Consulting

# Sulphuric Acid Supply Study

Report prepared for the Queensland Government

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## 1.1. Study rationale

Sulphuric acid is a key input into many existing mining-related operations in Queensland’s North West and North East Mineral Provinces. Current demand for sulphuric acid is predominantly met by domestic production as a by-product of copper and zinc smelters located in Mount Isa and Townsville. Glencore’s Mount Isa Mines Copper Smelter contributes 47% of the total current local sulphuric acid production capacity to the Queensland market. Glencore’s Mount Isa Mine’s copper operations and copper concentrator will close in the second half of 2025. Glencore expects the copper smelter to operate until 2030 subject to approval of additional capital investment.

In addition to potential sulphuric acid supply chain disruptions, demand for sulphuric acid is expected to surge, with a host of new projects which rely on sulphuric acid at various stages of development across the North West and North East Minerals Provinces.

In response to this potential significant demand-supply imbalance, the Queensland Government, through the Department of State Development and Infrastructure (DSDI), engaged CRU International (CRU) and Core Resources (Core) to undertake a comprehensive study into the supply and demand of sulphuric acid in the North West and North East Minerals Provinces of Queensland.

This study set out to:

- Identify the global supply and demand for sulphur and sulphuric acid over the medium and long term
- Identify the supply and demand for sulphuric acid in the North West and North East Minerals Provinces over the medium and long term
- Forecast global pricing for sulphur and sulphuric acid
- Forecast pricing for imported sulphur and sulphuric acid delivered to various demand centres in the North West and North East Minerals Provinces
- Identify global market trend drivers for sulphur and sulphuric acid
- Identify options for the supply of sulphuric acid that meet the demands of current and proposed critical mineral, value-add phosphate, grid storage electrolyte and chemical manufactures in the North West and North East Minerals Provinces.

This report summarises the findings and views of the authors only, and does not represent the views of the Queensland Government. Any recommendation or advice made in this report is solely at the discretion of the authors, and in no way suggests the Queensland Government is bound to any form of action or outcome whatsoever.

## 1.2. Why is Sulphuric Acid critically important to Queensland?

Availability of sulphuric acid is crucial to Queensland industry, underpinning existing fertiliser production and minerals processing. Without a readily available and cost-effective source of sulphuric acid, some existing mining-related projects are unlikely to remain commercially viable, and a raft of new critical minerals and battery-related manufacturing projects may not be feasible. A lack of available sulphuric acid, therefore, has a strong likelihood to reduce economic activity and employment opportunities in the North-

West and North-East Minerals Provinces and severely hamper efforts to develop new and essential critical minerals, value-added fertilisers and battery electrolyte manufacturing projects in these regions.

Demand for sulphuric acid in the North West and North East Minerals Provinces has historically been dominated by phosphate fertiliser production at Incitec Pivot Limited's (IPL) Phosphate Hill operation, with relatively minor demand coming from minerals processing (e.g., leaching of oxide copper ores) and industrial applications (e.g., water and wastewater treatment). Total **demand for sulphuric acid in 2023 was approximately 1.23 million tonnes** (Mt), 95% of which was consumed by phosphate fertiliser production.

This demand has largely been met by the production of sulphuric acid from waste sulphur dioxide gas streams at metal smelters, including Glencore's Copper Smelter located in Mount Isa and Sun Metals' Zinc Smelter located in Townsville. At present, the State achieves a good supply-demand balance, with relatively small volumes of sulphuric acid and sulphur prill (granulated elemental sulphur, which is burnt to produce acid) imported into the State to supplement local acid production.

A significant portion of the region's current of sulphuric acid supply is subject to a high degree of uncertainty in the future. Glencore's **Mount Isa Copper Smelter**, which provides waste gas to IPL's **Mount Isa Acid Plant**, provided sulphur-rich feedstock for 47% of Queensland's acid production in 2022. Glencore is set to close its copper mining operations in Mount Isa by mid-2025, potentially reducing copper concentrate throughput and output of metallurgical waste gases from the Mount Isa Mines Copper Smelter. The smelter is planning to operate until 2030[1], shifting to operate solely on third-party copper concentrates from mid-2025. Importantly, continued Mount Isa smelter operations beyond 2025 are contingent on capital being available to maintain the asset, including the capital-intensive smelter re-brick every 4 years. While there is no official announcement on changes to Mount Isa Copper Smelter throughput, it is unclear if supply of economically-viable third-party concentrates is sufficient for the smelter to operate at full capacity, and thereby supply sufficient acid feedstocks to meet current demand. The Mount Isa Copper Smelter is a critical asset in Queensland's sulphuric acid supply chain, supplying the largest acid user in the State, IPL's **Phosphate Hill Mine** operation, with the bulk of its acid demand. With the potential underutilisation of the smelter beyond 2030, there is a high degree of uncertainty about the future availability of nearly 50% of the Queensland acid supply chain.

In addition to potential supply chain disruptions, demand for sulphuric acid is expected to surge. A host of new critical minerals projects which fundamentally rely on sulphuric acid, are in various stages of development across the State, including a suite of **vanadium** projects around Julia Creek, battery **electrolyte** manufacturing in Townsville, a large **nickel-cobalt** project near Greenvale and a host of **copper** oxide developments across the northwest. Total **demand for sulphuric acid in 2035 is expected to reach 2.86 Mt** from operating, committed and probable projects. Although somewhat unlikely, if all current speculative projects were to be developed, the total demand in 2035 could be as high as 5.23 Mtpa.

With current sulphuric acid demand at approximately 1.23 Mtpa and future demand forecast to be approximately 2.86 Mtpa (or as high as 5.23 Mtpa), there is clearly a need to take action to ensure that existing and new minerals projects have access to acid feedstocks for their operations. Without sufficient acid supplies, many mining projects across regional Queensland face an uncertain future.

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[1] Glencore media statement. 18/10/2023. "Mount Isa Mines operational changes". Available at: https://www.glencore.com.au/media-and-insights/news/mount-isa-mines-operational-changes

## 1.3. Report summary

This section presents a summary of key topics covered by this report.

### 1.3.1. Sulphuric Acid sources

Sulphuric acid (chemical formula: $H_2SO_4$) is the world's most widely produced and used inorganic chemical. Due to its acidity, reactivity, corrosiveness, affinity with water, low cost of production, the abundance of sulphur-based feedstocks and widespread adoption in chemical processes, sulphuric acid has many applications in fertiliser production, minerals processing and industrial uses. These attributes mean that sulphuric acid is the most suitable acid able to meet the requirements of the North West and North East Minerals Provinces.

Approximately 60% of global sulphuric acid is produced by burning sulphur in a sulphur burner acid plant, with 95% of the global sulphur produced as a waste by-product of refining hydrocarbons. A further 30% of global sulphuric acid is produced by converting metallurgical waste gas, from metal smelters such as Glencore's Copper Smelter and Sun Metals' Zinc Refinery, into sulphuric acid. The remaining 10% of global sulphuric acid production in 2022 was from pyrite roasting (6%), recycling (2%) and other processes (2%).

### 1.3.2. Sulphuric Acid demand in the North West and North East Minerals Provinces

The North West Minerals Province (**NWMP**) and North East Mineral Province (**NEMP**) have a current total sulphuric acid demand of approximately **1.23 million tonnes per annum** (Mtpa), which is largely met by converting metallurgical waste gas from Glencore's Mount Isa Copper Smelter (between 450-550 ktpa of sulphuric acid) and Sun Metal's Townsville Zinc Refinery (450 ktpa of sulphuric acid). Approximately 120 thousand tonnes per annum (ktpa) of granulated sulphur (prill) is imported from Canada and burnt at IPL's Mount Isa Acid Plant to produce an additional 330 ktpa of sulphuric acid. At present, around 95% of the North West Queensland sulphuric acid market is used in the manufacture of phosphate fertilisers, with the remainder used in metals leaching, chemical manufacturing and water treatment.

By far the largest consumer of sulphuric acid is IPL which consumes approximately **1.16 Mtpa** at its Phosphate Hill operation. IPL sources approximately **850 ktpa** of sulphuric acid from its Mount Isa Acid Plant (which uses Glencore's metallurgical waste gases and imported sulphur prill as its feedstocks) and approximately **280 ktpa** from Sun Metals.

Glencore announced on 18 October 2023 that it expects to cease all copper mining in the Mount Isa region by the second half of 2025, when remaining mineral reserves at its Enterprise, X41 and Black Rock mines are no longer viable to extract. Glencore also announced that copper smelting in Mount Isa and refining in Townsville are expected to continue operating until 2030, subject to capital being allocated, by processing third-party concentrates from other mines in the region and elsewhere. This decision may reduce throughput through smelter and could remove 47% of the current local sulphuric acid supply capacity from the Queensland market.

In the near future, proposed new critical minerals projects, particularly for vanadium and nickel-cobalt, are forecast to increase demand for sulphuric acid to approximately **2.8 Mtpa** (probable projects) and up to **5.2 Mtpa** (including speculative projects in the development pipeline).

### 1.3.3. Global production of Sulphur and Sulphuric Acid

In 2022, 90% of global sulphuric acid production was reliant on by-products from other sectors, principally the oil/gas (for 99% of sulphur prill) and metals refining sectors (for metallurgical waste gas). This places the sulphuric acid market in a difficult position, as demand increases for acid are not a key driver for capacity expansions in petroleum or metals smelting. In a further complication, the global availability of sulphur for sulphuric acid production is tightly bound to the fate of hydrocarbon refining, which is expected to contract in response to global decarbonisation efforts over the next few decades.

The global production of **sulphur** in 2022 was 65 Mt and is expected to reach 90.5 Mtpa by 2045, before declining in line with decarbonisation-driven reduction in hydrocarbon production.

Global **sulphuric acid** production has grown at a CAGR of 2.2%, from 220 Mt in 2010, to 285 Mt in 2022. This growth was primarily driven by expansions production in Asia, with around 90% contributed by China, which itself experienced a 49% increase in production from 2010 to 2022. Smelter expansions are set to drive sulphuric acid supply growth in Asia and Europe from 2023 as additional copper smelters come online to satisfy growing electrification-related metals demand.

### 1.3.4. Global demand for Sulphur and Sulphuric acid

Key drivers of global demand growth will be increased fertiliser application and battery-related metals growth. Total global demand for sulphuric acid is forecast to increase at a CAGR of 3.5%, from 295 Mt in 2023 to approximately 350 Mtpa by 2028.

The metals sector has seen demand for sulphuric acid grow significantly due to the emergence of copper and nickel leaching technologies. As global economies pledge to boost investments in electrification and renewable energy, a boost in demand is expected to come from battery metals, such as high-pressure acid leaching (HPAL) to recover nickel and manufacturing of sulphate-based precursors for battery cathodes.

With increasing global demand for sulphuric acid, particularly in SE Asia, we expect to see increasing competition to secure tightening supplies of internationally traded sulphur and sulphuric acid. The combination of these trends could see potential scarcity of available supplies to mine operators in Queensland.

### 1.3.5. Sulphuric Acid supply options for the North West and North East Minerals Provinces

Two main options for the supply of sulphuric acid have been examined in this report. They include:

- import of sulphur prill and/or sulphuric acid through the Port of Townsville. The sulphur prill would feed a sulphur burner acid plant to produce sulphuric acid
- locally and regionally produced pyrite concentrates that can feed a pyrite roaster acid plant to produce sulphuric acid. Pyrite concentrates can be produced from live tailings and through the reprocessing of existing tailings dams.

Other options not examined by this report could include:

- a third technology, developed by Cobalt Blue, has shown that it can produce elemental sulphur as a by-product from treating pyrite concentrates. Sulphur produced using this method could be distributed to end-users for sulphuric acid generation through a sulphur burner acid plant operation. The technology is currently at the demonstration plant level of development
- continuation of the copper smelter at Mount Isa with treatment of off-gases
- diversion of metallurgical gases from the lead smelter at Mount Isa, with a current life of mine to 2036, to IPL’s acid plant.

### 1.3.6. Imports of sulphur prill and/or sulphuric acid through the Port of Townsville

*Import of sulphur*

To meet the forecast supply gap for Operating and Probable projects (Scenario 2) through seaborne trade alone, imports of sulphur would need to reach approximately 500 ktpa by 2027 and grow to approximately 900 ktpa by 2031. The Port of Townsville has a current sulphur import capacity of approximately 170 ktpa. After completion of the ongoing port expansion, the maximum import capacity is expected to be approximately 254 ktpa without additional investment in portside logistic upgrades. This is still well-short of the 357 ktpa required to meet demand for Operating projects only (Scenario 1).

*Import of Sulphuric Acid*

Direct imports of sulphuric acid via the Port of Townsville are unable to meet the forecast supply gap for any of the scenarios considered. The average trade (import and export) of sulphuric acid in the last three financial years through the Port of Townsville was of approximately 70 ktpa. At the completion of port expansion, Townsville is expected to have a sulphuric acid import capacity of around 200 ktpa. Relying solely on the import of sulphuric acid is not expected to be feasible, except to fill small shortfalls in supply.

*Cost of Sulphur and Sulphuric Acid imports*

Principal international trading partners for the Port of Townsville are Canada for sulphur, and South Korea and Japan for sulphuric acid. The cost of both commodities from these locations has a direct impact on current acid-users in Queensland and potentially the viability of proposed new mining operations. The cost of sulphur from Canada is expected to jump from US$ 110 per metric tonne in 2023, to US$ 200 per metric tonne in 2035, a more than 80% increase. The scenario is similar for sulphuric acid, where the cost per metric tonne from South Korea is expected to increase about 75% between 2023 and 2035, while acid from Japan is expected to see an increase of 145% over the same period.

Both sulphur prill and sulphuric acid experience significant commodity price volatility. In 2022, for example, the price of sulphur skyrocketed to US$ 459 /t before plummeting to a near decade low of US$ 77 /t. Similarly, the cost of sulphuric acid has previously changed from highs of US$ 105 /t to negative values. It is important to note that prices can fluctuate dramatically, significantly impacting operations that heavily rely on sulphuric acid and cost certainty.

When including the cost of international shipping and inland freight, the site-delivered cost of sulphur and sulphuric acid is much higher. For example, where sulphuric acid is imported from South Korea and transported to Phosphate Hill via rail, the total cost is AU$ 350 /t in 2023 and is expected to rise to AU$ 470 /t in 2035. Where sulphur prill is imported from Vancouver and transported to Phosphate Hill via rail, the total cost is US$ 220 / t in 2023 and is expected to rise to US$ 350 in 2035.

The potential rapid expansion in demand for sulphuric acid in Queensland will place pressure on existing acid-related infrastructure, such as the Port of Townsville and the road and rail systems that service the NWMP and NEMP. Increased demand for imported sulphur prill or sulphuric acid will likely require significant investment in port capacity, port-side infrastructure and specialised acid railcars unless sustainable local production can be achieved.

### 1.3.7. Local production of Sulphuric Acid in the North West and North East Minerals Provinces

Sulphuric acid produced from waste metallurgical gas from Glencore's Mount Isa Mines Copper Smelter is currently by far the cheapest source of acid for IPL, the State's largest acid user, with the cost of acid essentially comprised of the conversion (operation of the Mount Isa Acid Plant) and transport (rail from Mount Isa to Phosphate Hill) as the metallurgical gases are a free feedstock for the Mount Isa Acid Plant.

With the potential retirement of the Mount Isa Copper Smelter in coming years, there is urgent need to secure cost-effective domestic sulphuric acid production capacity to support both existing operations (mainly Phosphate Hill) and new projects in the development pipeline.

Sulphur-rich feedstocks will need to be developed to supply new domestic sulphuric acid production. Pyrite (an iron sulphide mineral) is a common waste component of metalliferous mines. The NWMP and Central Queensland host abundant sulphur-rich resources, mainly pyrite, which could sustain decades-long local production of sulphuric acid. Many of these resources reside in mining waste in the form of tailings dams and could also be extracted from live tails of existing operations or from reprocessing of legacy tailings impoundments.

*Pyrite feedstock considerations*

The reprocessing of tailings to produce a pyrite concentrate that can feed either a pyrite roaster acid plant or a sulphur burner acid plant is considered the most feasible option for the long-term supply of sulphuric acid for the NWMP and NEMP.

The processing of pyrite for sulphuric acid production does have significant benefits:

- well-proven technologies exist to convert concentrated pyrite feedstocks into sulphuric acid or elemental sulphur
- modular plants are available to harvest pyrite from remote sites, potentially allowing a campaign-based sequential approach to recovering pyrite from multiple sites
- concentration of pyrite requires only a simple flotation circuit, reducing process complexity
- de-sulphurising residual tailings will result in reduced acid mine drainage issues, potentially reducing environmental capping costs for TSFs and reduced environmental liabilities
- recovery of pyrite from legacy tailings will require new tailings impoundments to be built to contain residual tailings, allowing industry and Government to support new tailings dam designs and apply modern engineering standards, resulting in improved long-term environmental outcomes for the State
- can provide a sustainable pathway to recover ancillary minerals (such as cobalt), thereby capturing additional value and improving resource utilisation in the State
- may be economically viable in today’s environment of acid/sulphur prices and by-product credit value, particularly for a large, centralised acid-producing facility
- pyrite roaster acid plant generates excess electrical energy, which can be exported to the local grid
- development of these resources is likely to trigger new economic activity.

Despite their availability in the NWMP, the NEMP and Central Queensland, these resources:

- are not always accessible and are geographically dispersed
- require mine operators to find value in processing their tailings to recover valuable by-product metals, produce a pyrite concentrate feedstock, and de-sulphurise their Tailing Storage Facilities (TSFs)
- have complex mineralogies
- are capitally intensive to develop
- may require costly new TSFs to be approved and constructed to store reprocessed tailings after extracting pyrite concentrates
- require regulatory reform, including specific licencing and/or liability arrangements to be addressed
- require access to available land, water and electricity

- require access to cost-effective transport and logistics to transport concentrates to acid production facilities
- some tailings resources contain heavy metals such as lead, zinc and arsenic which can lead to a range of issues, including environmental, health, regulatory, contamination and operational challenges.

### 1.3.8. Sulphuric Acid production options for the North West and North East Minerals Provinces

Core Resources, a Queensland-based engineering firm, reviewed several sulphuric acid production options with consideration of the following for each option:

- definition and characterisation of available pyrite sources, size of the resource, amenability to processing, potential processing rates and lifespan of each resource and the volume of pyrite concentrate produced
- high-level techno-economic review of sulphur burning and various pyrite concentrator and roaster options/ configurations to establish sulphur burning or pyrite processing rates and indicative sulphuric acid production rates and associated costs
- tailings reclamation and movement costs, flotation costs, pyrite and sulphur transport costs, roaster / acid plant costs, sulphur burner/ acid plant costs and sulphuric acid movement costs
- options were developed to an early Class 5 Study level with a margin of + 50% and -30% in absolute terms.

Due to confidentiality and commercial-in-confidence reasons, the Engineering Scoping Study and details of the sulphuric acid supply options considered in the Study will not be released in this report.

### 1.3.9. Sulphur versus Sulphuric Acid logistics considerations

The decision on whether to locally produce sulphur prill (granulated elemental sulphur) or sulphuric acid will have a significant impact on logistics requirements and future development. For example:

- sulphur prill can be transported as a dry bulk good in enclosed trailers, shipping containers and bulk bags, whereas sulphuric acid requires specialised vessels such as specially-lined ISO tanks for GATX railcars. Transporting sulphuric acid involves following safety precautions to prevent leaks, spills and contamination
- sulphur prill can be stored in silos, whereas sulphuric acid must be stored specialised tanks
- sulphur prill has excellent free flowing properties and a low tendency to stick or agglomerate, making it suitable to handle as a dry bulk good. Sulphuric acid requires specialised handling equipment including dedicated loading/unloading facilities
- while sulphur is generally easier and cheaper to transport, it requires considerable specialised plant at the demand centre to convert it to sulphuric acid.

### 1.3.10. Domestic options for the supply of Sulphuric Acid

*Ability of existing Australian domestic producers to meet North West and North East Minerals Provinces' demand*

Given sulphuric acid is a sub-product of metals smelters, smelters will only increase their production of sulphuric acid if the metal they produce is under favourable economics. Extra sulphuric acid supply will need to come from sulphur burners. There are only three sulphur burners operating in Australia. Two are in Western Australia and the third is located at IPL's Mount Isa Acid Plant operation. Interstate acid suppliers have consistently been unable to supply sulphuric acid users, with the supply gap filled via the import of sulphuric acid and sulphur.

Unlike sulphuric acid, sulphur is obtained in Australia almost exclusively by imports with a maximum of 53kt of sulphur produced domestically in 2022. In 2022, 750 kt of sulphur was imported.

Additionally, given the distance between Western Australia and the NWMP and NEMP, the transport costs alone would be significantly higher than producing it in Phosphate Hill, for example, and distributing within the region. This distance would incur a cost of nearly US$ 300 /t to transport sulphuric acid via road in 2023.

This indicates that, under current production levels, interstate supply is not a reliable option to supply the burgeoning growth in Queensland sulphuric acid demand.

*Ability of existing Queensland producers to meet North West and North East Minerals Provinces demand*

Given the likely cessation of copper smelting in Mount Isa by 2030, or earlier, and with a situation where no imports of sulphur or sulphuric acid were contemplated, the Townsville Zinc Refinery would need to accommodate the entirety of NWMP and NEMP demand (2,858 ktpa by 2031 in Scenario 2). To respond to this demand, capacity at the Townsville Zinc Refinery would need to increase by an additional 5 times current levels. It seems unlikely that an expansion of this size would be contemplated by Sun Metals.

# 2. Key findings

The following conclusions have been drawn from this study:

- Sulphuric acid is a **critical feedstock** for critical mineral processing, value-add fertiliser manufacturing and battery electrolyte manufacturing. Without sufficient sulphuric acid available to the NWMP and NEMP, the viability of many current and proposed projects could be in doubt.
- Historically, sulphuric acid demand and supply in the NWMP and NEMP has remained largely in balance at approximately **1.23 Mtpa**, met by converting metallurgical waste gas from Glencore's Mount Isa Copper Smelter and Sun Metal's Zinc Refinery into sulphuric acid.
- By far the largest consumer of sulphuric acid is IPL which consumes approximately **1.16 Mtpa** at its Phosphate Hill operation. IPL sources the bulk of sulphuric acid from its Mount Isa Acid Plant (which uses Glencore's metallurgical waste gases and imported sulphur prill as its feedstocks), with the remainder purchased from Sun Metals in Townsville.
- With metallurgical gases available as a free feedstock, sulphuric acid produced from Glencore's Mount Isa Mines Copper Smelter is by far the cheapest source of acid for IPL, with the cost of acid essentially comprised of the conversion (operation of the Mount Isa Acid Plant) and transport (rail from Mount Isa to Phosphate Hill).
- Glencore announced on 18 October 2023 that it expects to cease all copper mining in the Mount Isa region by the second half of 2025. Glencore also announced that copper smelting in Mount Isa and refining in Townsville are expected to continue operating until 2030 by processing third-party concentrates from other mines in the region. With metallurgical gases from the Mount Isa Mines Copper Smelter providing 47% of the current local sulphuric acid supply to the market, underutilisation of the smelter and eventual retirement will significantly impact sulphuric acid supply in the region.
- In the near future, proposed new critical minerals projects, particularly for vanadium and nickel-cobalt, are forecast to increase demand for sulphuric acid to approximately **2.8 Mtpa** (Probable projects) and up to **5.2 Mtpa** (for all proposed projects including speculative).
- Two main options for the supply of sulphuric acid have been examined in this report, including:
    - the importation of sulphur prill and / or sulphuric acid through the Port of Townsville. The sulphur prill would feed a sulphur burner acid plant to produce sulphuric acid
    - the local production of sulphuric acid through the reprocessing of tailings to produce a pyrite concentrate that can feed either a pyrite roaster acid plant or a sulphur burner acid plant operation to produce sulphuric acid
        - a hybrid of this option produces sulphur prill directly from pyrite feedstocks. This technology is currently being developed by Cobalt Blue, who have demonstrated that it can recover valuable minerals, such as cobalt, from pyrite concentrate. The process produces elemental sulphur as a by-product, which can be granulated into sulphur prill and distributed to end users for sulphuric acid generation via a sulphur burner acid plant at the end user site. While the technology is currently at the demonstration scale, interest in the technology has been shown from miners in the region.
- Indicative costs for imported sulphur delivered to Phosphate Hill range from US$ 220 (2023) to US$ 350 (2035). Indicative costs for imported sulphuric acid delivered to Julia Creek range from US$ 201 (2023) to US$ 303 (2035). CRU expects that locally-produced sulphur and/or sulphuric acid would trade at a reasonable discount to imported products.

- Due to commercial reasons, IPL and Sun Metals were unable to disclose their sulphuric acid costs during this study.
- Imports of sulphur prill and sulphuric acid are unlikely to meet long-term demand due to:
    - increasing global competition to secure tightening supplies of internationally traded sulphur and sulphuric acid
    - the Port of Townsville will likely require significant investment in capacity enhancements if imports are required to exceed 170 ktpa for sulphur and 200 ktpa for sulphuric acid. Despite ongoing Port of Townsville capacity enhancements being delivered as part of the $250 million Channel Widening and $1.64 billion Expansion Project, additional investment in portside logistic infrastructure will be required to increase port throughput rates for sulphur and/or sulphuric acid.
- The NWMP and Central Queensland hosts **sufficient pyrite resources** to sustain decades-long domestic sulphuric acid production.

  The processing of pyrite for sulphuric acid production does have significant benefits:

    - well-proven technologies exist to convert concentrated pyrite feedstocks into sulphuric acid or elemental sulphur
    - modular plants are available to harvest pyrite from remote sites, potentially allowing a campaign-based sequential approach to recovering pyrite from multiple sites
    - concentration of pyrite requires only a simple flotation circuit, reducing process complexity
    - de-sulphurising residual tailings will result in reduced acid mine drainage issues, leading to significantly reduced environmental capping costs for TSFs and reduced environmental liabilities
    - recovery of pyrite from legacy tailings will require new tailings impoundments to be built to contain residual tailings, allowing industry and Government to support new tailings dam designs and apply modern engineering standards, resulting in improved long-term environmental outcomes for the State
    - can provide a sustainable pathway to recover ancillary minerals (such as cobalt), thereby capturing additional value and improving resource utilisation in the State
    - are economically viable in today’s environment of acid/sulphur prices and by-product credit value, particularly for a large, centralised acid-producing facility
    - pyrite roaster acid plant generates excess electrical energy, which can be exported to the local grid
    - development of these resources is likely to trigger new economic activity.

  However, these resources:

    - need to be accessible and are geographically dispersed
    - require mine operators to find value in processing their tailings to recover valuable by-product metals, produce a pyrite concentrate feedstock, and de-sulphurise their TSFs
    - have complex mineralogies, often requiring bespoke technology solutions to process
    - are capitally intensive to develop

  - may require costly new TSFs to be approved and constructed to store reprocessed tailings after extracting pyrite concentrates
  - require regulatory reform, including specific licencing and/or liability arrangements to be addressed
  - require access to available land, water and electricity
  - require access to cost-effective transport and logistics to transport feedstock from source sites to processing sites.

- The resources with the greatest potential for acid production NWMP are as follows:
  - Ernest Henry Mine (EHM)
  - Mount Isa Mines (MIM)
  - Walford Creek
  - Other smaller pyrite resources such the Capricorn Copper, Osborne and Selwyn tailings
- Potential solutions for local sulphuric acid production are extremely complex to develop. The relationship between acid-reliant projects, their geographies, freight and logistics providers, availability of sulphur-rich feedstock resources and commercial realities are complex. This complex supply chain is heavily dependent on the incumbent operators, and preservation of both the scale and cost base is an important factor. Their role alongside potential new entrants will need to be carefully considered to develop a comprehensive solution to Queensland's sulphuric acid supply issues.
- Additionally, the decision on whether to import or locally produce sulphur prill or sulphuric acid will have a significant impact on logistics channels development. For example:
  - Sulphur prill can be transported as a dry bulk good in enclosed trailers, shipping containers and bulk bags, whereas sulphuric acid requires specialised vessels such as specially-lined ISO tanks for GATX railcars. Transporting sulphuric acid involves following safety precautions to prevent leaks, spills and contamination
  - Sulphur prill can be stored in silos, whereas sulphuric acid must be stored specialised tanks
  - Sulphur prill has excellent free flowing properties and a low tendency to stick or agglomerate, making it suitable to handle as a dry bulk good. Sulphuric acid requires specialised handling equipment including dedicated loading/unloading facilities
  - While sulphur is generally easier and cheaper to transport, it requires considerable specialised plant at the demand centre to convert it to sulphuric acid.
- Building local sulphuric acid production capacity will be capital intensive.
- In addition to the capital required to construct sulphuric acid plant options, further significant investment will be required for ancillary infrastructure, such as rail sidings, tailings recovery, tailings impoundments, acid wagons, acid storage and loading/offloading facilities.
- A sulphuric acid supply solution without access to Mount Isa Mines (Glencore) or Ernest Henry Mine (Evolution Mining) substantial pyrite resources and existing supporting infrastructure will most likely rely on the sourcing of pyrite feedstocks from multiple, smaller, geographically dispersed sites, some of whom may lack supporting infrastructure that can be utilised – potentially significantly increasing technical, environmental, logistical, investment and coordination complexity.
- Despite some excellent mine waste characterisation completed in recent years by the University of Queensland (UQ), contained pyrite resources are generally poorly understood, mainly due to the prior focus on characterising critical mineral or by-product mineral commodities rather than sulphur.

- Sulphur burning to produce sulphuric acid has the potential to generate significant by-product electricity, due to exothermic chemical reaction involved, which can be exported to the local grid to generate additional project revenue and provide reliable generation capacity in the far west of the State. A 780 ktpa sulphur burner, for example, could generate 38MW of electricity for export to the grid under base-load operations.

- Solutions to the forecast sulphuric acid supply shortages and coordinate a viable sulphuric acid supply chain are going to require extensive collaboration between stakeholders including:
    - current operators and future project proponents
    - infrastructure operators
    - transport and logistics service providers
    - local, state and federal government agencies
    - local communities.

# 3. About this report

This Study was commissioned by the Queensland Government through the Department of State Development and Infrastructure (DSDI) to better understand the importance of sulphuric acid to Queensland's minerals sector and how the supply chains for sulphuric acid need to evolve to meet changing market dynamics.

This report has been prepared for public release and summarises the outcomes of the Study presented to Government, however key data has been removed to avoid disclosing potential commercial-in-confidence or sensitive information.

## 3.1. About the authors

**CRU International** ("CRU") has been the world's leading information provider to the metals, mining and fertiliser industries for the past 50 years. CRU employs over 400 specialists in the commodities sector from offices in all the key commodity regions – Europe, North and South America, India, China, SE Asia, North Asia and Australia.

CRU Consulting is committed to providing informed and practical advice to meet the needs of our clients and their stakeholders. Our extensive network, deep understanding of commodity market issues, and analytical discipline, mean that we can assist clients in their decision-making process.

CRU has great depth of experience across the mineral commodity markets. The organisation routinely advises governments and companies on commodity markets and their affect both upstream resource development and downstream processing/manufacturing.

**Core Resources** ("Core") is a comprehensive Resource Development Partner that guides clients through every stage of a project's life cycle. They excel in project definition, metallurgical testwork, process design, engineering, project implementation, and on-site support.

The team has a wealth of experience across a wide spectrum of metals and minerals, including precious metals like gold and silver, base metals such as copper, nickel, cobalt, lead, and zinc, as well as treating impurities like arsenic and antimony, along with emerging battery metals like graphite and vanadium.

The integration of a specialist metallurgical testwork laboratory with a process engineering group distinguishes them in the industry, enabling them to provide a knowledge-based service that benefits their clients. This unique combination is the backbone of their offering.

## 3.2. Report structure

**This report is an abridged version of a more comprehensive report prepared for the Queensland Government.**

This report is divided into 10 sections:

1. **Executive Summary:**

This section provides a summary of the report.

2. **Key findings:**

This section provides a suite of key findings from this study.

3. **About the report**:

This section provides context for this study.

4. **About Sulphuric Acid**

This section provides an overview of sulphuric acid, the minerals-related markets which rely on sulphuric acid and describes potential substitutes.

5. **Global market for Sulphuric Acid:**

This section describes the global sulphuric acid (and sulphur) markets, and investigates supply, demand, pricing and trend drivers in these markets.

6. **North West and North East Minerals Provinces Sulphuric Acid market:**

This section provides an overview of Queensland projects which produce, demand or otherwise rely on sulphuric acid. Annualised production and consumption of acid is forecast to 2039 for these operations and an aggregated supply/demand balance presented for various scenarios of the likelihood of supply or demand occurring.

7. **The potential of imports to meet forecast demand:**

This section evaluates the role of imports in potentially meeting the supply deficit of sulphuric acid in Queensland.

8. **Engineering Scoping Study:**

Due to commercial-in-confidence issues, the framework and results of the Engineering Scoping Study are not available in this report.

9. **Appendices:**

This section provides background information relevant to the contents of this report.

# 4. About Sulphuric Acid

## 4.1. Sulphuric Acid overview

Sulphuric acid (chemical formula: $H_2SO_4$) is the world's most widely produced and used inorganic chemical. Due to its acidity, reactivity, corrosiveness, sulphur content and affinity with water, sulphuric acid has many applications in fertiliser production, minerals processing and industrial uses.

Due to its corrosive properties, the storage, handling, and shipping of sulphuric acid are not trivial, leading to inherent advantages of locally producing it if there is sufficient demand.

There are three main ways to produce sulphuric acid:

- **Sulphur burning**: In this process, sulphur is burned in the presence of oxygen to form sulphur dioxide ($SO_2$), which is further oxidised in the presence of a vanadium catalyst to form sulphur trioxide ($SO_3$). Finally, sulphur trioxide reacts with water forming sulphuric acid.

  Approximately 95% of elemental sulphur (S) is recovered as a by-product from refining oil, oil sands and natural gas (the remaining 2% is mined). Recovered sulphur is granulated to improve handling, and often referred to as "sulphur prill".

  This production method supports approximately 60% of the global sulphuric acid production. Since sulphur burning dominates the global market of sulphuric acid, the price of acid is greatly affected by the sulphur market.

  Importantly, this process is exothermic, generating steam which can be harnessed with turbines to produce electrical power.

- **Pyrite roasting**: In this process, pyrite ($FeS_2$) is roasted at high temperatures to form sulphur dioxide gas, leaving behind iron oxide (rust) as a byproduct. Given pyritic ores generally range from about to 20 to 50% in sulphur content, the remainder often include dangerous impurities such as arsenic, which needs to be removed via scrubbers, for example.

  Pyrite is typically sourced as a flotation concentrate from mining metal sulphide ores. Iron cinders can be recovered as by-products and used in the steelmaking or cement industries.

  Compared with sulphur burning, the energy and environmental compliance costs of pyrite roasting are higher. Coupling those factors with the low value of the process by-product, it is not unexpected that sulphuric acid via pyrite roasting represents a minor share (10%) of the global total production.

- **Smelting of base metal concentrates**: sulphuric acid can be obtained as a by-product of smelting base metals concentrates (such as copper, zinc, lead, and nickel). The biggest advantage of this technique is the low cost attributable to sulphuric acid production. Generally, one tonne of metal concentrate produces one tonne of sulphuric acid.

## 4.2. Global Sulphuric Acid dependent markets

This section discusses global minerals markets which are dependent on sulphuric acid and where acid is either consumed or produced in each processing chain. Factors affecting acid demand, including disruptors, are also discussed.

Not all of these minerals-related markets are applicable in the Queensland context, however, they have been included to provide an overview of sector and geographic demand for sulphuric acid and how international competition for globally traded acid may impact Queensland operators.

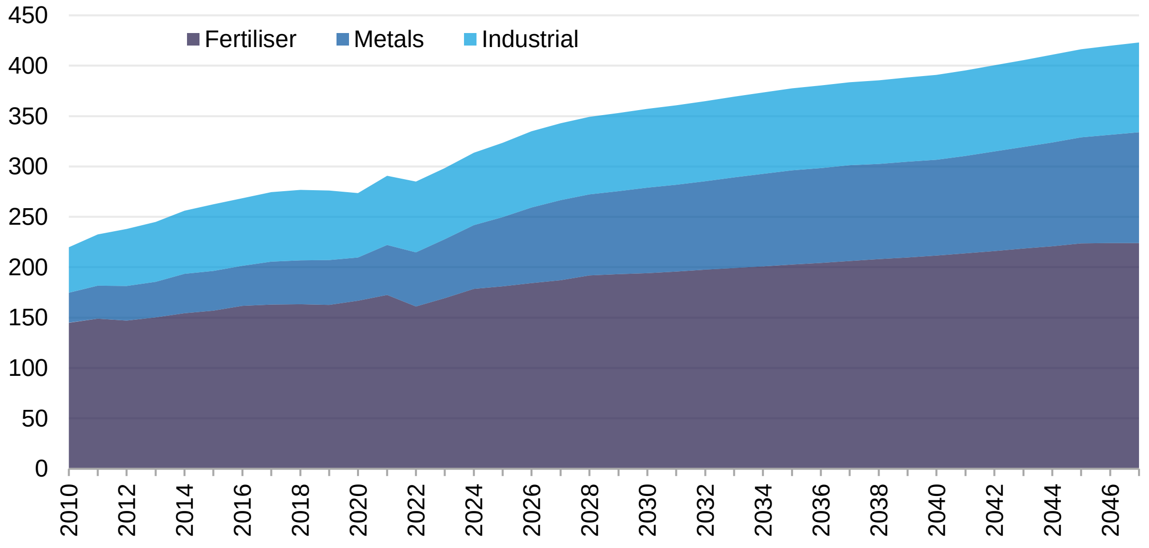
Sulphuric acid demand can be split into three main categories:

- **Fertiliser** production is the largest consumer of sulphuric acid globally, representing 57% of total global demand in 2022. Growing populations and higher incomes tend to result in higher food consumption, which will drive greater fertiliser usage rates and thus production. Fertiliser use is expected to increase global sulphuric acid demand from 161 Mt in 2022 to 224 Mt in 2040, at a compound annual growth rate (CAGR) of 1.8%.

- **Metals** are the fastest growing demand centre for sulphuric acid worldwide. The green transition and electrification trend is increasing the demand for critical minerals and mineral chemicals. This is increasing the use of sulphuric acid as a leaching agent to extract critical minerals from ores, for chemical synthesis and battery electrolyte manufacture. These trends are pushing metals processing demand for sulphuric acid from a market share of 19% in 2022 to 24% in 2040. This correlates to a growth in global sulphuric acid demand from 54 Mt in 2022 to 94.8 Mt in 2040, representing a CAGR of 3.2%.

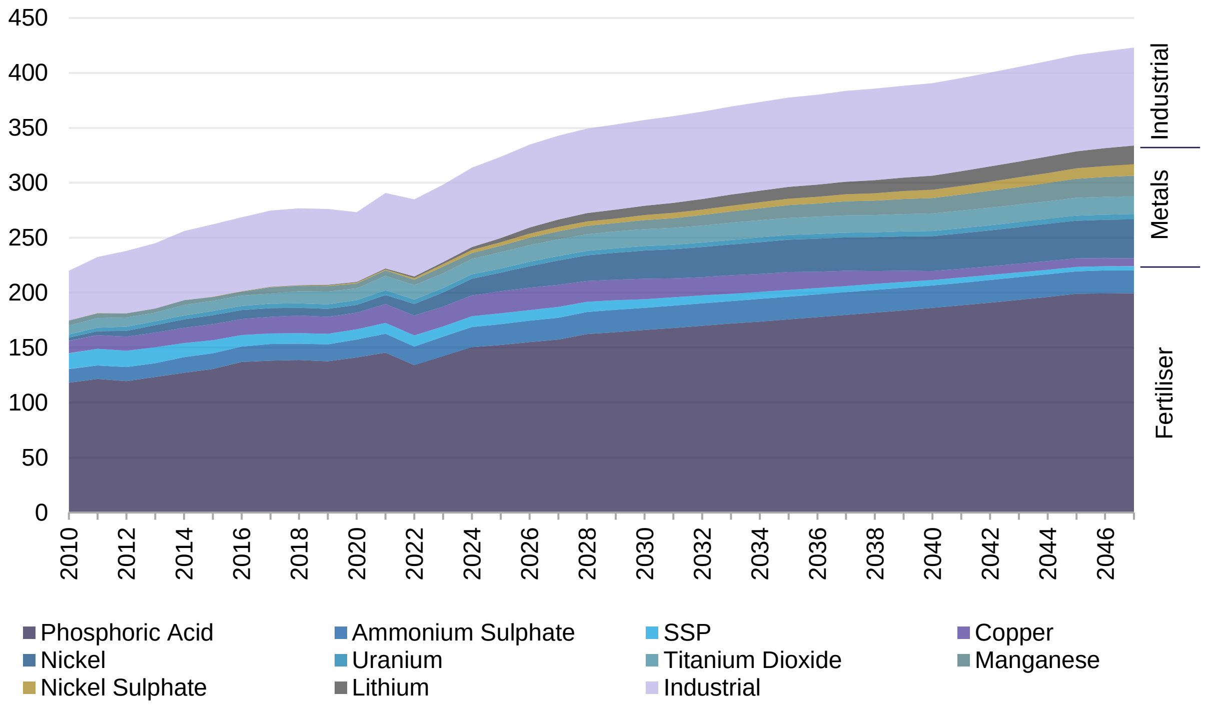
- **Industrial** demand for sulphuric acid comes from a range of industrial processes, such as in waste and water treatment as well as the manufacture of dyes, glue, textiles, paper and firefighting foam. Industrial use is expected to increase global sulphuric acid demand from 70.3 Mt in 2022 to 84.3 Mt in 2040, at a CAGR of 1%.

*Figure 1: Global Sulphuric Acid demand by sector, 2020-2047 (Mtpa)*



DATA: CRU
NOTE: Fertiliser = phosphoric acid, ammonium sulphate, SSP. Metals = copper, nickel, uranium, titanium dioxide, manganese, nickel sulphate, and lithium.

*Figure 2: Global Sulphuric Acid demand by end use, 2010-2047 (Mtpa)*



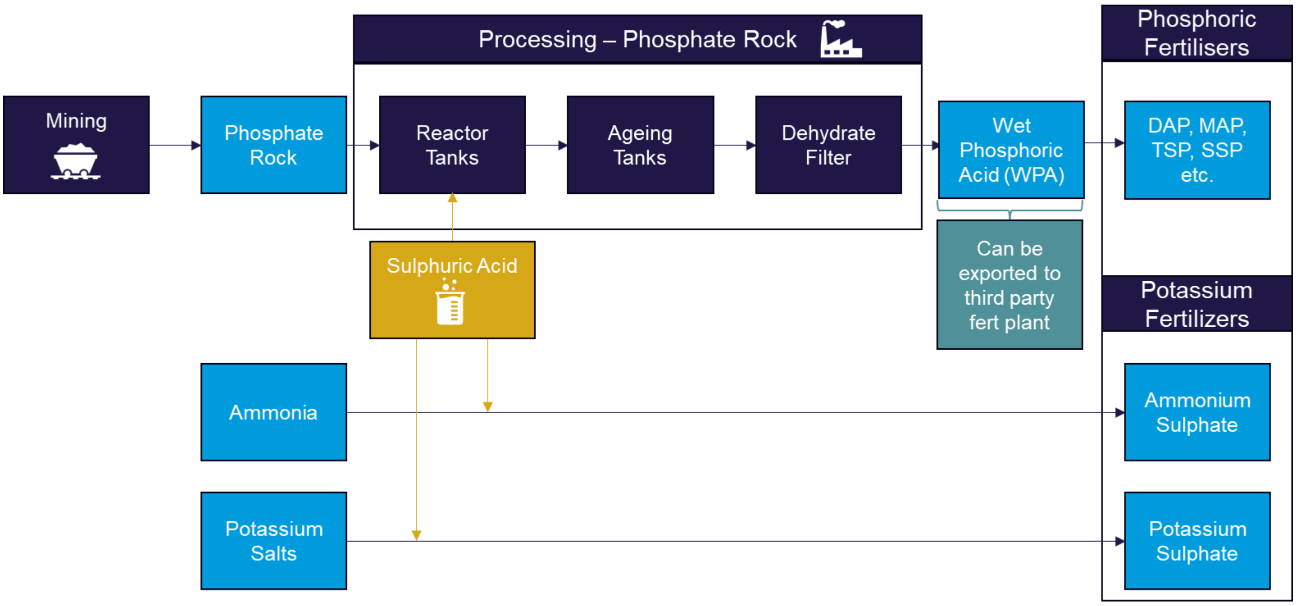
DATA: CRU

### 4.2.1. Phosphate Fertilisers

Phosphate-based fertilisers are produced by reacting phosphate rock with sulphuric acid. Phosphate rock is mined, ground, and placed in reactor tanks with sulphuric acid. This solution is then moved to an ageing tank, before being run through a dehydration filter. The process produces **wet phosphoric acid** (WPA), which is then reacted with ammonia to produce several phosphoric fertilisers, including: **di-ammonium phosphate** (DAP), **mono-ammonium phosphate** (MAP), triple superphosphate (TSS), and single super phosphate (SSP). In the process, sulphuric acid is consumed as a feedstock.

Sulphuric acid is also used in potassium fertiliser production, although in far smaller volumes when compared to phosphates. **Ammonium sulphate** is made by reacting ammonia with sulphuric acid. **Potassium sulphate** is produced by reacting potassium salts with sulphuric acid. Consumption rates of sulphuric acid in these processes are minimal compared to phosphoric fertilisers.

*Figure 3: Phosphate fertiliser production – Sulphuric Acid consumption*



Phosphate fertiliser demand is forecasted to increase throughout the forecast period, following an anomalously weak year in 2022. This demand increase comes about mainly from developing economies, where populations and incomes are rapidly increasing, pushing higher food consumption and thus driving higher fertiliser demand. This demand growth for fertilisers will ultimately drive higher sulphuric acid consumption, a necessary ingredient in phosphoric fertilisers.

Collectively, acid-dependent fertilisers accounted for 57% of global sulphuric acid demand in 2022 and is expected to consume 54% by 2040. Phosphate fertilisers account for 47% of global sulphuric acid demand as of 2022, and with fertiliser supply expected to increase in the medium term, sulphuric acid demand is expected to also increase. Ammonium sulphate production accounted for 6% of global sulphuric acid demand in 2022. Single super phosphate (SSP) consumed approximately 4% of global sulphuric acid demand in 2022.

Although expansions for phosphoric acid and phosphate fertiliser production will increase the need for sulphuric acid, almost all capacity expansions in Morocco, Brazil, and India are being met with additional sulphur burners. Thus, sulphuric acid trade will not be absorbed directly by expansions. Furthermore, current Canadian exports of sulphur to Australia will perhaps see limited changes as Canada currently has no sulphur trading with India, Morocco, or Brazil, despite large quantities of phosphoric acid already being made there. The United States may see additional sulphur imports from Canada as they increase phosphoric acid production, but these increases in production are expected to be minimal compared to other regions.

**Implications for Queensland:**

Global consumption of sulphuric acid for phosphoric acid production is dominated by China (44.4 Mt of acid in 2022), Morocco (19.5 Mt), United States (18.2 Mt) and Russia (11 Mt). In comparison, Australia consumed approximately 1.1 Mt for phosphoric acid production in 2022, placing the country as the 16th largest consumer of acid for phosphoric acid production globally.

Morocco is the only significant producer with a deficit of sulphuric acid production domestically, indicating additional imports of acid are required to meet demand there. This demand may soak up some Canadian sulphur production moving forward, however the implications of the increased global demand for fertilisers will have minimal effect in Queensland.

### 4.2.2. Copper

Copper (Cu) occurs primarily in sulphide and oxide ores, with both having different processes to arrive at refined copper metal due to the variation in their chemistries. This processing variation ultimately dictates the quantity of sulphuric acid that is consumed and produced when manufacturing copper metal.

**Copper sulphide** ore is processed at a mine site, going through crushing, grinding, flotation, thickening, and filtering to produce a concentrate which contains approximately 25-40% copper. This copper concentrate product can then be further processed at the mine site, or more usually it is transported to a third-party smelting and refining plant. The copper concentrate is then placed in a smelter, which removes unwanted minerals, and produces large quantities of sulphur dioxide. This sulphur dioxide is then often processed in an acid plant to produce sulphuric acid. Copper matte is produced following smelting (~70% copper), which is placed in a converter, removing further sulphides, and producing more sulphur dioxide, which can also be used to produce sulphuric acid. Following fire refining, copper anodes are produced which are finally electro-refined to produce 99.99% pure copper metal. The electro-refining process uses a dilute sulphuric acid as the electrolyte; however, the quantities are often not too large, and large portions of the electrolyte can be reused. It is important to note that the transportation of copper concentrate from a mine site to a copper smelter can often mean most of the sulphuric acid consumption and production occurs close to the copper smelter, rather than at mine sites themselves.

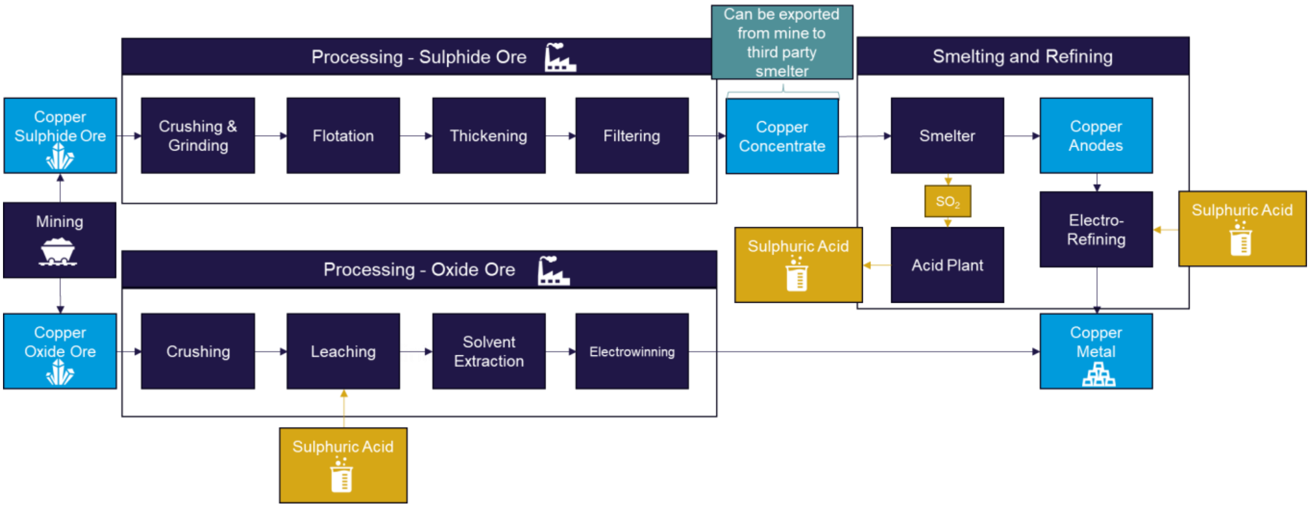
**Copper oxide** ores are typically processed using an acid leach and Solvent Extraction – Electrowinning (SXEW) process. The acid leach involves spraying a fine mist of sulphuric acid over beds of crushed copper oxide ore to remove copper from the ore and produce an acidic acid-copper leachate. This leachate is mixed with an organic solvent to create a copper electrolyte to which is then further processed through an electrolytic cell to produce copper metal (99.99% copper) on the cathode of the electrolytic cell. This overall process is typically a net consumer of sulphuric acid, noting acid is typically recycled through the SXEW process.

Processing of copper sulphide ores using the electro-refining method produces large amounts of sulphuric acid through smelting and converting of the sulphide ore. Small amounts are also consumed during the refining process, but much of this can be recycled and has minimal material effect on sulphuric acid balances. This sulphuric acid production occurs where the copper concentrate is refined, usually not at the mine site. Processing copper oxide uses small amounts of sulphuric acid to leach the copper from the ore. This acid can usually be recycled to a high degree. Any acid consumption occurs at the mine site.

Out of both processes, electro-refining (processing sulphide ores) is the major production type. Although oxides are more abundant, they are often more difficult to extract economic quantities of copper from. Electro-refining is responsible for around 83% of refined copper production, a market share which is expected to have further gains in coming years.

As electro-refining produces large quantities of sulphuric acid at the copper metal production plant (usually not the mine) and is the predominant process for producing refined copper, increases in countries refining output due to growing copper demand will heavily affect regional sulphuric acid output.

*Figure 4: Copper production – Sulphuric Acid consumption*



Copper demand will rapidly grow from now until the middle of the century given its relevance in electrification. The sharp rise is especially due to renewable energy technologies requiring up to 5 times more copper than similar non-renewable ones. The consequential supply gap will drive new mining and recycling projects. Since copper processing can both produce and require sulphuric acid, the global sulphuric acid will be affected accordingly.

The total global copper demand is expected to increase from 2022 to 2035 at a CAGR of 1.9%. Historically, large portions of copper demand were due to construction related enterprises, with China being a heavy driver. Increasingly going forward, the driver of demand will be seen outside of China, in Asia (ex. China), with copper demand relating to renewable energy technologies and infrastructure. In terms of sulphuric acid in the copper market, the growth in demand will drive the supply, where the majority of sulphuric acid is being produced during the electro-refining of copper.

China and Japan combined hold almost 60% of all smelting and refining outputs for copper in 2022. With demand increases and a majority share expected specially in Asia, this refining share is expected to remain, with an upside of a slight increase. This growth in copper demand will increase refining output as well as sulphuric acid production within Asia. China is expected to see increased capacity as well, despite lowering domestic demand, causing increased exports of copper expected in coming years. A lot of this involuntary smelter acid production will be captured by growing phosphate and battery chemical production (both mine processing and battery chemistry synthesis), limiting the short-term need of acid export, and creating disruptions in the market. Over the past 6 to 7 years, Chinese imports of sulphuric acid have decreased almost 80 kt into Australia, while Japanese imports have decreased almost 65 kt.

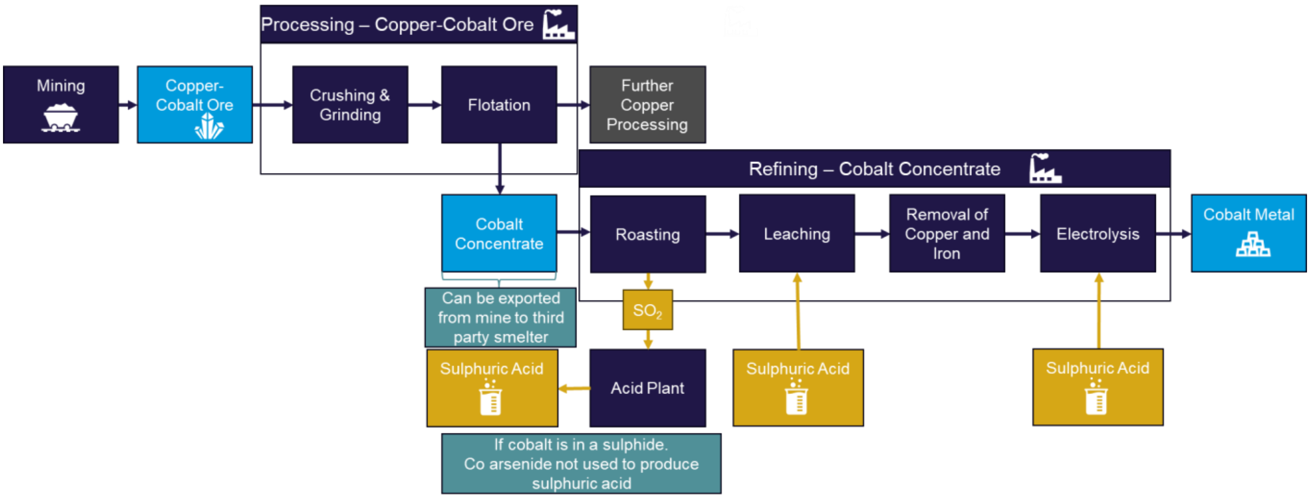
**Implications for Queensland:**

Copper demand globally will lead to higher smelter capacity, especially in Asia. China will increase its sulphuric acid output via smelting from 43 Mt in 2022 to 50 Mt in 2027, while Japan, will increase from 4.9 Mt to 5.3 Mt. In 2027, smelting will represent 47 % and 83 % of total sulphuric acid production in China and Japan, respectively. Both countries will be net positive and able to export excess sulphuric acid produced, most likely to neighbouring countries. Given that demand for sulphuric acid in southeast Asia will more than double in the same period, exports from Japan and China will likely reach those markets rather than Australia. Indonesia is the greatest demand centre; however, coupled with its increased production capacity leads to minimal import expected in 2027. Philippines, with its increased phosphoric acid production and nickel leaching projects, poses a threat to Australian sulphuric acid supply as it will be required to import 3x the volume of sulphuric acid that Australia needs.

### 4.2.3. Cobalt

Cobalt (Co) ores are mined, crushed, and ground, and the resulting slurry is then floated to extract a cobalt concentrate. This concentrate is then roasted. If the concentrate is a sulphide (rather than an arsenide), sulphur dioxide is produced which can be converted to sulphuric acid. The quantities of sulphuric acid produced are limited, and current production often does not capture the sulphur dioxide, unlike the copper production. This roasted concentrate is then leached, with the solution then being treated to remove copper and iron. Finally, if the copper and cobalt were in an oxidised state, electrolysis in a sulphuric acid solution is conducted, otherwise regular electrolysis is used to extract the cobalt. As the cobalt concentrate can be sold from the mine, the sulphuric acid intensive refining process often occurs elsewhere than the mine.

*Figure 5: Cobalt production – Sulphuric Acid consumption*



Cobalt is used for a range of purposes, such as a catalyst, as an alloy, cemented carbides, and in some lithium-ion battery chemistries. Cobalt demand is expected to increase over the years, as battery production grows for both energy storage and electric vehicles. This growth in demand will drive further supply, especially out of Africa, which requires sulphuric acid for leaching. As well as processing of cobalt, refining cobalt metal and producing chemicals from cobalt consumes sulphuric acid. Growth will be seen almost exclusively in China and Indonesia. Similar to the cobalt metal production, the production of chemicals will see sulphuric acid in the Asian region be taken up by projects in China and Indonesia. Importantly, China sources sulphur from Canda, which may result in competition with Australia for sourcing.

Despite higher cobalt demand arising out of the back of growing EV production and the need for short duration battery storage, the supply of cobalt is largely linked to copper and nickel production, where cobalt is a common by-product. Globally, cobalt supply is expected to increase by 136 kt from 2022 to 2040. This growth is mainly from increased production in Africa (in particular, in the DRC) and Indonesia. Africa will experience a supply growth from 2022 to 2040 at a CAGR of 2.6%. Indonesia will see less volume growth in absolute values, increasing in the same period at a CAGR of 12.5%.

**Implications for Queensland:**

Supply growth in Africa is unlikely to materially impact Australian sulphuric acid supply chains, as most sulphur and sulphuric acid is sourced both from within the region and the Middle East. However, given the prevalence of artisanal mines in the DRC and the reports of child labour within those mines, there is a push for cobalt sources outside Africa. Australia, with 1.4 Mt of stated reserves in cobalt, is the second country with the highest world share (18 %). Increased cobalt production is expected in Australia from 3 kt in 2022 to 16 kt in 2027. However, production or consumption of sulphuric acid within the country related to cobalt extraction or processing are expected to be minimal, as most of the Australian cobalt concentrate will be processed in China.

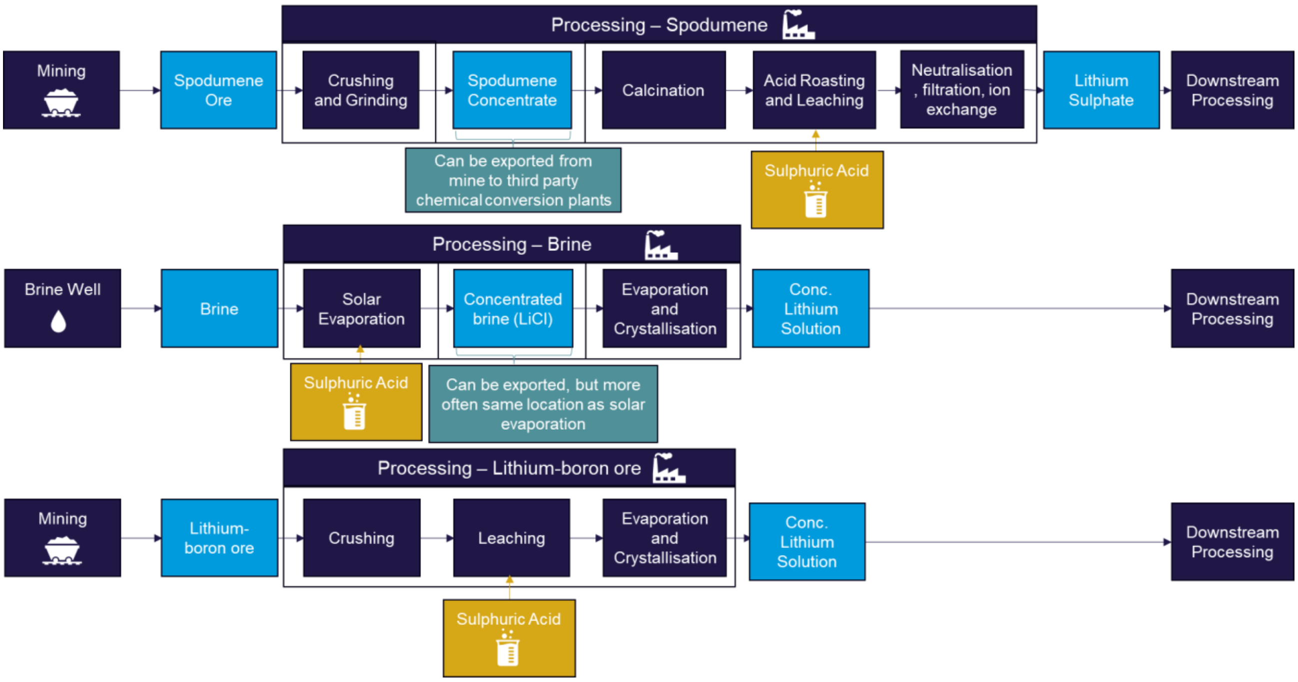
### 4.2.4. Lithium

Despite being a metal in its elemental form, lithium (Li) is mostly consumed as chemical compounds. Historically, lithium was predominantly used in industrial end-uses such as in glass manufacturing and as additives in ceramics, as well as for smelting and casting. Today, lithium's main use is in lithium-ion batteries which are used in a wide range of applications, such as in mobile devices and electric vehicles. In recent years, lithium demand in batteries has grown exponentially and that trend is expected to continue.

Out of all of the sulphuric acid dependent markets, the lithium chemicals sector is expected to see the largest growth in sulphuric acid consumption going forward. The rapid growth in demand for Li-ion battery chemistries, and the resulting demand for lithium-based chemicals which require sulphuric acid in their production, are expected to have a massive disruptive impact on the acid supply chain.

Lithium comes from three main sources: spodumene ore, brine, and lithium-boron ore, with each having different production processes. All consumption of sulphuric acid occurs at the location where lithium hydroxide and lithium carbonate are produced.

*Figure 6: Lithium production – Sulphuric Acid consumption*



To meet growing global demand for lithium-ion batteries, producing regions are expected to increase processing capacity for lithium derivatives, such as lithium carbonate and lithium hydroxide. Lithium carbonate in particular is forecast to have the largest capacity growth. As sulphuric acid is consumed in the processing stage, regions experiencing capacity growth will entail possible disruptive consumption of sulphuric acid.

**Implications for Queensland:**

China will near triple its consumption of sulphuric acid in its lithium industry, growing at a CARG of 22.7% (2022-2027), reaching 3.9 Mt in 2027. South Korea and Indonesia are both expected to increase lithium processing, reaching 100 kt and 140 kt in acid demand by 2027, respectively. Higher acid demand in these countries is expected to be largely met by expanding domestic (copper) smelter capacity and burning of imported sulphur.

Importantly, Australia's sulphuric acid demand for lithium production is expected to grow at a CAGR of 57% (2022-2027), reaching 453 ktpa by 2027.

New lithium processing projects and lithium hydroxide capacity expansions in Western Australia will add additional strain on Queensland's ability to source sulphur and sulphuric acid both domestically and internationally, compounded by Australia's declining acid-generating smelter capacity in coming

### 4.2.5. Nickel

Nickel (Ni) has traditionally been used for metals plating to protect against wear, as well as an additive to alloys, especially in steel to produce stainless steel. Nickel is also a key component of lithium-ion batteries, where it is used in cathode chemistries. As a consequence of rapidly expanding demand for electric vehicles (EVs) and energy storage, nickel demand has soared. The nickel industry is the second fastest growing sulphuric acid dependent market after lithium globally. Sulphuric acid is used to leach nickel from ore, as well as to produce nickel sulphate ($NiSO_4$), a key ingredient in Li-ion battery cathodes.

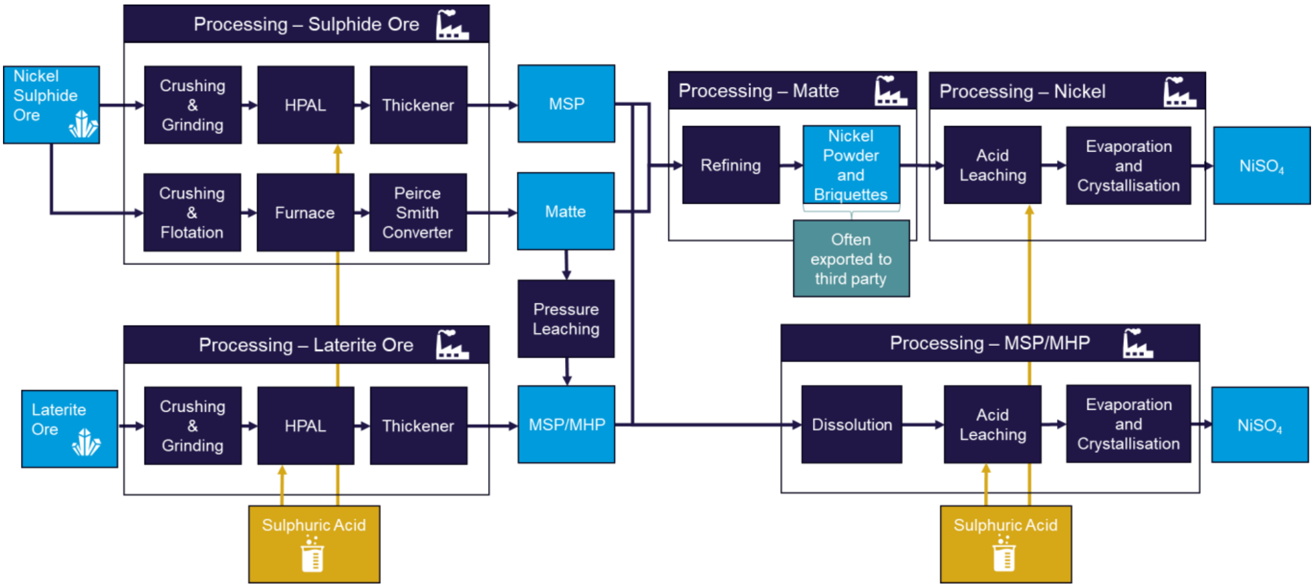
Primary nickel comes from two main sources: nickel sulphide ore and laterite ore. Whilst the nickel value chain is extremely complex and involves many intermediate products and finished products, we focus on the branches of the value chain which consume sulphuric acid.

For both sulphide ore and laterite ore, nickel can be extracted by the high-pressure acid leach (HPAL) process, which involves crushing and grinding the ore, followed by leaching at high pressure with sulphuric acid, and subsequent thickening to produce mixed hydroxide precipitate (MHP) or mixed sulphide precipitate (MSP). MHP and MSP can then be dissolved and leached with additional sulphuric acid, then evaporated and crystallised to produce nickel sulphate.

Alternatively, nickel sulphide ores can also be crushed and floated, roasted in a furnace, and run through a Peirce Smith converter to produce nickel matte. Although this process does not directly use sulphuric acid, matte can be refined into nickel powder and briquettes, which can then be acid leached to produce nickel sulphate. Matte can also be pressure leached to produce MSP which can then be used to produce nickel sulphate, although this method is less common.

Nickel production will consume approximately 7% of the global sulphuric acid by 2027, and variations in nickel output will have a large impact on acid supply chains. Many types of primary nickel production require sulphuric acid. Global primary nickel production consumed 10.5 Mt of sulphuric acid in 2023, and is expected to grow at a CAGR of 20% to 2027. Nickel sulphate production is the fastest growing consumer of sulphuric acid at a CAGR of 24.6% to 2027, with forecast global demand for sulphuric acid for nickel sulphate production expected to reach 3.9 Mt by 2027. Nickel sulphate production is heavily dependent on sulphuric acid, placing significant pressure on the sulphuric acid market.

*Figure 7: Nickel production – Sulphuric Acid consumption*



**Implications for Queensland:**

Nickel sulphate production in East Asia (China, Japan, South Korea, and Taiwan) will shift demand for sulphuric acid from 1.5 Mt in 2022 to 3.2 Mt in 2027. Indonesia will also increase its need for sulphuric acid for nickel sulphate production from 25 kt in 2022 to 400 kt in 2027. In Australia, an increase from 9 kt in 2022 to 140 kt in 2027 for nickel sulphate production is expected, placing increased demand on Australian domestic acid production.

Chinese supply growth will affect sulphuric acid availability arising from general nickel primary production growth, absorbing additional Canadian sulphur supply and Asian sulphuric acid supply that could have otherwise supplied the Australian market. The growth in nickel sulphate production in JKT means that South Korean exports of sulphuric acid to Australia could dwindle as smelter by-product acid is increasingly used domestically there.

Similar to the lithium market, the extra demand for sulphuric acid in Asia will be met by new imported sulphur burning and domestic smelter by-product acid capacities, straining Queensland's ability to procure sulphur and sulphuric acid from existing regional sources.

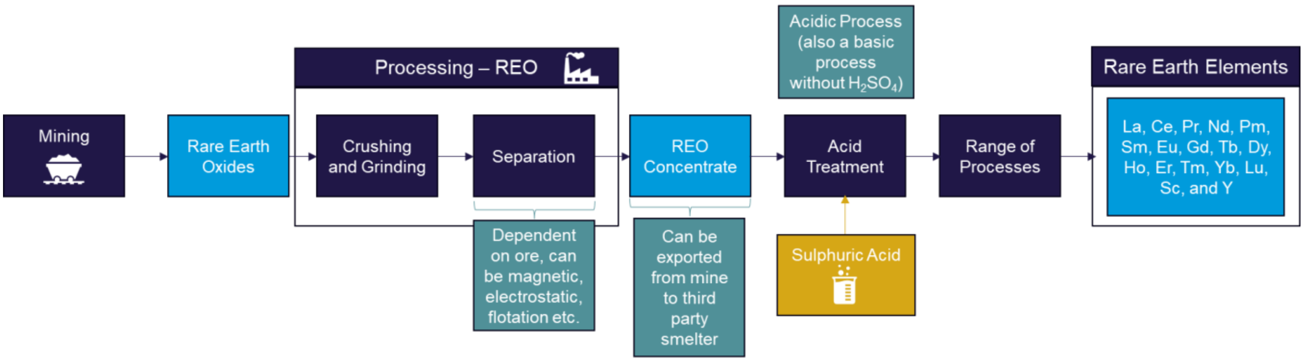
### 4.2.6. Rare Earth Elements

Rare Earth Elements (REE) refer to a group of 15 elements that occur in relatively low concentrations, making them often uneconomical to mine, and thus "rare". REEs, especially neodymium (Nd, in the form of NdFeB) and praseodymium (Pr) are used in magnets, metal alloys, catalysts, and a range of additives for different processes. Currently, REE's use in powerful permanent magnets make them useful in the production of EVs and wind turbines, and their use as an alloy to strengthen metals makes them useful in structural components in renewable technologies. This renewable energy focus is driving the growth in consumption of REEs globally.

Due to the variety of REEs and the range of minerals they are found in (more than 200), REEs extraction techniques can differ massively. In general, the process involves mining and comminution, followed by separation based on physical and/or chemical properties of the ore, often involving gravimetric, magnetic, electrostatic, flotation and other separation techniques. This produces a rare earths oxide (REO) concentrate, which is roasted and placed in an alkali or acidic solution (the latter via sulphuric acid mixing).

The need for sulphuric acid in the acid treatment stage, coupled with increasing global demand for REEs, will drive up sulphuric acid demand.

*Figure 8: Rare Earth Element production – Sulphuric Acid consumption*



**Implications for Queensland:**

Chinese production increases may lead to extra imports of Canadian sulphur, resulting in further pressures on Australian acid feedstock sourcing. Furthermore, consumption of domestic acid supply in China will lower exports to Australia, further pressuring acid availability. Similarly, growing REE production in Australia will see more pressure and competition for domestic sulphuric acid going forward, however it should be noted that the volumes of sulphuric acid in REEs are relatively small and thus will not cause large disruptions in Australia or Queensland.

### 4.2.7. Uranium

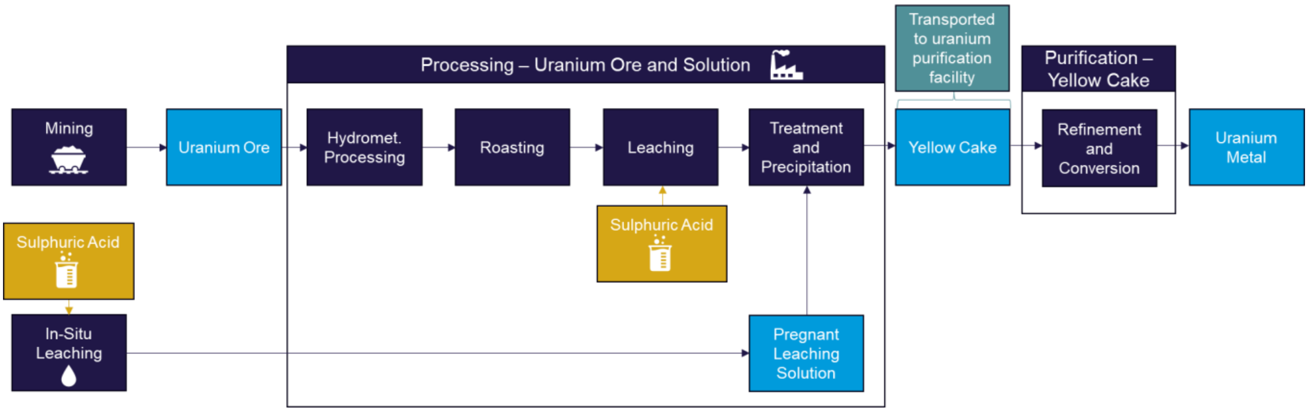
Uranium (U) is used almost exclusively in nuclear power reactors, with small amounts utilised for medical and defence purposes. Uranium is expected to see moderate growth over the coming years as nuclear power capacity grows, especially in Asia.

Uranium is produced in three ways: in-situ leaching being the most prominent, followed by conventional mining, and finally through by-product production. All these production methods require consumption of sulphuric acid, and thus the growing demand for uranium will affect sulphuric acid and sulphur markets globally.

Uranium demand is expected to increase to meet nuclear energy needs. In response, global mine supply will increase at a CAGR of 5.4% from 2022 to 2027, outpacing demand to make up for depleting stockpiles that are currently being used. Both in-situ leaching and conventional mining techniques will provide the majority of supply. In-situ leaching, due to the large portion of ground being leached, requires larger amounts of sulphuric acid, and will thus be a major driver for sulphur and sulphuric acid disruptions globally.

Kazakhstan dominates global uranium production (43% of market share in 2022) and currently supplies a large portion of its production to China and other Asian countries where demand is seen to have the highest forecast growth rate globally. Historically, Kazakhstan has sourced almost all its sulphur and sulphuric acid from Uzbekistan and Russia. Pre-2009 however, sulphuric acid availability for uranium projects in the country was an issue, leading to the setup of a sulphuric acid coordination council aimed at providing strategies to ensure stable sulphuric acid supply in the country. With expected growth coming online, sourcing sulphuric acid and sulphur outside of Uzbekistan and Russia may be necessary. With large domestic sulphuric acid production projects, such as the Kazatomprom's (a major uranium producer) 800 ktpa sulphuric acid plant coming online in 2024, sulphur may need to be sourced from elsewhere, possibly putting strain on global trade.

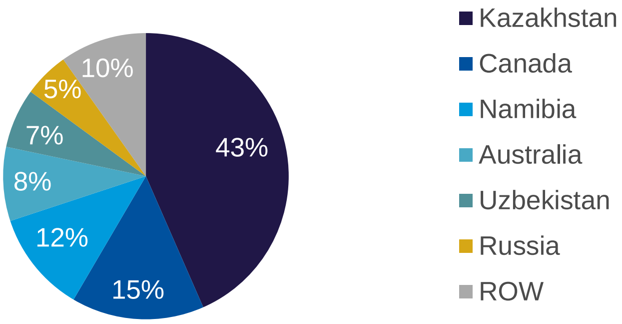
*Figure 9: Uranium production – Sulphuric Acid consumption*



Uranium production is set to stagnate in Canada, where all sulphuric acid is produced domestically through burners fed by domestic sulphur production. As such, Canada will provide little risk to global sulphuric acid or sulphur flow. The United States similarly will see minimal growth and uses an alkali solution for in-situ leaching. Africa is expected to see increased uranium production, especially in Namibia and Niger, with sulphur being sourced domestically and from the Middle East. This will thus limit competition for Australia with sourcing sulphur or sulphuric acid due to African uranium production.

Australia produced 8% of global uranium in 2022, despite holding 28% of total global resources. Although currently limited expectations of uranium production growth, due to large resources and volatility of Australia's stance on nuclear power and uranium mining, there is some upside risk of uranium production, and thus sulphuric acid consumption, increasing in the next 10-20 years, further disrupting the sulphuric acid market.

*Figure 10: Regional supply of Uranium by region, 2022 (%)*



Data: World Nuclear Association

**Implications for Queensland:**

The recent growth in global uranium demand and subsequent supply response, has placed increasing demand on sulphur and sulphuric acid markets. Similar with growth trends in other acid dependent markets, further growth in uranium production may see increased competition for sulphur and sulphuric acid globally.

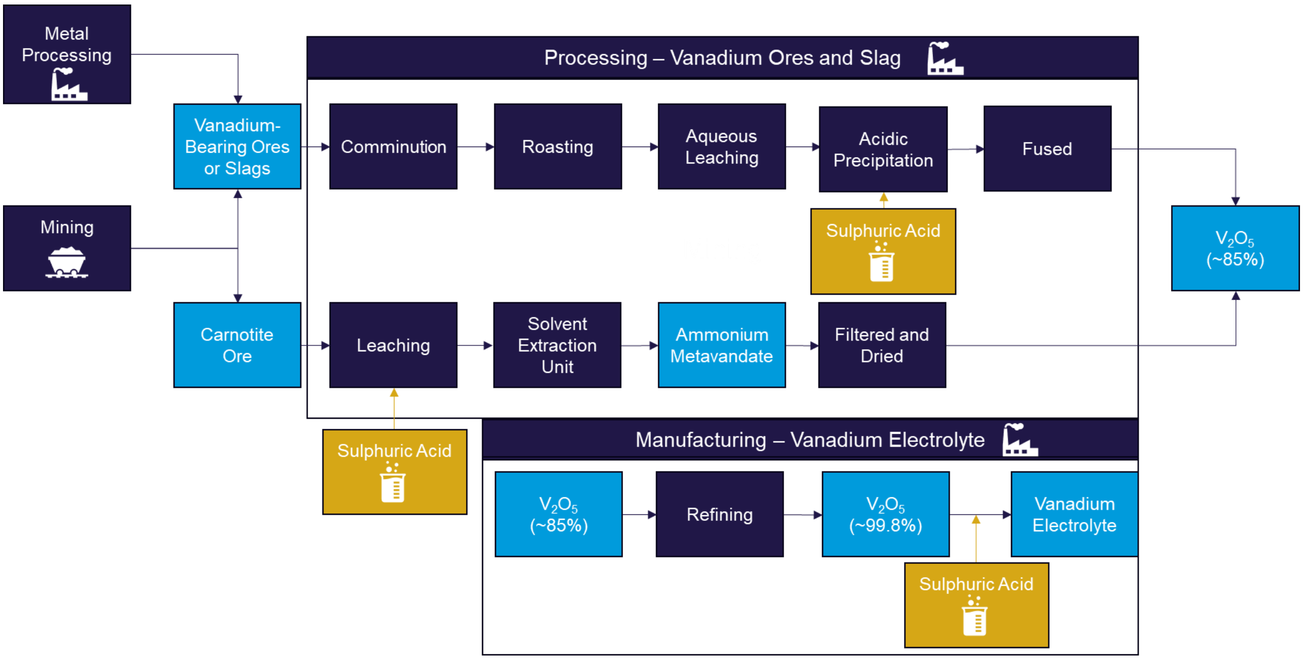
### 4.2.8. Vanadium

Vanadium (V) is a metal currently used predominantly as an alloy additive to provide additional strength, toughness and wear resistance to steel alloys. Vanadium is also used as a catalyst and additive to chemical products, for strengthening and reducing weight of titanium alloys in aerospace applications. Of particular interest to Queensland is the growing area of vanadium demand as the main component of the electrolyte in Vanadium Redox Flow Batteries (VRFBs). Increasing demand for VFRBs to support renewable-dominated energy networks is expected to result in this market segment being the fastest growth area for vanadium globally. The impact of increased VFRB demand on sulphuric acid is two-fold: additional vanadium will need to be mined which uses sulphuric acid as a leaching agent, and as the solvent for the battery electrolyte.

Vanadium can be recovered from primary mining of ores, certain naturally occurring hydrocarbons and refinery slag. Generally, vanadium-containing materials are broken down to an acceptable size, roasted in a furnace, leached with water, and then leached with an acidic solution, most often containing sulphuric acid. This leaching is generally consumed at the mine, or where the vanadium pentoxide is being produced. The leached product is then fused at high temperatures to produce a technical grade ~85% vanadium pentoxide, which can be further refined to 99.8% vanadium pentoxide. The exception to this process is carnotite ore, in which sulphuric acid leaching is used on the ore to extract the vanadium content.

As well as sulphuric acid use in the recovery of vanadium, a growing usage in the industry is as the solvent for the electrolyte in VRFBs. Large volumes of dilute sulphuric acid (~32%) are required in the electrolyte to dissolve the poorly soluble vanadium. Refined grade vanadium pentoxide is mixed with a high-purity sulphuric acid (free of iron, copper, zinc, aluminium oxide, etc.) to produce a vanadium electrolyte, which is the main component of the VRFB.

*Figure 11: Vanadium production – Sulphuric Acid consumption*



Demand for vanadium outside of VFRBs is relatively stable, however VFRBs are expected to be broadly deployed for utility-scale energy storage to support renewable energy generation, which will increase demand for both vanadium and sulphuric acid. Whilst the rollout of VFRBs has been relatively modest to date, CRU forecasts that VFRB adoption for utility-scale storage will rapidly expand over coming years. This expansion will place pressure on sulphuric acid supplies, particularly for high-purity acid used in electrolyte manufacture.

The growth in electrolyte production will have a direct impact on Australian sulphuric acid supply chains. Europe will have the least impact as the region will see the least growth, with most of its sulphur sourced from the Middle East, which does not compete directly with Australian supply chains. This may change as crude oil production decreases in the Middle East (refer to Section 5.1.1). Both China and USA will be more disruptive to Australian supply chains as both regions are the two largest importers of Canadian sulphur along with Australia. China will also disrupt sulphuric acid imports directly, as South Korea may find shipping to the nearer Chinese market easier, while the Chinese sulphuric acid exports to Australia will lower due to higher domestic usage.

As well as electrolyte production, sulphuric acid is also used in the processing of vanadium. This overall growth in vanadium demand will result in the need for additional supply, as current supply is well below future demand. This will result in increased sulphuric acid consumption at mines in addition to sulphuric acid consumed in electrolyte production.

**Implications for Queensland:**

Increasing demand for vanadium in VFRBs applications is expected to place pressure on sulphuric acid supplies, particularly for high-purity acid used in electrolyte manufacture. There is potential that Queensland acid users will face increasing competition to secure sufficient supplies of internationally traded sulphuric acid and sulphur.

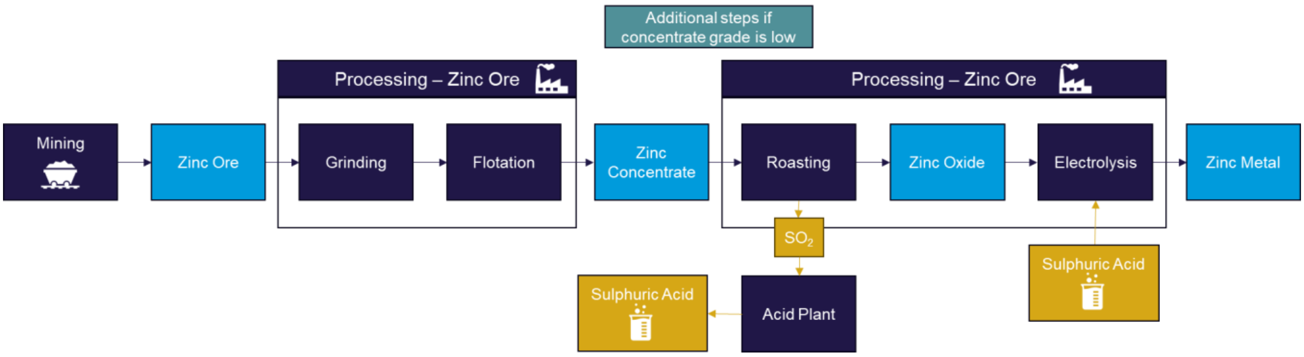
### 4.2.9. Zinc

Zinc (Zn) is mainly used for galvanising steel to increase corrosion resistance, as well as being used to make various metal alloys. Although zinc will not see massive growth compared with some other sulphuric acid dependent markets, there will be tangible increases in both demand and supply as galvanized steel and various metal alloys are increasingly used. Sulphuric acid is both produced and consumed, through smelting of zinc concentrates and during electrolysis of the zinc metal, respectively. Sulphuric acid is also used in the galvanizing process.

Zinc is extracted from mined ore through grinding and flotation to produce a zinc concentrate which is typically sold to smelters or traders. At the smelter, the zinc concentrate is roasted to produce zinc oxide, a process which produces sulphur dioxide waste gas which can be converted to sulphuric acid in an acid plant. Following roasting, the zinc oxide is placed into dilute sulphuric acid for electrolysis which reduces the zinc oxide to produce zinc metal. The sulphuric acid produced during this process is greater than the volume consumed as a dilute solution is used for electrolysis.

During galvanising of steel with zinc, for surface preparation of the steel, pickling is often used. Pickling involves placing the steel in an acidic solution, often sulphuric acid, to remove excessive grease and dirt from the exterior. Following this, the steel is placed in molten zinc to galvanize the outside.

*Figure 12: Zinc production – Sulphuric Acid consumption*



Unlike many other sulphuric acid dependent markets that will see rapid growth over the forecasted period due to the growing push for a green transition, zinc will see a more modest growth rate. Growth will be driven by general demand for galvanized steel and an array of metal alloys, rather than a strong change in end-use or demand for a current product increasing rapidly. This moderate growth in demand for zinc means that supply needs to see similar growth over the same period. Growths in refined zinc production will lead to additional sulphuric acid being produced.

**Implications for Queensland:**

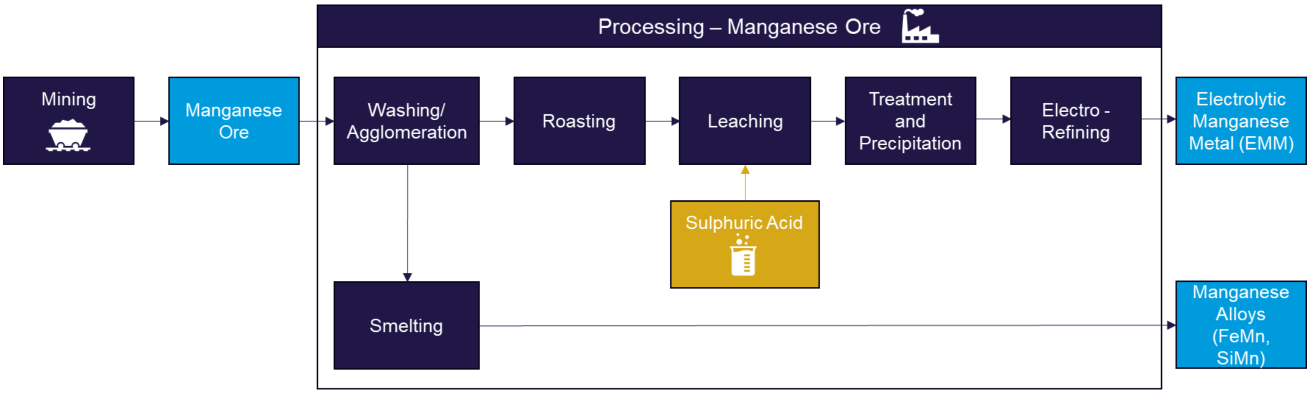
Marginal increases in zinc smelting capacity globally are expected to correspond to similar increase in sulphuric acid production from sulphur dioxide waste gas streams. Much of this slight increased acid production is expected to be absorbed by domestic demand and therefore unlikely to impact global acid markets which Queensland companies might rely upon.

### 4.2.10. Manganese

Manganese (Mn) is a metal used mostly as an alloy for steels and aluminium, as well as an additive to fertilisers, ceramics, and glass, and more recently, in battery chemistries. Manganese is processed into two main forms, manganese alloys (ferromanganese and silicomanganese), and electrolytic manganese metal (EMM), used as a chemical additive and in battery chemistries. Currently, manganese alloys comprise the largest portion of market share, however growing battery demand is expected to drive EMM into a higher growth rate than its alloy counterparts. EMM is the only type of manganese that requires sulphuric acid for its production.

Manganese ore is usually extracted in open pit mines, and commonly washed and/or agglomerated, depending on its characteristics and subsequent processing route. To produce EMM, manganese ore is roasted to produce manganese oxide (MnO) calcine, which is then dissolved in sulphuric acid. This solution is treated to precipitate unwanted minerals and elements from the solution. Once purified, the solution is placed in an electrolytic cell, where an electric current passing through the solution deposits the manganese on the cathode. Cathodes are removed periodically, with the manganese being hammered off and heated to remove hydrogen, forming the EMM.

*Figure 13: Manganese production – Sulphuric Acid consumption*



EMM demand is expected to increase to meet the growing demand for certain battery chemistries, especially in EVs. This growth in demand will induce additional EMM production, which will increase demand for sulphuric acid in regions that produce EMM. This increase in acid use will be seen mainly in China due to its large global share of EMM production. As EMM is a relatively minor consumer of sulphuric acid, this growth in EMM production seen in China will have relatively minor disruptions on overall sulphuric acid trade and consumption globally. Most of the increased EMM-related sulphuric acid consumption in China is expected to be met by domestic sulphur burning and acid by-product acid from copper smelting.

**Implications for Queensland:**

Increasing EMM production, particularly in China, is expected to rely mainly on domestic acid capacity and unlikely to significantly impact sulphuric acid or sulphur markets which Queensland companies might rely upon.

## 4.3. Substitutes for Sulphuric Acid

**Sulphuric acid dominates the global acid market** for several reasons, including:

- Low cost of production
- Abundance of sulphur-based feedstocks
- Widespread adoption in chemical processes

A major application of sulphuric acid is for the leaching of metal oxide ores. Given that for this application, the only relevant chemical property required is sufficient acidity, other acids could fit the purpose.

Some of the most common acids are sulphuric, hydrochloric, phosphoric, nitric, oxalic, citric, and acetic. Despite not being the strongest acid available, there are several advantages for opting for sulphuric acid. Sulphuric acid contains two acidic hydrogens, as opposed to hydrobromic acid and hydrochloric acid, which contain only one. This effectively means that the volume of sulphuric acid required is nearly halved for the same corrosiveness and leaching ability compared to these other two acids. Those acids that have multiple acidic hydrogens are phosphoric and citric acids, both with three, and oxalic acid with two. Phosphoric and oxalic acids require sulphuric acid for their manufacturing and given their weaker acidity ability, have limited applications as a leaching agent. Acetic acid has the lowest acidity which is too weak to substitute for sulphuric acid. Nitric acid is the closest candidate given its strength, has sizeable global production and does not require sulphur or sulphuric acid at any stage of production, however, since the main manufacturing process is the energy-intensive Harber-Bosch method, the price is one of the highest amongst all the acids.

*Table 1: Characteristics of the principal types of acids*

| Type of acid | Acidity strength | Production method(s) | Relative Price | Global production |
|---|---|---|---|---|
| Hydrobromic acid ($HBr$) | Strongest | By the chemical reaction between bromine ($Br_2$), water and either sulphur or phosphorus. Sulphuric acid is a side product when using sulphur. | $$$$$ | < 1 Mtpa |
| Hydrochloric acid ($HCl$) | Strongest | Co-produced during silica manufacturing or via sulphuric acid, via chlorination of organic chemicals or via the reaction of hydrogen ($H_2$) and chlorine ($Cl_2$) | $$ | 20 Mtpa |
| Sulphuric acid ($H_2SO_4$) | Strong | Via the burning of sulphur or pyrite ($FeS_2$) under wet conditions or co-produced via the smelting of sulphidic ores | $$ | 300 Mtpa |
| Nitric acid ($HNO_3$) | Strong | Chemical rection between ammonia and nitric oxide in the presence of a metal catalyst. Ammonia is made by the high energy consuming Haber-Bosch process. | $$$$$ | 60 Mtpa |
| Oxalic acid ($C_2H_2O_4$) | Medium | Chemical rection between ethylene glycol, nitric acid and sulphuric acid | $$$ | < 1 Mtpa |
| Phosphoric acid ($H_3PO_4$) | Medium | 80% of the total global supply is made by wet process, which requires sulphuric acid | $$$ | 4 Mtpa |
| Citric acid ($C_6H_8O_7$) | Weak | Sugar (bacterial) fermentation | $$ | 2 Mtpa |
| Acetic acid ($CH_3COOH$) | Weakest | Bacterial fermentation or chemically via a catalysed reaction between methanol and carbon monoxide | $ | 25 Mtpa |

DATA: CRU, Public information

# 5. Global market for Sulphuric Acid

## 5.1. Historical and forecasted supply and demand

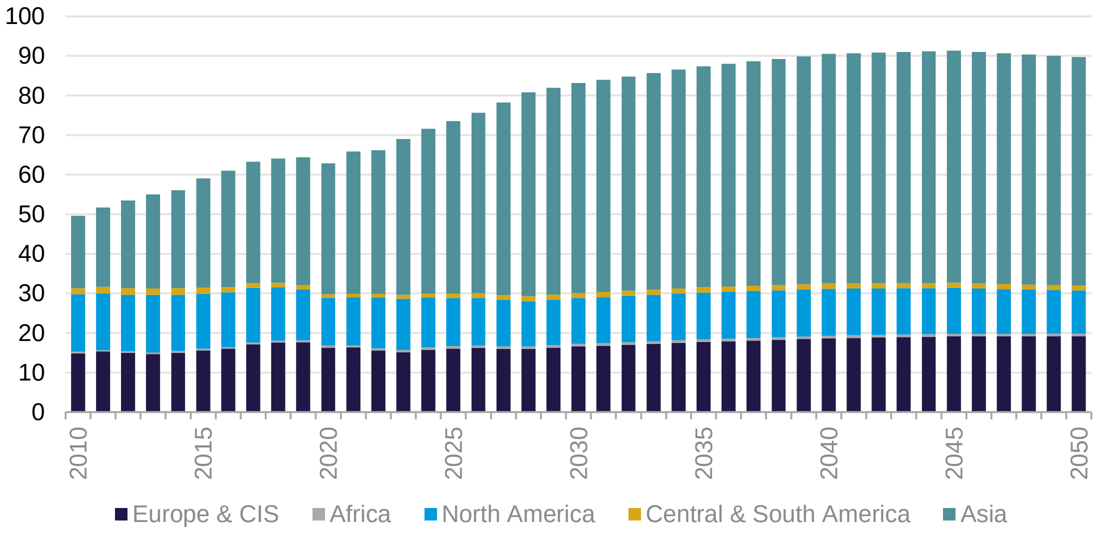
### 5.1.1. Sulphur

Sulphur prill **is the source of approximately 60% of global sulphuric acid** production, and therefore the sulphur market is one of the key drivers of the sulphuric acid market.

**Sulphur supply by region**

Global supply of **sulphur** has increased from 50 Mt in 2010 to 66 Mt in 2022 at a CAGR of 2.4%. The increase in sulphur production since 2010 has primarily been driven by growth in Asia. The Middle East has played a key role in this supply increase, witnessing 105% growth from 9 Mt in 2010 to 19 Mt in 2022, and is forecasted to reach 27 Mt by 2027. Smaller increases are seen in East Asia, particularly Chinese which grew from 3.2 Mt in 2010 to 9.42 Mt in 2022. In contrast, Europe and CIS have witnessed a more sluggish growth rate of 3.6% from 2010 to 2022. The Americas have experienced dampened production, with supply levels in Canada in 2027 forecasted to be 50% less than production in 2000 due to the closure of some oil and gas plants.

*Figure 14: Forecasted supply of Sulphur by region – base case, 2010-2050 (Mt)*



DATA: CRU

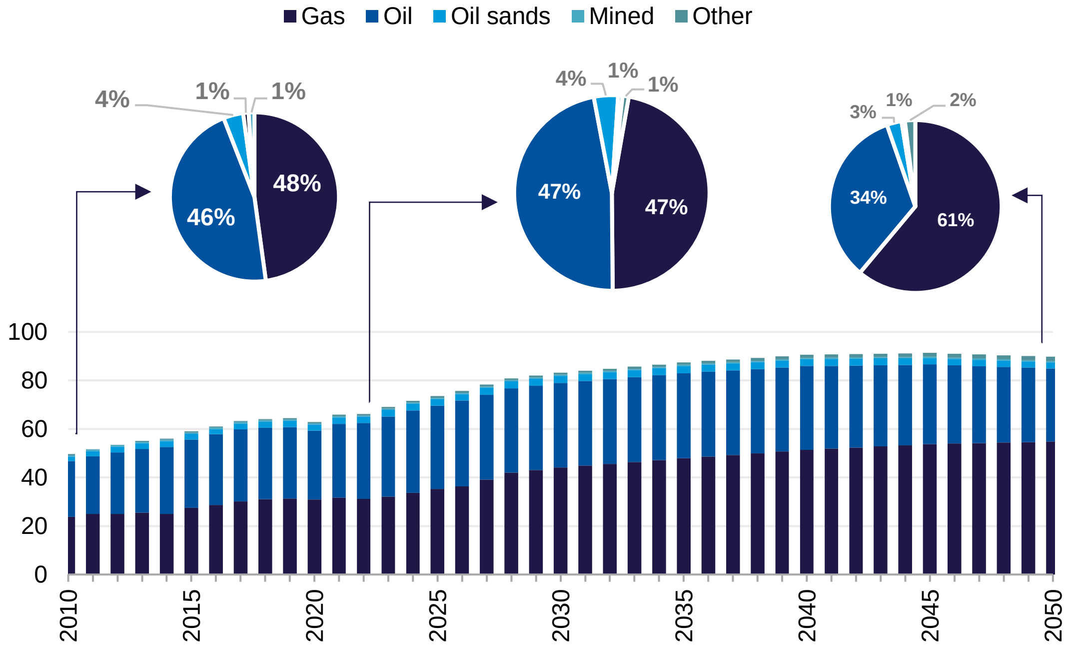
Despite a short-lived global supply drop in 2020 to 63 Mt, supply growth is expected to increase due to the commisioning of new projects, with 2023 supply levels expected to increase up to 68 Mt. Although there has been a production surge in 2023, the high significant growth rate is expected to be short-lived. Additional production growth is expected in the Middle East due to newly commissioned projects ramping up soon which will accentuate the short term impact where supply growth is forecast to increase in 9 Mt between 2023 and 2028. Within the Middle East, the supply increase is mainly by Kuwait and UAE, which have easy access to international markets allowing for their production to reach consumers much faster than competitor producers. UAE alongside with China account for 52% of total supply in 2028, which primarily focuses on large projects.

**Sulphur supply by production process**

The bulk of global sulphur supply is recovered from the refining of raw hydrocarbon resources such as natural gas and crude oil. Gas reserves are often rich in hydrogen sulphide ($H_2S$) and other sulphur species which need to be removed for environmental compliance and to prevent equipment fouling. Up to 98% of the sulphur is captured using a multi-stage catalytic process, starting with acid gas removal (AGR) to produce a sulphur-rich gas stream, which is burned in a Claus furnace to produce sulphur dioxide gas. This gas is then cooled to precipitate elemental sulphur across a series of reactor beds.

Global production of sulphur was 66 Mtpa in 2022 and is expected to reach a peak of 91 Mtpa by 2045, before declining in line with decarbonisation-driven reduction in hydrocarbon production, particularly in North America and Europe. A significant share of sulphur production is primarily sourced via natural gas (gas-based) and crude oil (oil-based) with these sources consistently making up to approximately 95% of total sulphur production. The remaining sulphur production is sourced via oil sands-based processes and sulphur mining. Over the next few years, growth in existing and new Middle Eastern facilities will be a key factor driving global sulphur production.

*Figure 15: Long-term Sulphur production by source – base case, 2010-2050 (Mtpa)*



DATA: CRU

## Sulphur supply outlook

*Table 2: Medium-term supply outlook by region*

| Region | Key medium-term findings |
|---|---|
| **Middle East** | In the Middle East, supply is expected to grow from 17 Mt in 2023 to 29 Mt in 2028, with 3.5 Mt of increased production coming from capacity additions in the UAE from the Shah Gas field. Saudi Arabia, Kuwait and Iran will also experience increased production through existing project ramp ups. Collectively, sulphur production in the Middle East is expected to dominate global sulphur supply by doubling their share of world production from 18% in 2010 to 35% in 2028. |
| **Asia** | The share of world supply from Asia is set to increase from 37% in 2010 to 63% by 2028. This is primarily driven by sulphur production in China followed by India, with Chinese sulphur production forecast to increase by 43% from 9 Mt in 2022 to 13 Mt in 2028. A mixture of oil and gas-based sulphur production will contribute to the increased sulphur supply in Asia. |
| **North America** | North American sulphur supply is forecast to decrease by 15% in world sulphur share from 2010 to 2028. US oil-based sulphur production is expected to fall from 7.9 Mtpa in 2023 to 6.9 Mtpa by 2028, and its gas-based sulphur is expected to decrease marginally from 2.5 Mtpa to 2.1 Mtpa over the same period. Canadian gas-based sulphur production is expected to fall from 1.8 Mtpa in 2023 to 1.6 Mtpa in 2028, with its oil-sands sulphur production remaining at 2.6 Mtpa over the same period. |
| **Europe** | Sulphur supply in Europe has been impacted by the geopolitical constrains from the war in Ukraine. Among other restrictions, European sanctions against Russian imports were imposed in late 2022 and early 2023 for refined petroleum products. This, alongside with decarbonisation efforts, will reflect no significant increases in sulphur production. Between 2010 and 2022, there has been a 66% decline in gas-based sulphur production in Western Europe. This was primarily driven by Germany's loss in production capability after previously being highly reliant on Russian gas to meet their energy needs. |

The implications of decarbonisation are tied to production intensity and the composition of future sulphur production. Global focus on cutting carbon dioxide emissions will impact fossil fuel production and as such, impact the supply of sulphur from these sources. The composition of sulphur production in 2022 reflected an even split at 48% for both production sourced from gas-based sources and oil. However, in the longer term, supply produced from gas will eventually overtake oil, with gas-based sulphur supply projected to comprise 61% of total sulphur production in 2050.

As high sulphur content gas projects are brought to market, the production intensity of sulphur is also forecast to grow. Notably, trends in recent years reflect the development of sweet, shale gas plays but the future trajectory of gas is unlikely to rely on sweeter gas as shale gas extraction is not feasible in all regions.

## Sulphur demand by region

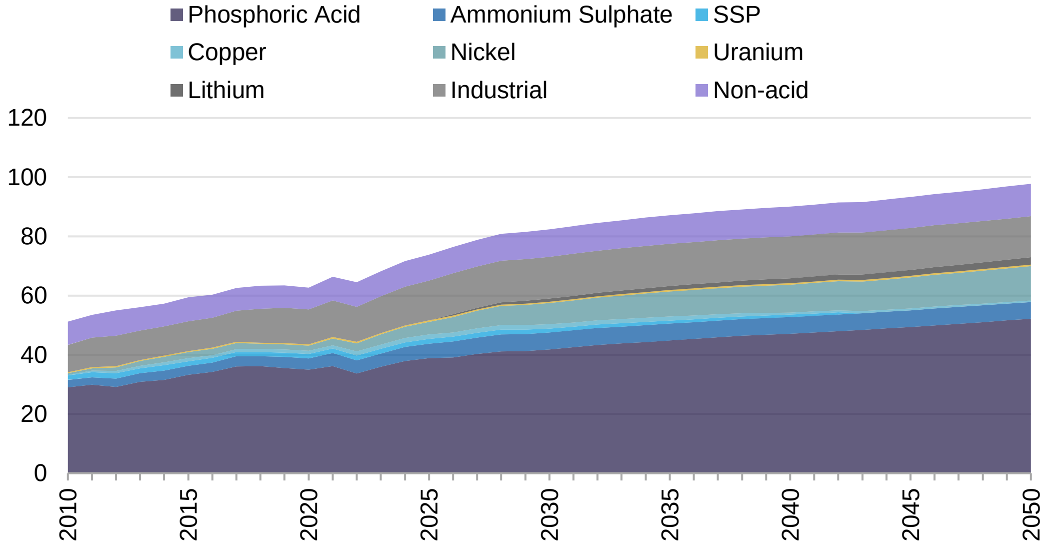
Global sulphur demand has grown from 51 Mt in 2010 to 65 Mt in 2022. Asia has accounted for the largest increase in demand amongst other regions with East Asia being the primary driver. From 4.6 Mt demanded in 2000, East Asia's demand for sulphur has more than quadrupled, reaching 18.5 Mt in 2022. This can mainly be attributed to demand derived from mainland China which itself accounts for approximately 57% of total sulphur demand from Asia. There has been large substitution from pyrites to sulphur alongside growing industrial demand. Other regions in Asia also experienced increases but not to the same magnitude whereby Middle Eastern demand increased by 3.6 Mt and South Asian demand increased by 0.9 Mt from 2010 to 2022. Outside of Asia, Africa also witnessed an increase from 7.3 Mt in 2010 to 10.3 Mt in 2022 with approximately 75% of the change in demand deriving from the demand growth in Morocco. Europe and CIS collectively have experienced minimal growth in demand as an increase of 1.9 Mt from the CIS between 2010 to 2022 was offset by a decrease in European demand worth 1.0 Mt during the same time.

### Sulphur demand by end use

Demand projections for sulphur by each key use have been linked to relevant forecast indices or macroeconomic indicators, including projections for food demand, economic growth, and future metals production.

Historically, when considering the demand for sulphur by use, mineral fertilisers have carried the dominant share of both sulphur and sulphuric acid consumption. Fertilisers produced from phosphoric acid alongside ammonium sulphate and SSP have consistently accounted for almost 60% of global sulphur demand throughout 2010 to 2022. Approximately 85% of total fertiliser-based sulphur demand is attributed towards phosphoric acid production, leaving the sulphur market heavily dependent on the cyclical global phosphate market. However, despite the overall share of phosphoric acid in global sulphur demand decreasing from 57% in 2010 to 52% in 2022, the overall demand growth is still driven by phosphoric acid.

*Figure 16: Global Sulphur demand by use, 2010-2050 (Mtpa)*



DATA: CRU

Sulphur demand recovery expectations are also supported by forecasts for fertiliser demand indicating more stability from 2025 onwards. The existing trend will continue as phosphoric acid-based fertilisers dominates total demand, followed by, metals and industrial uses which support total consumption but are not key drivers of change. Notably, nickel and lithium-based demand are forecast to increase their contribution to total consumption by 2027 with 1 Mtpa of demand increase versus total consumption growth of 2 Mtpa. Globally, demand recovery in immediate years is heavily dependent on phosphate driven growth but this will slowly shift towards lithium-based demand in the battery market from around 2025 onwards in many regions including but not limited to China, USA, and Brazil. Nickel based sulphur consumption is also projected to increase due to the commissioning of several projects in Indonesia.

### Sulphur demand outlook

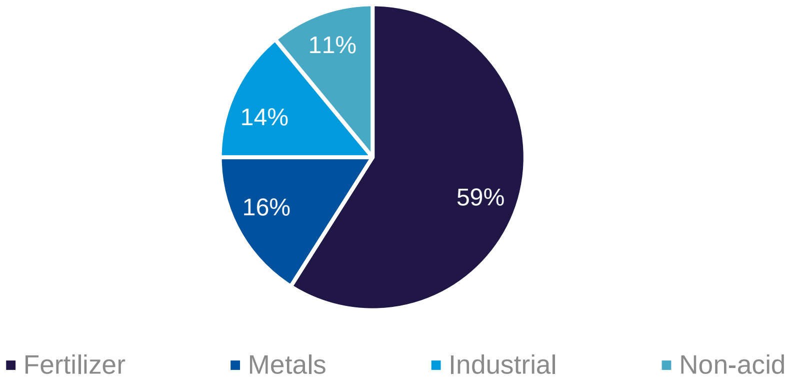
*Table 3: Medium-term Sulphur outlook by region*

| Region | Key medium-term findings |
|---|---|
| **Morocco** | Moroccan sulphur imports are expected to continue to increase with projections of a 46% increase in sulphur imports from 2023 to 2028. This demand growth is primarily caused by increased phosphate affordability pushing increased phosphate export sales. After reducing import requirements, Morocco will increase its sulphur imports in 2024 which will be the first year of significant positive demand growth since 2020. |
| **China** | In China, the easing of phosphate export restrictions in 2023 and the resurgence of the fertiliser sector drove sulphur demand. Improved efficiency in fertiliser application and strict Government restrictions on over-application of phosphate fertilisers is expected to shift sulphur consumption away from phosphate production and towards battery materials by 2027. Although Chinese sulphur import demand is set to decline, increased domestic sulphur production will outpace demand recovery in coming years. Consumption growth is then set to be split between a rebound in the phosphate sector and growth of industrial end-use, particularly in the battery and chemicals industry. |
| **Indonesia** | Indonesian sulphur consumption has notably increased to 1.73 Mtpa in 2022 and is projected to rise even further to 4.86 Mtpa by 2027 due to the rapid rise in nickel HPAL projects. 47% of the change in global nickel-based sulphur demand can be accounted for by Indonesian consumption where it is forecast to increase by 2.8 Mtpa from 2022 to 2027. This is due to the addition of nickel production capacity through nickel-based project growth focused on established sites. |
| **USA** | Sulphur demand is set to slightly increase as previously idled burner capacity is expected to restart operating. From here, the largest portion of US sulphur consumption is from phosphate sector end usage, with industrial uses also supporting total US consumption. From 2025 onwards, lithium-based sulphur is set to rise with the start of Lithium Americas and Ioneer projects that both include plans for sulphur burners. |
| **Brazil** | Brazil's demand growth is primarily centralised around growth in the phosphate sector with phosphoric acid-based sulphur demand expected to increase by 0.4 Mt between 2023 and 2028. Brazilian sulphur imports are also forecast to increase from 1.93 Mtpa in 2022 to 3.08 Mtpa in 2027 due to the commissioning of new projects such as Serra do Salitre alongside existing consumption capacity. Total sulphur demand is set to climb to 3.35 Mtpa in 2027, up from 2.32 Mtpa in 2022. |

In terms of regional growth, USA and Morocco have been identified as the largest contributors to import growth in 2023. After a drop in imports in 2022, the figure in 2023 reaches a historic level with forecasts suggesting total import growth will amount to 3 Mt. The surge in imports is expected to settle by 2027. In line with their growing self-sufficiency in this area, China is expected to decline imports levels from 2024 onwards. Total sulphur consumption in China is only set to increase by 1.7 Mt from 2023 to 2028. However, growth in consumption in India, Indonesia, Brazil, and Morocco will offset losses from lower volumes of Chinese imports.

The long-term demand outlook for sulphur is heavily dependent on factors driving the demand for sulphuric acid consumption. A more detailed discussion can be found in Section 5.1.2.

*Figure 17: Long term demand for Sulphur, 2000-2050 (Mt)*



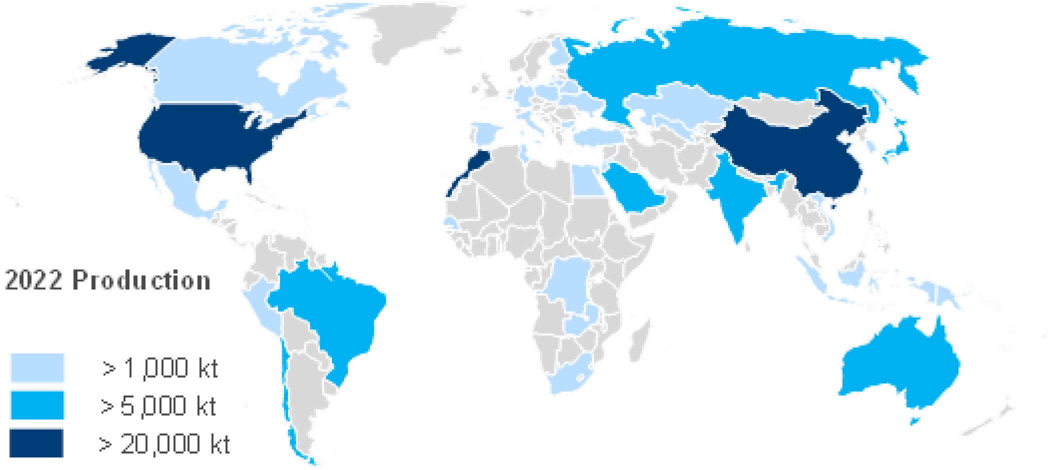
DATA: CRU

### 5.1.2. Sulphuric acid

**Sulphuric Acid supply by region**

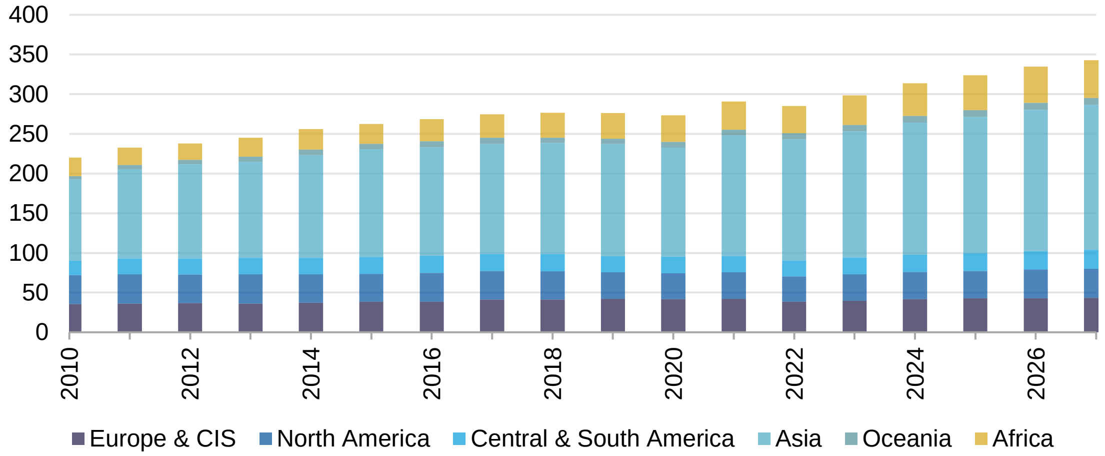
The global supply of sulphuric acid has grown at a CAGR of 2.2%, from 220 Mt in 2010 to 285 Mt in 2022. As illustrated in *Figure 19*, this growth is primarily driven by expansions in sulphuric acid production in Asia. Approximately 90% of sulphuric acid supply from Asia in 2022 is contributed by China, which itself has experienced a 49% increase in production from 2010 to 2022. Another key player in the market is Morocco, where supply has increased from 11.8 Mt in 2010 to 18.3 Mt in 2022, leading supply growth trends in Africa. Conversely, North America experienced a decrease in production, where USA supply in 2022 is down to 28.3 Mt in from 32.6 Mt in 2010.

*Figure 18: Total world Sulphuric Acid supply overview in 2022*



DATA: CRU

*Figure 19: Global Sulphuric Acid supply by region, 2010-2027 (Mt)*



DATA: CRU

### Sulphuric Acid supply by process

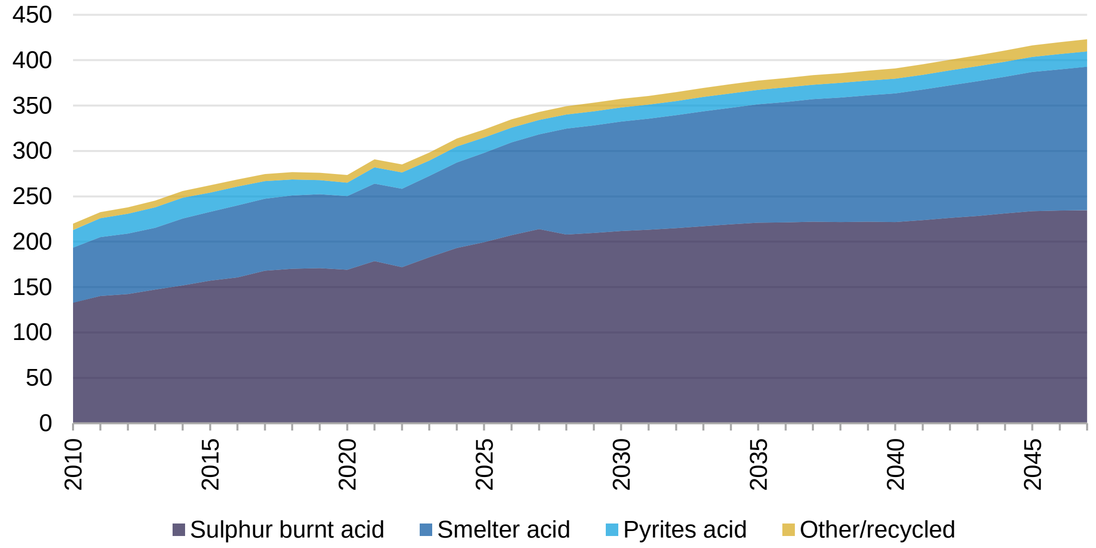
In 2022, 90% of global sulphuric acid production was reliant on by-products from other sectors, principally the oil/gas (for 99% of sulphur prill) and metals refining sectors (for metallurgical waste gas). This places the sulphuric acid market in a difficult position, as demand increases for acid are unlikely to be the main driver for capacity expansions in petroleum or metals smelting.

Historically, sulphur-burning has been the primary source of sulphuric acid supply (60% share in 2022), and this trend will continue in the foreseeable future, with production from sulphur-burning forecast to increase from 172 Mt in 2022 to 222 Mt by 2040. Sulphur-burnt acid production will continue to increase, especially in regions such as Indonesia, Morocco, and Brazil. In China alone, demand recovery in both phosphate and battery markets will drive sulphur-burnt acid supply up by 2.5 Mt in 2023.

Smelter acid production (30% share in 2022) is forecast to increase from 86.3 Mt in 2022 to 141.4 Mt by 2040, with regions such as China and India accommodating much of the production increases due to large smelter capacity extensions. The expected growth in the battery metals market will be crucial in determining future trends in the composition of sources of sulphuric acid. Increases in smelter acid production have also been essential to recent supply growth.

The remaining 10% of global sulphuric acid production in 2022 was from pyrite roasting (6% at 17.8 Mt), recycling (2%) and other processes (2%). CRU expects that pyrite roasting will contract to around 16.3 Mt by 2040 due to poor environmental performance. The environmental remediation cost of mining pyrites is high due to the toxic waste generated (often containing arsenic) and the susceptibility of pyrite oxidation, leading to difficulties in controlling acid mine drainage and avoiding groundwater contamination.

*Figure 20: Total world Sulphuric Acid supply by source, 2010-2047 (Mtpa)*



DATA: CRU

### Sulphuric Acid supply outlook

The limited availability of storage capacity and the difficulty in building large stockpiles supports sulphuric acid supply and demand to remain essentially balanced over the medium and longer term. After previous supply declines in 2022, smelters are set to drive supply growth in Asia and Europe from 2023. Particularly, growth in smelter capacity in China, India and Indonesia is expected to add 10 Mt from 2023 figures by 2028. Supply increases are also expected in Africa given demand driven additions of extra sulphur-burning capacity in Morocco and DR Congo. Indonesia is regarded as a key player in the medium-term outlook especially with the ramp up of supply tied with several newly commissioned nickel leaching operations that include both sulphur burnt and pyrites acid. In all, world supply is expected to expand by approximately 21% between 2022 to 2027, reaching 343 Mt by 2027. The growth in the battery metals industry could also offer an opportunity to absorb surpluses as sulphur availability tightens and prices start to increase. Smelter capacity expansions are also likely to be more disruptive to the global trade balance as additions from Asia (excluding China) will be primarily export orientated.

After previously experiencing a slump in supply, Morocco is expected to have the second highest contribution to sulphuric acid supply following Indonesia with forecasts suggesting an addition of 10.4 Mt of acid production between 2022 to 2027.

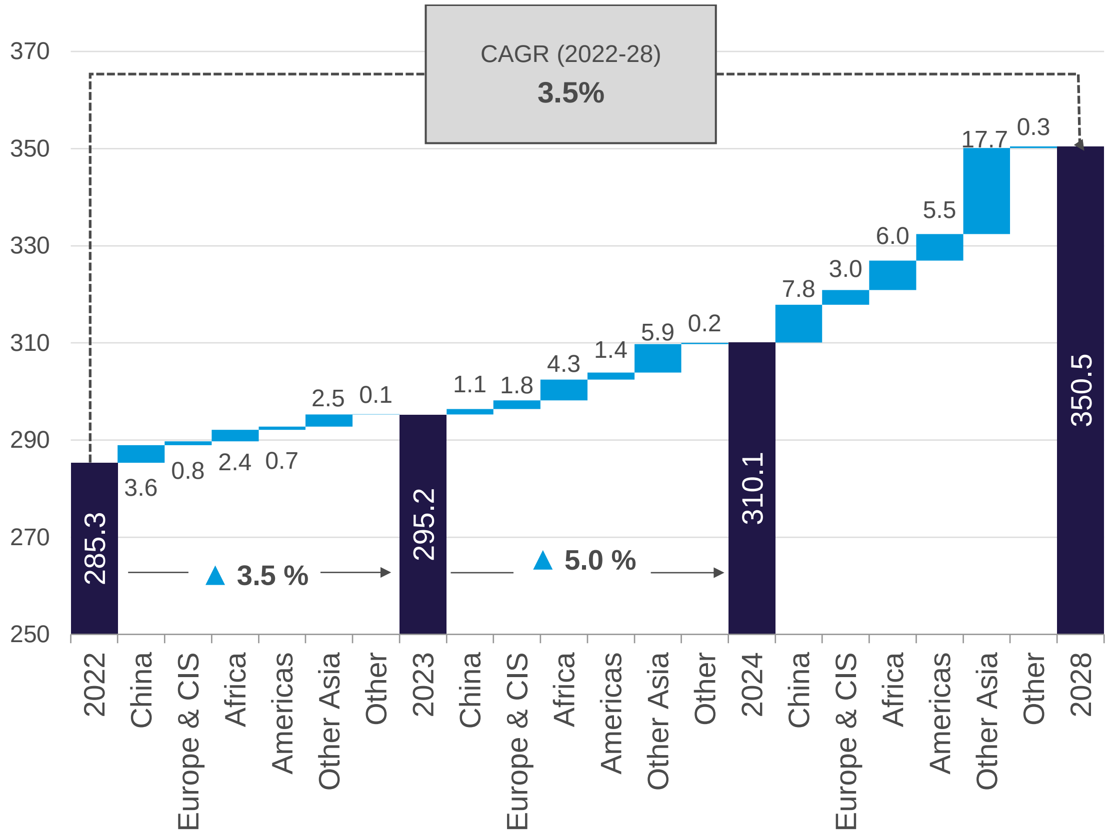
*Table 4: Medium-term outlook for Sulphuric Acid by region*

| Region | Key medium-term findings |
|---|---|
| **Morocco** | After previously experiencing a slump in supply, Morocco is expected to have the second highest contribution to the increase in world supply following Indonesia wherein supply is forecasted to increase from 18.4 Mt in 2022 to 28.7 Mt in 2027. This has largely been driven by growth in phosphate demand alongside capacity extensions. The OCP Group is expected to contribute another 2.6 Mt of sulphur-burning capacity in 2024 and their operations will continue to increase total sulphuric acid supply by 2027. Importantly, the growth in supply is forecast to drive down imports of sulphuric acid to approximately 0.7-0.8 Mt in 2023 from 2.08 Mt in 2022. Import trends until 2027 are expected to stay lower than historic levels as a result. |
| **China** | China's supply of sulphuric acid is expected to increase from 104.9 Mt in 2022 to 114.5 Mt in 2027 which is primarily driven by expansions at existing smelters. In 2023, new smelter capacity was added, with the largest addition of 0.95 Mt of sulphuric acid supply at Daye in Hubei. Expansions at Baiyin, Guangxi and new capacity from Jinchaun Copper and Nanguo Copper will contribute to this surge in smelter acid production. Notably, demand recovery witnessed in their phosphate and battery metals market will also push an additional 4 Mt worth of sulphur burnt by 2027. |
| **Indonesia** | Indonesia has emerged as a key player in the sulphuric acid market because of massive growth in their nickel industry. Supply is expected to increase from 4.6 Mt in 2022 to 17.1 Mt in 2027. Indonesia's increase in supply in this period will make the highest contribution to the increase of total world supply. This is mainly driven by an 8.9 Mt increase in sulphur- |

| Region | Key medium-term findings |
|---|---|
| | burnt acid and a 1.1 Mt increase in pyrites production from 2022 to 2027. The vast expansion in Indonesia's nickel industry and forecasts of high cathode output has been the underpinning factor of their demand driven increase in sulphuric acid supply. Amongst the several nickel projects that are to be commissioned over upcoming years, the Merdeka/Tsingshan AIM project was commissioned in 2023 Q4 with a capacity of 1.2 Mt of pyrite-based acid supply. New smelting capacity is also due to be commissioned in 2024 at Freeport Indonesia Gresik with acid supply totalling 1.7 Mt at full capacity. |
| **India** | Similar to other regions in Asia, Indian supply growth is tied to increases in smelter capacity with total sulphuric acid supply set to increase from 11.5 Mt in 2022 to 15.8 Mt in 2027. New smelting capacity will be seen at Hindustan Zinc at Doswada and at Adani Mundra. Although not as large, sulphur-burnt production in India is also expected to increase by a total of 2.6 Mt from 2022 to 2027. This is derived from a combination of increases from existing burner capacity and new sulphur burners from PPC, IFFCO and CIL from 2024 onwards. Indian production capacity growth only keeps pace with demand expansion. Import volumes are expected to be maintained above 1.4 Mtpa as new smelter capacity is expected to export additional volumes. |
| **USA** | After a slump in sulphuric acid supply from 2020-22, sulphuric acid supply is forecast to increase by 5.1 Mt by 2027. The supply recovery is primarily driven by increased utilisation of existing assets. The purchase and intended rehabilitation of the Augusta sulphur burner in Georgia is expected to increase merchant acid production capacity by 0.45 Mt per year from 2024. Although the project by Ioneer at Rhyolite Ridge is yet to start, it is expected to make a significant contribution to supply expectations by 2027. |
| **Brazil** | Total South American sulphuric acid supply is projected to increase by 3.6 Mt from 2022 to 2027 which is almost entirely driven by increases in Brazilian production totalling 2.9 Mt. New sulphur burning capacity is expected to commission in 2023 H2 with capacity of 0.45 Mtpa sulphuric acid with 0.05 Mtpa oleum. In contrast, Chile has experienced a contraction in their total acid production after the closure of the Ventanas smelter scheduled at the end of 2023. The loss of the Ventanas smelter in Chile partially offsets the upwards revision. Ventanas produced 0.34 Mt of the 2.75 Mt of sulphuric acid produced by Codelco in 2021. |

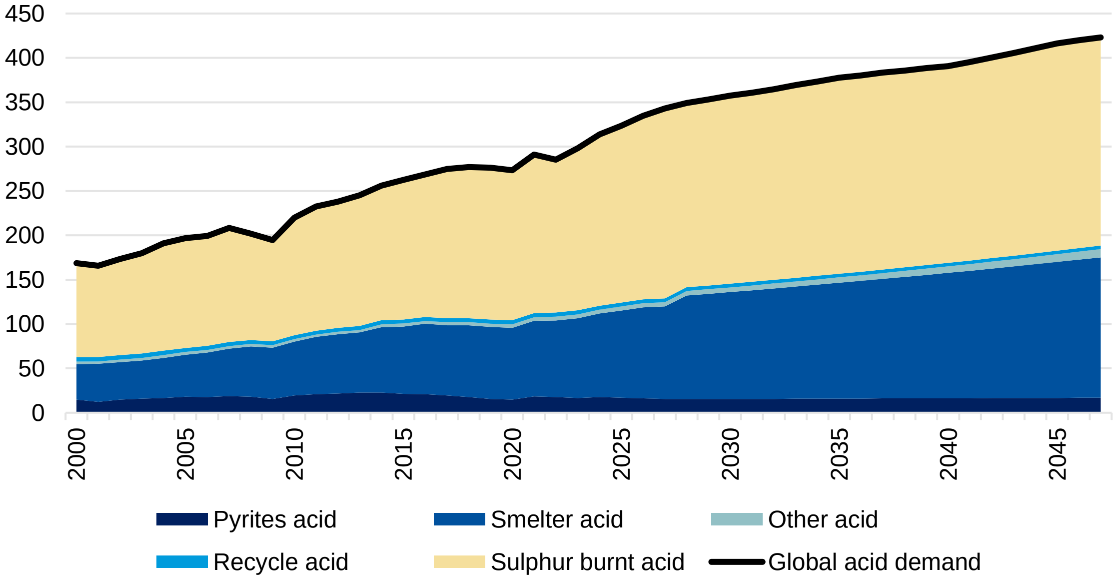
The main raw materials used to produce sulphuric acid are sulphur, base metals smelter off-gases or pyrites. Supply forecasts for smelter-based sulphuric acid are built from long-term metal production forecasts from primary smelters. In line with the growing pressure for environmental efficiency in the capture of sulphurous off-gases, the ratio of acid produced per tonne of metal is expected to increase in the long run. **Due to closure of aged plants in China, pyrites-based acid supply is forecast to decline at a CAGR (2026-2046) of -2.9%.**

*Figure 21: Y/Y Sulphuric Acid supply growth by region, 2022-2028 (Mtpa)*



DATA: CRU

*Figure 22: Long term Sulphuric Acid supply filled by sulphur-burnt acid production*



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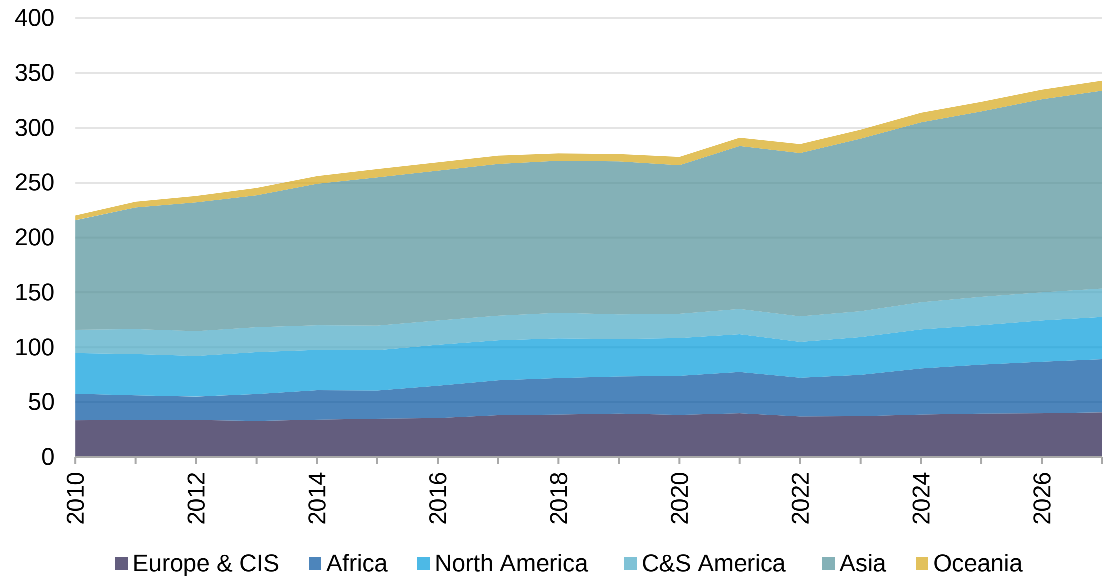
As expected, growing global demand for any commodity requires some combination of expansions at existing production centres and the startup of new production to satisfy demand. When considering the required rate of investment to reach market balance, the closure of existing facilities due to either resource depletion, technological obsolescence or environmental inefficiency will be instrumental. The supply gap analysis suggests that even the forecasted planned capacity will not be able to provide for the market in the long term.

### Sulphuric Acid demand by region

Over the past decade, Asia has driven demand for sulphuric acid and this trend is only set to continue. The total world sulphuric acid consumption has increased at a CAGR (2010-2022) of 2.2% increasing from 220 Mt in 2010 to reach 285 Mt by 2022. East Asia has historically dominated sulphuric acid consumption with China's share of global acid consumption being 36% in 2022. After a series of fertiliser market supply controls coupled with general downturn in macroeconomic conditions, sulphuric acid demand contracted globally in 2022. Demand recovery has primarily been led by regions such as the United States, Morocco, Russia, the Middle East, and Asia. Alongside China's growth in consumption, Indonesia will continue to become a key player in total acid consumption in upcoming years.

*Figure 23: Global Sulphuric Acid demand by region, 2010-2027 (Mtpa)*



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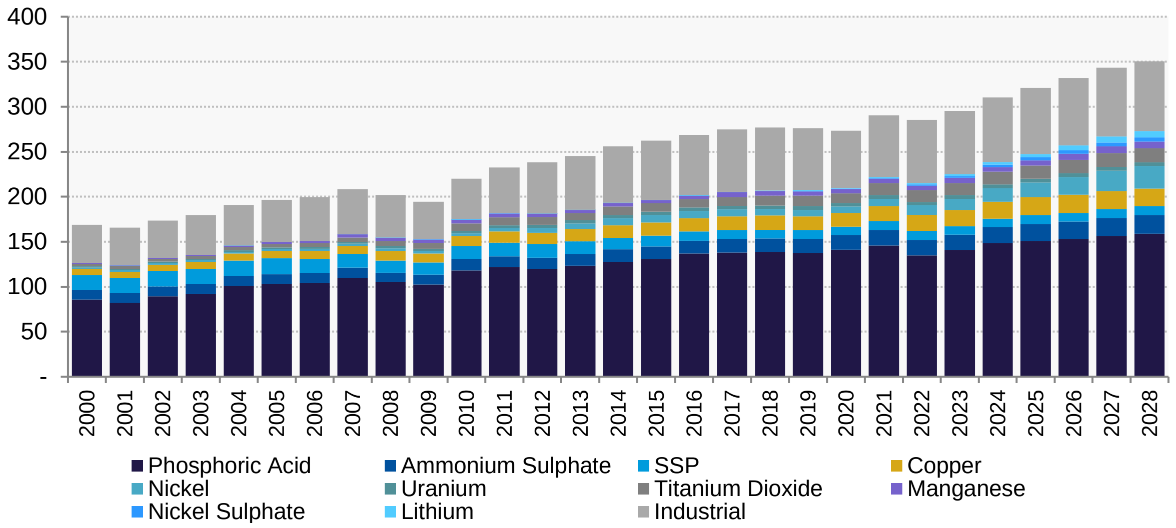
### Sulphuric Acid demand by process

The key nutrient classes that consume sulphuric acid are phosphate and nitrogen. Sulphuric acid consumed during the production of wet process phosphoric acid along with SSP accounts for the phosphate sector-based demand for acid. Ammonium sulphate demand is forecast as a component of the total nitrogen demand in the long term. Historically, fertiliser driven demand has dominated total acid consumption with phosphoric acid driven demand increasing by 16 Mt from 2010 to 2022. Acid consumption for industrial purposes has also been significant and will continue this trend with forecasts expecting industrial-based acid demand to reach 76 Mt by 2027, up from 45 Mt in 2010. Sulphuric acid demand is also derived from the metals sector primarily for metal leaching purposes with copper and titanium dioxide historically being the main contributors. The composition of acid consumption for metals has increased from approximately 10% in 2010 to 17% of 2022 global sulphuric acid demand.

*Figure 24: Global Sulphuric Acid demand by process, 2000-2028 (Mtpa)*



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### Sulphuric Acid demand outlook

Total global demand for sulphuric acid is forecast to increase at CAGR of 3.5% (2023-2028) from 295 Mt in 2023 to reach approximately 350 Mtpa by 2028. Key drivers of global demand growth to 2028 will be fertiliser recovery and metals-based growth. After the decline in 2022 demand driven by the fertiliser market supply controls, the rebound in 2023 is centralised on the reversal of phosphate export controls but also broader economic recovery in China. From now to 2028, although demand growth is primarily dominated by phosphate capacity in Morocco, Brazil and India, there is a significant incoming push from the demand for metals processing. In terms of composition, phosphate-based demand accounts for 40% of total demand growth to 2027 whilst nickel-based demand accounts for 20% of the total demand increase.

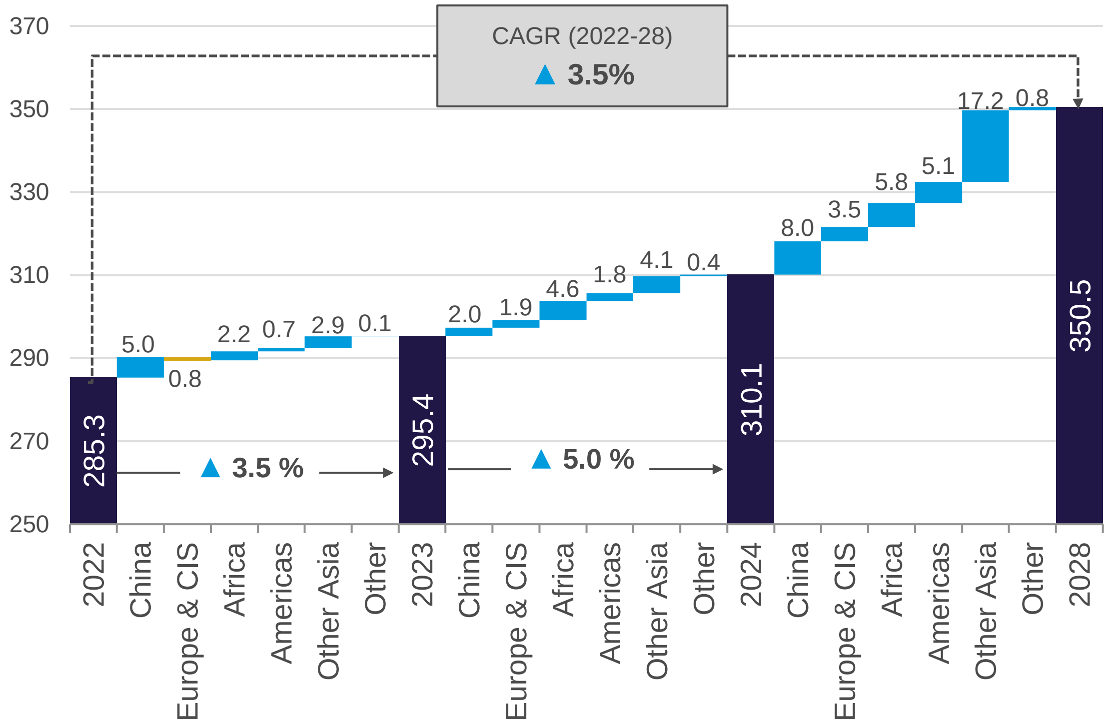
*China:* In 2022, China faced their first drop in sulphuric acid demand since 2016, with a 1.6 Mt reduction in acid consumption. However, their acid demand rebound in 2023 is divided between recovery in phosphate exports and an expansion in battery metals processing. Fertiliser-based demand from both phosphoric acid and ammonium is estimated to increase from 50.7 Mt in 2022 to 54.4 Mt in 2027. Similarly, there is an expected increase in metals-based demand, specifically for titanium, manganese, nickel sulphate and lithium, with lithium-based acid consumption projected to have the highest increase from 1.4 Mt in 2022 to 3.9 Mt in 2027. With domestic demand set to increase over the coming years, net exports are also expected to decline further. From 2022 to 2023, battery demand for vehicles increased by over 40% and trends in this market will continue to dictate the trajectory of sulphuric acid demand.

*Indonesia:* Indonesia has been a unique case regarding their sulphuric acid demand with acid consumption forecast to increase more than 3-fold from 2022 to 2027. High pressure acid leaching (HPAL) nickel projects will revolutionise the Indonesian market for sulphuric acid. HPAL generators mostly plan to install sulphur burning capacity to supply acid and hence sulphur burners will supply most of this new consumption. Nickel-based acid demand is expected to rise from 0.89 Mt in 2021 to 13.0 Mt in 2027. Although historically, fertilisers made up the majority of the demand in Indonesia, the share of nickel demand will dominate by reaching 77.3% of total acid consumption in 2027. The growth in consumption demand, expected to rise by 1.8 Mtpa, is split between nickel leaching, manganese processing and the startup of nickel sulphate production. Significant demand exists within industrial applications, however, the majority of this is domestically supplied sulphur burnt sulphuric acid. Hence, because of capacity additions, sulphur-burnt acid production within Indonesia is also expected to increase to 12.8 Mt by 2027, up from 3.9 Mt in 2022.

*USA:* Total acid consumption in the US is expected to increase by 4.6 Mt from 30.9 Mt in 2022, reaching a total of 35.5 Mt by 2028. Phosphoric acid consumption has historically remained pertinent to sulphuric demand incoming from the US. However, after a 1.9 Mt drop in 2022, phosphoric acid-based demand for sulphuric acid is set to remain relatively consistent at approximately 21 Mt over the next few years. The increased consumption here is tied to higher utilisation at phosphate operations. This is coupled with lithium-based demand expected to contribute to total acid consumption from 2025 onwards with expectations of total lithium-based sulphuric acid demand set to reach 1.9 Mt by 2027. Lithium demand will be a factor to consider however revised lower from 2025 due to slower project commissioning timeline.

*Morocco:* Moroccan acid consumption is forecast to increase by 10.1 Mt from 2022 to 2027 and is almost entirely driven by phosphoric acid-based demand for sulphuric acid. However, capacity extensions will outpace both demand changes and import levels from 2024. Decreased total utilisation rate at phosphate operations and lower opportunistic acid purchases triggered weaker acid demand in 2022. From 2023 onwards, import decline will continue as acid imports will be displaced by increased utilisation of local sulphur-burnt acid supply.

*Figure 25: Y/Y Sulphuric Acid demand growth by region, 2022-2028 (Mtpa)*



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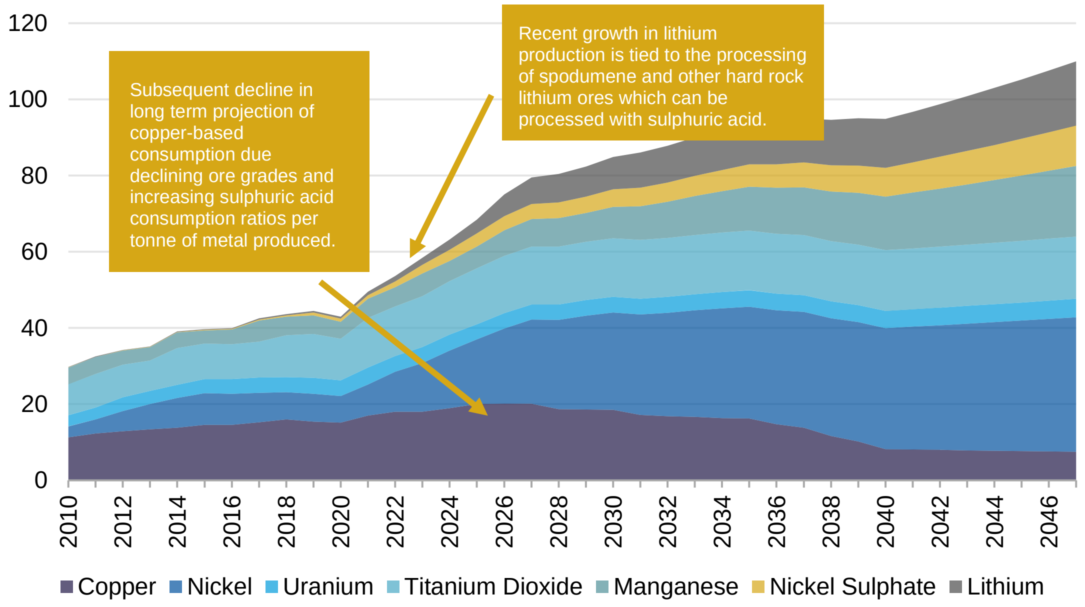
*__Metal-Leaching based demand__*

Sulphuric acid demand within the metals sector has grown significantly since 2001, with the copper and nickel industry initially driving this growth. However, the growing push for decarbonisation has resulted in increasing investments in electrification and renewable energy resulting in forecasts for other battery metals surpassing acid demand derived from copper. The trend for future sulphuric acid consumption is heavily dependent on the increasing demand for Electric Vehicles (EVs) which further drives the need for batteries and related critical minerals. Moreover, the rise in poorer ore quality being leached will likely boost acid consumption per unit of ore over the long term.

Unlike copper-based acid demand, nickel-based acid consumption is set to grow and reach 24.6 Mt by 2046. Nickel leaching is expected to increase due to the lack of large high grade nickel sulphide deposits and the relative abundance of laterite reserves. This further increases the demand for acid consumption, considering that many nickel laterite projects use large quantities of sulphuric acid for acid leaching via hydrometallurgical processes.

Acid consumption derived from the battery metal demand will continue to increase from now until 2046 with the industry mainly dominated by NMC (nickel, manganese, cobalt) and LFP (lithium, iron, phosphate) batteries (*Figure 26*). Although historically lithium production was centred around lithium brines, a process independent of sulphuric acid, recent production involves the processing of spodumene and other hard rock lithium ores which do require sulphuric acid. Similarly, the processing of nickel sulphate is critical in the production of cathode precursors in batteries, and hence, acid demand from this sector is forecasted to grow to 16.8 Mt by 2046 (CAGR, 2027-2047 = 4.5%). In terms of battery metals, manganese driven demand for acid is expected to increase the most reaching a total of 18.5 Mt by 2046. Current growth in Electrolytic Manganese Metal (EMM) is targeting the conversion of manganese ores to EMM and then further to manganese sulphate.

*Figure 26: Long term Sulphuric Acid demand for metal leaching, 2010-2046 (Mtpa)*



Subsequent decline in long term projection of copper-based consumption due declining ore grades and increasing sulphuric acid consumption ratios per tonne of metal produced.

Recent growth in lithium production is tied to the processing of spodumene and other hard rock lithium ores which can be processed with sulphuric acid.

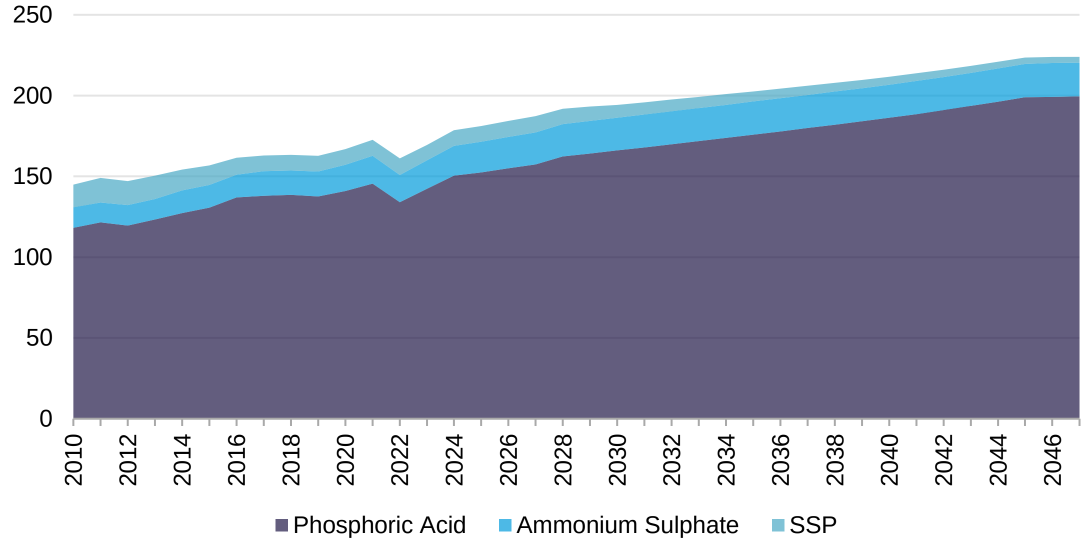
DATA: CRU

*Fertiliser-based demand*

Demand for sulphuric acid in fertiliser production is dependent on the outlook on food consumption and the ability of the agricultural sector in meeting this demand through crop production. In the longer term, the key drivers affecting acid demand for fertilisers will be food consumption, population growth and changes in income, and both labour and agricultural productivity. Climate change, resource availability and technological changes will act as structural components influencing fertiliser demand.

Phosphates will continue to dominate long-term fertiliser-based sulphur demand to 2050 with phosphoric acid-based demand forecast to reach 199.3 Mt by 2046, up from 146.7 Mt in 2022. This growth in acid consumption is the result of both higher phosphate rock (containing phosphorus pentoxide, $P_2O_5$) volumes and declining ore grades causing higher sulphuric acid consumption per tonne of product. Ammonium sulphate-based demand follows next whilst acid demand for SSP is forecast to decline globally. Regardless of the product still being popular in Brazil, India, China and Oceania, acid demand for SSP is set to decline from 10.3 Mt in 2022 to 3.6 Mt by 2046.

*Figure 27: Long-term Sulphuric Acid demand for fertilisers, 2010-2046 (Mtpa)*



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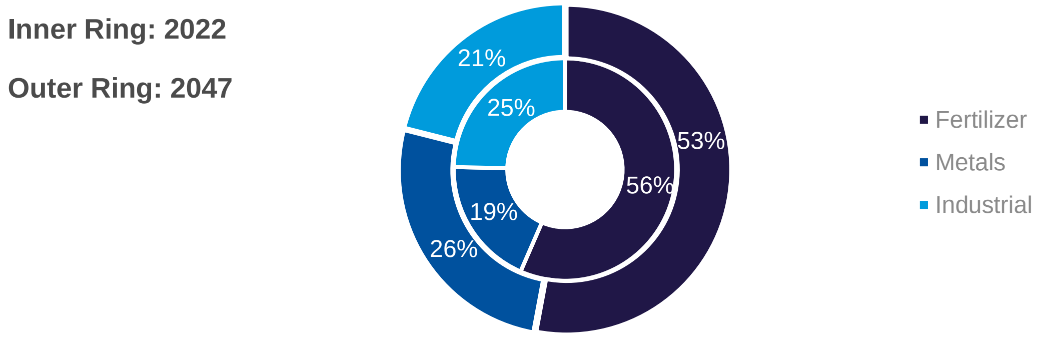
In 2022, sulphuric acid demand was split 56% for fertilisers, 25% for industrial usage and 19% for metals. By 2047, the share of acid demand used within the metals sector will slightly increase with forecasts projecting that metal-based acid demand will increase to 26%. Long term metals consumption growth is most likely going to outpace both fertilisers and industrial applications as increasing metals are required to meet electrification goals.

*Industrial demand*

Industrial demand for sulphuric acid comes from a range of industrial processes, such as in waste and water treatment as well as the manufacture of dyes, glue, textiles, paper and firefighting foam. Industrial use is expected to increase global sulphuric acid demand from 70.3 Mt in 2022 to 84.3 Mt in 2040, at a CAGR of 1% in line with general growth in manufacturing activity.

*Figure 28: Long term share of Sulphuric Acid demand, 2022 vs. 2047 (%)*



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## 5.2. Historical pricing

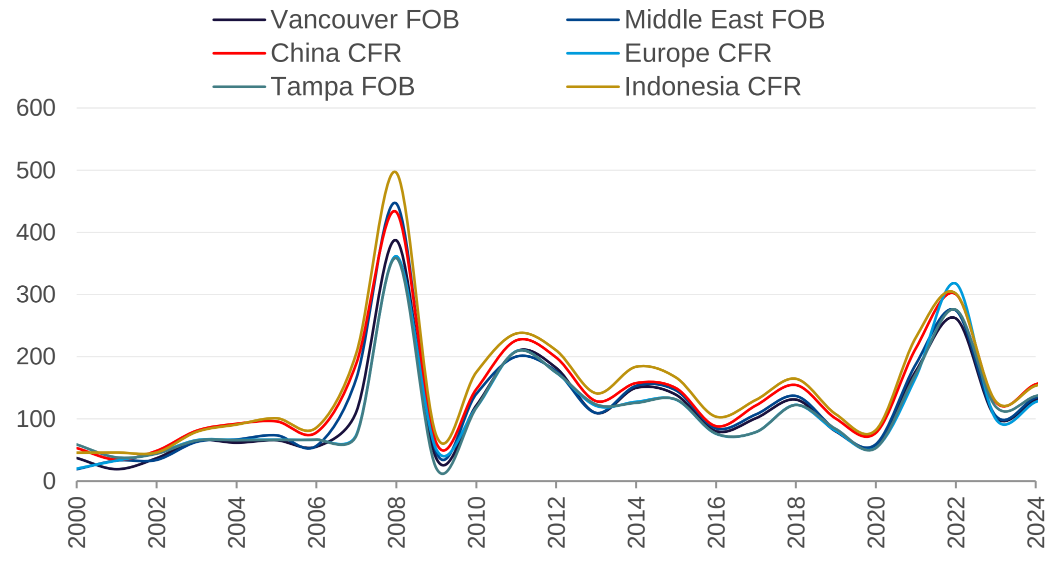
Actual prices fluctuate cyclically and when determining the long-run trend price, CRU utilises a forecast of the industry's long run marginal costs (LRMC). The LRMC accounts for the cost of production at the last plant/operation required to meet demand. Under this methodology, it is assumed that in the long run prices will trend towards the LRMC in a competitive market. It is important to note that the LRMC prices are not reflective of what actual prices will be in a particular year but an indication of the direction of long-term prices. Various demand and supply drivers will push prices to continue to move in cycles, oscillating around the general long-term trend.

Price volatility is an inherent characteristic of commodity markets. Often, supply is slow to respond to changes in demand due to the lead time required for investment in supply. Supply constraints with high capital costs also promotes constant barriers in increasing production levels.

### 5.2.1. Sulphur

The sulphur market has increased the frequency and scale of volatility. The increased fluctuation in sulphur prices is reflective of greater volatility in other fertiliser and commodity markets. Prices have generally been on a downwards trend since 2014 due to increased sulphur supply. Occasional spikes were witnessed in late 2017 and 2018 as a result of changing prices in demand markets. The most recent price surge was a result of higher prices in end-use markers along with tight supply environment which caused an increased premium relative to historical relationships.

*Figure 29: Sulphur price historical, 2000-2023 (US$ /t nominal)*



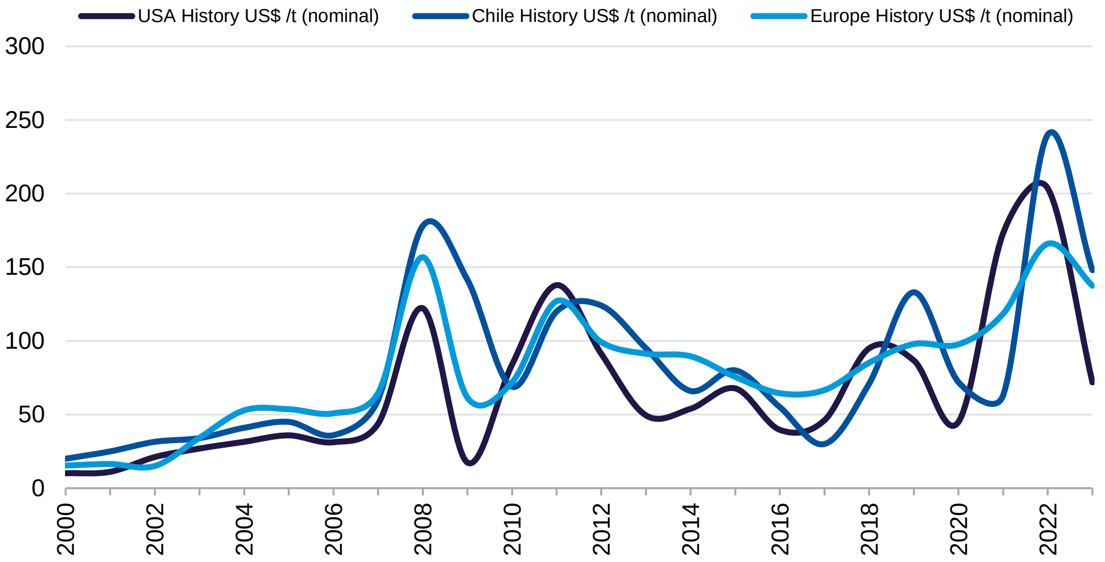
DATA: CRU
NOTE: Price forecasts have been removed from this report

### 5.2.2. Sulphuric Acid

Similar volatility and cyclicality will also be a characteristic of sulphuric acid markets. In recent years, the sulphuric acid market has experienced increased levels of price volatility. This has been a historic characteristic of the market primarily due to the disparity between demand and supply that can be much more significant than other commodity markets. It is also because involuntary production is the main supply route for the traded product.

In the medium term, the major determinants of sulphuric acid price levels are the balance of global supply and demand and the manner and speed with which suppliers can react to changes in the balance. The forecast considers the macroeconomic outlook for key demand markets including fertilisers and metals alongside changes in capacity and production at individual operations both supplying and consuming sulphur and sulphuric acid.

*Figure 30: Historical price of Sulphuric Acid, 2000-2023 (US$/t nominal)*



DATA: CRU; the dashed line indicates forecast
NOTE: Price forecasts have been removed from this report

## 5.3. Market trend drivers

The sulphuric acid market experiences price volatility, particularly in recent years. When by-product acid supply exceeds traded market demand, the price must fall to encourage sulphur-burners to reduce output and buy merchant acid. Acid prices can then fall to be low or negative at FOB to incentivise purchases. When demand exceeds supply, high sulphuric acid prices are observed, however, unlike other commodity markets, those periods of high prices do not necessarily trigger new capacity. The disparity between demand and supply can be significant and is due to involuntary production being the major supply route for the traded market. In other words, smelter capacity additions are independent from sulphuric acid demand. Importantly, in line with the expectation of increasing environmental efficiency in the capture of sulphurous off-gases, the ratio of acid produced per tonne of metal is expected to increase in the long-run. Even if demand is set to overcome supply significantly, new sulphur-burning capacity is likely becoming online as there is no long-term raw material scarcity for sulphur feedstock (*Figure 31*, lightest blue). Sulphur-burnt sulphuric acid production will then be the long-run driver of the sulphuric acid price. The pyrites acid sector is not considered an area of future investment due to poor environmental performance and is forecast to decline in market share.

Demand for fertilisers is determined by food consumption and agriculture’s ability to meet this demand through crop production. Growth in sulphuric acid consumption is not only the result of higher phosphorous pentoxide production volumes, but also an increased sulphuric acid consumption per tonne of product due to declining phosphate rock ore grades. The fertiliser industry is the major consumer of sulphuric acid and will continue to be in the long term (*Figure 31*, being phosphoric acid the darkest blue).

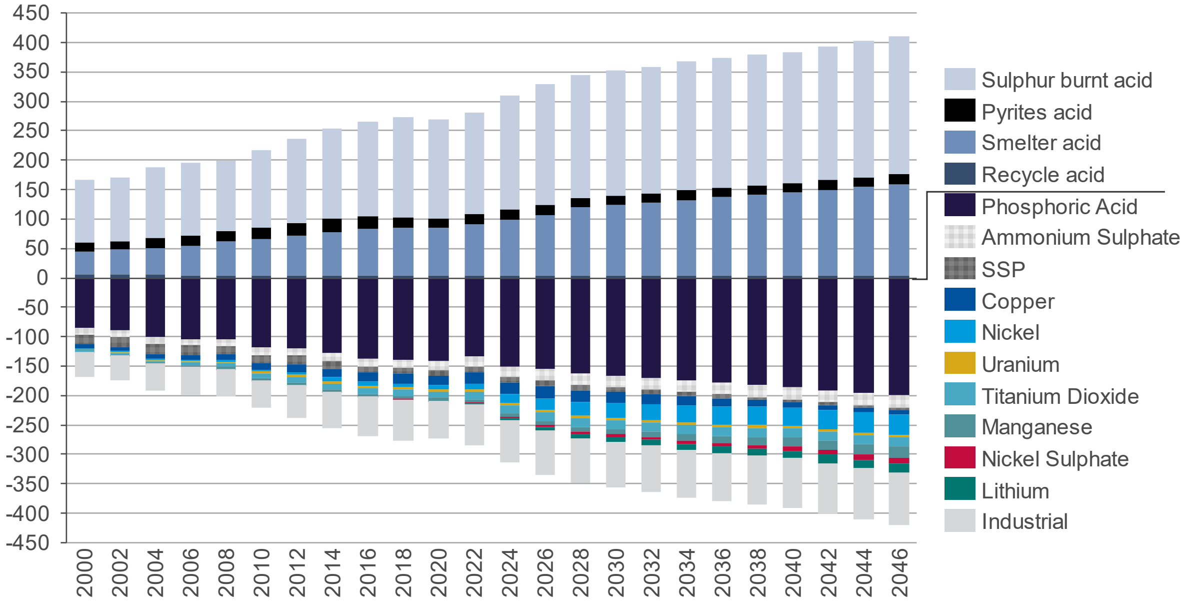
In the metals sectors, sulphuric acid demand has grown significantly from 2000 to 2022 because of the emergence of copper and nickel leaching technologies. As global economies pledge to boost investments in electrification and renewable energy, a boost in demand is expected to come from battery metals. All battery metal inputs require acid consumption in their production process. The increase in demand in the copper industry was driven by the abundance of copper oxide ore bodies in Chile and more recently in the

African Copperbelt (DR Congo and Zambia). Chilean copper oxide reserves are forecast to decline as ore bodies are depleted, while African oxide resources will remain a feature of the market in the long term. The long-term trend in the copper sector is for a peak and subsequent decline in sulphuric acid consumption related to heap leaching as oxide resources are depleted and more sulphide deposits are developed. Nickel leaching is forecast to grow in the long term as the lack of large, high grade nickel sulphide deposits and the relative abundance of laterite reserves mean that in the long-term nickel laterite projects will increasingly be developed to meet demand. Many of these projects use acid leaching via hydrometallurgical processes, boosting acid consumption.

The industrial sulphuric acid sector is forecast to continue to grow in line with industrial production (IP) growth. The growth forecasts for IP indicate a slowing growth rate at the end of the long run in comparison to earlier years as increases in output begin to be limited by the inability to continually increase productivity.

As discussed in Section 5.1.2, the supply gap shows that neither today’s existing sulphuric acid capacity nor the forecast planned capacity will provide the market with supply in the long term. Sulphur-burnt sulphuric acid capacity is, in most cases, located in demand markets. New capacity may be required in a demand market whilst global overcapacity persists. In a deficit market, sulphur-burners can fill the supply gap through investment or increased operating rates. Conversely in an oversupplied market, again sulphur-burners can modulate supply to meet demand rather than smelters.

*Figure 31: Global supply and demand of Sulphuric Acid, 2000-2046 (Mtpa). Supply is shown in positive values and demand in negative values*



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# 6. North West and North East Minerals Provinces Sulphuric Acid market

## 6.1. Sulphuric Acid overview

The **North-West and North-East Minerals Provinces** of Queensland are home to several existing and proposed mining operations which both consume and produce sulphuric acid. The current sulphuric acid market in the State is a complex relationship between copper/zinc smelter operations, rail logistics and demand from phosphate fertiliser production. Acid demand is expected to soar in coming years (see *Section 4.2*), which is expected to require additional local acid production capacity and place increased pressure on local port and rail infrastructure.

### 6.1.1. Sulphuric Acid Production

Considerable volumes of sulphuric acid are produced at Mount Isa and transported via rail to IPL's **Phosphate Hill** operations, where the acid is used as a feedstock for phosphate fertiliser production. The **Mount Isa Copper Smelter**, owned and operated by **Glencore**, processes copper concentrates from Glencore's own operations and third parties to produce a copper anode with a 99.7% purity. The anode is then transported via rail and road to Glencore's Townsville Copper Refinery (CRL), where the copper anode is submerged in an acidic copper sulphate solution and electrolytically refined into a copper cathode with a purity of 99.995%.

Smelting of copper concentrates at Mount Isa produces a stream of waste metallurgical gas, mainly comprised of sulphur dioxide, which is ducted to IPL's **Mount Isa Acid Plant**, where the gas is scrubbed, converted to sulphur trioxide and liquified into 98% sulphuric acid, then railed to **Phosphate Hill**. The relationship between Glencore Copper and IPL Acid operations is symbiotic – Glencore needs to have an offtake for its metallurgic gas to minimise harmful emissions adjacent to the city of Mount Isa, and IPL needs a low-cost source of sulphuric acid for its nearby Phosphate Hill operations. IPL's **Mount Isa Acid Plant** operates on a 4-year cycle, aligned with the copper smelter 4-year maintenance cycle.

IPL's **Mount Isa Acid Plant** also includes a sulphur burner, where sulphur prill is burnt to produce sulphur trioxide gas, which is converted to sulphuric acid. This sulphur burner is designed to top up acid production from the acid plant and currently consumes all of the sulphur prill imported from Canada via the Port of Townsville. The total nameplate capacity of the Mount Isa Acid Plant is 3,700 tpd of acid production.

**Glencore** announced on 18 October 2023 that it expects to cease all copper mining in the Mount Isa region by H2 2025, including Enterprise, X41 and Black Rock mines. Copper smelting in Mount Isa and refining in Townsville are expected to continue operating until 2030 by processing third-party concentrates from other mines in the region. The Environmental Authority (EA) for the smelter expires in 2036. Given that Glencore is awaiting capital approval for further extensions of the Mount Isa Mines Copper Smelter, the possibility of its operation beyond 2025 has been assumed as uncertain. In this report, the demand for sulphuric acid by IPL was assessed as being consistent over time regardless of gas feed from the Copper Smelter going offline.

The potential use of the Glencore Mount Isa Mines lead smelter may be a viable alternative for the supply of metallurgical gas.

The **Sun Metals Zinc Refinery**, located in Townsville and owned by **Korea Zinc Company**, is another major sulphuric acid producer, with capacity for **450 ktpa** of acid output. Sulphide-rich mineral concentrates are sourced from mines in Australia, Alaska, and South America, and refined at Sun Metals to produce special high grade (SHG) zinc ingots at 99.995% purity, as well as a range of commercial by-products.

Sulphuric acid is a major by-product of the refining process, with the plant producing approximately 450 ktpa of 98% sulphuric acid. The refinery hosts acid storage and loading facilities for GATX rail wagons and tanker trucks, in addition to storage tanks at the Port of Townsville to facilitate acid exports. Sulphuric acid produced by Sun Metals is predominantly sold to IPL's **Phosphate Hill** operation (~280 ktpa), delivered via GATX wagons) and local mining operations, as well as small volumes to Townsville-based **Cleveland Bay Chemical Company** for use in chemical manufacturing, distribution to local industry and water treatment.

### 6.1.2. Sulphuric Acid Consumption

By far the largest consumer of sulphuric acid in Queensland at present is IPL's **Phosphate Hill** operations. There, sulphuric acid is used in the production of phosphoric acid which is used in the production of approximately 1 Mtpa of ammonium phosphate fertilisers, including di-ammonia phosphate and mono-ammonia phosphate.

**Phosphate Hill** sources its sulphuric acid from a combination of waste metallurgical gas and sulphur burning at its **Mount Isa Acid Plant** (~850 ktpa), and from acid shipped via rail from **Sun Metal's Zinc Refinery** (~280 ktpa) in Townsville. Sulphuric acid produced from Mount Isa waste metallurgical gas is by far the cheapest source of acid for IPL, with the cost of acid essentially comprised of the conversion (operation of the Mount Isa Acid Plant) and transport (rail from Mount Isa to Phosphate Hill).

Phosphate Hill's proximity to the large phosphate resource yields a low-cost phosphate rock input. However, high relative costs for consumables (acid and natural gas), freight and remote location workforce push Phosphate Hill into the second or third quartile of the cost curve on a fertiliser output basis through the commodity cycle. As a consequence, high production volumes are the major driver to maintain profitability, especially in times of commodity price volatility.

In addition to Phosphate Hill, there is currently one other operating, and several proposed, phosphate operations in the NWMP. Apart from relatively minor demand for sulphuric acid in manufacturing of specialist animal feeds (MCP/DCP), these other operations will not produce phosphoric acid. Key factors involved in the decision to not produce phosphoric acid include the lack of readily available sulphuric acid and the high capital costs of establishing new sulphuric acid supply chains.

**Chatham Rock Phosphate's Korella Project** is planned to produce direct application phosphate rock for the domestic market. Chatham also intends to produce approximately 30 ktpa of monocalcium phosphate (MCP) for the Northern Territory cattle feed market at a proposed plant in Cloncurry, with production expected to commence in mid-2026. Whilst Chatham will not consume sulphuric acid in its phosphate rock mine, the Cloncurry MCP plant is expected to consume sulphuric acid.

Approximately 130km northwest of Mount Isa is the **Paradise South** and **Paradise North** projects by **North West Phosphate (NWP)**. The company is planning to produce approximately 1 Mtpa of phosphate concentrate for direct application markets in SE Asia, a process which uses no sulphuric acid. NWP is considering downstream applications that will use sulphuric acid.

The **Ardmore Phosphate Project** by **Centrex** (ASX: CXM) commenced mining operations in 2020 under a trial mining phase, producing beneficiated phosphate rock for Australian and New Zealand direct application markets. Ardmore does not consume sulphuric acid.

A major potential demand area for sulphuric acid is a raft of proposed vanadium projects in the **Julia Creek** area. Here, low grades of vanadium oxide present in oil shales of the Toolebuc Formation are proposed to be extracted by open pit mining and acid leaching. The leaching stage is the primary use of sulphuric acid, with the amount of acid required closely linked to carbon and calcite content of the host rocks, demanding 50-100 tonnes of sulphuric acid per tonne of vanadium pentoxide output. It is important to note that vanadium extraction from the Toolebuc is in its infancy and as mining process flow sheets and metallurgical studies are further advanced, some economising and recycling of acid could affect the current apparent demand for sulphuric acid by the Julia Creek projects.

Of the current seven (7) vanadium projects under development at Julia Creek, some are more advanced down the development pathway than others and all are dependent largely on the future uptake of VRFB and resulting surge in vanadium pentoxide demand, as the current vanadium pentoxide market size is not sufficient to accommodate all of these projects (and others currently being developed globally). However, if all of these projects are converted to mines at the current planned scale of operations, the **aggregated demand at Julia Creek for sulphuric acid is more than 2,900 ktpa** (for context, Phosphate Hill has a demand of approximately 1,200 ktpa).

Immediately north of the Flinders Highway is the **Saint Elmo Project** being developed by **Multicom Resources** (a private company) to initially produce vanadium pentoxide (3 ktpa) and high purity alumina (6 ktpa). Multicom is one of the most advanced among the Julia Creek vanadium players, having mining leases granted in September 2021. The project will consume sulphuric acid.

The **Vecco V+HPA Project** (formerly Debella) is being developed by private company **Vecco Group** to produce 5.5 ktpa vanadium pentoxide and 2 ktpa high purity alumina (HPA). The project is currently undergoing feasibility studies and applied for a mining lease in October 2023. Vecco is also developing **VRFB electrolyte manufacturing** capacity in Townsville. The project is expected to consume sulphuric acid for ore leaching, and additional high-purity acid for electrolyte manufacturing. Vecco's current plan is to import sulphur prill for acid generation at Julia Creek.

**QEM** (ASX: QEM) is developing its flagship **Julia Creek Project** immediately south of the Flinders Highway and along strike from Saint Elmo (Multicom). This advanced exploration project is targeting the production of vanadium pentoxide (10 ktpa) and oil from a resource touted as one of the largest vanadium deposits in the world (2,850Mt Mineral Resource). The project is expected to consume sulphuric acid. QEM has also proposed a 250MW to 1,000MW hybrid solar/wind renewable project to feed into the **CopperString** transmission project planned by the Queensland Government to link isolated Mount Isa to the National Energy Market (NEM). In addition to its Julia Creek asset, QEM has entered into agreements with IPL and Sun Metals to recycle spent vanadium-bearing catalysts from their respective operations in Queensland.

**Richmond Vanadium Technology** (ASX: RVT) is developing the **Richmond – Julia Creek Vanadium Project**, an advanced exploration project comprised of three prospects including Lilyvale with a maiden Ore Reserve of 459Mt @ 0.49% vanadium pentoxide. According to a recent PFS, Richmond is aiming to commence production with an output target of 12.7 ktpa vanadium pentoxide over an initial 25-year mine life, producing a 1.8% vanadium pentoxide concentrate on-site and beneficiating to battery grade (98% vanadium pentoxide) in Townsville. Richmond has entered into a partnership with **Thorian Energy** for the offtake of vanadium pentoxide from Richmond for the manufacture of VRFB electrolyte in Townsville. Richmond recently commenced a BFS.

**Critical Minerals Group** (ASX: CMG) is developing the **Lindfield Project** near Julia Creek, targeting a 4Mtpa ROM throughput operation from shallow oxide resources to produce approximately 17 ktpa of battery grade (98.5%) vanadium pentoxide targeting the battery electrolyte sector. CMG are also considering production of high-purity alumina (HPA, 4 ktpa) and molybdenum trioxide ($MoO_3$) as by-products. Lindfield is expected to consume sulphuric acid. CMG recently completed a Scoping Study for the Lindfield Project.

**Velox Energy Materials** (TSXV: VLX, formerly Currie Rose Resources) is developing its **North Queensland Vanadium Project** in the Julia Creek area. Initial development is focussed on the Cambridge deposit, immediately adjacent to Richmond's Lilyvale Project. Velox is still in the exploration phase of the project and has not defined targeted mine output – as such, no estimate is given for its demand for sulphuric acid at this stage.

**Ausvan Battery Metals**, a subsidiary of Crest Resources (CSE: CRES), is developing the **Allaru Vanadium Project** to the north of Julia Creek. The company is reportedly undertaking a scoping study, however little information is available at present – as such, no estimate is given for its demand for sulphuric acid at this stage.

In the nickel space, the **Sconi Battery Minerals Project** being developed by **Australian Mines** (ASX: AUZ), is located near Greenvale, approximately 220km northwest of Townsville. Laterite ore will be mined from three separate approved mining leases and processed through a high-pressure acid leach (HPAL) plant to extract nickel, cobalt and scandium. Sconi will produce a mixed hydroxide precipitate (MHP) containing nickel (71 ktpa) and cobalt (7 ktpa), primarily used as a raw material input for lithium-ion battery production in the electric vehicle (EV) industry under an initial 6-year offtake agreement with LG Energy Solution. The HPAL plant is expected to consume sulphuric acid over a 30-year mine life, produced from imported sulphur prill via an on-site sulphur burner.

The **Walford Creek** deposit being developed by **Aeon Metals** (ASX: AML) is a polymetallic copper-cobalt-zinc-nickel project located in far North West Queensland, around 350km North West of Mount Isa. The project is well advanced, having gone through various feasibility studies. Aeon is targeting a 3 Mtpa ROM mine over a 14+ year mine life, aimed at producing approximately 20 ktpa copper concentrate, 23 ktpa zinc in sulphate, 2.8 ktpa cobalt in sulphate and 1.1 ktpa in nickel sulphate. Current flow sheets for the proposed processing plant will produce a leached polymetallic concentrate from which copper cathode will be produced, with the residue refined into a mixed hydroxide precipitate (MHP). Sulphuric acid is used to leach the MHP to produce battery-grade cobalt and nickel sulphates and agricultural-grade zinc sulphate. Importantly, the sulphide orebody is comprised of approximately 40% pyrite, making this orebody attractive for producing a pyrite concentrate for downstream sulphuric acid production. It should be noted that neither concentrating pyrite or acid generation are part of Aeon’s current process plan.

A key sulphuric acid demand in Queensland has historically been copper miners, and this will continue into the future. Near-surface copper mining operations typically extract from an oxide zone, which is part of the orebody exposed to oxidising groundwater. Copper oxide ores typically require leaching, using sulphuric acid, to breakdown copper oxide and carbonate minerals. North West Queensland is a centre for copper exploration and is expected to contribute to new discoveries and mines over coming decades. A portion of these discoveries will likely be comprised of partial oxide orebodies, the development of which will require sulphuric acid for heap leach activities.

**Chinova** (privately owned by Shanxi Donghui Energy Group) operates the Osborne Mine, around 150km south of Cloncurry, as part of the Chinova Cloncurry Project which brings ore from satellite mines to the Osborne plant. Chinova’s **Mount Dore Heap Leach Project** is currently being planned, having gone through feasibility studies, and will require sulphuric acid for heap leaching over an 11-year period.

**Austral Resources** (ASX: AR1) operates the Lady Annie Mine to the north west of Mount Isa. As an extension to this operation, Austral has commenced the **Anthill Project**, which will require sulphuric acid for heap leach activities before transitioning to the sulphide zone. Brownfield exploration is expected to yield further copper oxide resources in the area, which will likely require additional sulphuric acid for heap leaching, however no estimate is given for demand for sulphuric acid at this stage.

**Cleveland Bay Chemical Company** is a Townsville-based chemical manufacturing and distribution company, which sources sulphuric acid directly from the Sun Metals Zinc Refinery. Acid is repackaged or diluted for distribution to local industry (galvanising), mining, agriculture (sugar) and water treatment applications. Acid is also used as a feedstock to produce aluminium sulphate (liquid alum), principally used as a clarifying agent in water treatment for drinking and sewerage wastewater.

### 6.1.3. Sulphuric Acid Infrastructure

Infrastructure related to sulphuric acid in Queensland is dominated by a few stakeholders, who operate acid-related assets relevant to their business.

IPL owns and operates the **Mount Isa Acid Plant**, which includes acid storage tanks, a compound for storing sulphur prill and acid loading facilities on a dedicated rail spur for loading GATX rail wagons. In addition, IPL owns a fleet of 145 GATX railcars, the only fleet capable of carrying sulphuric acid in Queensland. Operating between Mount Isa and Phosphate Hill, each trainload is between 22 to 26 railcars, with each railcar holding 58 tonnes. The advantage of the GATX system is that the number of filling points is greatly reduced, requiring only 4.5 hours to load compared to 40 hours for a conventional train of tank cars. The GATX tank cars are interconnected by hoses so that once a car is filled, the acid will then pass through the car and into the next and so on. At **Phosphate Hill**, IPL operate a rail offloading facility, which pumps acid from the GATX trains into large, dedicated storage tanks.

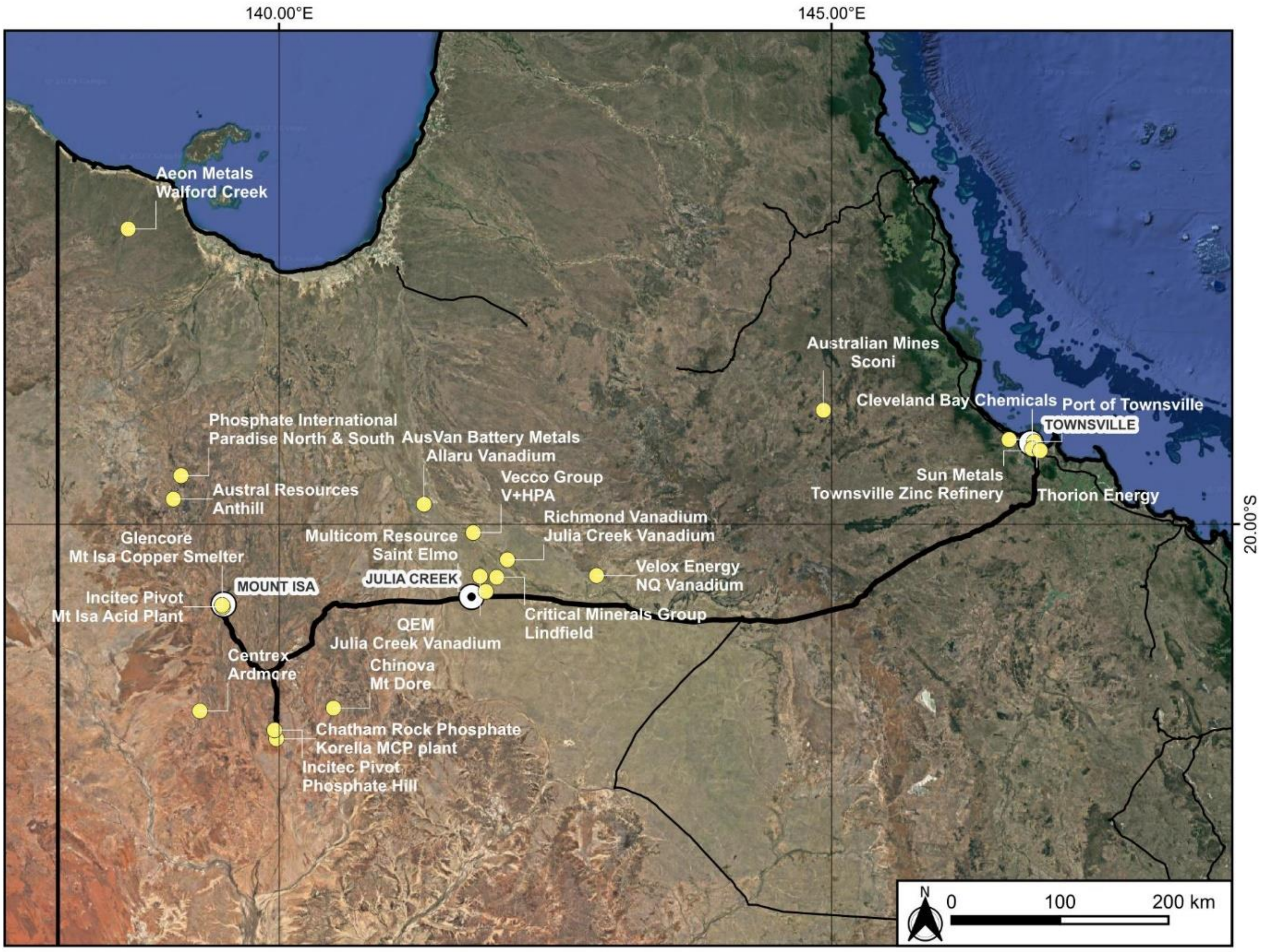
**Sun Metals** owns and operates an integrated acid plant at their **Zinc Refinery** in Townsville, which includes acid storage tanks as well as acid loading facilities for both tanker trucks operated by the **Cleveland Bay Chemical Company** and GATX railcars operated by **IPL**.

The **Port of Townsville** is the primary port servicing the NWMP, with 8 operating berths situated on 300 ha of land. The port currently has an annual throughput of more than 6 million tonnes. **Sulphur prill** is imported as dry bulk cargo primarily on berths 8 and 10 at typical transfer rates of 200 tph, with average shipment size of 12,290 tonnes. In FY2021/2022, 115kt of sulphur prill was imported over 9 separate shipments, representing approximately 10% of total dry bulk imports and near 5% of total imports. All prill imported currently goes to IPL's Mount Isa Acid Plant. **Sulphuric acid** is both imported and exported via Berth 1 only as wet bulk cargo at typical transfer rates of approximately 225 tph. Since 1996, acid transfers via the port have been export only as Sun Metals ships excess acid produced to global markets. Peak acid exports occurred in FY2018/2019 at 152kt over 21 separate shipments. However, exports have since dwindled, with FY2022/2023 recording only 23kt of sulphuric acid exported.

*Figure 32: Photo of Incitec Pivot's GATX railcars*

Source: Australian Transport Safety Bureau

*Figure 33: Map of NW-NE Minerals Provinces showing Sulphuric Acid market participants*



DATA: CRU, Google Maps, Geoscience Australia

## 6.2. Forecast Sulphuric Acid demand and supply

CRU assessed the demand for sulphuric acid at an asset level by conducting interviews with industry stakeholders, typically the operator of the relevant asset, and using CRU's internal asset database. Supply was also assessed by stakeholder interview and CRU's existing production database.

Based on gathered supply and demand data, CRU has developed multiple scenarios to demonstrate the potential supply deficit of sulphuric acid required to be met to achieve mineral project development in NW-NE Queensland (*Figure 34)*. Each scenario presents the aggregated demand and aggregated supply for sulphuric acid based on the project "status", which identifies where each project is on the development pathway at this time according to CRU's Project Gateway System. This approach essentially provides a view of aggregated supply/demand for different levels of certainty that specific supply or demand will materialise.

Given the potential status classification available to projects (operating, committed, probable, possible and speculative), there are four possible scenarios:

- **Scenario 1** includes only operating assets that supply and/or demand sulphuric acid (also includes committed projects, however there are none in this class at this time).
- **Scenario 2** includes all operating and probable projects.
- **Scenario 3** includes all operating, probable and possible projects.
- **Scenario 4** includes all operating, committed, probable, possible and speculative projects.

It is important to note that as an individual project is further developed over time and the project reached new milestones, the likelihood that project will be successfully developed improves and that project's "status" could change. Another important consideration is that individual projects could be deemed unviable in future, potentially removing that project's relevant supply or demand from the aggregated figures. Additionally, further feasibility studies or testing by project operators may refine the volumes of acid supply or demand. These factors mean that the scenario system is dynamic over time as project certainty is resolved or announcements are made by operators.

Aggregated supply and demand for sulphuric acid in each Scenario considered is shown in *Table 5*. Supply and demand for each asset is not disclosed in this report due to commercial-in-confidence reasons.

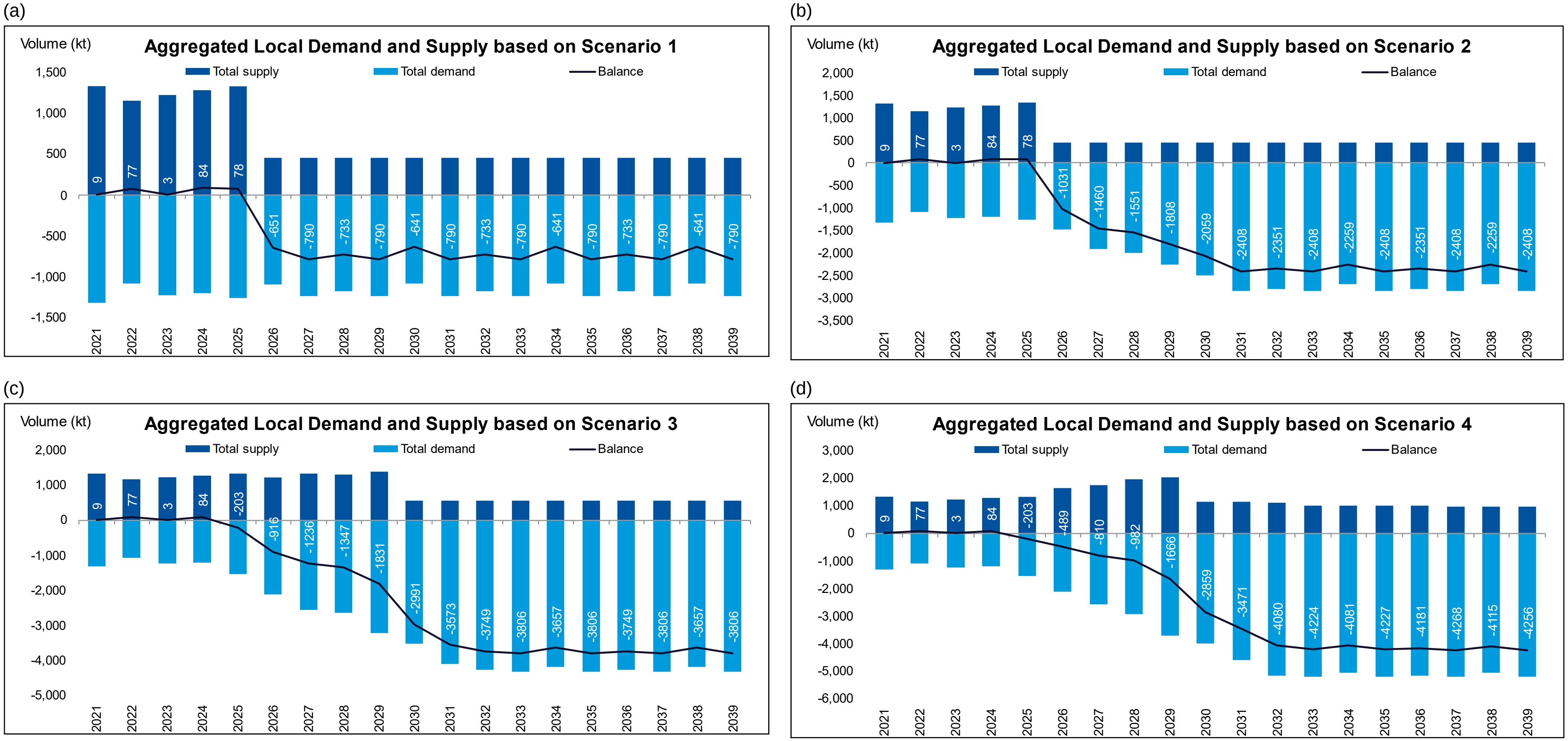
*Table 5: Local supply and demand for Sulphuric Acid in thousand tonnes per annum (ktpa)*

| **Scenario** | | **Annualised Sulphuric Acid volume, in kt** | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ***2021*** | ***2022*** | ***2023*** | ***2024*** | ***2025*** | ***2026*** | ***2027*** | ***2028*** | ***2029*** | ***2030*** | ***2031*** | ***2032*** | ***2033*** | ***2034*** | ***2035*** | ***2036*** | ***2037*** | ***2038*** | ***2039*** |
| 1 | Supply | 1328 | 1160 | 1232 | 1286 | 1338 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 |
| | Demand | 1320 | 1083 | 1229 | 1203 | 1260 | 1102 | 1240 | 1183 | 1240 | 1091 | 1240 | 1183 | 1240 | 1091 | 1240 | 1183 | 1240 | 1091 | 1240 |
| | Balance | 9 | 77 | 3 | 84 | 78 | -651 | -790 | -733 | -790 | -641 | -790 | -733 | -790 | -641 | -790 | -733 | -790 | -641 | -790 |
| 2 | Supply | 1328 | 1160 | 1232 | 1286 | 1338 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 | 451 |
| | Demand | 1320 | 1083 | 1229 | 1203 | 1260 | 1482 | 1910 | 2001 | 2258 | 2509 | 2858 | 2801 | 2858 | 2709 | 2858 | 2801 | 2858 | 2709 | 2858 |
| | Balance | 9 | 77 | 3 | 84 | 78 | -1031 | -1460 | -1551 | -1808 | -2059 | -2408 | -2351 | -2408 | -2259 | -2408 | -2351 | -2408 | -2259 | -2408 |
| 3 | Supply | 1328 | 1160 | 1232 | 1286 | 1338 | 1214 | 1338 | 1318 | 1402 | 547 | 547 | 547 | 547 | 547 | 547 | 547 | 547 | 547 | 547 |
| | Demand | 1320 | 1083 | 1229 | 1203 | 1541 | 2130 | 2574 | 2665 | 3233 | 3538 | 4120 | 4296 | 4353 | 4204 | 4353 | 4296 | 4353 | 4204 | 4353 |
| | Balance | 9 | 77 | 3 | 84 | -203 | -916 | -1236 | -1347 | -1831 | -2991 | -3573 | -3749 | -3806 | -3657 | -3806 | -3749 | -3806 | -3657 | -3806 |
| 4 | Supply | 1328 | 1160 | 1232 | 1286 | 1338 | 1641 | 1765 | 1965 | 2049 | 1161 | 1131 | 1097 | 1010 | 1004 | 1007 | 996 | 966 | 970 | 979 |
| | Demand | 1320 | 1083 | 1229 | 1203 | 1541 | 2130 | 2574 | 2947 | 3715 | 4020 | 4602 | 5177 | 5235 | 5085 | 5235 | 5177 | 5235 | 5085 | 5235 |
| | Balance | 9 | 77 | 3 | 84 | -203 | -489 | -810 | -982 | -1666 | -2859 | -3471 | -4080 | -4224 | -4081 | -4227 | -4181 | -4268 | -4115 | -4256 |

DATA: CRU, industry stakeholders

NOTES: Scenario 1 – operating projects only, Scenario 2 – operating and probable projects only, Scenario 3 – operating, probable and possible projects, and Scenario 4 – all projects

*Figure 34: Aggregated local Sulphuric Acid supply, demand and the balance*



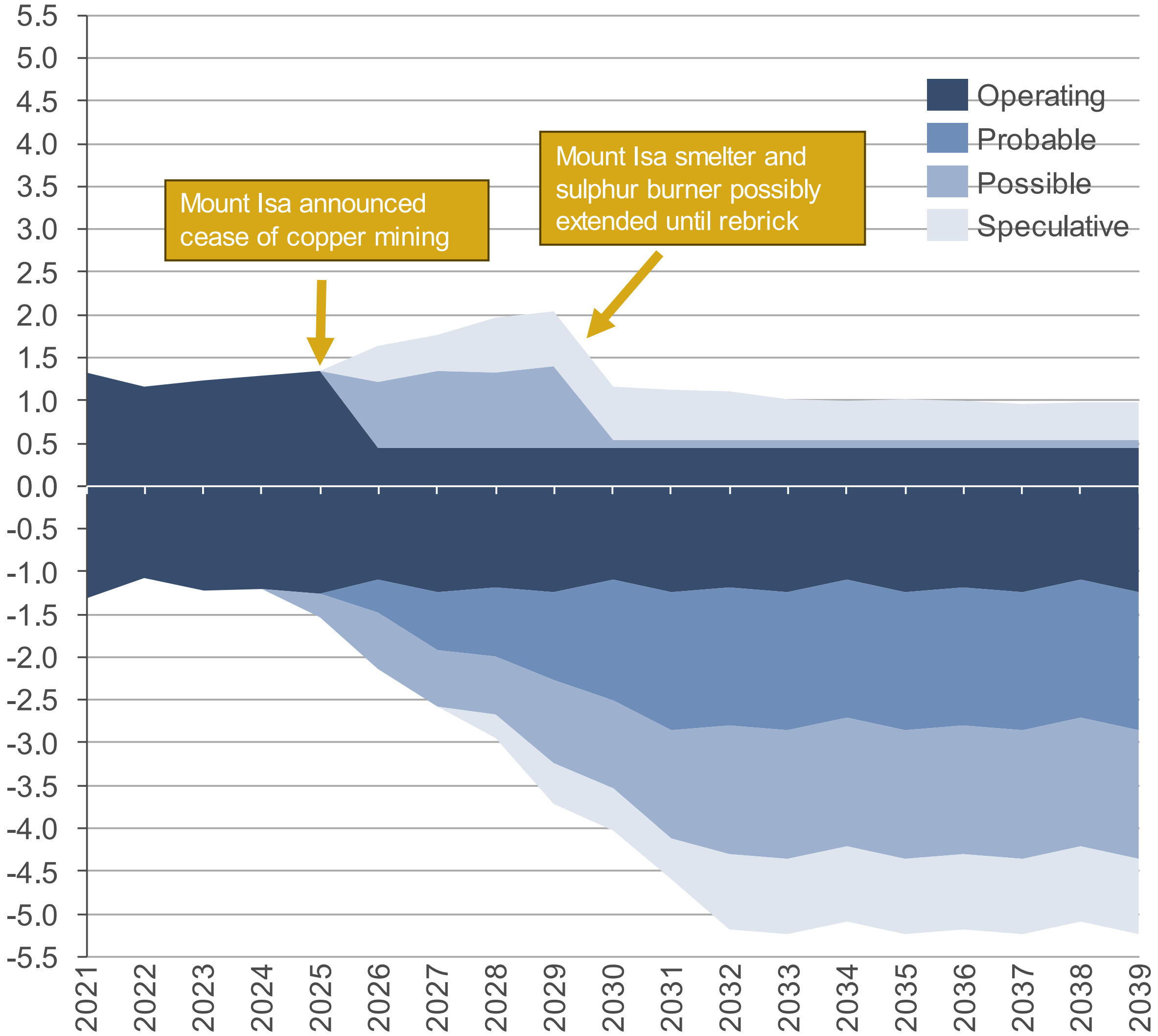
DATA: CRU

NOTES: (a) Scenario 1 – operating projects only, (b) Scenario 2 – operating and probable projects only, (c) Scenario 3 – operating, probable and possible projects, and (d) Scenario 4 – all projects

NOTE: Supply is shown in darker blue (positive values) and demand in lighter blue (negative values) and the balance represented by a black line (difference between supply and demand)

Based on these scenarios, a supply and demand balance can be drawn *(Figure 35)*. A supply gap is expected as early as 2025 (Scenario 3 or 4, of 200 kt) or 2026 (Scenario 1 and 2, of 650 kt and 1000 kt, respectively). A maximum supply gap of 4.3 Mtpa is found in Scenario 4 in 2037.

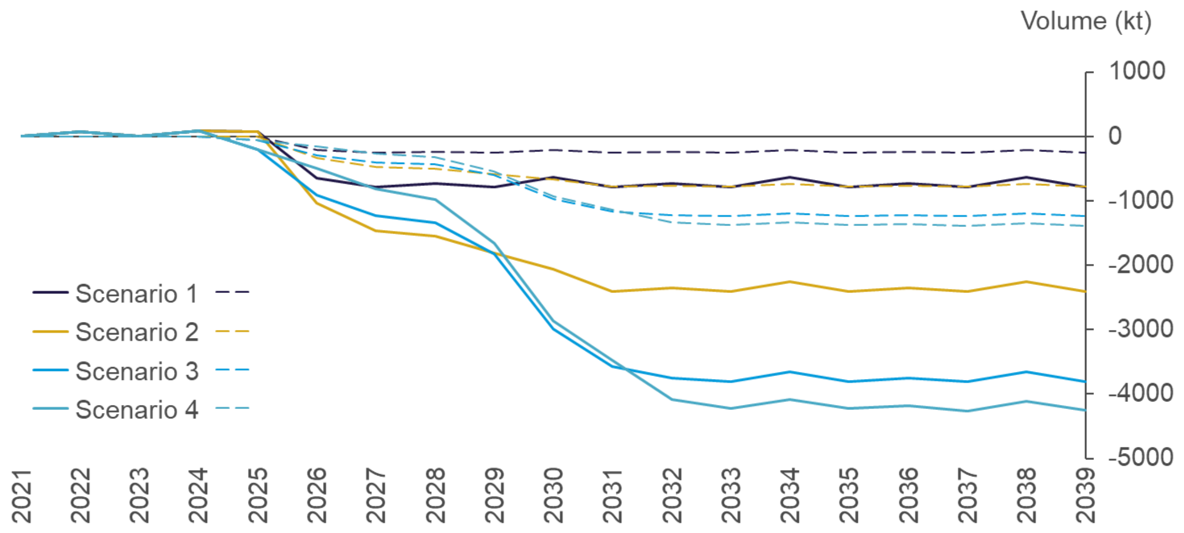
*Figure 35: Local supply and demand, 2021-2039 (Mtpa) -separated into likelihood of project proceeding.*



DATA: CRU
NOTE: Projects supplying sulphuric acid are shown with positive values while projects that consume acid are shown with negative values

There are several ways to meet the supply gap, one of them being the import of sulphur prill. In sulphur terms, as it can be seen in *Figure 36*, where the gap of sulphuric acid based on each scenario was converted into sulphur equivalent, the earliest requirements would be of 66 kt in 2025 (scenarios 3 and 4), followed by 213 kt or 337 kt in 2026 (Scenario 1 and 2, respectively). The largest requirement would be of 1,400 kt in 2039 (Scenario 4). Considering that new operations require a minimum of 3 years from its concept to full operation, it is evident that the import of sulphur will be unavoidable as it will need to support the region until 2027, at least. The maximum volume of sulphur required between 2023 and 2027 for scenarios 1-4, respectively, are 213, 477, 404 and 264 ktpa. If new operations become online only after 2029, the import of sulphur could be of approximately 600 ktpa (Scenario 3). Importing these quantities of sulphur would not only strain the port, rail, and road infrastructure, but also the only current sulphur burner in the region, which belongs to IPL, as it is already operating at near capacity (their utilisation rate was 93% in 2022). Importantly, given its integration with Mount Isa's smelter, the sulphur burner cannot operate without the smelter operating.

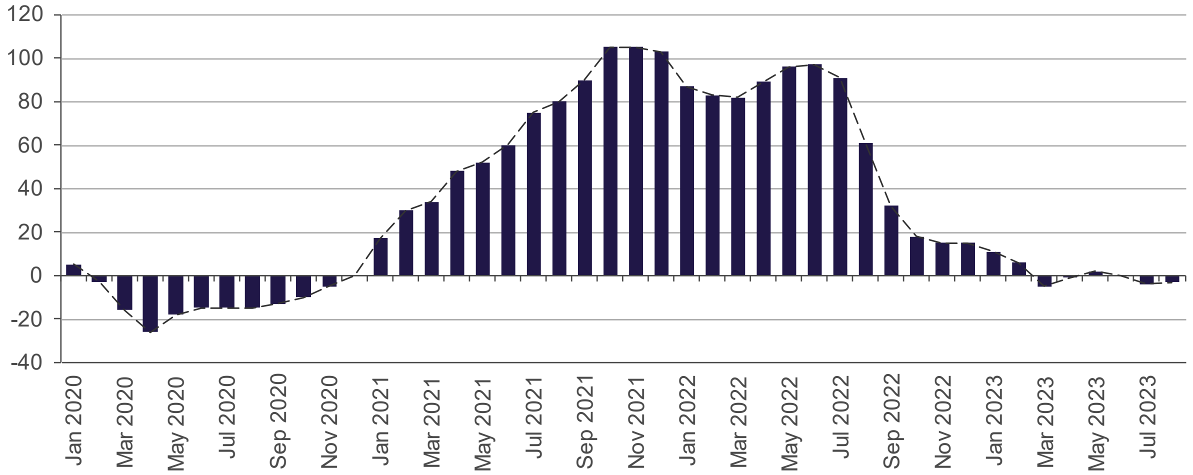
*Figure 36: Forecast supply gap in each Scenario, Sulphuric Acid (solid line) and equivalent in sulphur (dashed line)*



DATA: CRU
NOTE: Negative numbers indicate supply shortage

Alternatively, there is the possibility of importing sulphuric acid instead, likely from countries such as South Korea and Japan. The benefit of importing sulphuric acid is that the commodity price oftentimes is very low or even negative when sourced from smelters during peak production periods (*Figure 37*). Importantly, from a supplier perspective, it will generally be preferable to sell sulphuric acid locally at a more predictable price than expose their product to international price volatility. For sulphuric acid users, securing supply from international sources is high-risk, with a fluctuating market presenting challenges such as access to suitable bulk freight carriers, currency fluctuations and uncertainty regarding security of long-term supply.

*Figure 37: Monthly averaged Sulphuric Acid prices from Japan/South Korea (FOB, 2020-2023 US$/t)*



DATA: CRU

When factoring in the demand profile, Queensland will likely see a change in the main consumers of sulphuric acid, shifting from value-add phosphate to metals leaching in mining and grid storage electrolyte producers (*Figure 38*). Note that the export of sulphuric acid ceased in 2023 in all scenarios as local demand was given access priority of sulphuric acid, rather than the international/interstate market.

Even when maintaining current operations (Scenario 1), without an alternative supply of sulphuric acid, there may be a deficit in sulphuric acid supply in 2026 resulting from the possible curtailment of the Mount Isa Copper Smelter due to the closure of the Enterprise, X41 and Black Rock mines, and resultant decreased acid output. The potential consequences of a sulphuric acid shortfall may have tangible impacts on IPL's Phosphate Hill operation as Phosphate Hill is Australia's only producer of value-added phosphate fertilisers this could have ramifications for Australia's agricultural sector and Australia's trade balance for phosphate fertilisers.

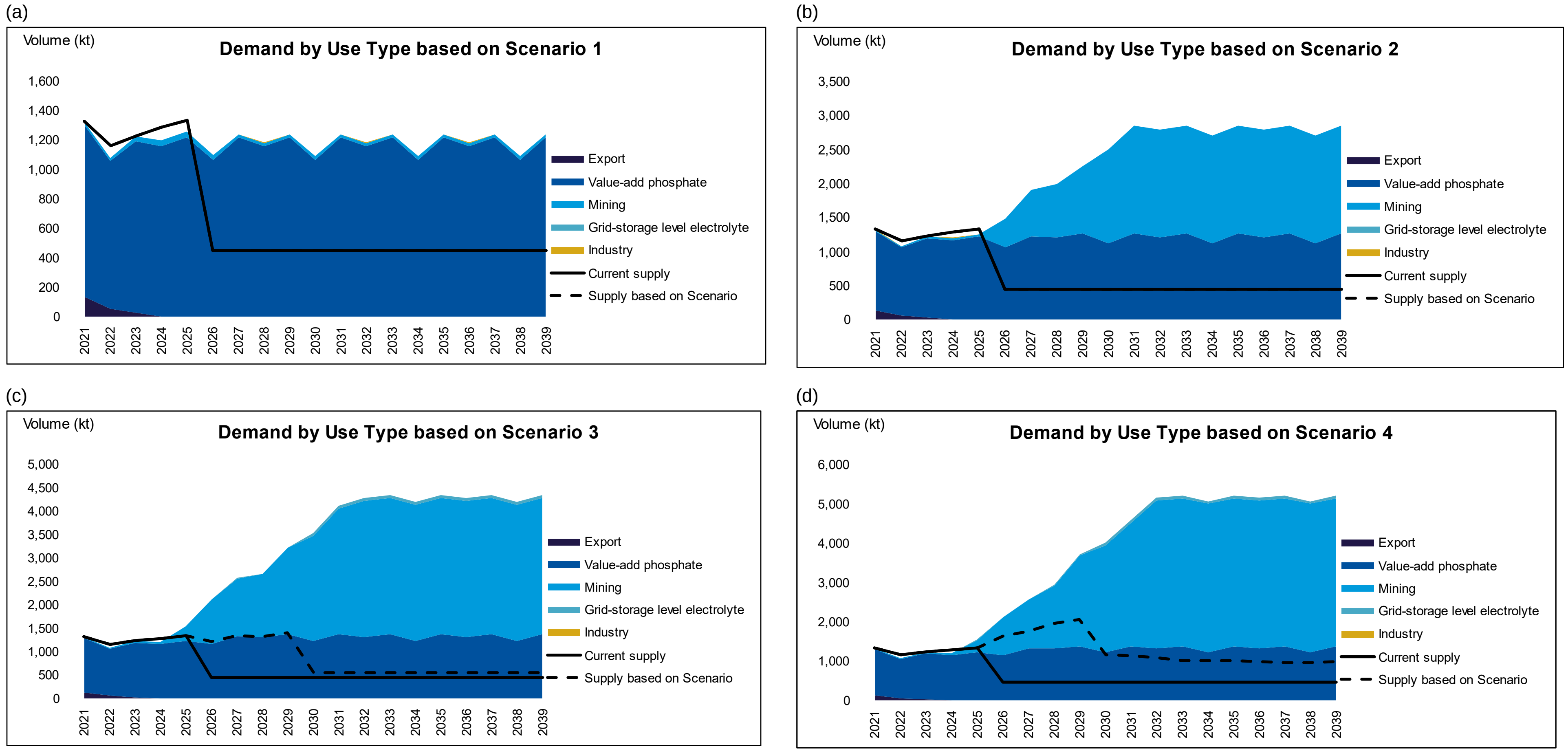
The large demand from mining in *Figure 38* can be further divided into more granular categories: material type or chemical process, as shown in *Figure 39*.

The main future drivers for sulphuric acid, once solely dominated by phosphate, now also include nickel, and vanadium. Nickel is required for solar technologies and batteries (generally automotive) while vanadium is key for high-strength steel production and energy-grid storage. Most cathode active materials (CAMs) are nickel-based. Cathode active materials are a major supply chain risk for western manufacturers. The underinvestment in CAM production capacity in Europe and North America, coupled with non-existent investment in Australia, implies that battery cell manufacturers will have to largely rely on CAM supply from Asia to support domestic battery production. If Queensland wants to grow cell manufacturing capabilities, a secure sulphuric acid supply for both nickel and vanadium mine operations will be vital.

There are some uncertainties arising from the validity of the sulphuric acid demand figures obtained from vanadium project proponents. Recycling, for example, is yet to be proved feasible. However, even with some uncertainty regarding recycling, large volumes of sulphuric acid are still expected to be required in the acid leaching circuit. Furthermore, even in the most optimistic supply case (Scenario 4), the supply will be insufficient to meet the requirements of all vanadium operations.

Finally, to design the optimal location of new sulphuric acid supply plants, we can categorise the scenarios based on the demand locations (*Figure 40*).

*Figure 38: Aggregated local Sulphuric Acid demand by end use type*

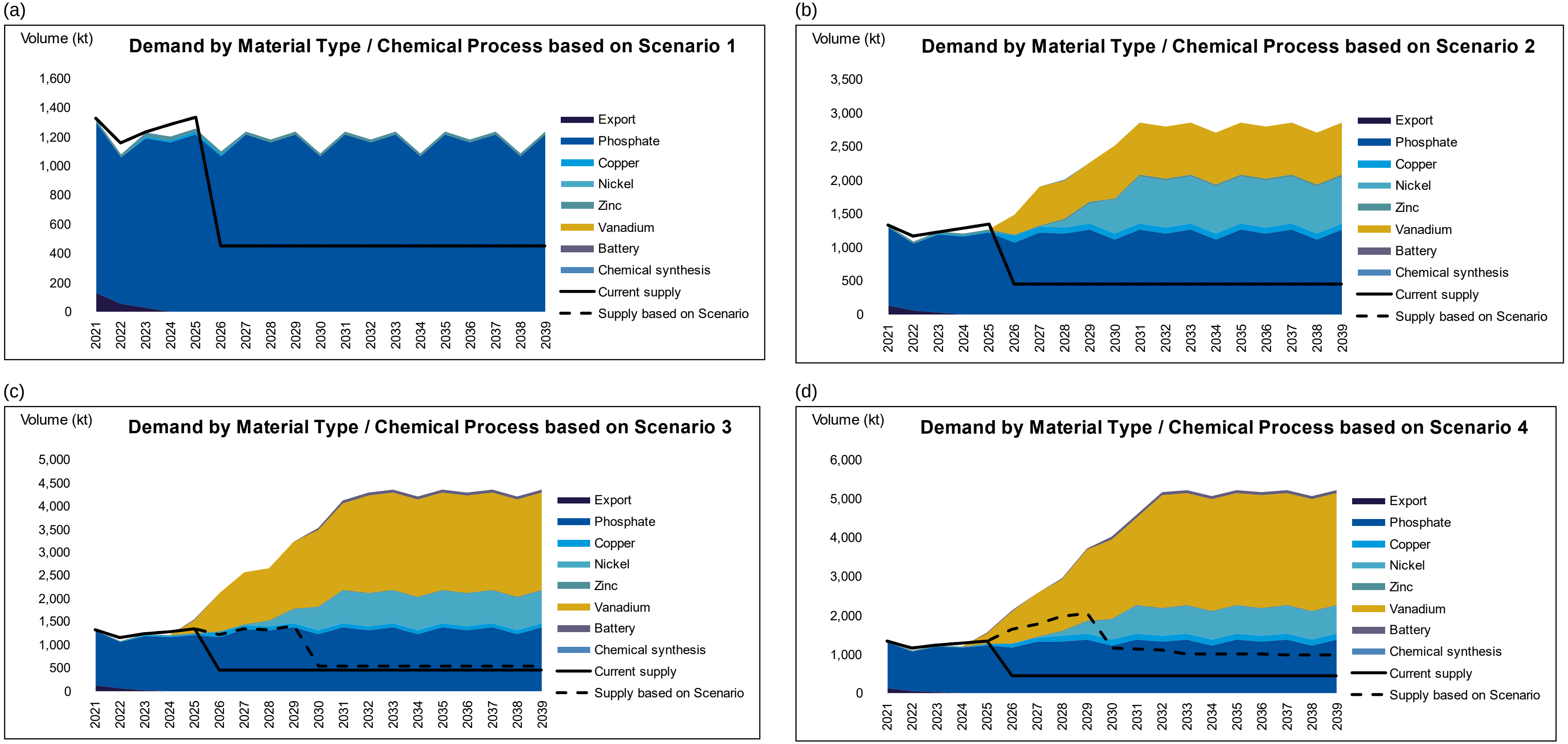


DATA: CRU

NOTE: (a) Scenario 1 – operating projects only, (b) Scenario 2 – operating and probable projects only, (c) Scenario 3 – operating, probable and possible projects, and (d) Scenario 4 – all projects

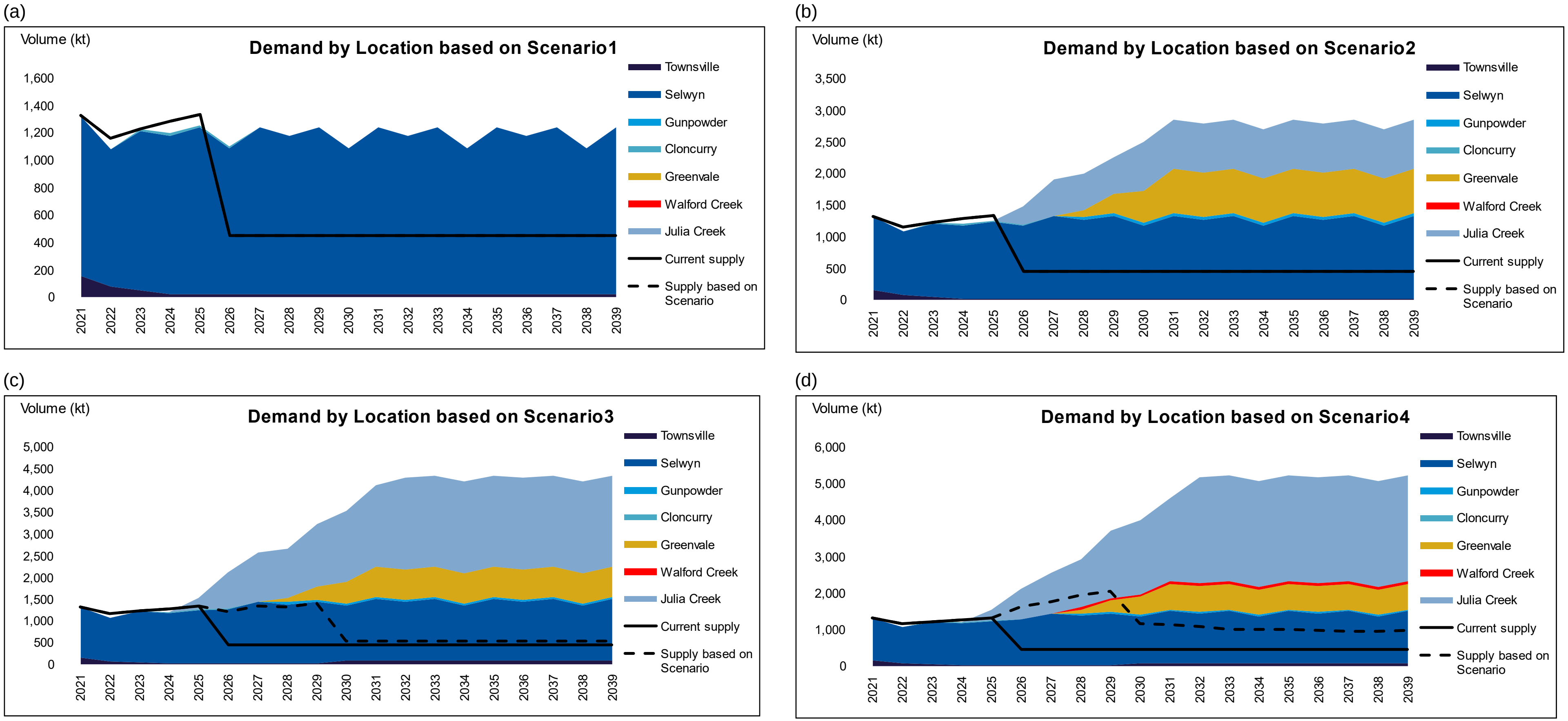
NOTE: In all graphs, the supply considering only current operations was plotted as a solid line and the supply based on the given scenario was plotted as a dashed line. In the graphs (a) and (b), the supply based on scenario is the same as the supply considering only current operations.

*Figure 39: Aggregated local demand by material type or chemical process*



DATA: CRU
NOTE: (a) Scenario 1 – operating projects only, (b) Scenario 2 – operating and probable projects only, (c) Scenario 3 – operating, probable and possible projects, and (d) Scenario 4 – all projects.
NOTE: In all graphs, the supply from only current operations is plotted as a solid line, and the supply based on the given scenario is plotted as a dashed line. In the graphs (a) and (b), supply based on each scenario is the same as the supply considering only current operations

*Figure 40: Aggregated local Sulphuric Acid demand by location*



DATA: CRU

NOTE: (a) Scenario 1 – operating projects only, (b) Scenario 2 – operating and probable projects only, (c) Scenario 3 – operating, probable and possible projects, and (d) Scenario 4 – all projects.

NOTE: In all graphs, the supply from only current operations is plotted as a solid line, and the supply based on the given scenario is plotted as a dashed line. In the graphs (a) and (b), supply based on each scenario is the same as the supply considering only current operations

## 6.3. Factors impacting supply of Sulphuric Acid

Several **industry stakeholders** have provided insights into the **challenges of sulphuric acid supply**. Many of these challenges are related to the remoteness of the mining sites for feedstock and end-users, concerns around transport infrastructure and the high cost of rail freight, high investment costs associated with new acid-generating plant, environmental risk of new technologies, regulatory uncertainty, market uncertainty (particularly for vanadium redox flow batteries) and volatility of the commodities market (e.g., sulphuric acid, fertilisers, and cobalt).

Given the remoteness of many mine sites, new and current operations must account for high fixed costs and difficult feedstock logistics. These factors are decisive for some operations, such direct application phosphate projects (Ardmore, Korella, Paradise South) which export phosphate rock instead of producing a more valuable product, such as phosphoric acid, in part due to a lack of readily available sulphuric acid supply. Remoteness also exacerbates access to utilities, including electricity, gas, and water. Power grid connection is important, not only for access to reliable energy, but in the case of sulphur burners, the exothermic chemical reaction taking place generates substantial steam, which can be converted into electrical energy via a stream turbine. Connection to the grid allows this by-product energy to be exported to the grid, providing potential revenue and a generation source in the region.

**Transport logistics present a key challenge for both sulphuric acid and its feedstocks**. The transport cost is significant for any mine operator. Being a hazardous liquid material, transporting sulphuric acid requires specialised ISO tanks or GATX railcars. These tanks/wagons are expensive to acquire and maintain, requiring additional specialised high-pressure pumping and docking facilities for acid loading and unloading. An additional complication occurs in the case of rail line closure, where the GATX wagons carrying sulphuric acid require security or the driver to remain with the consignment, incurring additional cost not seen in other commodities. In Queensland, acid wagons and docking infrastructure are privately owned and represent a major capital cost for new mining operations, even when the rail infrastructure itself is already available. GATX railcars are specific to their design purpose (carrying acid in this case), meaning that shipments are one-way, nearly doubling the cost of transport as the wagon will most likely return to its initial location empty.

**Transporting sulphur prill or pyrite concentrates is less problematic**, being able to be handled as dry bulk goods, and therefore require less specialised processes and infrastructure. The simpler transport logistics for these is offset however, as the end user that would incur the capital cost of a sulphur burning/pyrite processing facility for in-situ production of sulphuric acid.

### 6.3.1. Rail constraints

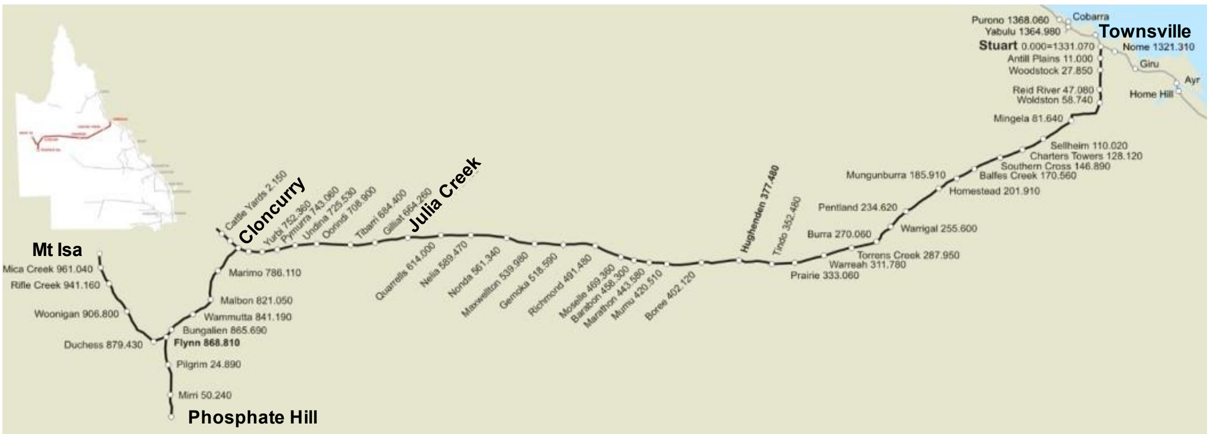
The Mount Isa Line responsible for carrying the bulk of sulphuric acid and sulphur across inland Queensland, is frequently touted by project operators as the most expensive rail network in Australia. The high cost of using this network places considerable burden on mine operators, significantly raising the cost of importing reagents (such as sulphuric acid) to site. Study industry interviewees indicated that the high cost of this network is attributed to a variety of factors, including:

- Underutilisation of the network (50-60%)
- Slow travel sections
- Short and poorly-spaced passing sidings
- High maintenance costs
- Common closure due to flooding and speed restrictions due to extreme heat
- Narrow gauge limiting carrying capacity
- Cost of back-hauling empty wagons

Fluctuations in rail freight costs are based on many contributing factors including above-rail service provider competition, mining production output supporting demand for access and other supply chain disruptions.

Queensland Rail (QR) owns and operates the **Mount Isa Line**, a system comprised of 1,032 km of track which extends from Stuart (near Townsville) to Mount Isa and includes the Phosphate Hill Branch (*Figure 41*). The line is a critical link from the NWMP to the Port of Townsville, where most bulk products are exported. The Mount Isa Line and carries minerals concentrate, fertiliser, acid, mining inputs, refined metals, and cattle. The Inlander passenger service also operates on the line.

*Figure 41: Current rail system evidencing Mount Isa line and Phosphate Hill Branch from Townsville*



SOURCE: Queensland Rail

The Mount Isa Line has a capacity of approximately 8-10 Mtpa, however typically carries approximately 4-5 Mtpa. The system is operated out of the Townsville Train Control Centre. The maximum train length permitted on the Mount Isa Line is 1,009 m between Stuart and Mount Isa. Stuart station is 10 km from the Townsville station. Other limitations/restrictions apply between Stuart and Townsville Jetty and Phosphate Hill Branch. Importantly, information about the rollingstock availability could not be obtained by industry stakeholders. Aurizon is the main rail operator for bulk and intermodal freight on the line with infrastructure at the Port of Townsville and Mount Isa/Cloncurry. Pacific National previously operated on the rail line until 2021 and might have rollingstock available in storage. Qube Rail is operating Glencore-owned wagons and leased locomotives.

The Mount Isa Line is subjected to some of the harshest weather conditions in Queensland, and is prone to impacts from:

- **Flooding**: the monsoonal wet season in Queensland is generally from January to April, when monthly rainfall of 400 mm or more can occur. Tropical cyclone events also occur during the summer months. The Mount Isa Line is built across floodplains and a portion of the line is often subject to flooding, resulting in track closure and speed restrictions being imposed.

- **Extreme heat**: ambient temperatures along the line can be extreme, reaching above 45 ºC and below 3 ºC. Extreme heat can cause track instability. To reduce the risk of an incident, QR may impose temporary speed restrictions over sections of the track, or blanket speed restrictions on the network, as a precautionary measure during extreme heat events.

The rail is narrow gauge (1,067mm) single track. Size and weight restrictions, along with ageing infrastructure requiring a lot of maintenance, contribute to the Mount Isa Line being a high-cost corridor for bulk transport per tonne. Ailing sections of track, or newly maintained track are subjected to speed restrictions, impacting cycle times. Commonly, some parts of the track require trains to slow to a speed of 40 km/h. Other constraints include short passing siding lengths, and limited passing opportunities, which imposes limits on train length. Importantly, given that the rail line is underutilised, it results in higher access charges for current users to support the infrastructure cost base.

It should be noted that the Mount Isa Line undergoes regular maintenance and capital works, with a focus on improving system resilience to disruptive weather events. These works and other initiatives are designed to reduce impacts on the freight transport in the region and are dependent on increased network usage.

- FY2022, A$25m invested on replacing 24 km of track from Cloncurry to Mount Isa with new concrete sleepers and ballast as well as 10 kilometres of new rail to bolster safety and reliability of the line.
- FY2020, A$67.6m bridge abutment and scour repairs in nearby drains and creeks, stonework including gabion flood protection to embankments, and further drainage and cleaning works as required to improve flood resilience.

### 6.3.2. Road constraints

The North-West and North-East Minerals Provinces are extensively connected by roads (*Figure 42*). In 2019, road transport carried approximately 65% of all freight tonnages in Queensland, followed by rail (32.5%), coastal shipping (2.4%) and air (<1%). The Flinders Highway connects the NWMP to Townsville's processing and export facilities. Similar to rail, the roads in the region are often affected by wet weather conditions causing closures.

While sulphuric acid, sulphur prill and pyrite concentrate could technically be transported to and from Townsville to Mount Isa by road, DTMR suggests the use of the rail as the optimal mode, especially on key strategic locations such as the Mount Isa corridor.

When trucks are used to transport sulphuric acid or sulphur, road trains can be used, each carrying between 57 t (in a twelve-axle A-double road train) to 82 t (in a seventeen-axle A-triple road train) of sulphuric acid and 100 t for sulphur at a time and have their speed limited to 90 km/h.

*Figure 42: Road network between Townsville and Mount Isa*

DATA: Modified from the Department of Transport and Main Roads.

### 6.3.3. Port constraints

The **Port of Townsville** is the primary export hub for the NWMP. The port has 8 operating berths, is situated in 300 ha of land, and currently has an annual throughput of more than 6 million tonnes. Major trading partners include South Korea (19% share), China, Australia, Indonesia, and USA (6% share).

The key trades in the Port of Townsville are, from highest to lowest, dry bulk (70% share), wet bulk, containers, and break bulk. Dry bulk cargo includes mineral concentrates and ores, fertilisers, sugar, cement, sulphur, animal feedstuffs and coking coal. In FY2022/2023, sulphur was responsible for approximately 14% of dry bulk imports, and 5% of total imports. The port facilitates trade in a large variety of liquid bulk commodities, including petroleum products, sulphuric acid, caustic soda, tallow, and molasses, together accounting for approximately 15% of total trade throughput. In 2022/2023, sulphuric acid was responsible for 8% of wet bulk exports, and 0.5% of total exports.

Trade is expected to grow in the Port of Townsville, from 6.8 Mt in 2023 to 26 Mt by 2050, with a trade value of A$30 billion. This growth is expected to include 6.5 Mt of mining products and 7.5 Mt of liquid products. As discussed previously, given the corrosiveness of sulphuric acid, transporting it must always be carefully considered to ensure a safe transportation. While sulphuric acid can be transported from the Port of Townsville, via privately owned wagons, along the Mount Isa Line, there is also the option to use the MILI (Mount Isa Line Integrated) Freighter owned by Aurizon and well-integrated with the Port of Townsville. The rail operator, Aurizon, can also transport containers and iso-tank containers, avoiding the use of road for bulk transport.

Currently, Berth 1 is where trade of sulphuric acid occurs, where it is on a 29% berth capacity. Sulphur trade occurs in berths 8, 9, and 10, with a volume ratio of sulphur imports of 45%, 15% and 40%, respectively. Berths 8, 9 and 10 have a utilisation rate of 29%, 42% and 51%. All berths have a maximum functional utilisation of approximately 80%, except Berth 10, which is 59%. This equates to a maximum **import capacity of 170 ktpa of sulphur and nearly 200 ktpa of sulphuric acid**, as of FY2022/23. Importantly, since there are priority arrangements on some berths (such as vessels containing cement or sugar, or cruise and navy ships having priorities in certain berths), this limit might not be always reachable.

Importantly, the Port of Townsville is currently undergoing an **Expansion Project**, a capital investment of A$1.64 billion and involves dredging of 11.48 million cubic metres of sediment to widen and deepen the Sea and Platypus Channels and an expanded harbour basin, establishing a 152-hectare reclamation area, construction of 4km of rock revetments and a 700m western breakwater (subject to need) and the construction of six new berths. This Expansion Project will significantly improve the capacity of the Port of Townsville, allowing vessel sizes to increase from 200m to 300m in length for the upgraded parts of the port. This may not be the case for vessels intending to use Berth 1 where trade of sulphuric acid occurs, or other inner harbour berths. Increased ship sizes will potentially allow sulphur and acid importers to save on shipping costs, however the Expansion Project will not improve ship loading/unloading rates without additional infrastructure upgrades.

The **Port of Gladstone**, which is the largest port in Queensland, could be used as an alternative to Townsville to import the necessary sulphur and sulphuric acid to NW-NE Mineral Provinces. The Port of Gladstone is located 829 km south of Townsville and has a total throughput of more than 120 Mtpa, being 80% exports. The major export at the Port of Gladstone is coal (at almost 60% of total throughput), making it the fifth largest coal export terminal in the world. While the import and export of sulphuric acid and sulphur is not currently significant in the Port of Gladstone, the utilisation rate of the sulphuric acid berth is only 10%. Should the need arise, the Port of Gladstone has space to expand to accommodate future volumes. However, given the prohibitive cost of inland transportation (especially for sulphuric acid), use of this port in the context of a NWMP sulphuric acid supply chain is unlikely.

*Figure 43: Port of Townsville ship berths*

SOURCE: Port of Townsville

### 6.3.4. Feedstock availability

Feedstocks required for local sulphuric acid production to fill the supply gap will mainly be in the form of:

- **Sulphur**, either imported via the Port of Townsville or locally sourced. A good potential local source for sulphur is by reprocessing tailings using technology being developed by **Cobalt Blue** (ASX: COB). Using proprietary techniques, Cobalt Blue has demonstrated that it can recover valuable minerals, such as cobalt, from tailings. The process produces elemental sulphur as a by-product, which can be granulated into prill and distributed to end users for sulphuric acid generation.

  and/or

- **Pyrite concentrates**, produced by flotation separation of pyrite minerals from a pyrite-rich feed such as mine tailings.

This study included compiling information on known pyrite resources, including in-ground resources, and tailings from mine waste, both active mines and abandoned.

In the *Queensland Critical Minerals Strategy* (2023), the government allocated funding for the investigation of remnant mineralisation in mine tailings and waste rock across the State. This funding is targeted to undertake drilling, geochemical and mineralogical characterisation of tailings and waste-rock dumps on abandoned and operating mines sites principally to evaluate the presence and potential recovery of critical minerals. Although not complete or specifically geared toward identifying pyrite resources for sulphuric acid production, information from these studies is significant for this study as both volumetric and mineralogical data on pyrite were often available.

Information gathered on potential pyrite resources comes with the following important caveats:

- Data was gathered on a best-efforts basis given the scope of this study. No field work or testing was carried out as part of this study, forcing reliability on published information or discussion with industry stakeholders. Information on some sites has been kindly provided by the *University of Queensland's* **Sustainable Minerals Institute** from their ongoing waste characterisation work on selected mine sites. Importantly, information from active mine sites, such as Ernest Henry and Mount Isa is limited due to confidentiality provisions for active mining leases (MLs). Glencore at Mount Isa Mines have commenced a program of tailings testing and characterisation at the time of this report.

- Pyrite resources, including grade, was estimated for some sites due to lack of reliable data. For these, a conservative 4% pyrite grade was used to estimate potential resources. Of note, this includes Glencore's TSFs at Mount Isa, which could contain significantly higher grades once tested. Further volumetric and pyrite resource characterisation is warranted for this and other sites.
- Other pyrite resources almost certainly exist across the State, including pyrite orebodies encountered during mineral exploration which have been determined to contain sub-economic grades of metallic mineral resources (e.g., barren pyrite-dominated deposits). Further work identifying these in-ground resources is warranted.
- The data represents a first-pass compilation of information. Further work on compiling existing data and conducting field measurements is warranted.

Key information on identified **pyrite resources in Queensland** was collected during this Study. This data presents the location, type, potential grade (tenor) or pyrite mineralisation, potential resource size and theoretical maximum acid that could be produced via pyrite roasting (i.e., conversion of 100% of estimated resources).

A map showing the **size and distribution of potential pyrite resources** is provided in *Figure 44*.

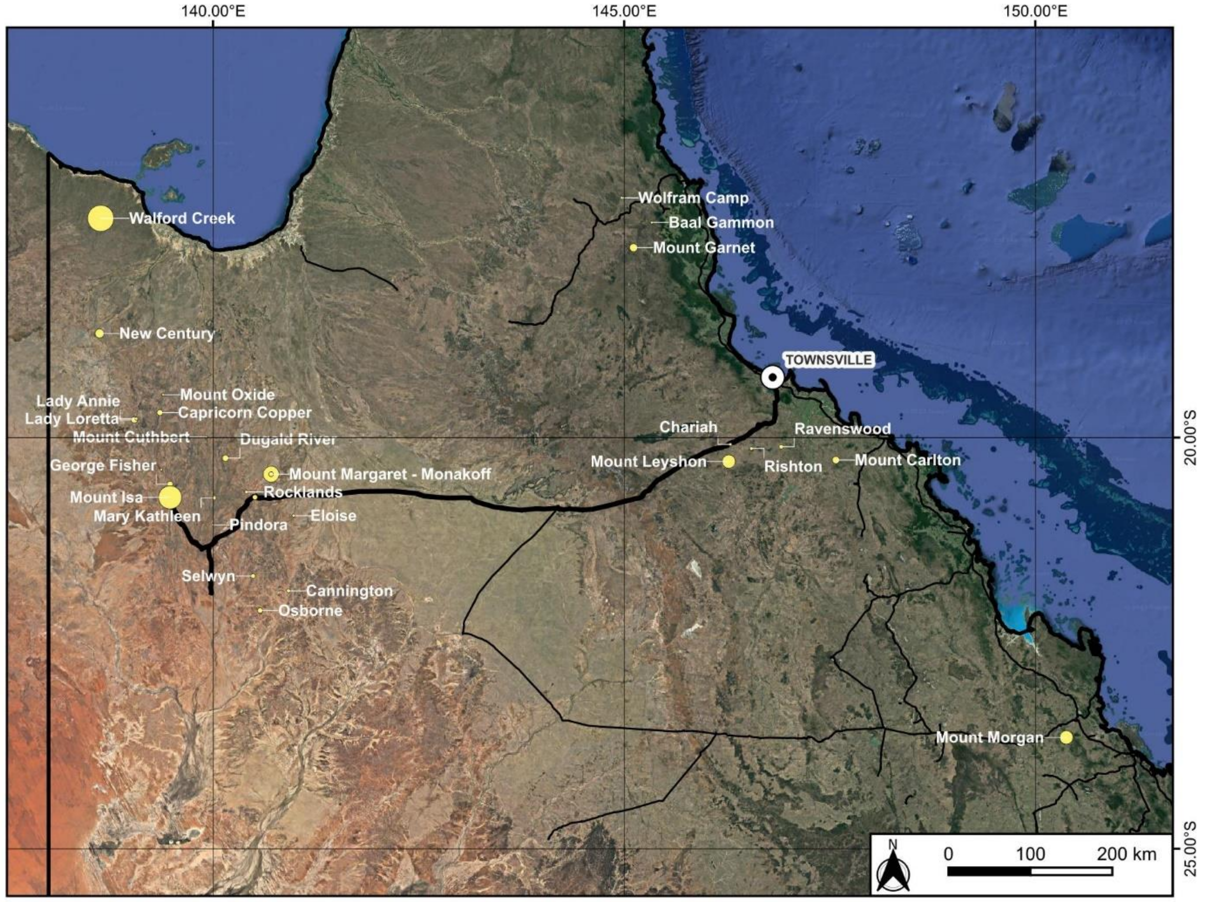
**Opportunities and constraints** for pyrite concentrate resources was further evaluated in the Engineering Scoping Study.

Processing existing, legacy or abandoned tailings and waste rock resources is not a trivial exercise and not without significant complications. Some important considerations include:

- **New tailings impoundments** may be required in many cases (subject to site specifics). As tailings are extracted and processed to recover pyrite (and other valuable commodities), the waste from that process will likely need to be stored in an entirely new TSF or tailings dam. The requirement for new tailings impoundment will introduce capital costs, environmental approvals, additional land use to name a few. There is also a beneficial outcome in that new impoundments will likely be far superior to legacy dams as they will need to comply with improved best practice and regulation.
- **Recovery of ancillary minerals** may be viable during recovery of a pyrite concentrate. Minerals not commercial at the time of mining or only partially recovered due to technological constraints at the time of mining, could potentially be recovered depending on new process techniques. Depending on the tailings mineralogy, this could include critical minerals, such as cobalt, REEs, copper, gallium, germanium, etc.
- **Regulatory constraints** around reprocessing abandoned or legacy tailings are not inconsiderable. In the *Queensland Critical Minerals Strategy* published in 2023, the Queensland Government indicated the need to facilitate secondary prospectivity for critical minerals. It was identified that to be able to recover critical minerals from mine waste, the right regulatory framework is required. The Queensland Government is in the process of reviewing the regulatory framework, including considerations of a new "Residual Mineral Recovery Tenure" and investigation into the current risk assessment criteria used to determine risk allocation in the Financial Provisioning Scheme. It should be noted that recovering sulphur from tailings renders them (more) benign, resulting in a better environmental outcome, and therefore stakeholders expect that the regulatory framework will favour sulphur reprocessing from mine waste and TSFs.

- **Mineral contaminants** may introduce additional challenges. Resources containing components such as arsenic, lead, uranium and zinc may be best avoided to minimise environmental, health and acid contamination issues.
- **Benign post-processed tailings** will not be guaranteed. Whilst removing a significant portion of pyrite, other sulphides (such as chalcopyrite, galena, sphalerite, arsenopyrite, etc) and residual pyrite will likely return to the new tailings. Whilst the recovery of a pyrite concentrate will drastically reduce the amount of contained sulphide minerals, and therefore reduce likelihood of acid drainage, some sulphide content will remain.
- **Transport logistics** are an important consideration, particularly in the vastness of North West Queensland and access constraints during the wet season. Longer distances in transporting pyrite concentrates to a pyrite burner facility can add considerable cost.

*Figure 44: Location of pyrite resources assessed in this study*



DATA: CRU, Google Maps, Geoscience Australia

NOTE: yellow circles denote the relative size of potential pyrite resources, black line represents the rail network

### 6.3.5. Water availability

Production of sulphuric acid requires considerable volumes of fresh water, with approximately 1 L of fresh water required to produce 5 L of 98% sulphuric acid.

The **North West Vanadium Supply Pipeline Project** being advocated by a number of Julia Creek vanadium proponents (QEM, Richmond Vanadium, Velox, CMG and Vecco) presented an Opportunity and Constraints Assessment prepared by Epic Environmental and Water Resources to the Queensland Government in May 2023. The assessment considered the opportunities and constraints of two proposed pipeline options and identified the availability of 20,850 ML/a of secure water. This water could be utilised by critical minerals projects in the NWMP as common user infrastructure. The proposal is being considered by Government.

Project proponents in the region are showing support for new freshwater dam capacity in the region. The **Cave Hill Dam** is proposed to be built on the Cloncurry River, approximately 20km south of Cloncurry. Current plans call for a 140,000 ML dam to be constructed to support local urban water security, agriculture and new mining projects. The proposal is being considered by Government.

# 7. The potential of imports to meet forecast demand

*Section 6.2 Forecast Sulphuric Acid demand and supply* of this report clearly demonstrates that a supply gap for sulphuric acid in Queensland will emerge in coming years, driven by potential changes on the supply side (in particular acid feedstock from Mount Isa Copper Smelter off gas), looming demand from vanadium, nickel-cobalt and copper projects under development and current demand from phosphate fertiliser manufacturing.

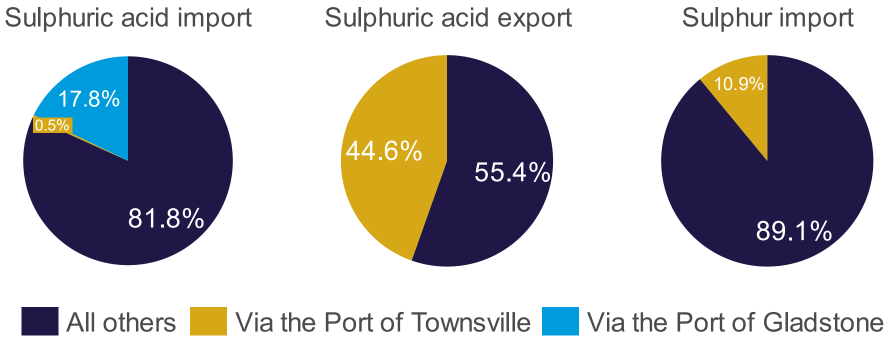
To fill this looming supply deficit, this report considers potential solutions, including:

- **Imports** of both sulphuric acid and sulphur (*this section*); and
- **New domestic acid production facilities** to produce sulphuric acid from sulphur prill (imported) or pyrite concentrates from mine tailings (*Section 8 Engineering scoping* ).

## 7.1. Overview of seaborne trade

During the past three years, imports and exports of both sulphur and sulphuric acid (*Figure 45*) are clearly divided between major ports. A large portion of the sulphuric acid into Queensland is imported via the Port of Gladstone for local use (approximately 20 ktpa). Over the past three years, the Port of Townsville exported nearly half of the total Australian sulphuric acid exports (more than 200 kt out of the total of 460 kt). While there has not been any export of sulphur from Australia between 2021 and 2023, the import of this commodity was also significant for the Port of Townsville, bringing in more than 300 kt in total over this period, all of which is used to generate additional sulphuric acid for the Phosphate Hill operation.

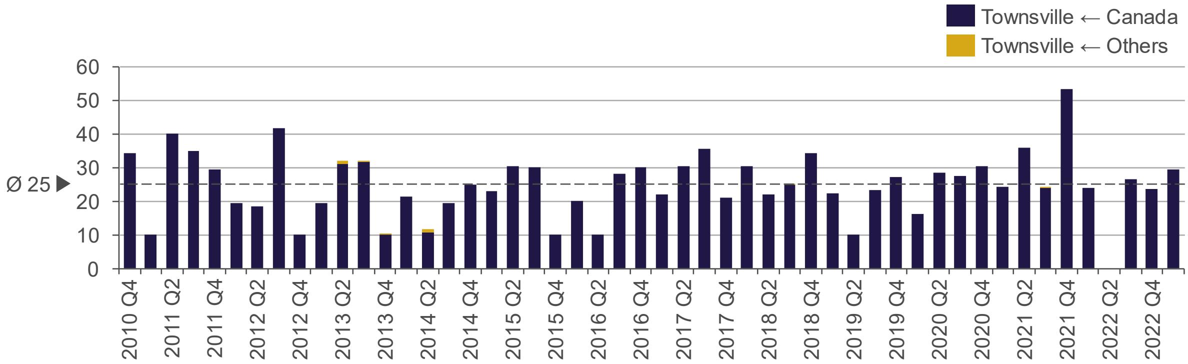
*Figure 45: Comparison of Australian imports and exports of Sulphuric Acid and Sulphur averaged over the period between 2021 and 2023.*



DATA: CRU
NOTE: No significant amount of sulphur was exported from Australia during this timeframe.

Trade data clearly shows that **Canada supplies the bulk of sulphur into Townsville** (*Figure 46*), with minor and sporadic quantities of sulphur imported from Qatar, Philippines, United Arabic Emirates, South Korea, and Russia (labelled as “Others” in *Figure 46*). An average 25 kt per quarter of sulphur was imported into Townsville over the last decade. No trading activity of sulphur is observed for the other ports in Central and Far North Queensland (Gladstone and Cairns).

*Figure 46: Sulphur imports (quarterly) into the Port of Townsville, 2010-2022, kt per quarter*

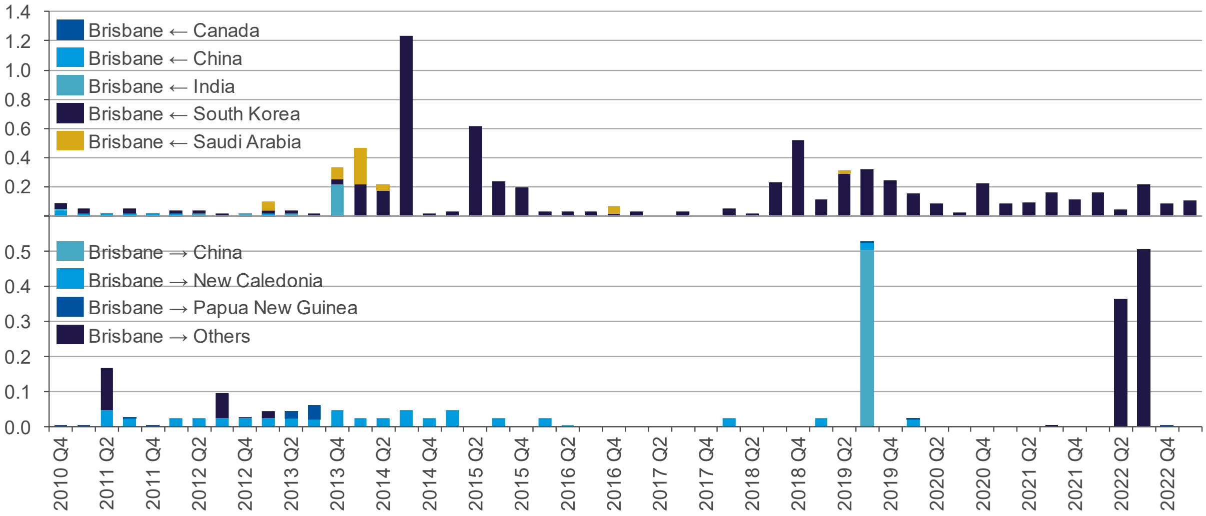


DATA: IHS Markit

NOTE: The *Φ* indicates the total average.

For completeness, trade in South-East Queensland (Port of Brisbane) has been included in *Figure 47*, which is a minor trade operation for sulphur. Imports of sulphur into Brisbane (*Figure 47*, top) have been historically from Canada, China, South Korea, and Saudi Arabia. However, this has been dominated by South Korea in recent years. Exports of sulphur from Brisbane have been a much less frequent transaction (*Figure 47*, bottom) with volumes of a historical maximum of 1 kt per quarter, but with significantly less import in recent years. In *Figure 47*, bottom, the label “Others” includes the United States of America, Indonesia, Hong Kong, Germany, New Zealand, Singapore, Japan, Italy, South Africa, and Vietnam.

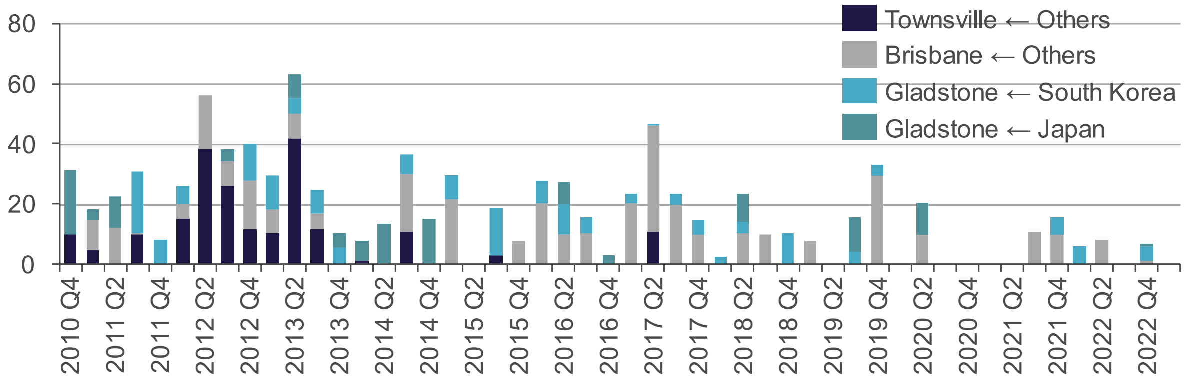
*Figure 47: Imports (top) and exports (bottom) of Sulphur via the Port of Brisbane, 2010-2023, kt per quarter*



DATA: IHS Markit

Some trading activity of sulphuric acid is observed within the various ports in Queensland (*Figure 48*). Expectedly, the import volumes are lower than sulphur, being generally less than half of the sulphur import volumes, given the logistic advantage of transporting the latter. Lately, the import of sulphuric acid in Queensland has been dominated by the port of Gladstone, which comes from South Korea and Japan. Despite few imports in recent years, The Port of Townsville has historically imported sulphuric acid from the Philippines, South Korea, China, Japan and from other regions within Australia (labelled as Others in *Figure 48*). In Brisbane, sulphuric acid is imported from Belgium, China, Germany, India, Japan, South Korea, Philippines, Singapore, and United States (labelled as “Others” in *Figure 48*). There is no import data for other ports in Queensland.

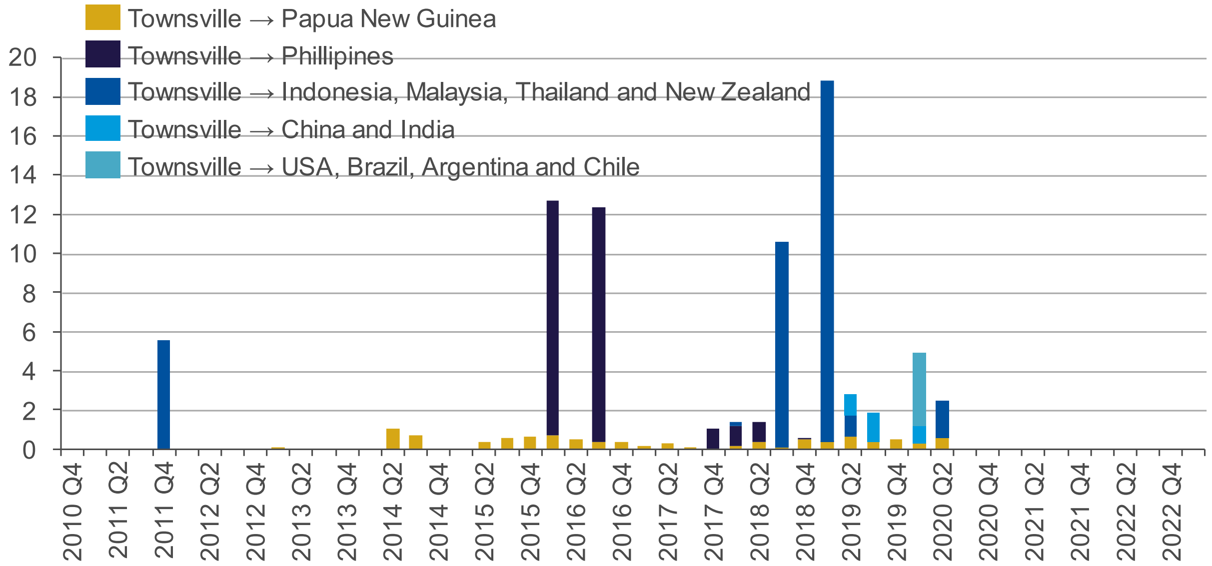
*Figure 48: Import of Sulphuric Acid via Queensland ports, 2010-2022 (kt per quarter)*



IA: IHS Markit

The export of sulphuric acid in Queensland fluctuates and is dominated by the port of Townsville, as it can be seen in *Figure 49*. The destination and volume of the exported sulphuric acid does not follow a particular trend indicating that the exported sulphuric acid is the leftover acid that the internal market did not consume and there are no large set deals amongst producers and international clients. Minor sulphuric acid export occurs in Brisbane on an average of 14 tonnes per quarter (not shown in *Figure 49*) to a range of destinations including Papua New Guinea, Fiji, New Caledonia, New Zealand, Qatar, Solomon Islands, Tonga, Vanuatu, and others.

*Figure 49: Export of Sulphuric Acid from the Port of Townsville, 2010-2022 (kt per quarter)*



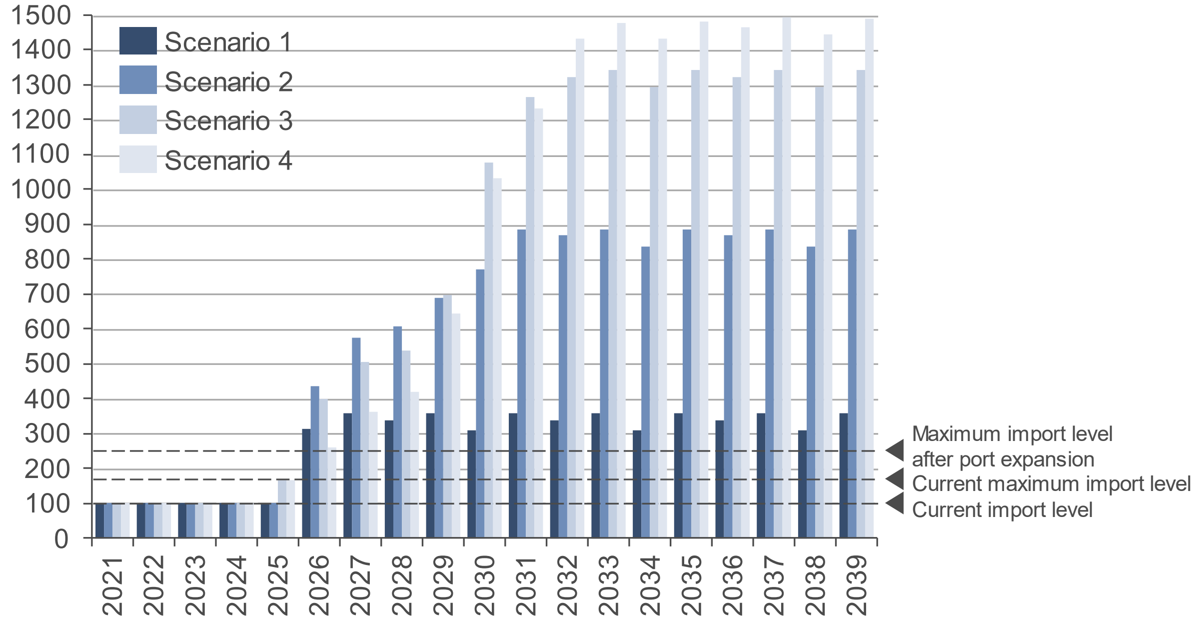
DATA: IHS Markit - the data from IHS Markit has not been updated for the export of sulphuric acid from the Port of Townsville since 2021

## 7.2. Meeting the forecast supply gap with seaborne trade

To meet the forecast supply gap in **Scenario 2** (Operating + Probable projects) through seaborne trade alone, imports of **sulphur** (for burning to produce acid) would need to reach 500 ktpa by 2027 and grow to 900 ktpa by 2031. Given that the Port of Townsville has a current sulphur import capacity of approximately 170 ktpa, **the import of sulphur alone would be unable to meet the Scenario 2 supply gap beyond 2025**.

The Port of Townsville **channel widening operation**, expected to be completed by June 2024, will accommodate vessels up to 300 m length (current limit is 200 m vessels) within the current port area. However, it should be noted that it is expected that many dry bulk operations (including sulphur) will continue to use current vessel sizes due to port operational constraints. After the **port expansion**, considering that no bulk handling facility is planned (therefore, the transfer rate will continue to be the same), the maximum sulphur import capacity is expected to be approximately 254 ktpa, **still well short of the 357 ktpa sulphur imports required to meet Scenario 1** (Operating projects only).

*Figure 50: Minimum imports of Sulphur to meet the supply gap for each Scenario, 2021-2039 (ktpa)*



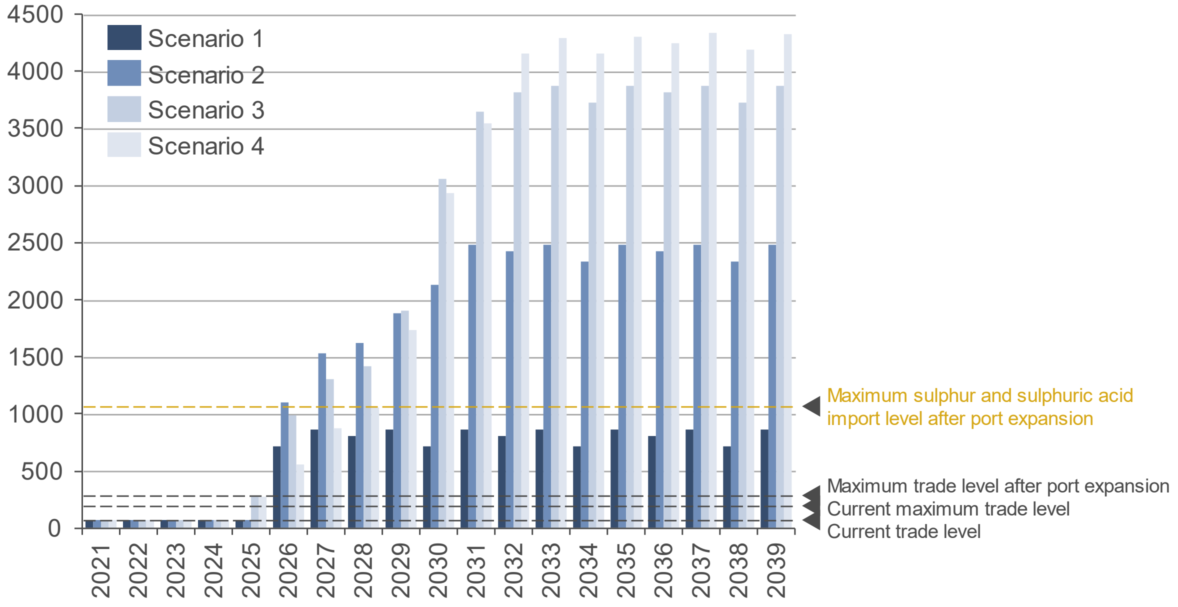
DATA: CRU

NOTE: Scenario 1 includes operating projects only, Scenario 2 includes operating and probable projects only, Scenario 3 includes operating, probable and possible projects, and Scenario 4 includes all projects

Direct **imports of sulphuric acid via the Port of Townsville are also unable to meet the forecast supply gap** for any of the Scenarios considered. The average trade (import and export) of sulphuric acid in the last three financial years in the Port of Townsville was of approximately 70 ktpa, it can be seen in *Figure 51*, that relying solely on the import of sulphuric acid is not feasible even after the port expansion.

Importing the maximum amount of sulphur and converting it to sulphuric acid, while importing the maximum amount of sulphuric acid, both after port expansion, leads to a maximum port capacity of 1068 ktpa of sulphuric acid equivalent. In this case, **importing both sulphur and sulphuric acid at near-maximum rates would meet Scenario 1** (i.e., currently operating assets only). This approach, however, would require investment in additional sulphur burner capacity to handle the volumes sulphur imported.

*Figure 51: Minimum import of Sulphuric Acid required to meet the supply gap in each Scenario, 2021-2039 (ktpa)*



DATA: CRU

NOTE: Scenario 1 includes operating projects only, Scenario 2 includes operating and probable projects only, Scenario 3 includes operating, probable and possible projects, and Scenario 4 includes all projects.

NOTE: The yellow line was determined by converting the maximum sulphur import level after port expansion to sulphuric acid and combining it with the maximum import of sulphuric acid after port expansion

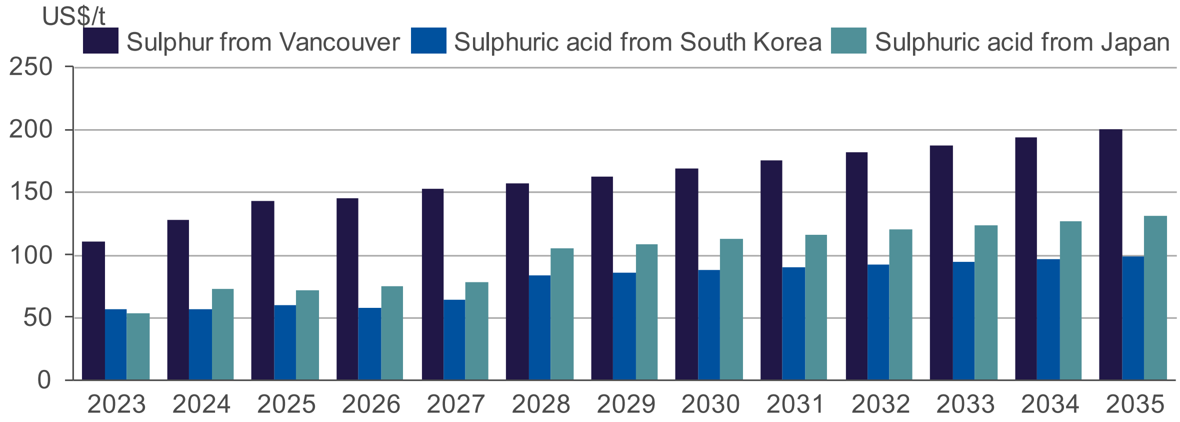
## 7.3. Cost of imports

Principal international trading partners for Townville provinces are:

- **Canada** for sulphur; and
- **South Korea** and **Japan** for sulphuric acid.

The cost of both commodities (*Figure 52*) from these locations has a direct impact on current acid-users in Queensland and potentially the viability of proposed new mining operations. The cost of sulphur from Canada is expected to jump from US$ 110 per metric tonne in 2023, to US$ 200 per metric tonne in 2035, a more than 80% increase. The scenario is similar for sulphuric acid, where the cost per metric tonne from South Korea is expected to increase about 75% between 2023 and 2035, while acid from Japan is expected to see an increase of 145% over the same period.

*Figure 52: Free on-board (FOB) cost of Sulphur from Canada and Sulphuric Acid from Asia*

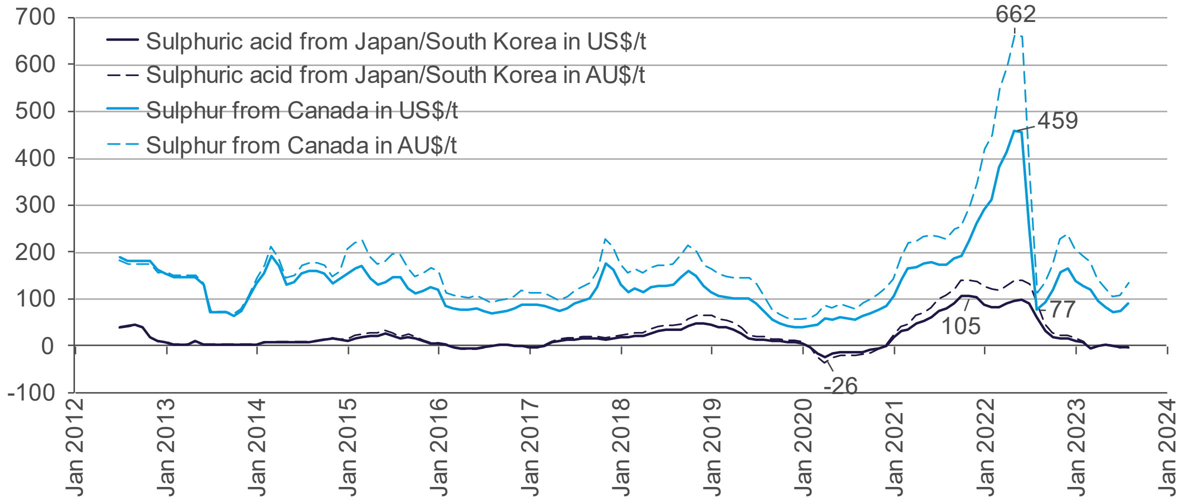


DATA: CRU

It is important to note that both sulphur and sulphuric acid experience significant price volatility, as demonstrated by historical monthly price charts (*Figure 53*). In 2022, for example, the price of sulphur skyrocketed to US$ 459 /t before plummeting to a near decade low of US$ 77 /t. Similarly, the cost of sulphuric acid has previously changed from US$ 105 /t to negative values. Throughout this report, we use the general price trend to provide forecast commodity prices (*Figure 52*), however it is important to note that **prices can fluctuate dramatically**, significantly impacting operations that heavily rely on sulphuric acid.

The uncertain and fluctuating trade market for both sulphur and sulphuric acid poses a limitation to relying heavily on the import of those commodities for local operations, especially in the long-term, where the uncertainties increase. Currency exchange volatility between the USD and AUD adds additional uncertainty to the cost of sulphur or sulphuric acid that Queensland-based operations will pay for their feedstocks.

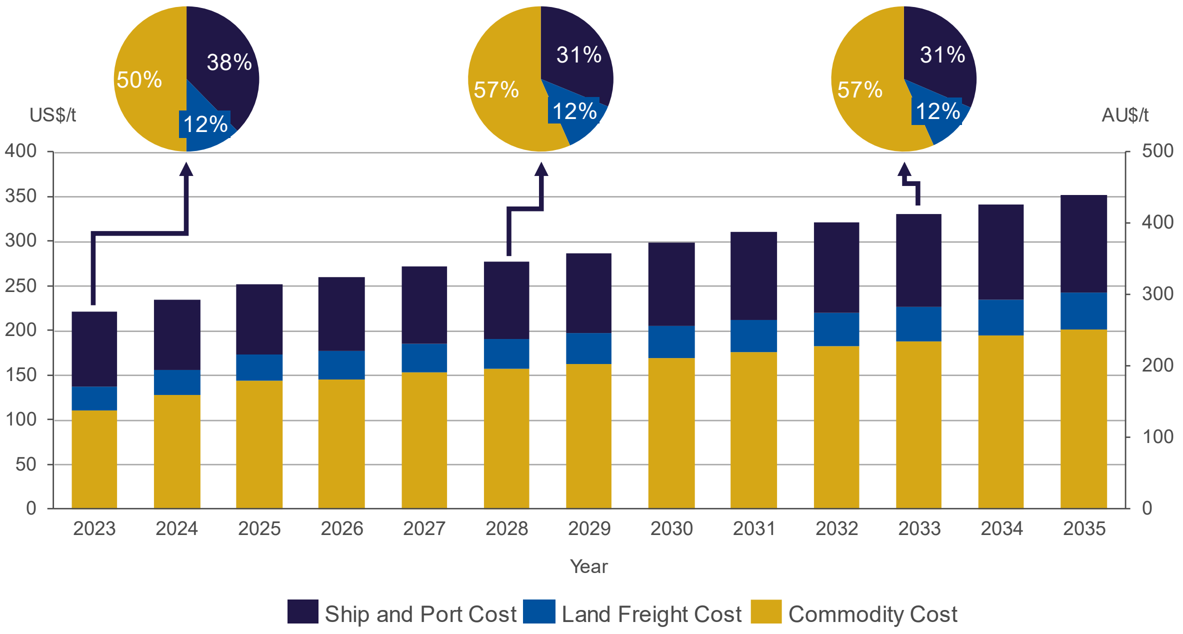
*Figure 53: Historical monthly prices of Sulphuric Acid from Asia and sulphur from Canada in both American dollars (solid lines) and Australian dollars (dashed lines). Both commodities were priced as FOB*



DATA: CRU

When adding the **cost of in-land freight and international shipping**, the site-delivered cost of sulphur and sulphuric acid is much higher (*Figure 54* and *Figure 55*). The delivered price of sulphur from Vancouver to Phosphate Hill, for example, is estimated to be comprised of 50% logistics costs. The commodity cost (i.e., sulphur FOB Vancouver) is expected to comprise an increasing portion of the site-delivered cost of sulphur over the next decade.

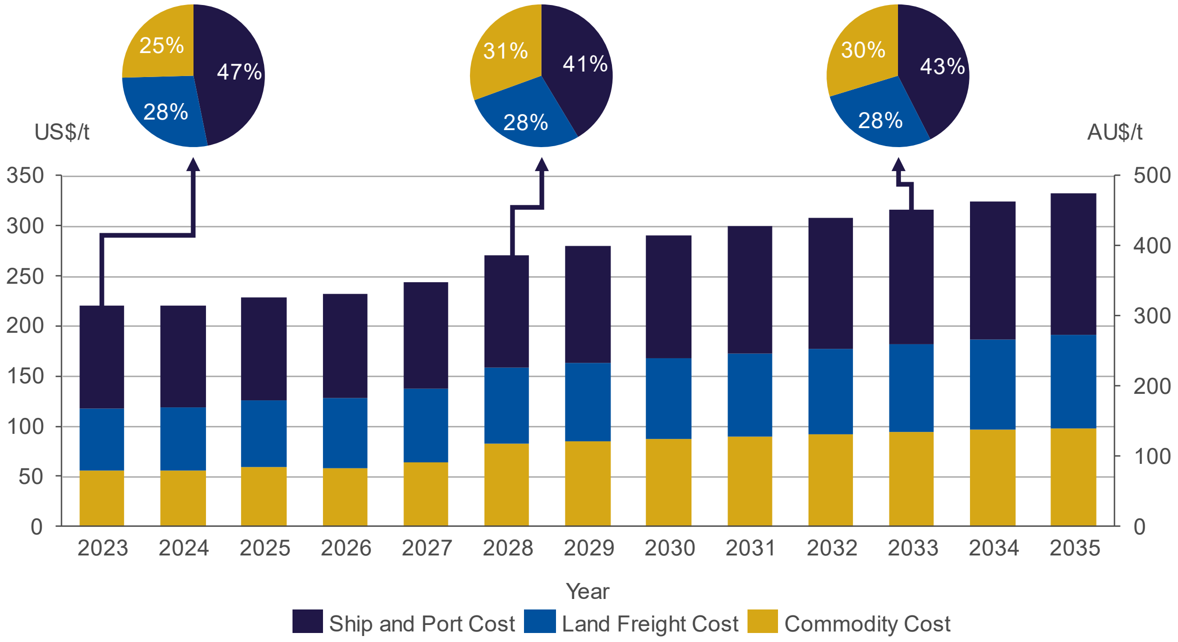
*Figure 54: Total cost of importing Sulphur from Vancouver to Phosphate Hill*



DATA: CRU
NOTE: commodity cost is FOB Vancouver

Whilst the raw commodity cost of sulphur (US$ 110 /t in 2023) is significantly higher than the cost of sulphuric acid (US$ 56 /t in 2023), the logistics cost of acid is significantly higher due to handling of liquid sulphuric acid compared to dry bulk sulphur. In a scenario where sulphuric acid is being imported from South Korea and transported to Phosphate Hill via rail, the total cost of AU$ 350 /t in 2023 and expected to rise to AU$ 470 /t in 2035 (*Figure 55*). The choice between importing sulphur or sulphuric acid depends on the viability of implementing a sulphur burner, given the associated costs of energy, water use and personnel required in the production. Importantly, given that 1 tonne of sulphur can produce 3 tonnes of sulphuric acid, it can be more economical to implement a sulphur burner if the associated production costs are 3 times less over the lifetime of the operation.

*Figure 55: Total cost of importing Sulphuric Acid from South Korea to Phosphate Hill*

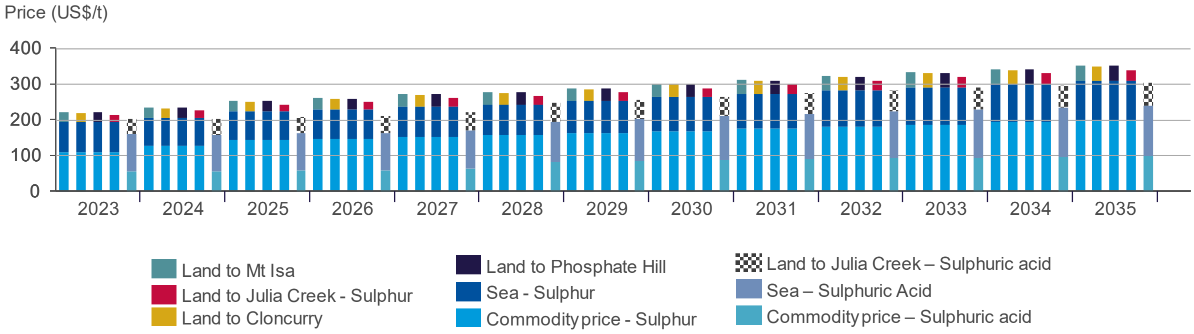


DATA: CRU
NOTE: commodity cost is FOB South Korea

The total cost of importing sulphur (from Vancouver) and sulphuric acid (from South Korea) to main locations within the NWMP and NEMPs is shown in *Figure 56*, below.

The delivered cost forecasts presented above for sulphur and sulphuric acid consider shipping, port and rail costs. However, **ancillary logistical cost considerations** are also important in the context of importing sulphur compared to sulphuric acid. Handling of sulphuric acid requires specialised facilities, including uncontaminated liquid offloading, secure storage tanks, railcar loading facilities at port, railcar offloading facilities at site, dedicated rail sidings at port and site, and specialised GATX wagons. All of these considerations require significant capital investment and ongoing operational maintenance. In comparison, handling of sulphur prill is far less capital intensive as it can be handled as a dry bulk commodity or packed in shipping containers.

*Figure 56: Cost of import and delivery of Sulphur from Vancouver and Sulphuric Acid from South Korea to various locations within the NWMP and NEMP*

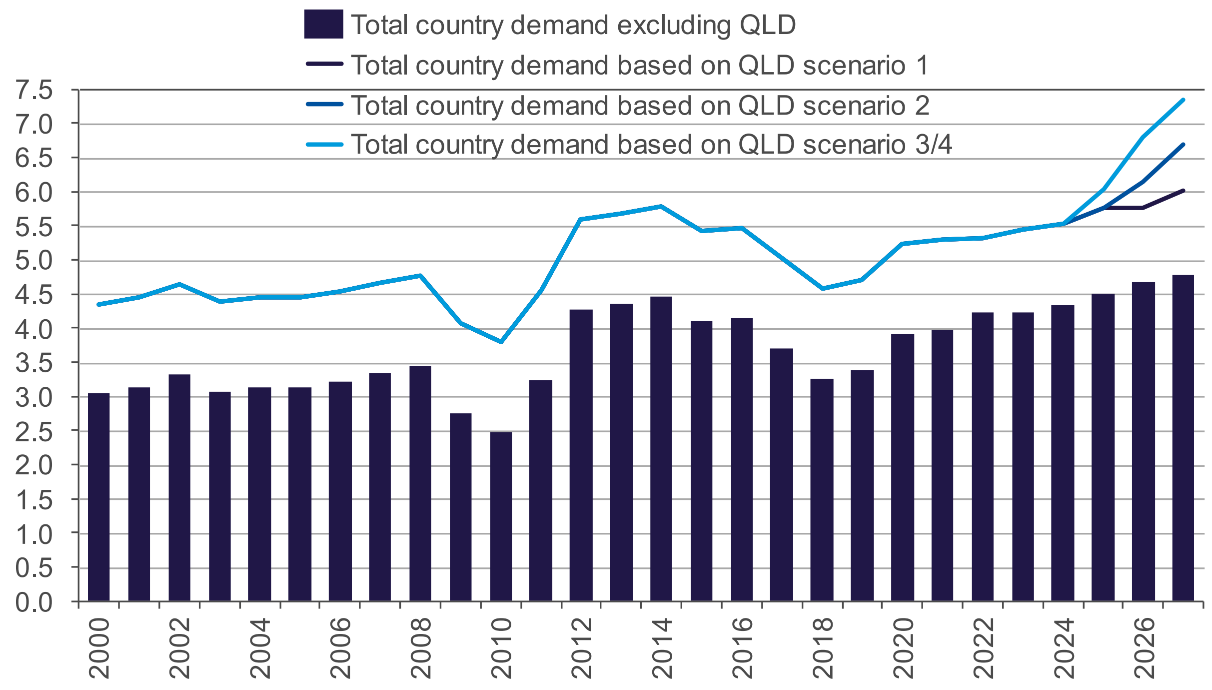


DATA: CRU
NOTE: Train transport was prioritised whenever possible, with the remainder transport done by road.

## 7.4. Ability of existing Australian domestic producers to meet NWMP and NEMP demand

Australia accounts for near 2% of the annual global consumption of sulphuric acid. Although a relatively small consumer, due to the isolated nature of the country, the large distances between its main cities, and the relatively small domestic production, meeting this demand can be a challenge. Sulphuric acid demand growth will occur throughout Australia, but significant growth will be seen in NWMP and NEMP due to a strong fertiliser base of consumption coupled with growing critical mineral industries that will be increasingly used throughout the green energy transition. From 2022 to 2027, Australian demand for sulphuric acid is expected to grow from 5 to 6 Mt at a CAGR of 3.7% (*Figure 57*). In that same period, NWMP and NEMP demand is expected to grow at more than 10% under scenario 2 (i.e., operating, and probable projects only) or 20% under scenario 3 or 4. Larger discrepancies are expected in the longer term (not shown in the graph).

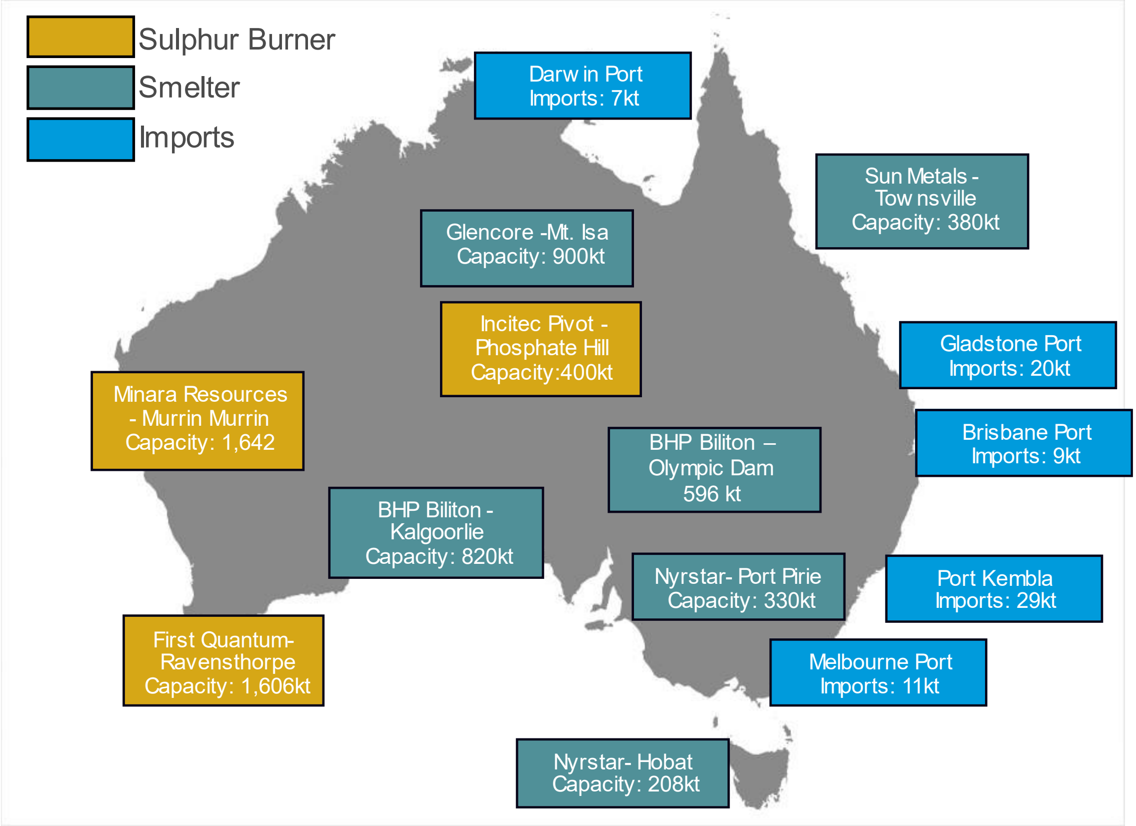
*Figure 57: Australian demand for Sulphuric Acid, with Queensland demand based on scenarios, 2000-2027 (Mtpa)*



DATA: CRU
NOTE: Scenario 1 includes operating projects only, Scenario 2 includes operating and probable projects only, Scenario 3 includes operating, probable and possible projects, and Scenario 4 includes all projects in NW-NE Mineral Provinces. Note that projects elsewhere in Queensland are not accounted for in this graph.

In 2022, Australia had installed capacity to produce nearly 7 Mt of sulphuric acid, split roughly 50/50 between sulphur burning production and smelter production based on the maximum capacity of the operations (*Figure 58*). Excluding acid producers in Queensland, the domestic capacity in 2022 was approximately 5.2 Mt. Importantly, this capacity was not reached given the utilisation rate is generally not 100%. During the same year, 76 kt of sulphuric acid was imported into Australia. First Quantum Minerals and Minara Resources, both in Western Australia, provide sulphuric acid for nickel leaching.

*Figure 58: Australian Sulphuric Acid production capacity and imports in 2022*



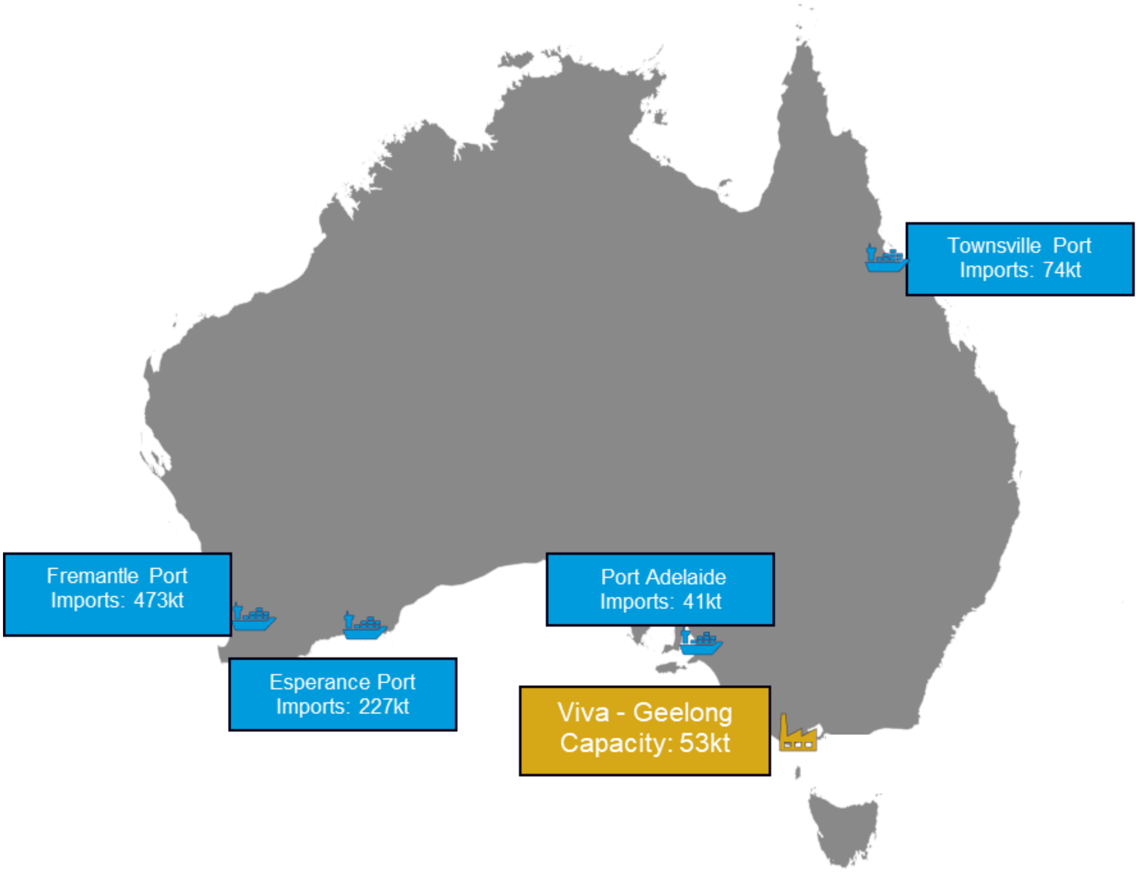
DATA: CRU

Unlike sulphuric acid, sulphur is obtained in Australia almost exclusively by imports. A maximum of 53 kt of sulphur could be produced in Australia, whereas overall imports reached over 750 kt in 2022 (*Figure 59*). In sulphuric acid terms, 750 kt of sulphur equates to 2.3 Mt of sulphuric acid. Since there are only three sulphur burners in the country, being able to produce in total 3.65 Mt of sulphuric acid, collectively, they operated at 63% utilisation rate in 2022. Given that IPL is operating at near full capacity (89%), there is scope to import extra sulphur to Minara Resources or First Quantum and ship sulphuric acid to NW-NE Minerals provinces. It is estimated that 1.3 Mtpa of sulphuric acid could be produced in Western Australia if 440 ktpa of sulphur could be secured from international sources.

Importantly, given the distance between Western Australia and the NW-NE Minerals provinces, the transport cost would be significantly higher than producing it in Phosphate Hill, for example, and distributing within the region. Murrin Murrin and Ravensthorpe are about 3,000 and 3,500 km from Phosphate Hill, respectively. This distance would incur a cost of near US$300 /t to transport sulphuric acid via road in 2023 (as opposed to about US$60 /t from Townsville Port). Shipping it is a better strategy and could be an option to explore once there is demand in Queensland before new suppliers become online and if First Quantum and Minara Resources have the facilities to transport sulphuric acid to the nearest port. However, the economics must be favourable, and sulphur must be secured under a low cost as, even when shipping, since Murrin Murrin is about 900 km from the nearest port (Geraldton), and First Quantum is 500 km from Perth, the transport cost would still be quite prohibitive.

Alternatively, one could consider increased supply from the smelters, however, as it has been discussed in *Section 4 About Sulphuric Acid*, given sulphuric acid is a sub-product of smelters, which will increase their production only if the metal they mine is under favourable economics, extra supply will need to come from sulphur burners.

*Figure 59: Australian Sulphur burning capacity and imports in 2022*

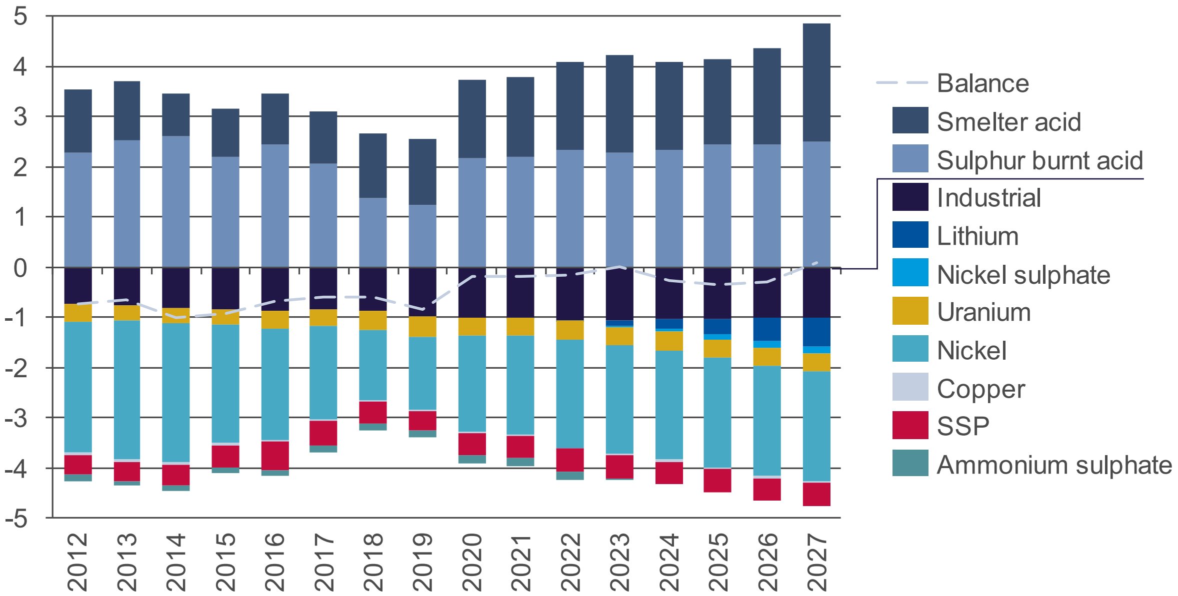


DATA: CRU

Australia (excluding Queensland) in 2022, nickel, industrial end-uses and fertilisers (SSP and ammonium sulphate) accounted for 51%, 25%, and 15% of sulphuric acid demand, respectively (*Figure 60*). Nickel production alone in Australia is expected to grow nearly 50% from 2022 to 2027, however, it will not drive up sulphuric acid consumption – major nickel projects additions such as West Musgrave (35 ktpa contained nickel production by 2027) and Odysseus (20 ktpa contained nickel production by 2027), both in Western Australia, will be producing nickel concentrate through dry grinding and flotation of sulphides, removing the need for sulphuric acid. Lithium and nickel sulphate are expected to see the most growth by volume and rate. Lithium is expected to grow from consuming 10 kt of sulphuric acid in 2022 up to 570 kt of sulphuric acid by 2027 at a CAGR of 126%. Acid demand from nickel sulphate production is expected to grow from 9 kt in 2022 up to 143 kt in 2027 at a CAGR of 73.5%.

As demonstrated in *Figure 60*, interstate acid suppliers have consistently been unable to supply sulphuric acid users, with the supply gap filled via the import of sulphuric acid and sulphur. This indicates that, under current production levels, **interstate supply is not a reliable option to supply the burgeoning growth in Queensland sulphuric acid demand**.

*Figure 60: Australian, excluding Queensland, supply (positive values) and demand (negative values) of Sulphuric Acid, 2012-2027 (Mtpa)*



DATA: CRU

# 8. Engineering scoping study

## 8.1. Scope of Work

### 8.1.1. Introduction

The primary objective of the engineering scoping study is to conduct a comprehensive high-level analysis of various options for acid production. This involves exploring methods such as the reclamation of old mine tailings to produce pyrite concentrate for roasting pyrite or burning sulphur to fulfil the anticipated future acid demand. The overarching goal at this stage is to identify the most promising acid production route or routes, which will then be subjected to a more in-depth and detailed analysis in subsequent engineering phases.

In light of the significant acid deficit anticipated for the NW-Queensland region following the recently announced shutdown of the Mount Isa Mines Copper Concentrator in 2025 and Smelter in 2030, coupled with the “probable” operational commencement of any vanadium producers in and around Julia Creek, there will be a need to explore and advance multiple engineering options to achieve a balanced supply and demand scenario for sulphuric acid.

### 8.1.2. Methodology

Core has concluded a comprehensive high-level techno-economic assessment of potential options aimed at meeting the future demand for sulphuric acid for the Queensland resources industry. In facilitating this evaluation, CRU and Core actively engaged in client meetings with prospective acid producers and consumers in the region.

The scope of the study encompassed the following key components:

1. Definition and characterisation of available pyrite sources, including pyrite in the form of tailings, waste rock and orebody. This involved assessing the size of each resource, its amenability to processing, and potential processing rates to determine the operational lifespan of each resource and the likely pyrite concentrate produced.

2. Execution of a high-level techno-economic review of sulphur burning and various pyrite concentrator and roaster options/configurations. This process aimed to establish achievable sulphur burning or pyrite processing rates, indicative acid production rates, and associated costs. The review commenced with the identification of viable options and incorporated the following considerations:

    - Evaluation of tailings reclamation and movement costs, flotation costs, pyrite and sulphur transport costs, roaster/acid plant costs, sulphur burner/acid plant costs and acid movement costs.

    - Generation of capital costs at an early Class 5 Study level, with a margin of +50% and -30% in absolute terms. Although further engineering work will be necessary for more precise cost estimates, this approach ensures a robust comparative analysis between options and enough detail to delete any obviously unviable options.

    - Determination of operating costs, accompanied by expected transport costs on a $/tonne basis. Accuracy was maintained within +50% and -30%.

    - Inclusion of simple block flow diagrams to enhance the description of the proposed options.

  - Conducting an analysis to evaluate the competitive advantages of each option, supplementing the CAPEX and OPEX figures.

The capital and operating costs presented for the various options are reflective of costs in Quarter 4, 2023. To maintain a consistent approach in comparing the engineering options, no allowances have been factored in for potential escalations in project expenses during equipment acquisition or installation phases. Given the expected variations in project timelines for each option, this method ensures a reliable basis for comprehensive comparison.

This study provides a solid foundation for informed decision-making, offering valuable insights into the technical, economic, and strategic aspects of meeting the sulphuric acid demand for the Queensland Resources industry.

### 8.1.3. Confidential

Due to commercial-in-confidence issues, the framework and results of the Engineering Scoping Study are not available in this report.

# 9. Appendices

## 9.1. Appendix A: Glossary of common terms

The following contains definitions of acronyms, terms and chemical formulas used throughout this report.

*Table 6: Glossary of common terms*

| Acronym | Description |
|---|---|
| $Al_2(SO_4)_3$ | Aluminium sulphate (alum) |
| AUD or AU$ | Australian dollar |
| CAGR | Compound annual growth rate |
| CAM | Cathode active materials |
| CFR | Cost and freight |
| CIS | Commonwealth of independent states |
| $Cl_2$ | Chlorine |
| $CO_2$ | Carbon dioxide |
| DSDI | Department of State Development and Infrastructure |
| DAP | Diammonium phosphate |
| DES | Department of Environment and Science |
| DTMR | The Department of Transport and Main Roads |
| EMM | Electrolytic manganese metal |
| EIS | Environmental impact statement |
| EV | Electric vehicle |
| $FeS_2$ | Pyrite, iron disulphide |
| FOB | Free-on-board (Incoterms) |
| GNR | Great Northern Railway |
| H1, H2 | First and second half of the year, respectively |
| $H_2SO_4$ | Sulphuric acid |
| HPAL | High pressure acid leaching |
| IHS | Information handling services |
| IP | Industrial production |
| IPL | Incitec Pivot Limited |
| JKT | Japan, Korea, and Taiwan |
| kt | Thousand metric tonnes = 1,000 metric tonnes |
| ktpa | Thousand metric tonnes per annum = 1,000 metric tonnes per year |
| ktpd | Thousand metric tonnes per day = 1,000 metric tonnes per day |
| LFP | Lithium ferro phosphate |
| LHS | Left-hand side |
| LRMC | long run marginal costs |
| MAP | Monoammonium phosphate |
| MHP | Mixed hydroxide precipitate |
| ML/a | Mega (million) litres per annum |
| MSP | Mixed sulphide precipitate |
| Mt | Million metric tonnes = 1,000,000 metric tonnes |
| Mtpa | Million tonnes per annum |
| Nd | Neodymium |
| NMC | Nickel, manganese, and cobalt |
| NW-NE | North-West and North-East |
| NWMP | North West Minerals Province |
| $P_2O_5$ | Phosphorous pentoxide |
| Pr | Praseodymium |
| Q1, Q2, Q3, Q4 | First, second, third and fourth quarter of the year, respectively |
| QLD | Queensland |
| QR | Queensland Rail |
| S | Sulphur |
| $SO_2$ | Sulphur dioxide |
| $SO_3$ | Sulphur trioxide |
| SSP | Singler superphosphate |
| SXEW | Solvent extraction – electrowinning |

| | |
|---|---|
| REE | Rare earth element |
| REO | Rare earth oxide |
| RHS | Right-hand side |
| ROM | Run of mine |
| T | Metric tonne |
| TFS | Tailings storage facility |
| tph | Tonnes per hour |
| tpd | Tonnes per day |
| TSP | Triple superphosphate |
| USD or US$ | United States of America dollar |
| $V_2O_5$ | Vanadium pentoxide |
| VRFB | Vanadium redox flow battery |
| WPA | Wet phosphoric acid |