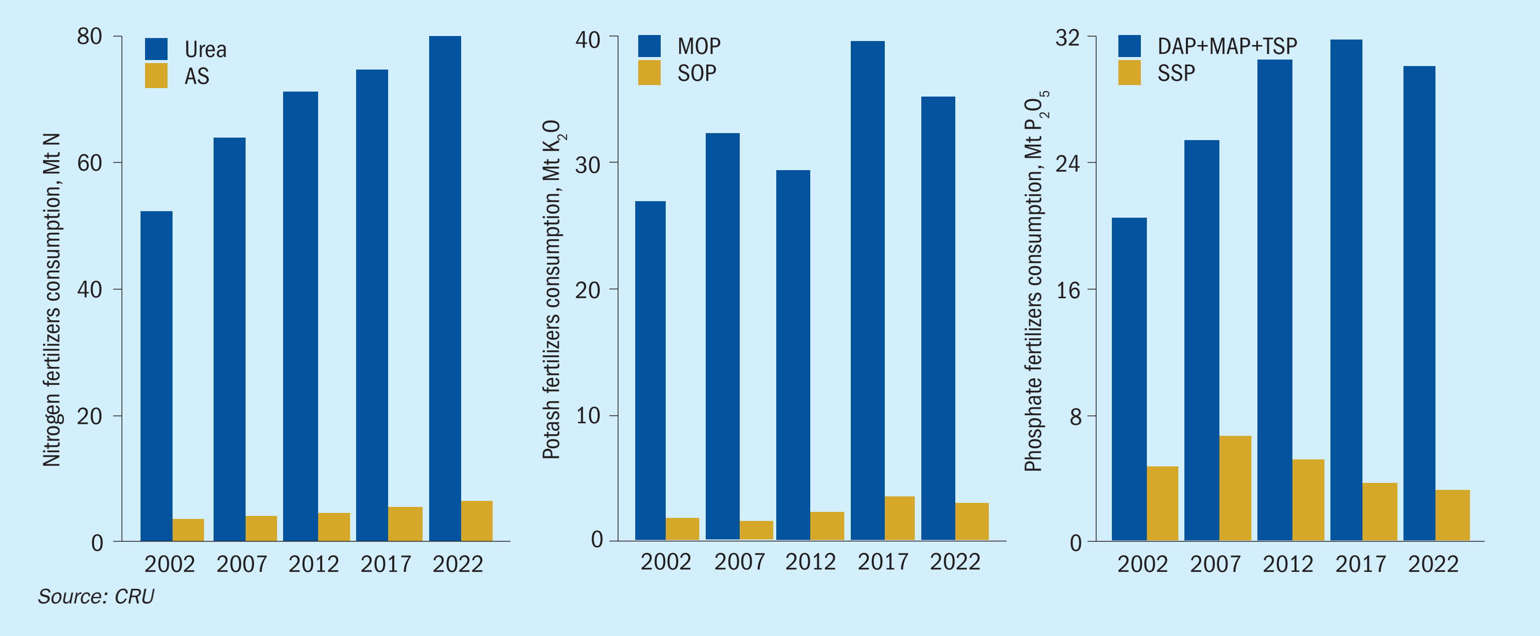
Source: CRU, FAO

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

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

Source: CRU

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



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

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

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

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

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

How does sulphur nutrient supply compare to crop demand?

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

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

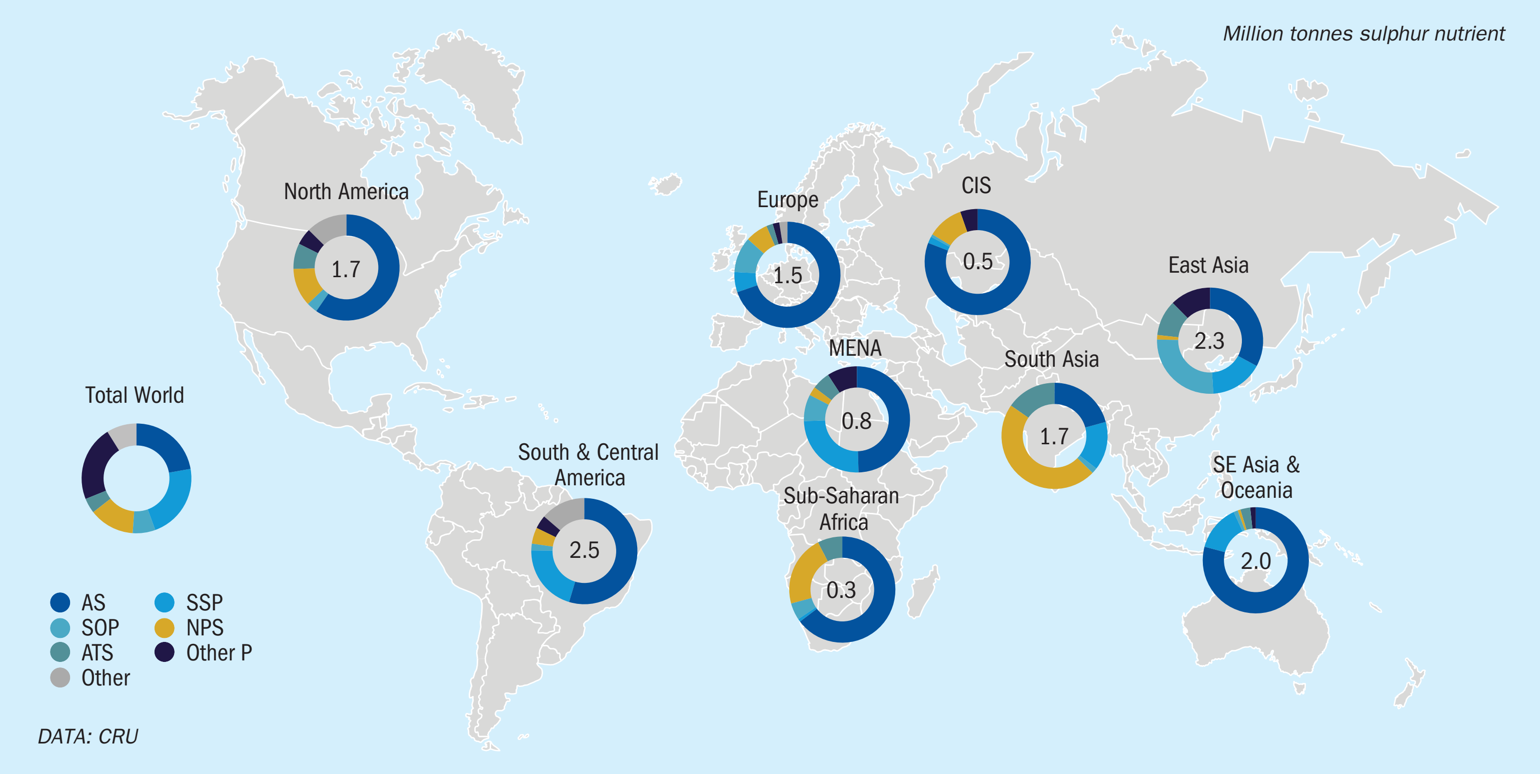


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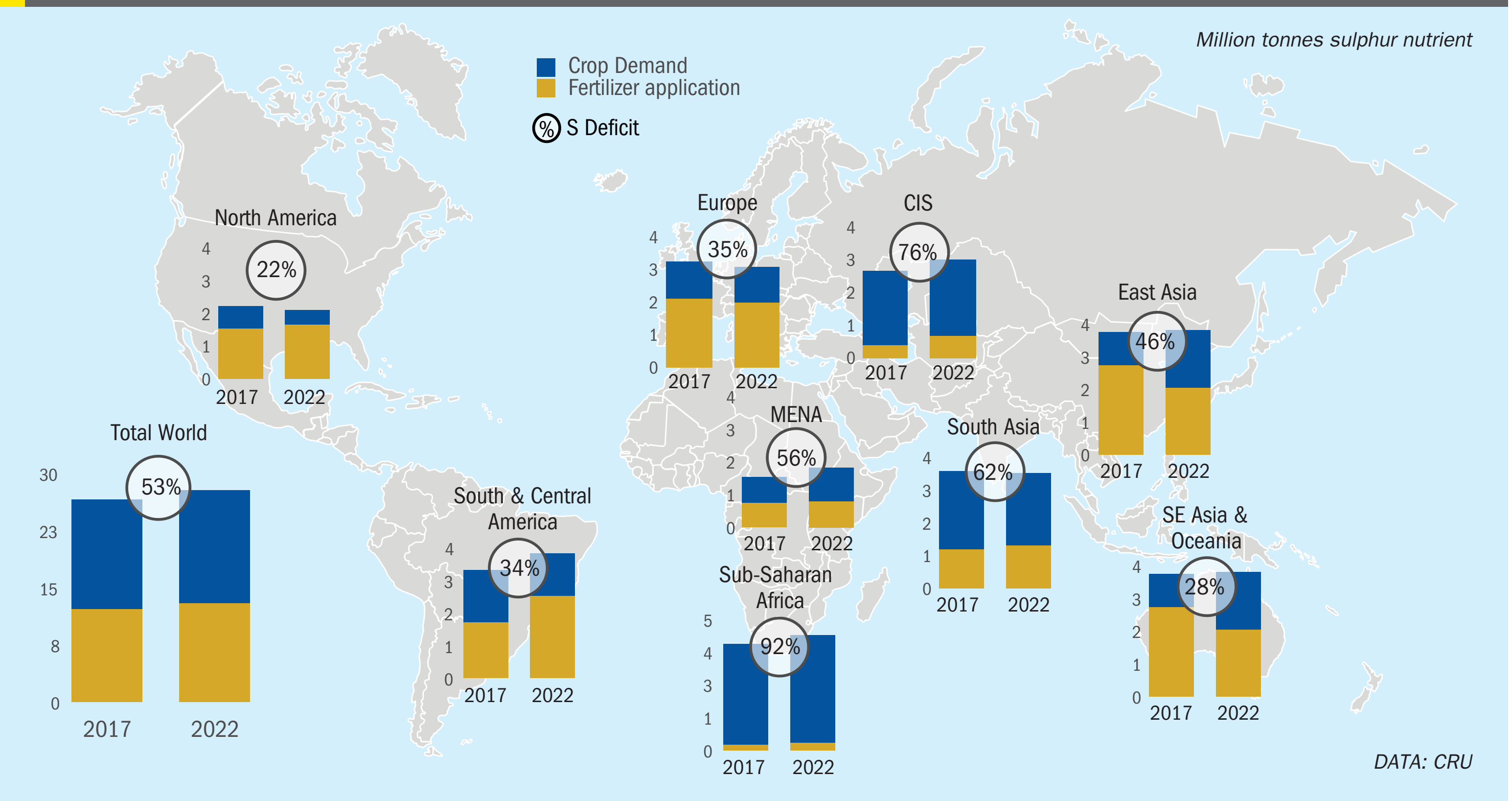
Fig 6: **Global sulphur nutrient crop demand and deficit, by region, 2017 versus 2022**



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

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

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

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

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

Prospects for sulphur demand

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

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

Sulphur nutrient supply expected to close the gap to crop demand

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

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

About the author

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TSI World Sulphur Symposium 2024

PHOTO: ISTOCKPHOTO.COM / SUSANNE NEUMANN

Scenic View of the St. Michaels Church from Broad St. in Charleston, SC.

The Sulphur Institute (TSI) held its World Sulphur Symposium in Charleston from April 2nd to 4th.

The Sulphur Institute's annual World Sulphur Symposium moved to the handsome southern city of Charleston, South Carolina in early April, bringing together more than 130 delegates from the sulphur and sulphuric acid industries to look at the prospects for those industries.

Global economic outlook

Dr. Georgy Egorov presented the global economic outlook. The past few years has seen some longer term trends emerge such as reshoring of overseas production, more fragmented markets and greater political risk, and uncertainty as regards the future of the EU, World Trade Organisation and Chinese economy - the Chinese economic 'miracle' seems definitively over.

In the short term, the world has recovered from the covid-induced recession. Inflation is high but falling, down to 4.1 % in the EU and 2.8% in the US, and stock markets have recovered and are growing. However, the evolution of multiple crises in Ukraine, the Middle East and Southeast Asia raises the potential for 'black swan' events. Energy and commodity prices have come down from their 2022 peaks but are still at elevated levels. The world is adapting to new realities, though the high price of gold is not a sign of confidence. Politically, populism and protectionism are on the rise and anti-globalisation has become mainstream, leading to supply chain risks, and the rise of 'nearshoring'.

Growth projections are for 3.1-3.2% globally, with emerging markets at 4-5% and developed economies 1.5-1.8%. Trade levels are higher than pre-pandemic levels but falling, with price differentials widening globally for some products. Overall, we are seeing a riskier, more fragmented world.

Oil and gas outlook

Mason Hamilton of the American Petroleum Institute presented his view of oil and gas markets. These have seen a rearrangement since 2022 – a disruption even greater than that of 2008-09. The US now supplies more oil and gas as OPEC has reduced supply and Russian gas is no longer going to Europe.

On the oil side the OECD has seen refinery closures since 2020, with new capacity coming onstream in Asia and the Middle East. The US has lost 1.3 million bbl/d of desulphurisation capacity during that period. Uncertainties remain over the path to so-called 'net zero', on policy, technology and economics with a wide variety in forecasts based on the underlying assumptions, which often do not include mineral or material constraints. The IEA's scenarios could see refining capacity roughly level out to 2050, or down to less than half its current value. What seems incontrovertible is that world energy demand is growing. There are demographic shifts, though migration will likely compensate for this in North America and Europe.

Lithium and metals markets

Dr. Rene LeBlanc forecast that there is a lithium supply gap ahead, from around 2027 onwards. This year almost 85% of global lithium output will be for battery production, with China dominating demand. However, Chinese lithium production costs are towards the top of the curve, meaning that there is an opportunity for new and emerging US lithium producers. Margins are currently good even at 'low' lithium prices.

Sulphur could play a key role in onshoring lithium production. Recovering metals takes 6 tonnes of acid per tonne of lithium cathode equivalent (LCE) from sedimentary rocks, and 3 tonnes/tonne LCE for hard rock. Cathode production also requires electrolyte grade sulphuric acid, producing sodium sulphate by-product.

Freight markets

The past few years have seen extremely volatile freight markets, peaking in 2021 and again in mid-2022, the former due to the recovery from covid and the latter because of the invasion of Ukraine. In 2023 new crises and disruptions have emerged, with drought affecting the Panama Canal and Houthi attacks on the Red Sea affecting routes via the Suez Canal. Panama traffic has been down more than 30% and only lower draft ships are able to pass, with slots being auctioned and higher freight rates as a result, pricing out many dry bulk cargoes, which have seen transits down 50%. Suez transits are down 65% in February 2024 compared to December 2023, and in March that increased to 72% down compared to December 2023. Avoiding Suez adds an extra 4-7,000 miles to a round trip. As a result container rates have tripled from March 2023 to March 2024. This has been coupled with higher low sulphur fuel oil prices, up 15%. Vessel supply is still tight, with historically low growth to fleets up to 2025. Climate change could continue to affect the Panama Canal going forward, leading to seasonal congestion and delays.

Supply chains

Two papers looked at supply chains. Dr Rachel Meidl of the Baker Institute for Public Policy discussed 'a systems perspective for navigating the complexities of sustainability and a circular economy'. The need for new minerals will lead to a fivefold increase in lithium demand and a doubling in nickel demand by 2050, she said. Sustainability and energy transitions will look different everywhere, but infrastructure and supply chains matter, the latter point borne out by Christ Sawchuk of Hackett Group, who looked at supply chain diversification and resiliency. The impact of the covid pandemic and sanctions on Russia has revealed vulnerabilities in supply chains, he said, and he reported on a series of benchmarking studies conducted by Hackett.

Sulphur fertilizers

Peter Harrison of CRU rehearsed the needs for and benefits of sulphur as a fertilizer. Peak sulphur deposition from smelters and coal burning power plants was the 1970s for Europe and North America, but this figure was actually closer to 2010 for China. These atmospheric deposition levels continue to fall, including from 2020 onwards for emissions from global shipping. This is contributing to a continuing sulphur deficit of more than 50% worldwide; around 20-30% in North America and Europe, but up to 60% in South Asia, and as high as 90% in sub-Saharan Africa. But increased awareness of this and application of sulphur fertilizer is leading to a slow and steady reduction.

In terms of agronomy, the timing of application of fertilizer can be more important than volume, and there can be a maximum impact according to the ratio of sulphur to other nutrients. The leading sulphur containing fertilizer continues to be ammonium sulphate (AS), along with single superphosphate (SSP) in the Middle East, North Africa, East Asia and South America, and NPS in South Asia. China relies upon AS, consuming around 65% of it, but NPS is developing rapidly in the US, Brazil and Africa, and substituting for mono- and di-ammonium phosphate.

The current sulphur deficit in North America is around 460,000 tonnes S per year. If this were fulfilled by ammonium sulphate it would represent an additional 1.9 million t/a of AS, a 45% increase on current demand, or an additional 5.5 million t/a of NPS (an increase of 250%).

Sulphur, acid and phosphate markets

Claira Lloyd of Argus closed the conference with a run through of phosphate, sulphur and sulphuric acid markets. Sulphur capacity growth is coming mainly from the oil sector at present, and sour gas to an extent, mainly in China, the Middle East (especially the UAE) and southeast Asia, including Malaysia, Indonesia and Thailand. There are also some production losses, due to refinery closures in Europe and elsewhere. New consumption is mainly for phosphoric acid for MAP/DAP production, but also LFP. There is also considerable demand from the metal sector, particularly nickel. Metals consumption could reach 22.9 million tonnes S by 2029. Lithium iron phosphate will be responsible for an additional 4 million t/a of purified phosphoric acid demand by 2029, but faces hurdles outside China.

In terms of sulphur trade, most of it is represented by demand in China, Morocco, Indonesia, Brazil and India. China's imports are shrinking and will shrink further, while Indonesia's demand is growing rapidly for nickel HPAL production. But Morocco may by the biggest importer by 2029 for phosphate production. Middle Eastern exports are rising, and North American exports falling.

On the acid side, the proportion of acid coming from sulphur burning is increasing, with new capacity in Africa, both Morocco and the Copper Belt, and southeast Asia. Indonesia is seeing growth in both smelter acid as well as sulphur burning acid capacity. Capacity losses have been in Australia and Lithuania. Market drivers include a reduction in merchant trade due to more integrated sulphur burning operations, lower demand from Chilean copper mining and more sulphur burners in Africa, with China becoming a swing exporter. New acid capacity in India, both from smelting and sulphur burning, will see India become a net exporter. Looking forward, battery recycling is becoming more important, and around 75% of this is based on sulphuric acid. This could add an additional 20 million t/a of acid demand by 2040. There is potentially a supply gas for acid from 2031 unless new capacity is added.

Finally, in the phosphate market, mine closures are forecast in North America, Israel and Australasia, leading to a 7% loss in rock output. Finished phosphate demand growth is projected to slow from 2026, with reduced consumption from China, balanced somewhat by new demand in South America and new capacity in Morocco and India. Chinese export restrictions will remain in place, leading to limited exports in Q1 and Q4 2024. Sanctions on Russia have altered the trade in phosphates, with Russian DAP now travelling to India and MAP to Brazil. The crisis in the Red Sea has affected phosphate rock and phosphoric acid supplies from North Africa to Asia, leading to lower affordability in e.g. India. ■

1 47 2 48 3 49 4 50 5 51 6 52 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

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MEScon returns to Abu Dhabi

CRU and UniverSUL Consulting, together with the event host, ADNOC, are delighted to welcome you back for MEScon 2024 at the Conrad Abu Dhabi, Etihad Towers from 20 to 23 May 2024.

Etihad Towers, Abu Dhabi.

The 2024 Middle East Sulphur Conference (MEScon 2024) organised by CRU and UniverSUL Consulting and hosted by ADNOC will take place at the Conrad Abu Dhabi, Etihad Towers in Abu Dhabi, UAE, from 20 to 23 May 2024.

The Middle East and Abu Dhabi, in particular, are at the epicentre of global sulphur and sour hydrocarbon production, making it the ideal location to host this premier event that will gather representatives from along the entire sour gas and sulphur value chain to promote technology and innovation, lessons learned, best practices, knowledge transfer, and R&D.

MEScon is devoted to networking, thought leadership, innovation and best practice operations across the entire sour gas and sulphur value chain. With the region's prominence in the global sulphur industry, MEScon is the place where the sulphur and sour gas community meet to discuss and debate the key strategic themes that are driving the industry.

> **"MEScon is the place where the sulphur and sour gas community meet to discuss and debate the key strategic themes that are driving the industry."**

The partnership of CRU and UniverSUL Consulting combines the respective strengths of market-leading analysis and technical expertise, which is reinforced by the support of the two largest sulphur producers in the world – ADNOC (Host Sponsor) and Aramco (Diamond Sponsor) – who are committed to making this the largest and most comprehensive sulphur conference in the world.

The 2024 agenda combines a carefully curated mix of 33 technical presentations and a wide range of technical workshops, panel discussions and technical poster presentations.

Peter Harrison, CRU's Principal Analyst, Sulphur and Sulphuric Acid, will set the scene for the event with an overview of the global sulphur market:

"The global sulphur market has been through a period of oversupply and lower prices since mid-2023. Increases in demand and prices are expected in 2024 with supply increased likely to slow. The recent surplus has been driven by destocking from long term inventory and a slowdown in demand. Despite the recent experience of surplus, the question of longer-term supply availability remains.

On a global scale sulphur supply is expected to still meet demand for many years to come but there are already regions of the world which are, or will soon be, witnessing supply decline and physical market shortages.

The Middle East region is a crucial component of current and future sulphur supply, and increasingly demand. Supply from the region already contributes significantly to global trade volumes with this share expected to grow over the coming years.

The MESCon event is a great example of how a blend of commercial and technical understanding will be essential for the future of the sulphur market. Future sulphur supply will likely be sourced from more technically complex assets and more consolidated in geographical location. Understanding both the operational and commercial challenges will be essential determining when, where and how supply will enter the market to meet growing global demand."

Key themes on the MEScon 2024 agenda are highlighted below:

- Shaping the future of energy and sulphur – world-class sour gas and sulphur projects
- Innovative sour hydrocarbon strategies, technologies and design approaches
- Gas treating excellence from wellhead to SRU
- Sulphur 4.0 – automation and digitalisation advances
- Sulphur handling experience from the world's largest producing region
- SRU/TGTU best practices in operation and design

A new feature of this year's conference is the Sulphur Youth Majlis Session. Nearly ten years after becoming the world's largest sulphur producing region (occurred in 2015), the Middle East is passionately focused on producing a new wave of talent that will drive the industry forward into the future. The Youth Circle Majlis Session offers a dynamic and inspiring platform for young professionals to explore, connect, and grow within the exciting and ever-evolving world of sour gas and sulphur.

This year will also see the return of the Operations Roundtable session (from MESPON days). This session promises to be one of the best global platforms for industry professionals to stay updated on the latest developments, exchange knowledge, and collectively work towards advancing the efficiency, safety, and sustainability of sulphur processing operations. ■

Sulphur Youth Majlis Session

The Sulphur Youth Majlis Session is a special gathering designed to inspire and guide young professionals (aged 38 years and younger) as they explore exciting career paths within the sour gas treating and sulphur fields. This session is crafted to foster meaningful connections, provide valuable insights, and equip attendees with the tools they need to embark on successful career journeys in these dynamic sectors. Key features of the Youth Circle Majlis Session include

- **Career exploration panels**: Engaging panel discussions featuring young professionals and industry experts will offer first-hand insights into various career paths within sour gas and sulphur. Attendees will gain valuable perspectives on different roles, responsibilities, and opportunities available, helping them make informed decisions about their career trajectories.
- **Networking opportunities**: The session will provide ample opportunities for networking and building connections with peers and mentors in other operating companies and the international sulphur community as a whole. Attendees will have the chance to engage in one-on-one conversations, group discussions, and networking activities, fostering a supportive community of like-minded individuals passionate about building and nurturing the sour gas and sulphur community.
- **Career guidance and mentorship**: Experienced professionals from the sour gas and sulphur industry will offer mentorship and guidance to young attendees. Whether it's sharing career advice, providing professional insights, or offering resume suggestions, mentors will play a crucial role in supporting the professional development of the next generation of industry leaders.

MEScon Operations Roundtable (open forum Q&A)

The MEScon Operations Roundtable is a premier platform where industry experts gather, in the world's largest sulphur-producing region, to facilitate open discussions on critical topics within the realm of sour gas treating, sulphur recovery, tail gas treating, sulphur forming & handling, and CO_2 capture along the sulphur value chain. Key highlights of the MEScon Operations Roundtable include:

- **Expert facilitated discussions**: Industry leaders with extensive experience in sour gas treating, sulphur recovery, and related areas lead engaging discussions on pressing issues, trends, and innovations.
- **Open exchange of ideas**: Participants have the chance to share their experiences, challenges, and successes, fostering a collaborative environment conducive to learning and problem-solving.
- **In-depth exploration of hot topics**: The forum covers a wide array of topics spanning the entire sulphur value chain, from gas treatment to sulphur handling and CO_2 capture, ensuring comprehensive coverage of relevant industry issues.
- **Networking opportunities**: Attendees have the chance to connect with peers, potential partners, and solution providers, facilitating valuable networking opportunities and potential collaborations.

MEScon

DAY 1 – MONDAY 20 MAY 2024

- **Carbon Capture In The Sulphur Value Chain Workshop**
- **MEScon Operations Roundtable (open forum Q&A)**
- **Sulphur Youth Majlis Session**

Technical showcase session

- Carbon capture options for gas processing plants – *Leorelis Vasquez & Nathan Smith, Worley Comprimo*
- SRU sweep/shutdown through the TGTU – *Jan Kiebert, Sulphur Experts Inc.*
- Efficient sulphur recovery using biotechnology – Developments in Thiopaq O&G – *Arthur van Asbeck, Paqell*
- SAMREF SRU catalyst management, retrofit and optimisation initiatives during the 2023 T/A
- Khalid Ghazal, Saudi Aramco Mobil Refinery Company Ltd. – *(SAMREF) & Johann Le Touze, Axens*

DAY 2 – TUESDAY 21 MAY 2024

- ADNOC welcome – *Abdulmunim Al Kindy, ADNOC Upstream*
- Aramco welcome
- MEScon opening remarks – *Fahad Al Wahedi, ADNOC Sour Gas*
- MEScon 2024 kickoff – *Angie Slavens, UniverSUL Consulting*
- Oil & gas / energy outlook – *Michael Nevin, io consulting*
- Sulphur market overview – *Peter Harrisson, CRU*
- The sweet taste of sour gas - the new Hail & Ghasha sour gas plant – *Hamda J. Almesmari & Nada Abujarad, ADNOC Group*
- Tanajib Gas Plant (TGP) - The new Aramco gas plant – *Khalifah Al-Salem & Ahmed Alzahrani, Aramco*
- Sulphur start-ups: Element 16's sulphur thermal energy storage (pilot plant in Oman) – *Parker Wells, Element 16 Technologies, Inc.*
- State of the industry and the Middle East – *panel session*

Innovative sour hydrocarbon strategies, technologies and design approaches

- Capitalise on extension of the sulphur value chain – *Chandra Shekar, ADNOC Sour Gas*
- Saudi Aramco "Sub-dewpoint sulphur recovery with interstage membrane (SSRIM)" – *John P. O'Connell, Aramco*
- Simulation-based analysis of the effects of feedwater distribution and tube layout on vapour hold-up in kettle-type waste heat boilers – *Nasser Mohieddin Abukhdeir, Continuum Engineering Inc. & Elmo Nasato, Nasato Consulting Ltd.*
- Maximising CO_2 recovery in existing assets with proprietary amines – *Ashraf Abufaris & Feras Kordi, BASF Middle East Chemicals LLC*
- Ammonia-based scrubbing for sulphur recovery – a Middle East perspective – *Inshan Mohammed, Sulphur Recovery Engineering*
- Direct fuel gas sulphur removal technology – *Strom Smith, Sulphur Operation Support Inc.*
- Innovative sour hydrocarbon strategies, technologies and design approaches – *panel session*

2024 preliminary agenda

DAY 3 – WEDNESDAY 22 MAY 2024

- **Welcome address**
- **Technical committee**

Gas treating excellence from wellhead to SRU

- Ultra-sour gas pipeline in-line inspection – an overview and case study of wall loss and crack detection ILI runs for CRA cladded pipe - *Saeed Al Blooshi, ADNOC Sour Gas*
- SRU acid gas ejectors for sour gas re-injection – *Seth Spear, Occidental Petroleum*
- Technology assessment – retrofit of existing acid gas removal units (AGRUs) using a novel technology – *Ibrahim Khan Mohabbath, ADNOC Gas*
- Strategies to control corrosion of an amine regenerator with elevated heat stable salts – *Ben Spooner, Amine Experts*
- Mercaptan removal options – *Jon Lewis, Worley Comprimo*
- Hot circulation mode for acid gas stripping from amines – *Yousef Alfnais, Aramco*
- Gas treating excellence from wellhead to SRU – *panel session*

Poster spotlight

- BTX removal through activated carbon beds; what have we gained and what have we learned? – *Hamed Alsowayigh, Aramco*
- Troubleshooting of reaction furnace burner in sulphur recovery unit of acid gas removal plant in KNPC-MAA Refinery – *Rizwan Ahmed Masood, KNPC*
- Sulphur recovery unit's water treatment online recommendation model – *Bader Alotaibi, Aramco*
- Best practice of evaluating SRU catalyst performance – *Abdulrahman Almashhaf, Aramco*
- Catalyst sulphidation in tail gas treatment: a comprehensive analysis of methods and best practice – *Girish Madupalli, AIMS*
- Testing novel catalysts for H_2S conversion to hydrogen – *Anton Manakhov, Aramco*

Automation and digitalisation advances in sulphur

- Improving control room operator performance with an AI-assisted copilot solution – *Suresh Kumar M., ADNOC* Gas
- Enhancing temperature monitoring for reaction furnaces through machine learning – *Abdullah A Alhumaid, Aramco*
- Sustainability initiative by automated start-up of SRU fired heaters – *Raghesh Karunakaran, ADNOC Gas*
- Smart advisory dashboard for optimised TGTU operation – *Dedik Rahmat Ermawan, Aramco*
- A case study to evaluate how a direct link between process simulation & plant data / historian can improve safety, reliability, and efficiency in operations – *Ganank Srivastava & Mostafa Shehata, Bryan Research & Engineering, LLC*
- Automation and digitalisation advances in sulphur – *panel session*

DAY 4 - THURSDAY 23 MAY 2024

- **Welcome address**
- **Technical committee**

Sulphur handling experience from the world's largest producing region

- Sulphur degassing technology options for SRUs – *Marco van Son, Worley Comprimo*
- Can we remelt sulphur in a pipeline that is full of solid? – *Robert Marriott, Alberta Sulphur Research Ltd*
- Sulphur pipeline's seasonal optimum flow correlation through machine learning – *Bader Alotaibi, Aramco*
- Eliminate fire and safety concerns and reduce H_2S emissions in large liquid sulphur tanks – *Pankaj Kumar, ADNOC Gas*
- SAMREF folds the final chapter of the sulphur dust challenges – *Khalid Ghazal, Saudi Aramco Mobil Refinery Company Ltd. (SAMREF) & Jeff Cooke, DuBois Chemicals*
- Transitioning from magnetic to vibrating screening technology at transferring tower 2 (TT2) sulphur station – *Mohammed Al Blooshi, ADNOC Sour Gas*
- Sulphur handling experience from the world's largest producing region – *panel session*

Poster spotlight

- Reducing fuel gas usage in SRU Claus burners for improved energy efficiency, BTEX destruction, and sustainable TGTU operations – *Mohammed Aldossary & Fahad Alfayez, Aramco*
- Decarbonisation of sulphur recovery unit utilising oxygen enrichment – *Amer S Alsaiari, Aramco*
- Effective sulphur pit handover for T&I – *Yahya Almousa, Aramco*
- Current-base monitoring with VFDs for enhanced sulphur handling – *Hamdan Al Shehhi, ADNOC Sour Gas*
- Offgas dynamic digital twin composition analyzer – *Abdullah Alhumaid, Aramco*
- Utilising process simulation to design an effective TGTU – *Ganank Srivastava & Mostafa Shehata, BR&E*

SRU/TGTU best practices in operation and design

- Challenges in sour gas feed processing at Mina Al Ahmadi acid gas removal plant (AGRP) – *Rizwan Ahmed Masood, Kuwait National Petroleum Company (KNPC)*
- Sulphur recovery plant instrumentation – today and tomorrow maximising availability & efficiency in sulphur recovery plants – *Jochen Geiger, AMETEK Process Instruments*
- Unconventional throughput recovery – SRU modified operational mode – *Vijay Algule & Al Sail Al Jaberi, ADNOC Sour Gas*
- Middle ground: Finding SRU/TGU improvements through catalyst selection – *Brian Visioli, Evonik*
- SRU/ TGTU best practices in operation and design – *panel session*

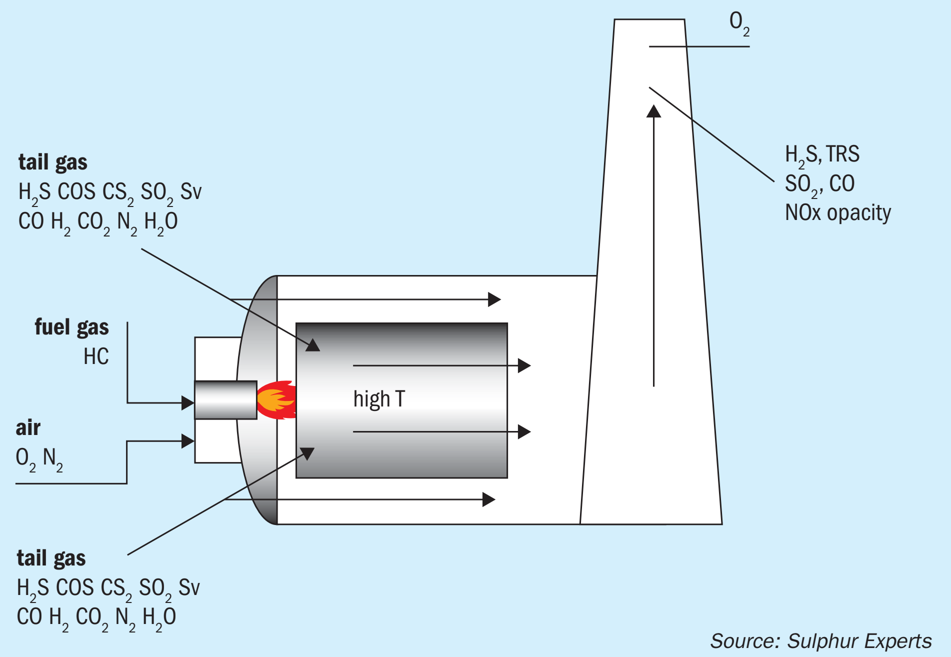
A better understanding of SRU incinerators

Sulphur Experts outline the steps required to determine optimised SRU incinerator operating conditions. Although a proper determination of the ideal SRU incinerator operating conditions for any given facility is complicated by a combination of inconsistent permitting standards and poor understanding of the role of the SRU incinerator, the payoff for incinerator optimisation is a significant decrease in natural gas usage with corresponding savings in operating costs, a decrease in CO_2 emissions, and a simultaneous reduction in NOx and SO_3 emissions.

The vast majority of the world's sulphur recovery units (SRUs) are required to process their tail gas streams in an incinerator prior to releasing them to the atmosphere. These incinerators, also commonly called thermal oxidisers, serve two primary purposes. The first purpose is to acceptably combust certain regulated chemical species present in the SRU tail gases before releasing them to the atmosphere. The second purpose is to release the incinerated tail gas to the atmosphere under conditions that will ensure that the residual amount of these same regulated chemical species is well dispersed and diluted in the atmosphere, so that when they eventually reach ground level they will be less than the regulated maximum ground-level concentrations.

Although both combustion and dispersion are improved by increasing the incinerator operating temperature and the excess oxygen concentration, increases in both of these parameters also requires more fuel. Since this incinerator fuel is almost always some type of hydrocarbon stream, most commonly natural gas, hotter operation with more excess oxygen corresponds directly to an increase in CO_2 emissions and higher operating costs. In the ideal case, therefore, the incinerator temperature and the excess oxygen concentration would both be maintained at the lowest possible values needed to meet the combustion and dispersion requirements for a given facility. This optimised operation will satisfy both the environmental requirements for the SRU while minimising operating costs and CO_2 emissions.

Fig. 1: **Common SRU incinerator components**



Source: Sulphur Experts

While some jurisdictions have long recognised this desire to balance all aspects of SRU incinerator operation against regulations and have provided clear guidance on how to determine the ideal point, other jurisdictions have not yet invested the time or effort. The USA is one such jurisdiction. USA SRU incinerators, on average, operate at temperatures and excess oxygen levels far above what is actually required to meet their permit requirements, with most SRU operators unaware of the exact regulations which govern their incinerator operations and also generally uninterested (until now) in pursuing incinerator optimisation opportunities.

Two recent trends, however, have begun to change this mindset in the USA: the increased price of natural gas and the increased focus on quantifying and then reducing CO_2 emission sources.

Components of interest

The list of regulated chemical species which are almost always present in the SRU tail gas being sent to the incinerator include: H_2S, TRS (H_2S + COS + CS_2 – collectively known as total reduced sulphur), SO_2, and CO.

The quantity of each of these components present in the incinerator feed stream(s) depends on the upstream SRU efficiency and operation.

Another commonly regulated chemical group, volatile organic compounds (VOCs), which include aromatic hydrocarbons such as benzene, toluene, ethyl-benzene, and xylene (BTEX), while not usually present in SRU tail gas streams, may be present in some cases.

In addition, although NOT present in SRU tail gas streams, NOx, and SO_3 may be created in the SRU incinerator itself under certain conditions and contribute to plume opacity which may be regulated.

Fig. 1 shows a representation of the species of interest in the SRU incinerator.

Applicable regulations

SRU incinerator regulations in the USA are complicated by the fact that they have both a federal (Environmental Protection Agency – EPA) component and a state component, and that regulations are often very site-specific depending on a plant's history and their specific permitting process or relationship with the local authorities. They are also often further complicated by the fact that regulations may contain some mixture of allowable SRU incinerator stack exit emissions and allowable maximum ground-level concentrations (MGLC), with no clear relationship between these two categories defined in the regulations nor understood by the SRU Operator.

The first step in determining the required SRU incinerator operating parameters for any site is a careful reading of all site-specific operating permits.

Compliance monitoring

For most SRU incinerators, the only emission component actively and continuously measured is SO_2, usually by an online analyser most commonly known as a continuous emission monitoring system or CEMS. While it is technically possible to add CO and NOx measurements to that same instrument, in practice it is very uncommon. H_2S and TRS measurements are technically very difficult if not impossible to achieve since the amount of SO_2 relative to these components results in interference problems for the CEMS instrument.

Therefore, instead of continuous measurements of H_2S, TRS, CO, and NOx, concentrations are commonly determined by conducting a "compliance test", in which a state-approved testing company using state-approved analytical methods determines these values during a relatively short test period. In many cases this compliance test is conducted only once, soon after the SRU incinerator was first brought into operation. In other cases the compliance test needs to be repeated at certain intervals, usually once every one to three years.

Although certain conditions must be met for the compliance test to be valid, such as the SRU operating near its design capacity, the operating parameters for the incinerator itself during the compliance test are left up to the operator. Consistent with the general confusion regarding how an SRU incinerator must operate, the compliance test parameters chosen by the operator are often arbitrary; using the incinerator design conditions, the EPA start-up conditions, previous test conditions, etc. This often leads to compliance tests being carried out at the wide range of conditions; 1,200°F (650°C) to 1,400+°F (760+°C) and with 2 to 5+% of oxygen.

A compliance test conducted at most of these "arbitrary" conditions will almost always result in emissions for all components being much less than allowable limits since:

- SO_2 is usually much less than allowable limits because of good upstream SRU operation, and is unaffected by incinerator conditions (ignoring moderate dilution effects);
- H_2S, TRS, and CO limits are also usually much less than allowable limits again primarily because of good upstream SRU operation (discussed in following section), although very hot incinerators with too much excess oxygen further reduces these residuals;
- Although NOx and SO_3 will increase with hotter temperature and excess oxygen content, there is usually not enough at any of the SRU incinerator conditions to exceed allowable limits.

If and when the initial compliance test passes, the SRU operator almost never experiments with different (i.e., cooler) temperatures and excess oxygen contents to discover if these would also result in a "pass". This means that the original arbitrary test condition then becomes the approved "pass" condition and dictates the required operation from that moment on. In short, operating conditions that were given little or no thought during the initial compliance test now become mandatory ongoing conditions and are simply replicated if regular compliance tests are needed.

In a few cases, the compliance test will fail at the initial arbitrary test condition, most commonly because of some combination of too much CO entering the incinerator (poor upstream SRU operation) or a strict CO emission limit. In these cases, the incinerator temperature is increased until a "pass" is achieved, and again this becomes the new regulated temperature with no more effort expended to reduce the CO inlet concentration nor to re-examine the permitted CO emission limit.

In reality, any incinerator operating condition that meets the permitted values during a compliance test can easily become the new approved conditions. The SRU operators simply need the incentive and the will to find the "ideal" conditions rather than just accepting the traditional values, and then to conduct another compliance test to prove the validity of the new, better condition. The "incentive" is that ideal conditions will usually significantly reduce operating costs, reduce CO_2 emissions, and even reduce emission rates of some pollutants such as NOx and SO_3.

Typical SRU incinerator inlet compositions

In the USA, the federal EPA requirement that an SRU incinerator emit less than 250 ppm of SO_2 means that the total amount of sulphur species (H_2S, COS, CS_2, SO_2, elemental sulphur) present in the SRU tail gas (the incinerator feed) needs to be at or less than that value (ignoring dilution affects from the incineration itself). To meet this requirement, most SRU designs include an amine-based tail gas treating unit (TGTU) that easily keeps the SRU tail gas sulphur species concentration to much less than 250 ppm. Based on 40 recent Sulphur Experts' tests on USA-based sulphur plants where measurements were available, the "average" or "median" value for H_2S concentrations exiting the TGTU and entering the incinerator were assumed to be 50 ppm of H_2S plus 15 additional ppm of COS and CS_2 (65 ppm total), for modelling purposes.

For an SRU incinerator that has clear emission limits assigned to it (ppm values or mass limits that can be converted to equivalent ppm values), destruction efficiencies and corresponding emission limits for H_2S and TRS can be modelled using simulation packages specifically designed for this purpose. These simulators require not only the incinerator inlet conditions, but also require information about the incinerator construction itself (i.e., residence time, "mixing efficiency", etc.). Although this means that every specific site would require its own site-specific model, for illustration purposes an "average" incinerator design was used along with varying incinerator feed H_2S concentrations to generate the curves presented in Fig. 2.

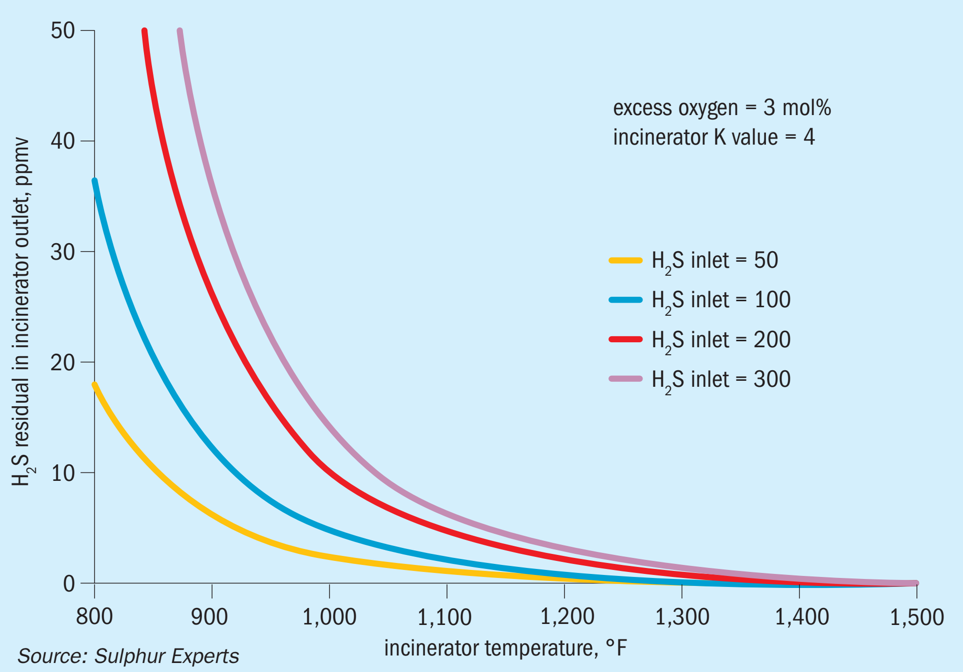
Using Fig. 2, the "typical" SRU tail gas feed H_2S of 50 ppm would need to be incinerated at around 850°F (455°C) to reduce the concentration to 10 ppm (residual) in the incinerator exit and around 975°F (525°C) to result in 3 ppm (at 3% excess oxygen). These values are much less than the 1,290°F (700°C) "average" incinerator temperature actually in use by USA incinerators.

Even in the "worst case", with 300 ppm of H_2S present in the SRU tail gas, suggesting a very poorly operated TGTU, 1,075°F (580°C) is all that is needed to have a 10 ppm residual H_2S, and 1,200°F (650°C) for 3 ppm.

Although identical modelling can be conducted for COS, CS_2, and TRS, they are not included in this article due to the fact that there is usually (but not always) a much smaller amount of them in the SRU tail gas than H_2S, and so destruction of these components to an acceptable value is almost always achieved whenever the conditions for acceptable H_2S destruction are met. So again, destruction of these components also does not require the very hot temperatures at which most SRU incinerators actually run.

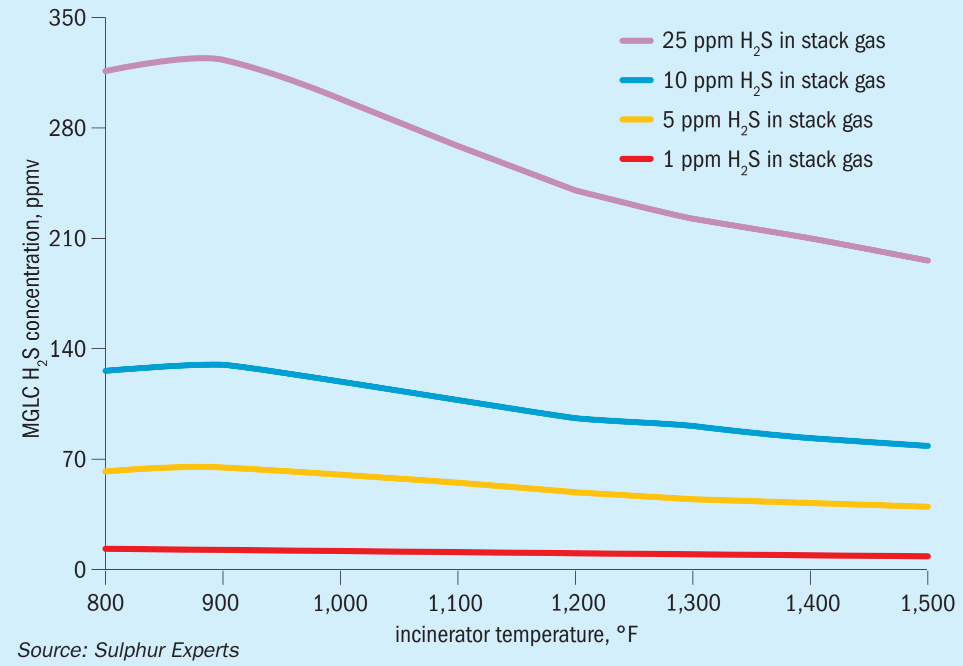
For those SRU incinerators without specific H_2S or TRS emission requirements, but that still want to adhere to the State's MGLC requirements, finding the acceptable incinerator temperature is complicated by the fact that dispersion modelling is required for the SRU incinerator exit gas. Again, modelling packages specifically designed for this purpose and acceptable to State authorities are available. These simulators require not only the incinerator outlet conditions and incinerator design information, but also require site-specific meteorological data. Again, although this means that every site should have its own site-specific model, for illustration purposes an "average" incinerator design and "default" meteorological conditions were applied to determine the MGLC for H_2S for a variety of SRU incinerator exit temperatures and exit H_2S concentrations. These data were used to generate the curves presented in Fig. 3.

Fig. 2: **Modelling of H_2S destruction in incinerators**



Source: Sulphur Experts

Fig. 3: **Modelling of H_2S MGLC values based on incinerator emissions**



Source: Sulphur Experts

These curves can be used in conjunction with State MGLC regulations to determine acceptable emission temperatures and concentrations. For example, the Texas requirement of 120 ppb for ground-level H_2S would require (for this specific modelled "average" incinerator design and "default" meteorological conditions) there be slightly less than 10 ppm of H_2S leaving the stack at any modelled temperature. Combining this knowledge with the data from measured COS + CS_2 values in USA SRU incinerator inlet streams data means that an incinerator temperature of 850 to 900°F (455 to 480°C) would be suitable for a "typical" SRU operation with 50 ppm of H_2S in the SRU tail gas, and around 1,100°F (590°C) even in the "worst case" of 300 ppm of H_2S in the SRU tail gas. Even in California, where the MGLC is 30 ppb for H_2S, SRU incinerator temperatures of no more than 1,200°F (650°C) would suffice.

In many cases, the H_2S and TRS concentrations present in the SRU tail gas are already less than the incinerator emission limits and less than the EPA limit where incineration is not required. In these cases, in theory, the stream could be released to atmosphere directly and a decision regarding some type of incinerator "standby" operation (keeping it hot only for an upset condition where incineration is required) may be appropriate.

The final SRU tail gas component that may require incineration is CO. Although the front-end Claus process used by SRUs actually generates significant CO concentrations from thousands of ppms up to percent levels, the amine-based TGTU technologies used by most SRUs employ a catalyst that reacts this CO to a much smaller concentration. If the TGTU catalyst is working well, CO concentrations leaving this unit would never exceed a few tens to a few hundreds of ppms.

For those SRUs that have no CO emission limits, the SRU tail gas CO concentration has no effect on the chosen incinerator operation and it can be adjusted to suit the H_2S/TRS requirements only.

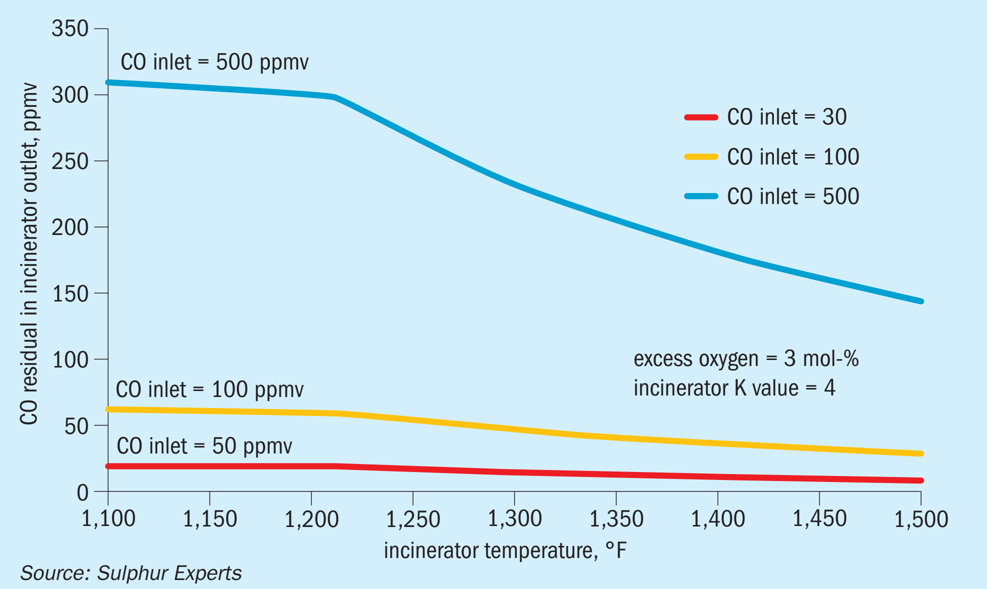
For those SRUs where the CO in the SRU tail gas is already less than the incinerator emission limit, which is the case for most well-run SRUs with "moderate" CO emission limits of 250 to 1,500+ ppm, again the amount of CO in the tail gas has no bearing on how to best run the incinerator and it can be adjusted to suit H_2S/TRS requirements only.

For those sites with strict CO emission limits in the tens of ppms, again the tail gas from a well-run SRU may already meet even these strict requirements, and destruction of H_2S/TRS will remain the limiting factor. It is only in the relatively few cases where the amount of CO in the SRU tail gas exceeds the emission limit when good incinerator CO destruction will be needed.

In these few cases, the required incinerator temperature depends on the inlet CO concentration and the CO emission limit. As with the H_2S modelling, CO destruction efficiency and corresponding stack gas content can be modelled using simulation packages specifically designed for this purpose. Again, every site would require its own site-specific model, but for illustration purposes an "average" incinerator design was used against a variable incinerator feed CO concentration to generate the curves presented in Fig. 4.

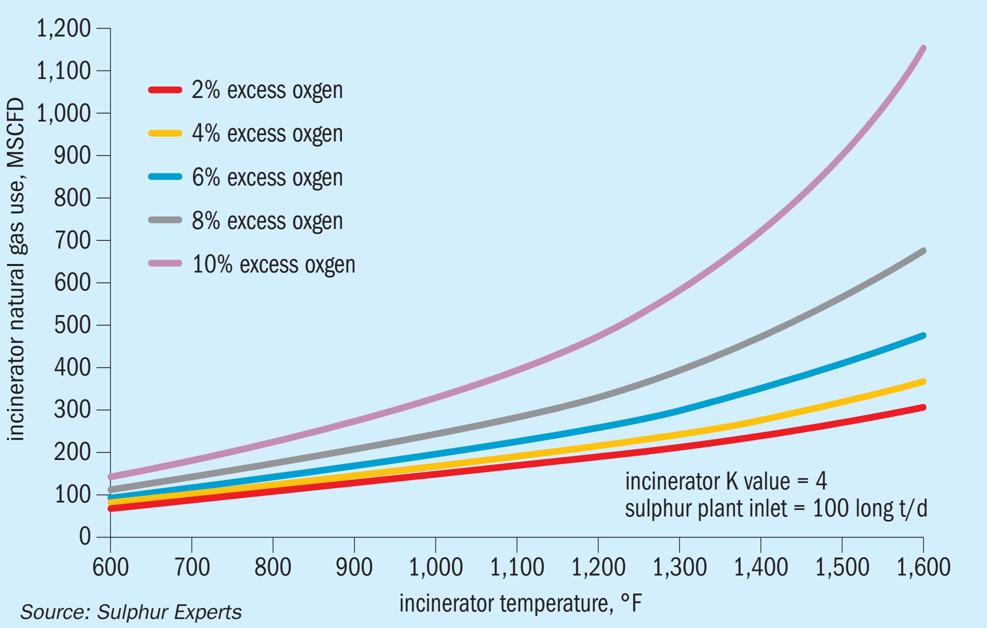
As shown in Fig. 4, good CO destruction requires the incinerator to be relatively hot, at least 1,250+°F (675+°C), to achieve a meaningful reduction in CO concentration. Any apparent decrease in CO emissions at a temperature cooler than this is essentially due to dilution effects alone.

Fig. 4: **Modelling of CO destruction in incinerators**



Source: Sulphur Experts

Fig. 5: **Incinerator natural gas use versus temperature and excess oxygen**



Source: Sulphur Experts

Therefore, destroying CO in the SRU incinerator requires temperatures of 1,250+°F (677+°C), and up to 1,500+F (815°C) in some cases, obviously eliminating the opportunity to optimise the incinerator. In these cases it may be wise to either lessen the amount of CO entering the incinerator by improving the TGTU operation, or to revisit the permit CO limit against the large environmental cost of CO destruction.

In many cases, the CO concentration (like the H_2S and TRS concentrations) in the SRU tail gas is already less than the incinerator emission limit. In these cases, again, incineration is not even necessary and a decision regarding some type of incinerator "standby" operation may be appropriate.

Incentive to optimise

As already mentioned, incinerator optimisation will reduce fuel gas consumption (usually natural gas) and the associated operating cost, reduce associated CO_2 emissions, and reduce the formation of pollutants such as NOx and SO_3.

Recently tested USA SRU incinerators were operating with between 2% and 10% excess oxygen, with an average of 5%. Historical work on SRU incinerators has shown that excess oxygen less than 2% lowers destruction efficiencies, while excess oxygen significantly greater than 2% does not improve contaminant destruction efficiency but merely increases fuel usage

1 47
2 48
3 49
4 50
5 51
6 52
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

Fig. 6: **Incinerator design examples – low 'K' incinerator (left) and high 'K' incinerator (right)**

Source: Sulphur Experts

(and associated operating cost, CO_2 emissions, NOx and SO_3 formation) with no other benefit. This is the reason why, in those few cases where excess oxygen requirements are included in permits, levels between 2 and 3% are usually stipulated.

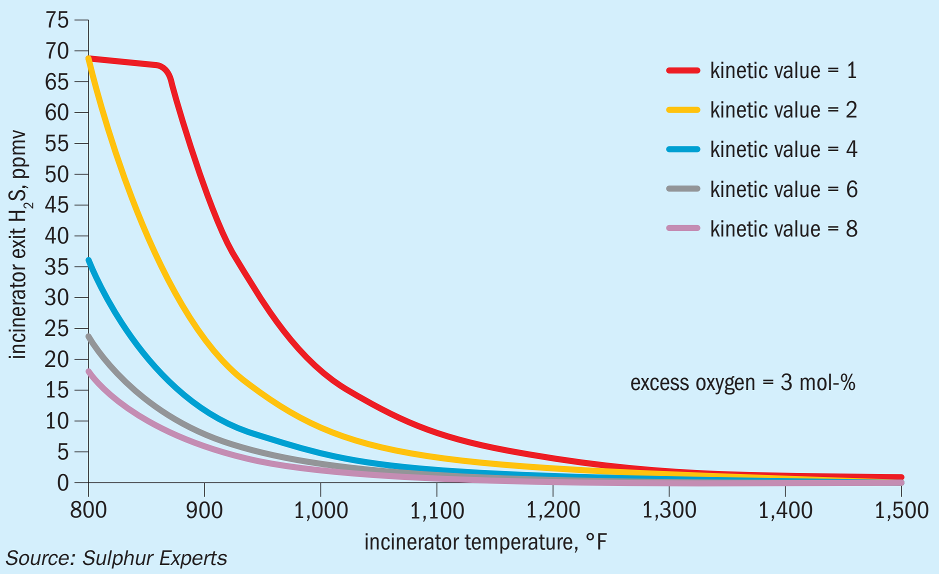
Fig. 5 shows the effect of oxygen concentration on fuel gas usage for a "typical" incinerator attached to a 100 long t/d SRU. Merely dropping the "average" 5% excess oxygen value to 2% excess oxygen and keeping the average temperature of 1,290°F (700°C), results in natural gas requirement declining from approximately 350 MSCFD (10 m³/d) to around 210 MSCFD (6 m³/d), a savings of 40%.

For this theoretical 100 long t/d facility, at a 2022 Q3/Q4 average price of around $6.5/million Btu, this represents nearly $400,000 in operating cost savings per year, plus a decrease in CO_2 emissions of 3,100 t/a. Escalating the one theoretical 100 long t/d SRU to the USA as a whole (approximately 20,000 long t/d of production from SRUs) the potential savings rise to $80million and 620 thousand tons of CO_2 emissions simply with this change alone. The savings for individual sites will obviously ratio up or down depending on the size of the SRU and the initial excess oxygen target, however, the potential savings of merely controlling the excess O_2 does indeed appear to be worth the hassle of ensuring regular manual or automatic adjustment of the incinerator air flow rate.

Using the same Fig. 5 data and combining a reduction in excess O_2 from 5% to 2% with a cooler operating temperature, from 1,290°F (700°C) down to 1,000°F (540°C), which would easily meet incinerator destruction requirements for most plants, the natural gas requirement declines from the starting 350 MSCFD (10 m³/d) to around 140 MSCFD (4 m³/d), a decrease of 60%. For the theoretical 100 long t/d facility, that is nearly a $600,000 annual operating cost savings plus a decrease in CO_2 emissions of 4,650 t/a. Applied to the USA as a whole, this represents potential savings of $120 million and 930 thousand tons of CO_2 emissions annually. Potential savings for individual sites will again ratio up or down depending on the size of the SRU, the initial excess oxygen concentration and temperature, and the final values. The potential savings, however, are large enough for most sites to spend the time and effort to conduct the type of evaluation presented in this paper.

One final potential route to save fuel in a SRU incinerator, in addition to evaluation and optimisation of the temperature and oxygen, is to mechanically upgrade the mixing / combustion efficiency of the incinerator itself. All of the destruction modelling shown in this article has been conducted using an "average" mixing efficiency (known as a "kinetic value") of "4". Fig. 6 shows examples of low and high "K" value incinerators, while Fig. 7 shows the effect of different kinetic values on the

Fig. 7: **Effect of incinerator mixing efficiency on H_2S destruction**



Source: Sulphur Experts

H_2S destruction efficiency, with improved (higher) kinetic values achieving the same H_2S destruction efficiency at a cooler and cooler temperature. Depending on the starting K value of a specific incinerator, and the fuel and CO_2 savings associated with upgrading the incinerator, mechanical upgrades such as burner changes, checker walls, air blowers, or full incinerator replacements may pay for themselves relatively quickly.

Additional considerations

There are also a number of other operating variables that might affect the ability of the SRU operator (and the permitting authority) to determine optimal operation. These are discussed briefly below.

Downstream heat exchange

Because of the relatively high operating temperature of most SRU incinerators, some designers and operating companies choose to add heat recovery (steam generators, steam superheaters, process gas exchangers, etc.) immediately downstream of the incinerator. Although relatively uncommon in the USA but customary in Europe, a number of USA SRUs do have this type of design. In these cases, extra natural gas burned in the SRU incinerator is not "wasted" since it provides additional thermal energy for the exchangers to recover. The ability to or desire to decrease the temperature and excess oxygen in these units, therefore, must also consider the downstream heat recovery systems.

Volatile organic compounds (VOCs)

As discussed previously, most SRU incinerators do not have VOCs in the SRU tail gas or in the fuel gas being used in the incinerator. In some cases, however, there may be VOCs in the tail gas, i.e., where impure hydrogen streams are added to the TGTU process gas. In other instances, VOCs may be added via a separate stream to the incinerator (i.e., with flash gases), or they may be present in the incinerator fuel (i.e., where refinery fuel gas is used instead of natural gas). If the VOC content is large enough and if the incinerator permit stipulates a VOC limit, then these components require much hotter temperatures, similar to those required for CO destruction (1,250+°F), which may restrict the optimisation opportunities for the incinerator.

TGTU bypassing

The amount of H_2S, TRS, and CO leaving the SRU when the TGTU is in operation is very small, meaning little if any incinerator destruction is required for these components. If, however, the TGTU is bypassed, all of these concentrations, especially for H_2S and CO, will increase significantly. For SRUs where TGTU bypassing is not allowed or not possible, then this does not factor into the determination of an optimised incinerator. For plants which can and do occasionally bypass the TGTU, however, a hotter SRU incinerator would be required to meet the same emission guidelines for those bypass periods.

This leaves the permitting authority and the SRU Operator with two options: 1) use the temperature needed for TGTU bypass operations all of the time, just to be ready for the occasional brief bypass; or 2) ramp up to the hotter temperature only when the TGTU is bypassed, recognising that it may take a few hours to achieve the necessary temperature (since ramp-up rates are limited by mechanically-acceptable temperature change rates for the incinerator). A number of jurisdictions outside of the USA use a two-tiered incinerator temperature approach to manage the with- and without-TGTU cases, and the US EPA has already set acceptable conditions for SRU "start-up and shutdown" that may also be applicable to TGTU bypass cases (i.e., 1,200°F and 2% excess O_2).

Incinerator quality

In a few of Sulphur Experts historical cases, SRU incinerators are so poorly designed or in such disrepair that they actually generate CO or soot (particulate matter – PM) in normal operation. Testing can confirm if this is true for any given incinerator and, in these cases, hotter temperature or more excess oxygen may be needed simply to overcome the poor design. Especially in these cases, mechanical upgrades to the incinerator (i.e. improvements in the "K" value) would likely pay out quickly in reduced fuel gas usage and CO_2 emissions.

Incinerator turndown

Certain incinerator designs may also simply not be mechanically capable of operating with the reduced fuel and air rates associated with optimised operation; they were designed for "worst case" conditions and may not have the "turndown" ability to operate at 50+% below this maximum firing rate. Again, in these cases, it would be wise to consider mechanical upgrades to improve their turndown to use less fuel gas and air.

Applicability to other jurisdictions

Although the primary focus of this article was on USA SRU incinerators, the same methodology is applicable to incinerator operations in any country and any jurisdiction:

- determine the precise emission or MGLC limits in place;
- determine the concentrations of the controlled species in the SRU incinerator feed gases;
- conduct modelling and then field testing to determine the lowest combination of excess oxygen and incinerator temperature that will achieve the required emissions;
- evaluate needed permit changes or discuss options with permitting authorities;
- change the incinerator operation.

This exact procedure has been in place in Alberta, Canada for decades, and is known as the "stack top temperature reduction", or STTR, program. Not surprisingly, Alberta SRU incinerators typically run between 600°F (315°C) and 1,000°F (540°C), with regular automatic or manual adjustments to the incinerator air flow, requiring significantly less fuel gas than comparable USA facilities.

Like in the USA, many other jurisdictions outside of Alberta have simply not put in the time and effort to understanding the exact SRU incinerator requirements for their specific facility. It is hoped that the incentives outlined in this article regarding fuel gas reduction, CO_2 emission reduction, and reduced NOx and SO_3 formation will also increase interest in this topic in other jurisdictions. ■

Acknowledgement

This article is an abridged version of a paper by Gerald E. Bohme and Peter J. Seville of Sulphur Experts Inc., "How better understanding of SRU incinerators can simultaneously save money and reduce emissions," presented at the Laurance Reid Gas Conditioning Conference February 20-23, 2023, Norman, Oklahoma USA.

Fine-tuning SRU incinerator burners

The Aecometric 3rd generation burner was developed, installed and commissioned for an SRU incinerator with increased stringent demands to reduce NOx emission and lower energy consumption. **Mason Lee** of Aecometric Corporation reports on the new burner design and performance. The emission test results show a significant improvement in addressing these environmental concerns to achieve low NOx (<50 mg/m^3) combustion and minimise CO (<200 mg/m^3) emissions.

Incinerator burners play a crucial role in waste management and industrial processes, but it comes with environmental challenges related to emissions of nitrogen oxides (NOx) and carbon monoxide (CO). Aecometric's 3rd generation incinerator burner represents a significant leap forward in addressing these environmental challenges by integrating advanced combustion techniques and emission control technologies to achieve low NOx combustion and minimising CO emissions.

PHOTO: AECOMETRIC

Fig. 2: 2nd generation incinerator burner installed at Habshan 5

Design principles and technologies

Careful control of combustion parameters and optimisation of burner operation by staging fuel and air is used to accomplish the even distribution of fuel and air while lowering the peak temperature profile within the combustion zone. Taking advantage of Aecometric traditional high intensity combustion technology, the design strategies employed in 3rd generation incinerator burners (Fig. 1) are aimed at optimising combustion efficiency while minimising pollutant emissions. Key design features of 3rd generation incinerator burner include:

- high intensity combustion with strong swirl within the combustor zone;
- advanced windbox configuration to incorporate features of staged combustion air and tail gas;
- secondary combustion air and tail gas introduced directly through the burner's windbox;
- high degree of rotational velocity to tail gas stream toward intense combustion at the entrance of the chamber;
- comprehensive turbulence enhancement, optimised air-fuel mixing, increasing flame stability to promote efficient and clean combustion;
- combustion operating burners under fuel-lean conditions to minimise flame temperatures and inhibit NOx formation;
- precision tail gas distribution systems to ensure optimal fuel distribution and airflow pattern to stabilise combustion, minimise CO formation and enhance combustion efficiency;
- combustion control systems to implement advanced control systems that monitor effluent emission parameters in real-time and adjust burner operation for optimal NOx reduction.

Fig. 1: **3rd generation incinerator burner configuration**

Source: Aecometric

PHOTO: AECOMETRIC

Fig. 3 3rd generation burner installed at Yangzi, SINOPEC

Case studies and performance evaluations

Based on the successful commissioning and operation of 2nd generation incinerator burners for Habshan 5 in 2013 (Fig. 2), extensive research has been conducted to develop and optimise combustion technologies aimed at further reducing NOx and CO emissions. This includes studies on combustion kinetics, pollutant formation mechanisms, and advanced combustion techniques such as lean combustion, staged combustion, and combustion simulation to support engineering design. These studies provide valuable insights into the practical implementation and performance improvement of the incinerator burners under real-world operating conditions.

The 3rd generation incinerator burners were designed, installed, commissioned and operated at SINOPEC Yangzi Petrochemical in 2024 (Fig. 3). The main features of the 3rd generation incinerator burner configuration are:

- The tail gas is split into three streams, introduced through the burner windbox, and pre-mixed with secondary combustion air prior to entering the incinerator.
- A high swirl ratio of primary combustion air ensures high intensity combustion.
- Integration of staged combustion air and fuel is accomplished to optimise the combustion process and eliminate peak temperature profile in the combustion zone at an early stage.
- Even airflow and tail gas flow patterns are ensured to enhance the turbulent mixing effect during combustion.
- The mild temperature distribution is obtained to promote low NOx emission and minimise CO formation for complete combustion.
- The burner is able to meet stringent emission regulations while maintaining high thermal efficiency.
- The advanced 3rd incinerator burner for SRU applications highlights the improvements in combustion efficiency and emission control.

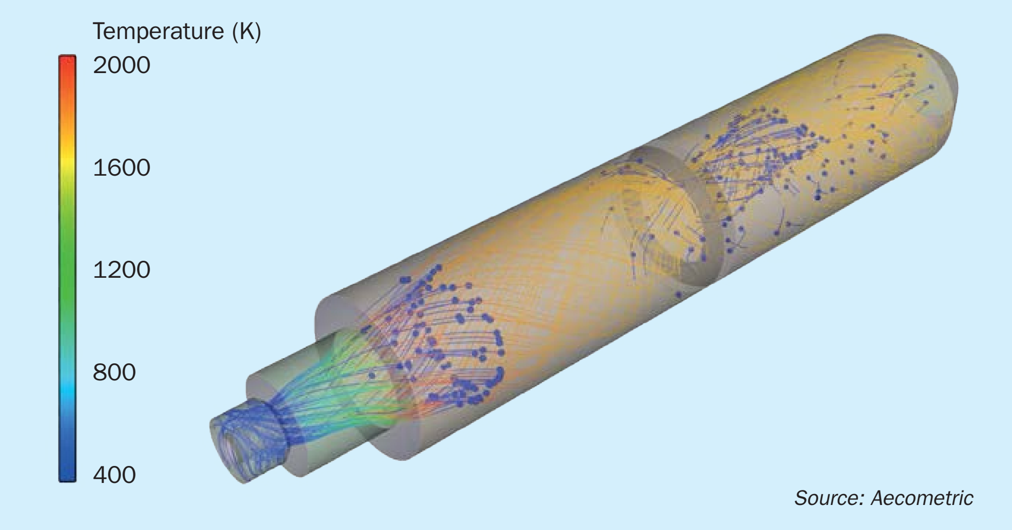
Table 1: **Summary of typical emission test results**

Case	Effluent temperature	Concentration						Concentration (corrected to dry at 3% O_2)	
		O_2	CO	CO_2	NO	NO_2	NOx	CO	NOx
	°C	%	mg/m³					mg/m³	
1	67.1	4.12	141	9.49	14.5	2.8	25	187.31	21.41
2	137.8	4.13	125	9.48	9.1	15.8	29.8	166.57	25.48
3	137.4	4.15	138	9.47	9.0	20.9	34.7	184.34	29.67
4	137.6	4.20	149	9.44	8.5	24	37	199.63	31.73

Source: Aecometric

Preliminary emission tests to extract representative samples of the incinerator (BU202) exhaust gases was conducted in April 2024 using specialised sampling equipment SICA 230-4NLDL. This model of gas analyser comes with the function to measure the concentration of species including O_2/CO/NO/NO_2 in real time. During the emission test, samples of the incinerator exhaust gases were collected at predetermined intervals over a specified period. The sampling location of the incinerator stack is located at a height of 70 m to ensure that the collected samples are representative of the emissions released into the atmosphere. To ensure the accuracy and reliability of the emission test results, QA/QC procedures including calibrating the

Fig. 4: **Proposed CFD combustion modelling**



Source: Aecometric

gas analyser were implemented throughout the testing process. The typical emission results are shown in Table 1.

Environmental impacts and benefits

The development of the 3rd generation burner for SRU incinerators represents a milestone in an improvement of clean and efficient combustion technologies, offering solutions to the environmental challenges associated with tail gas incineration and industrial processes. Through the efforts to lower emissions of NOx and CO from incinerators and other combustion sources multiple environmental benefits are achieved, ranging from improved air quality and environmental sustainability to climate change mitigation and public health benefits. These benefits underscore the importance of continued efforts to reduce emissions of these harmful pollutants.

Future directions and challenges

While 3rd generation incinerator burners have made substantial progress in reducing NOx (<50 mg/m³) and CO (<200 mg/m³) emissions, ongoing experimental sample tests at different operation scenarios associated with fine-tuning of the incinerator and advanced research and development efforts are needed to address remaining challenges and further improve burner performance. The development of advanced control algorithms and predictive modelling techniques including computational fluid dynamics (CFD) modelling (Fig. 4) are essential. These techniques have been proved to be instrumental in optimising combustion systems for lower NOx emissions. Looking ahead in the future, these efforts, techniques and tools will allow engineers to analyse combustion processes in detail, identify areas of high NOx formation, and develop mitigation strategies.

Sulphuric acid in the age of technology

In today's dynamic business landscape, digitalisation has become a powerful tool for companies seeking to enhance operations. By leveraging real-time plant data, organisations can create more meaningful interactions between operations teams, technical experts within the industry and the power of machine learning. **David Dericotte** and **Linda Colby** of Elessent Clean Technologies introduce the MECS® digital advisor, a web-based dashboard for plant performance assessment, troubleshooting and a supplemental mentoring tool for less experienced engineers and operators.

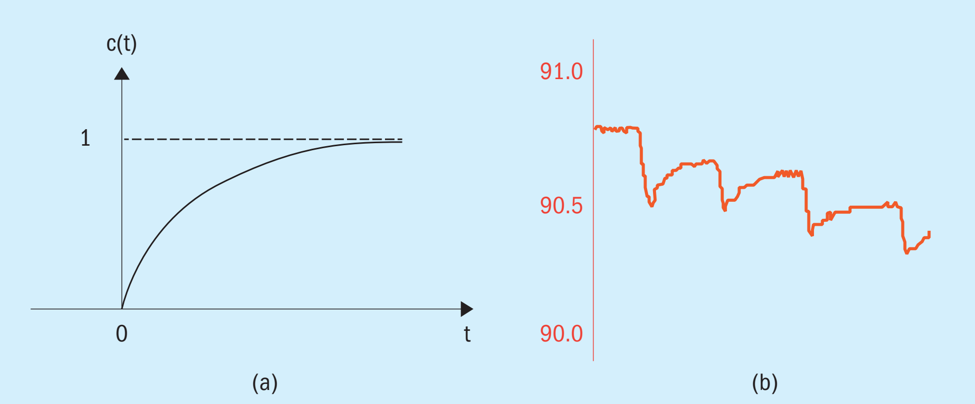
Traditionally, sulphuric acid plant operations have relied on legacy historian systems for data collection and knowledgeable staff with engineering insights and experience to interpret this data. These historian systems record process, lab and sometimes field-collected data without predictive algorithms, resulting in limited interaction with the operations team. However, the landscape is changing rapidly. Advanced analytics models, including machine learning and artificial intelligence, can be incorporated to go beyond traditional regression analysis. These tools can reveal hidden patterns and complex interdependencies, enabling more precise modelling of core plant functions for operations and maintenance planning. In addition, it addresses down-to-earth, day-to-day needs for real-time collaboration, integrated turn-around planning, and mentoring of new hires.

MECS® digital advisor is a web-based dashboard that provides clients with a graphical way to visualise their plant data. It functions similarly to how subject matter experts (SMEs) would evaluate data to assess plant performance and troubleshoot issues. It is custom-built for each individual plant based on the customer's latest set of P&IDs, instrumentation information, LIMS and CIMS data. Using the data from the instruments or tag data, custom dashboards are developed to visualise data via data trends, comparisons, ratios, data analytics and other leading indicators that predict plant performance. This is intended to help reduce process operational creep. Each graphic includes some level of explanation and operation direction. Dashboards can communicate progress on key improvement initiatives across multiple levels in the client organisation. Should the tracked key process variables or indicators exceed targeted limits or exhibit suspect behaviour, an event notification can be sent to SMEs and key customer personnel, if desired. Additionally, from the website, users can access, download, and print reports.

This type of in-depth data evaluation can also allow client and MECS engineers to better collaborate on turnaround planning. An example could be the review of the converter health. By comparing converter operational trends to previous MECS® PeGASyS™ data, catalyst screening and loadings can be better optimised.

Across multiple industries, companies are experiencing departures by many of their senior operations experts. And for new development grass roots acid plant applications, the plant sites can be remote with little surrounding infrastructure to facilitate quick, easy visits by experienced engineers. MECS® digital advisor can be set up to track changes and to make scripted recommendations on possible actions that can be reviewed through the website. If the problem persists, a call to one of the MECS SMEs may be warranted. It is one thing to see a change in a trend; it is another to understand what to do about it. MECS® digital advisor as well as developing a close relationship with MECS SMEs can provide mentoring to less experienced engineers and operators.

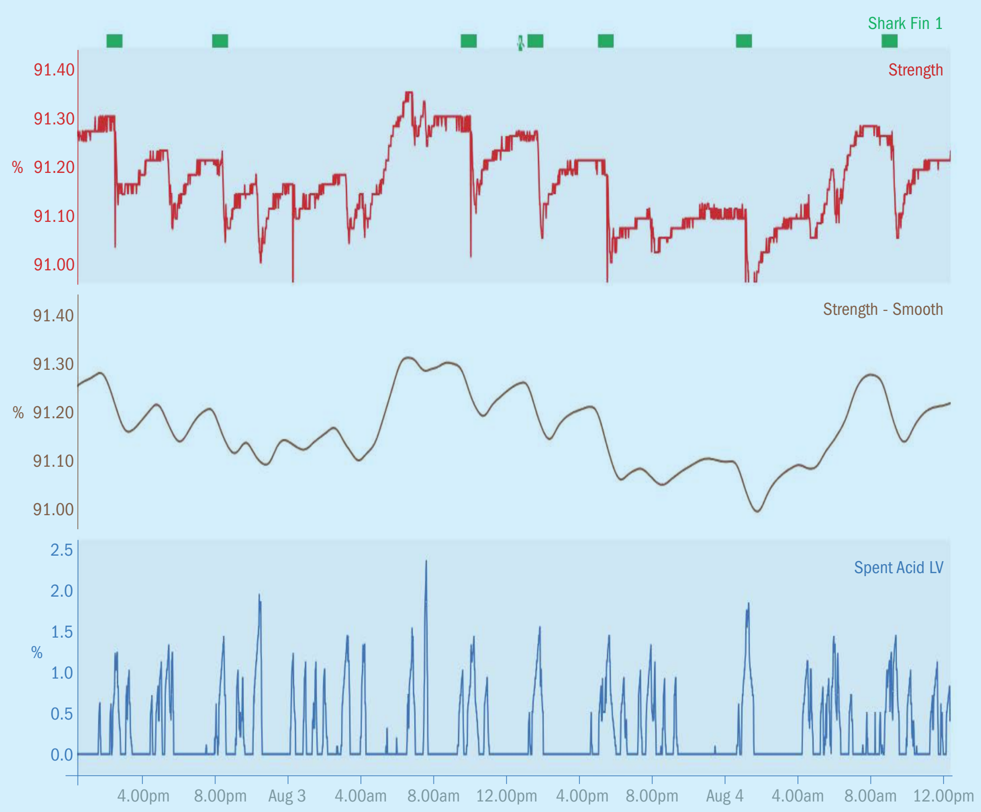
Fig. 1: **Characteristic first-order response to a step change (a) and recurring pattern in data signal (b)**



Source:

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Fig. 2: **Raw data, smoothed data and suspected root cause (valve position) trends to build shark fin pattern detector (condition) using Seeq® Workbench which is an embedded tool in the MECS® digital advisor. Green bars at top indicate a pattern detected (capsules).**



Source:

Fig. 3: **Signal quality before and after recommendations applied by customer, visualised and analysed using Seeq® Workbench**

Source:

MECS® digital advisor is designed to work with multiple data historians and data transfer mechanisms. MECS has used AVEVA Cloud Connect, developed an Edge device, and REST API as possible front doors to facilitate data exchange. MECS partnered with RoviSys™ who applied its deep development experience to create the integrated engine and security design behind the MECS® digital advisor. Data security is key to protecting both client intake data and MECS know-how. One of the first objectives of this tool creation was securing the system. MECS incorporated tools from:

- Microsoft Azure Cloud Hosting
- Authentication by Microsoft - Entra (Azure AD and B2C.)
- 24x7x365 Security Monitoring by SOC – cybersafesolutions.com
- Antivirus and IDS provided by Sentinel One

Safeguards using firewalls and multiple servers create a safe environment to share data.

Below are two different examples of how MECS® digital advisor is being used to better plant operations and safeguard equipment.

Spent acid strength is a key economic variable for sulphuric acid regeneration plants tied to alkylation units. Recently, using MECS® digital advisor to review detailed process data, an MECS SME noticed unusual behaviour in the output from a refractometer used to measure spent sulphuric acid strength, suggesting a problem with the instrument and/or the measurement environment or process control devices. After cross-checking several variables available within MECS® digital advisor, the SME confirmed that the observed response was real (not noise) and, within a few hours without having to interrupt the customer's engineering team, completed a detailed root cause analysis, identified the core issue affecting the process and prepared a presentation on the situation that included a recommended response strategy to the customer's operations team.

Using the tools available within MECS® digital advisor, including Seeq® (an advanced analytics, ML, & AI platform purpose-built for unlocking and visualising the insights hidden in time-series data), the SME walked the customer through the analysis work path, sharing background information to connect the core issue to the observed effects along with a historical analysis that quantified how frequently the issue had been occurring over the past several months. As the customer applied the MECS recommendations, the SME continued to monitor the key process variables via MECS® digital advisor to help the customer refine the solution and significantly improve the signal's accuracy.

The next few figures illustrate the analytical journey described above. Observe, the solution "tuning" period in the middle of the chart in Fig. 3, where the spent acid level valve signal shows relatively high amplitude then levels out as the solution is refined, and the significant decrease in the detected pattern after the final solution as evidenced by the significant reduction/elimination of the green capsules at the top of the chart in Fig. 3.

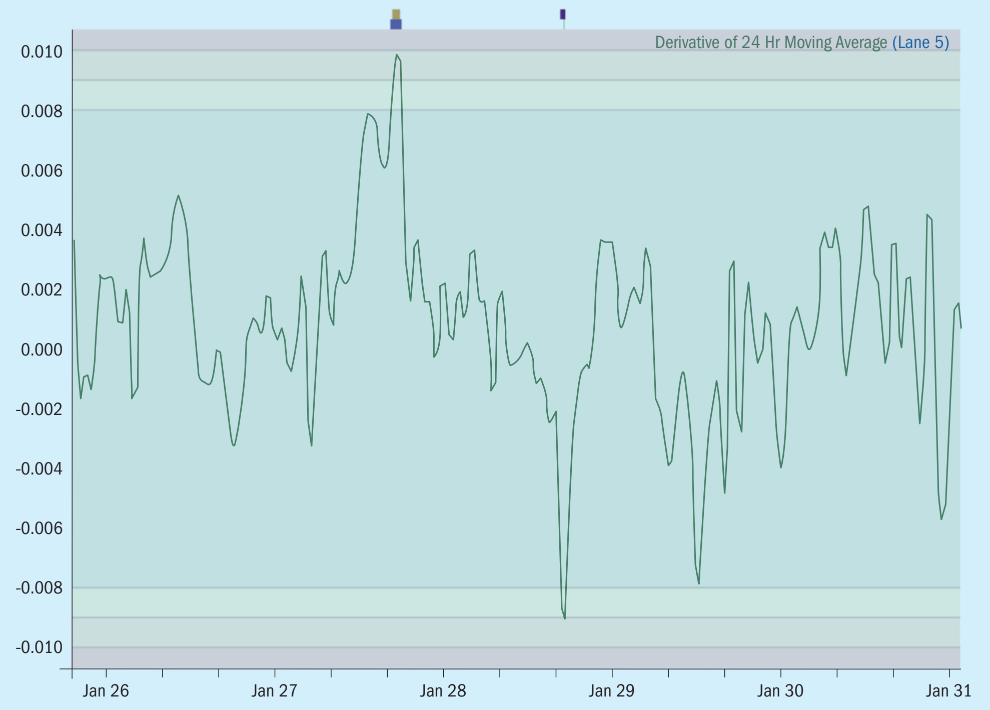
The next example illustrates MECS's efforts to continually improve methods for rapid detection of operational shifts within HRS™ units The earlier an issue is detected, and corrective action taken even before the alarm state is met, the better the outcome for the system.

In Fig. 4, the first derivative of HRS™ boiler steam generation to boiler feedwater ratio is tracked. Ideally, the slope should be flat, oscillating around zero. The system can statistically analyse the spikes in this ratio looking for a growing number of occurrences that may indicate an issue versus instrument or system noise. The system is also looking for a slowly rising trend that may indicate an equipment issue.

The HRS™ system instrumentation tracks the HRS™ boiler acid temperature in and out as well as the HRS™ boiler feedwater heater temperature in and out. Using this information graphically illustrates several delta comparisons (see Fig. 5). The HRS™ boiler feed water heater outlet temperature should always be less than the acid inlet temperature (bottom chart). The differential between the HRS™ boiler acid outlet temperature and the boiler inlet temperature should be greater than 6°C which is the trip point for the system (red zone), with the preference to be in the green zone about a 36°C delta. The colours provide banding that indicates a narrowing of the delta. And then in the example shown in Fig. 5, a return to normal, steady operation. Using this type of data, the operator and an MECS SME can work through an investigation decision tree.

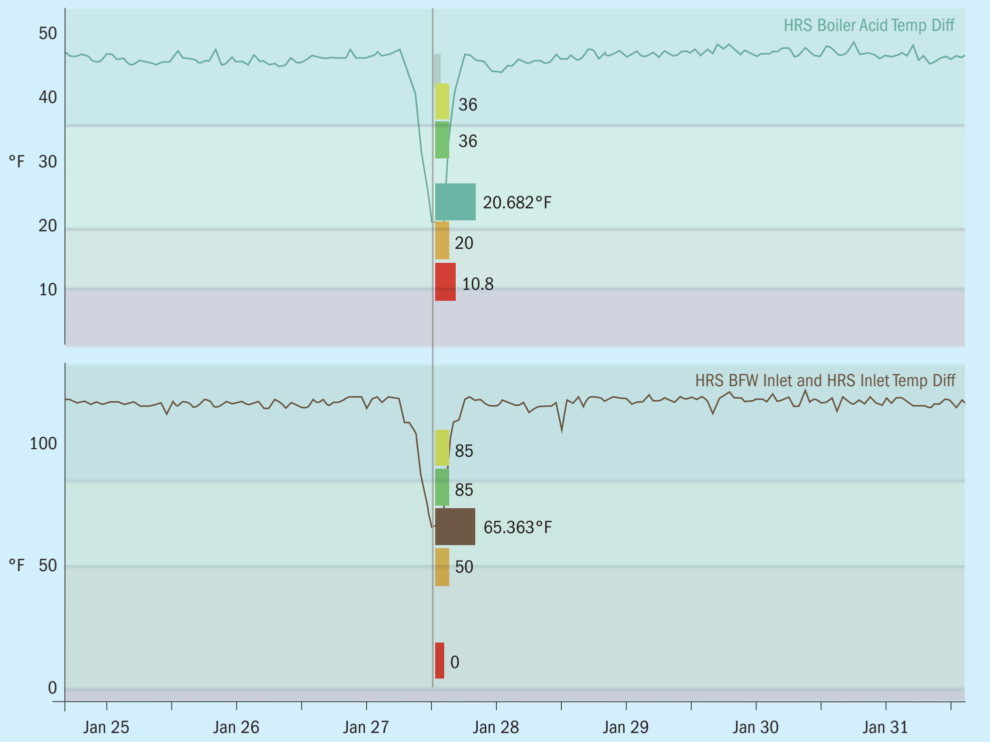
Technology is changing fast. Operations and engineering teams and technical experts can harness these new tools to help improve the operations of a mature industry. Many key variables within sulphuric acid plants may need close monitoring for evaluation. MECS® digital advisor is designed to create an operations team that is more informed, more responsive, and able to focus more time on key priorities. It provides a novel approach to visualising data compared to traditional DCS screens and can be a supplemental mentoring tool for less experienced engineers and operators. It allows MECS SMEs to respond faster than the traditional fly-in boots-on-the-ground approach.

Fig. 4: **Visualised and analysed using Seeq® Workbench**



Source:

Fig. 5: **Visualised and analysed using Seeq® Workbench**



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Taking digitalisation to the next level

Digitalisation is making a strong impact in the process industry and is providing an opportunity to have a positive impact on the production KPIs. Metso's Metals & Chemical Processing Business reviews the impact of digitalisation in the sulphuric acid industry today and discusses the concept of a future pit-to-port system within a digital eco-structure.

Hannes Storch, Collin Bartlett, Steffen Haus

The sulphuric acid industry has been driven by almost a century of improvements in process technology and equipment design. It is expected that this trend will continue, although not at the same rate as in earlier decades and with potential change in focus to consider the challenges associated with the mega-trends such as energy transition, circularity, etc.

One key area for future development will be digitalisation. As in other industries, digitalisation has made an entry into the sulphuric acid space in recent years and today plays an entirely different role compared to classical process technology and equipment modernisations/upgrades. By utilising digital tools based on first principle process simulations, there is also the potential to harness artificial intelligence (AI).

Even though this trend is still in its infancy, it is expected to have an ever-stronger impact on the industry in the future. Current demand for transparency in Environmental, Social and Governance (ESG) topics is expected to take place and existing technologies and emerging technical advancements may well require digitalisation to meet these needs.

A further aspect is consideration of the entire 'pit-to-port' operation within a digital eco-structure, meaning that digitalisation will not stop at the battery limits of any one plant section or industrial function (refer to Fig. 1).

Impact of digitalisation in the process industry

Looking back at the last 20 years in digitalisation in the sulphuric acid production process, a few key milestones can be identified regarding Metso's own digital development in the field of sulphuric acid and fluid bed technologies, and these are shown in Fig. 2.

The development of Metso's digital tools was from the beginning focussed on first principles solutions and on translating Metso's unique process and equipment know-how into a digital offering. As high-resolution process data upload is today a secure and safe way to allow remote support for customers, regardless of the location of site and supporting experts, the functionality has improved considerably.

The development milestones shown in Fig. 2 are only a few to exemplify the progress in the digital solutions available today. It can also be seen that the field of digitalisation covers a wide range of different operational aspects. While solutions such as process optimisers aim to increase operational efficiency (for example, of a roasting plant), remote data access targets a closer and seamless collaboration between experts from the equipment manufacturer and the operating company. Troubleshooting is thus simplified, timely, and support is provided more specifically and with a higher efficiency. In short, digital technologies play a key role to connect process industry experts around the globe.

Digitalisation is used to integrate process know-how and technology understanding into the daily operation of a process plant. Expert systems, optimisers, etc., are one way to digitalise know-how, making the know-how immediately available when required during on-site operations. Another opportunity, followed up very recently within Metso, is to review the process instrumentation or digital readiness of a plant with the dedicated target to allow for more advanced digital solutions to be considered.

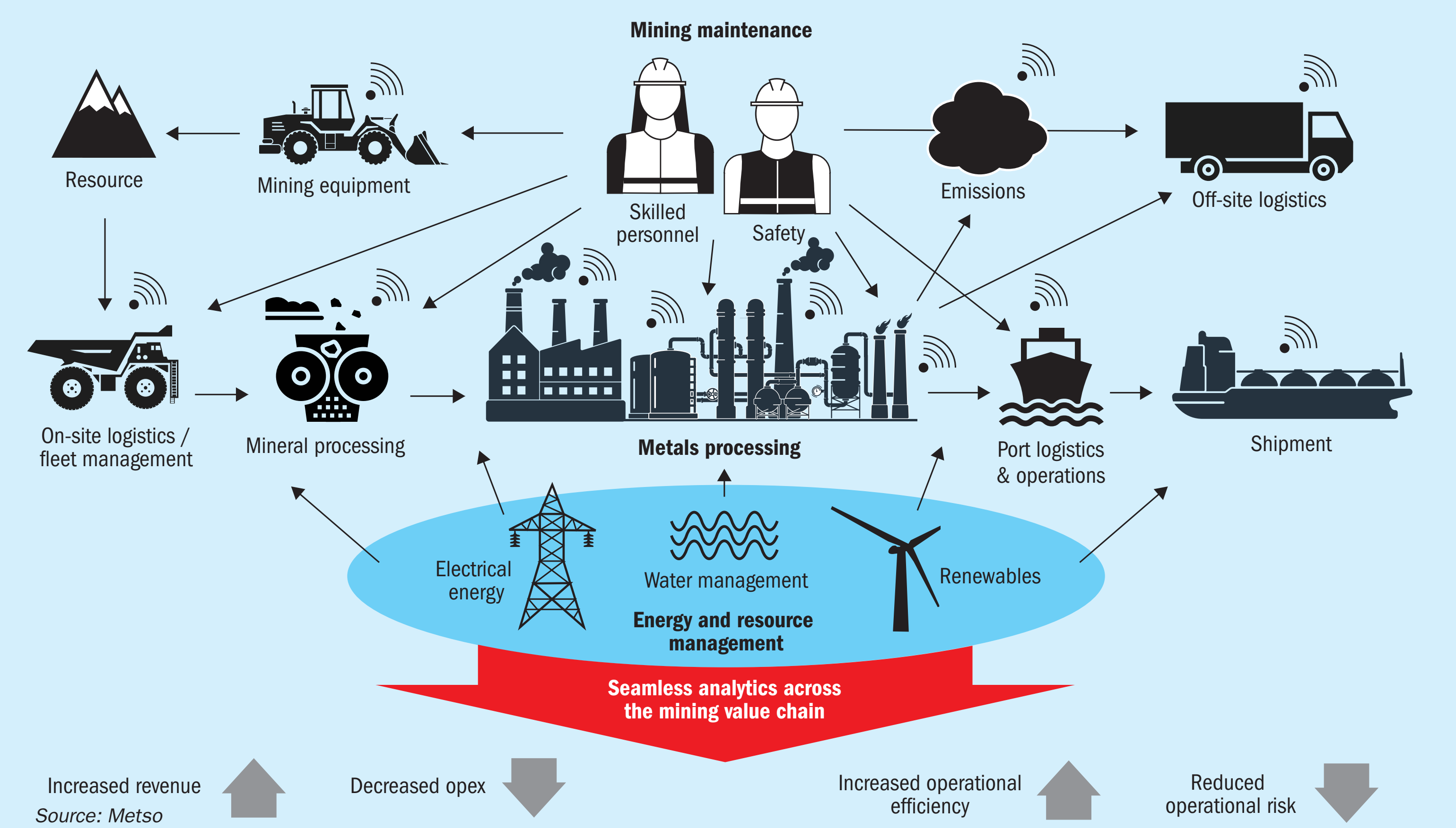
Embracing modern digitalisation solutions as described above, it becomes clear that today the road to key performance indicator (KPI) optimisation is driven by two main topics:

- First, and historically the strongest, the process and equipment technology steps were the first choice to enhance process KPIs. It must be noted, however, the huge process developments as in earlier decades cannot be expected in the future.
- Secondly, emerging in recent years and continuing with an even increasing impact, digital solutions and remote connectivity of equipment has entered the process industry. Digital solutions are starting to pay off for operating companies and are a measurable impact on production KPIs in a defined time scale. Today, further growth in demand of digital solutions driving operational KPIs can be expected and may also encompass future legislation on ESG reporting. Such solutions, targeting the production KPIs of equipment and plants, are an immediate solution now to drive the operation to higher KPIs.

Considering the 'central processing facility' in the pit-to-port graphic detailed in Fig. 1, there is a need to drill down into detail of the differing needs of the process value chain, plant or relevant process equipment within the facility. A simplified example is shown in Fig. 3.

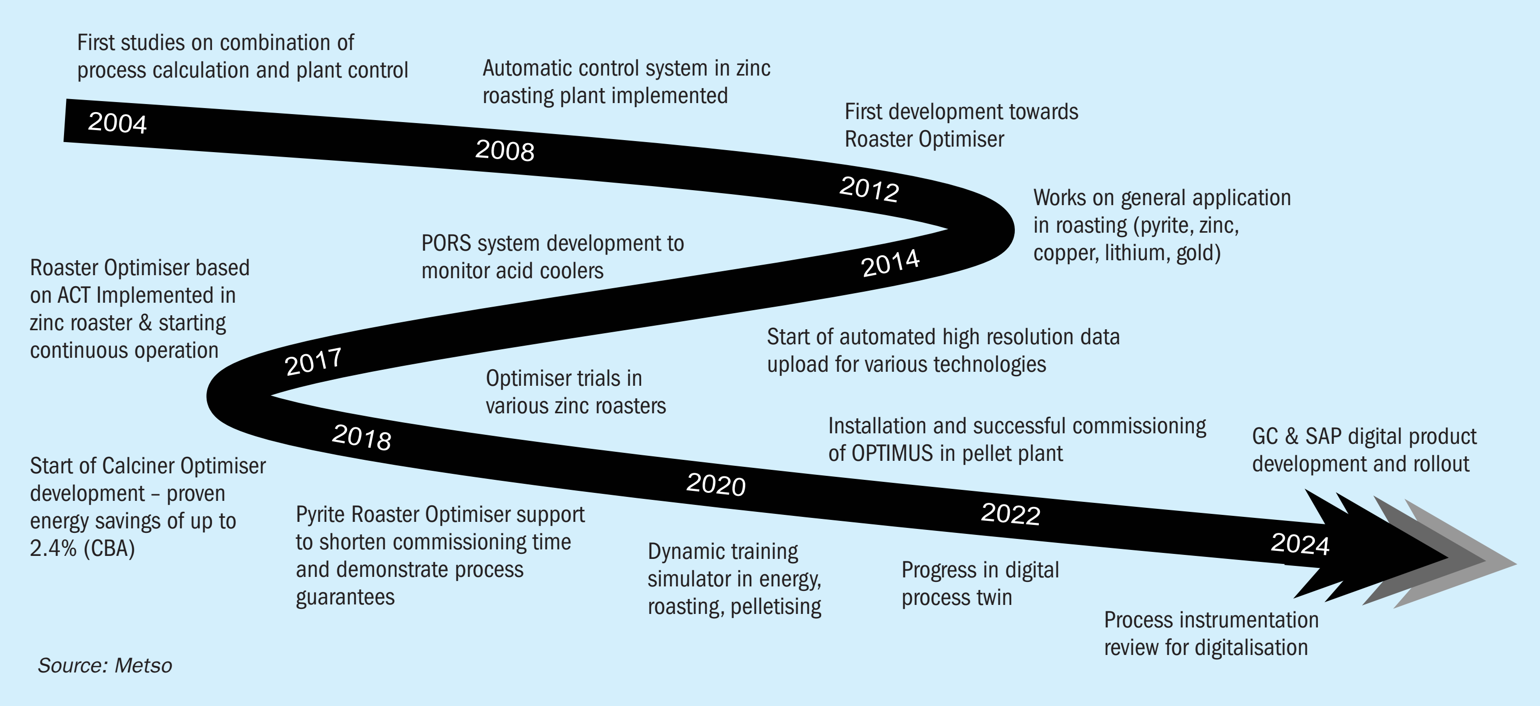
It should first be noted that the graphic considers a process value chain sub system associated with an overall pyrometallurgical process but could just as well be a stand-alone sulphur-burning sulphuric acid plant feeding a fertilizer complex.

Fig 1: **Extracting digital value from the 'pit-to-port' concept**



Source: Metso

Fig 2: **Key milestones of Metso's digital solution history (in sulphuric acid and fluid bed technology)**



Source: Metso

To completely enable pit-to-port digital connectivity and the associated operational and performance KPIs it is critical to drive transparency from all key individual process equipment of the plant and/or sub system.

Irrespective of the way data will be used, by way of AI or first principles tools, the greatest challenge for the current installed base of industrial plant is the understanding of the quality of data and the complexity of retrofitting the appropriate degree of instrumentation and associated data capture. This is particularly the case for older installations with limited instrumentation and control, whereas facilities built in say the past ten years may well require significantly less capital investment to attain the required degree transparency. It should also be noted that Metso's sulphuric acid plant offerings today take into consideration the needs of digital readiness from initial flowsheet development to equipment/plant supply. Development of new digital solutions will inevitably emanate from the execution of new greenfield projects and that these concepts in time will cascade back into the installed base.

The transition from historical upgrades of process and equipment to investments in digitalisation can also be observed in the focus of Research and Development (R&D) teams. As process development steps were dominant until a few years ago, many aspects of new developments have a focus on digitalisation today. In summary, digitalisation is making a strong impact in the process industry and is providing an opportunity to have a positive impact on the production KPIs with a surprisingly short return on investment.

As a process plant builder Metso's digital solutions are based on process understanding, expertise and experience that has been gained over decades of plant design, construction, commissioning, and troubleshooting. This knowledge, together with remote access digital tools, can now form the basis for analysis of on-site challenges in existing facilities. Metso know-how is today digitalised in the form of process models and not only used for process plant design, but to support operations in real-time. That said this is the full extent of Metso expertise and capability and the digital eco-structure associated with a pit-to-port system requires the involvement of other capable parties.

The digital eco system of a pit-to-port system

It is acknowledged that a process plant builder will not impact the digitalisation on an enterprise level. Making an impact on both the equipment/plant scale and on the wider site level will demand all stakeholders to consider partnerships and collaboration considering a 'sharing not owning approach'. It is expected that a key for successful digital transition will require effort from providers of a digital enterprise level eco-structures. These are in use in other industry sectors today, however utilisation of digital eco-structures in the process industry cannot yet be observed. Furthermore, the ability of an end-user to accept change management for a site-wide digitalisation journey, will be an essential success factor.

The challenges of pit-to-port digitalisation in the industry is multifaceted and require careful consideration. Key hurdles include:

- Many operations still rely on outdated legacy systems and infrastructure and integrating new digital technologies can be complex and costly. Upgrading existing systems whilst ensuring minimal disruption to ongoing operations is a significant challenge.
- The industry generates vast amounts of data from sensors, equipment, geological surveys, and other sources. Managing, storing, and analysing this data efficiently is crucial. At the same time, ensuring data accuracy, consistency, and quality is challenging, especially when dealing with remote/multiple sites and diverse data formats.
- As the industry becomes more connected, the risk of cyber threats increases and protecting critical infrastructure, intellectual property, and sensitive data is essential. Implementing robust cybersecurity measures and training staff to recognise and prevent cyberattacks are ongoing challenges.
- Transitioning to digital processes requires buy-in from all levels of the organisation and resistance to change can hinder successful implementation. Training the workforce to use new tools effectively and fostering a digital culture is a high priority for success.

Fig 3: **Digital tiers within an industrial plant complex**

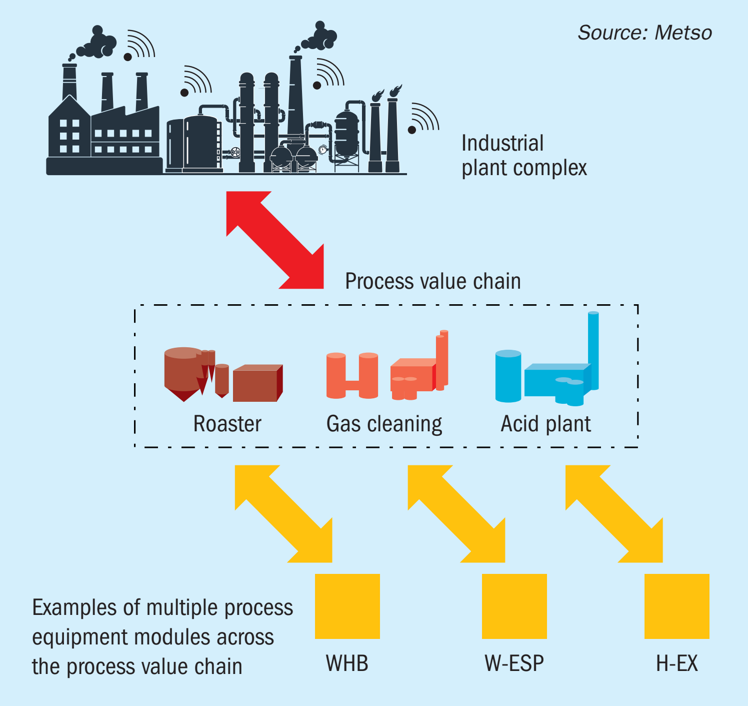
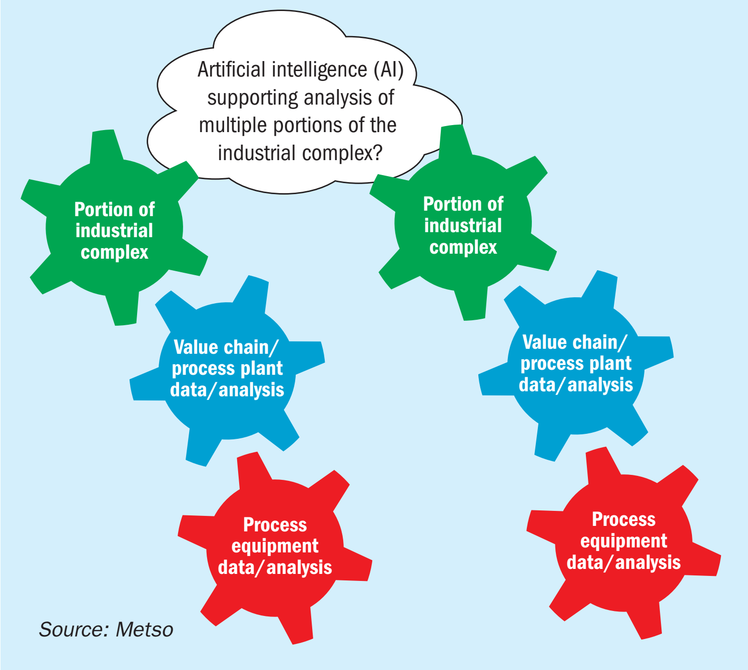


Fig 4: **The potential for AI to be the digital integrator at the enterprise level**



- Different enterprise software, hardware, and communication protocols often lack interoperability and integrating such diverse systems seamlessly is a challenge. Establishing enterprise standards for data exchange, communication, and interoperability is essential for efficient digitalisation.
- Investing in digital technologies can be expensive and the industry must weigh the costs against the potential benefits. Demonstrating transparent ROI and long-term value is essential to justify digitalisation investments.
- The industry must comply with various regulations related to safety, environmental impact, and the associated reporting - ensuring that digital solutions align with regulatory requirements.
- Digital solutions should be scalable to accommodate growth and changing operational needs and defining solutions that can adapt to different scenarios is essential.
- Balancing digitalisation with sustainability objectives (such as reducing energy consumption and minimising environmental impact) is critical. Ensuring that digital initiatives align with broader sustainability strategies is a challenge that needs to be met.

This extensive list of hurdles may lead some to conclude that the pit-to-port concept will never gain a foothold, however the emerging disruptor to the status quo may end up being artificial intelligence (AI) and its ability to process the massive amounts of data from multiple sources, formats and platforms (see Fig. 4). Some advanced industries are already harnessing this phenomenon and it is not beyond reality to expect that as further AI development takes place and such costs have been amortised, our industry may succumb to such tools.

Many recent consultancy reports (Accenture, McKinsey, etc.) indicate that the cost savings from such eco-structure optimisation could be significant – globally in excess of 400 billion USD in just the pit alone, and value chain logistics potentially reduced by a further 20%. These are potential savings are certainly worth considering for the blue chip leaders in our industry, allowing a digital momentum to commence for the industry as a whole.

Summary

Metso is committed to further digitalisation of its portfolio of equipment and process plant offerings that is required to ensure that it is 'digitally ready' as momentum grows for a comprehensive digital eco-structure in the industry. Metso believes that this digital development will inevitably emanate from the execution of new greenfield projects, and that the concepts in time will cascade back into the installed base.

Process plant builders' roots are in the field of process design and equipment design and technology. Not surprisingly, digital solutions will focus on equipment or process plants within their capability and expertise – each supplier must consider if this is strategically important enough for the future.

It is acknowledged, that a process plant builder with deep technical expertise on specific technologies cannot supply an operating company with a comprehensive pit-to-port digital solution. Such an eco-structure must enable connectivity and data security as well as data integrity for multiple plants on many production sites and it must connect both equipment and applications from multiple suppliers. This transformational journey involving site operations, enterprise digital integrators, together with multiple tiers of suppliers has only just begun and there is a significant road to travel.

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