Rimor Equity Research

In-depth • Long-term • Different

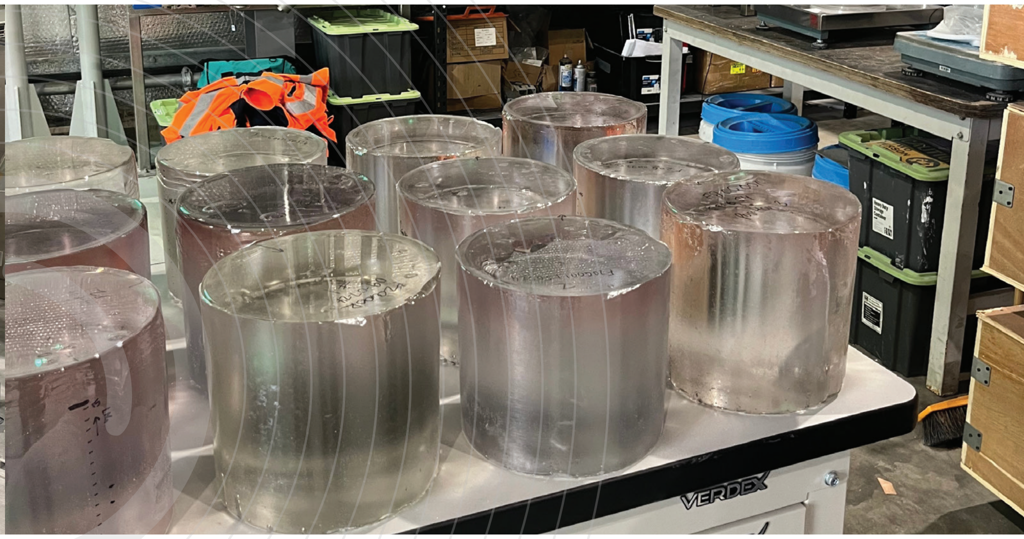
September 2025

Alpha HPA

Future-facing specialty aluminium chemicals

Scott Ryall
scott.ryall@rimorequityresearch.com.au
+61 459 110 791

Contents



Future-facing specialty aluminium chemicals

Alpha HPA (Alpha) has asked Rimor for assistance in educating investors on potential end-markets for the speciality aluminium chemicals it will produce at its Stage 2 production facility in Gladstone, due into operation by FY27. Alpha has a new method of production for such aluminium chemicals with fewer critical impurities, attractive production cost, lower environmental footprint and with specifications not commercially available. These advantages and its ability to tailor product characteristics offer optionality for development of new use-cases. It is less likely to displace supply to the LED market, the traditional use-case for high-purity alumina. We see Alpha's key opportunities are to grow with and, in some cases, enable growth in high-growth end-markets: semiconductors, lithium-ion batteries and direct lithium extraction. It also offers diversification of supply. It has letters of intent for >60% of Stage 2 capacity. The qualification process results in significant barriers to entry and its fully-financed manufacturing expansion is a differentiator. Price signals appear reasonable given it is not the key driver of customer decision-making and is not linked to commodity pricing.

A new method of production for specialty aluminium chemicals; including new chemicals

Alpha will produce specialty aluminium chemicals using an exclusively licensed solvent extraction, purification and refining process. Its ~A$50m Stage 1 facility is operational and providing samples for testing, qualification and small commercial sales allowing price discovery. Its Stage 2 production facility will have ~10ktpa capacity. Relative to current HPA (high-purity alumina) production, via leaching and calcination, Alpha has fewer critical impurities, an attractive production cost and lower environmental footprint. It also produces aluminium nitrate and alumina trihydrate in precursor steps, at purity levels not commercially available and with emerging applications in high-growth end-markets.

Enabling high-growth end-markets with product performance

The traditional high-volume market for HPA is LEDs (light emitting diodes), used in lighting, display backlighting and specialty applications. Alpha is less likely to displace material supply to these markets given current supply chains and vertical integration. Rather, it has opportunities to supply its specialty aluminium chemicals into high-growth markets: semiconductor manufacturing, lithium-ion battery (LIB) production and direct lithium extraction (DLE) – well matched to Alpha's technology and discussed in separate sections of this report. Alpha has the chance to grow with these markets and in some cases enable growth due to product purity, tailoring product characteristics to customer requirements and new high-purity chemical offerings. Alpha also offers customers the potential to diversify from current suppliers in Asia.

Significant barriers to entry: product qualification, fully-financed manufacturing expansion

As at 30 June-25, Alpha has executed LOIs (letters of intent) for >60% of Stage 2 capacity and expects to have covered all Stage 2 production under LOI by the end of CY25. This is indicative of success in customer product qualification processes, using production from its Stage 1 facility. These processes can take up to 3yrs, not only needing to meet customer requirements but also requiring downstream qualification with end-market manufacturers given the risks associated with product malfunction in high-value applications. As LOIs translate into sales and binding contracts, this creates a significant barrier to entry. Alpha expects its production cost to be in the bottom quartile and its fully-financed Stage 2 commercial production, due to ramp-up from FY27, offers supply chain credibility with customers.

A small proportion of end-product costs; pricing independent of commodity benchmarks

We analyse the value proposition for Alpha's specialty aluminium chemicals to the semiconductor manufacturing, LIB and DLE markets in this report. Price discovery reported by Alpha appears reasonable – the speciality chemicals offered by Alpha typically represent <5% of the cost of production (the exception is potential use of sapphire wafers in semiconductor manufacturing) and have a value proposition that means factors other than price are critical to customer decision making. Pricing of these specialty chemicals is also not linked to aluminium or alumina commodity prices.

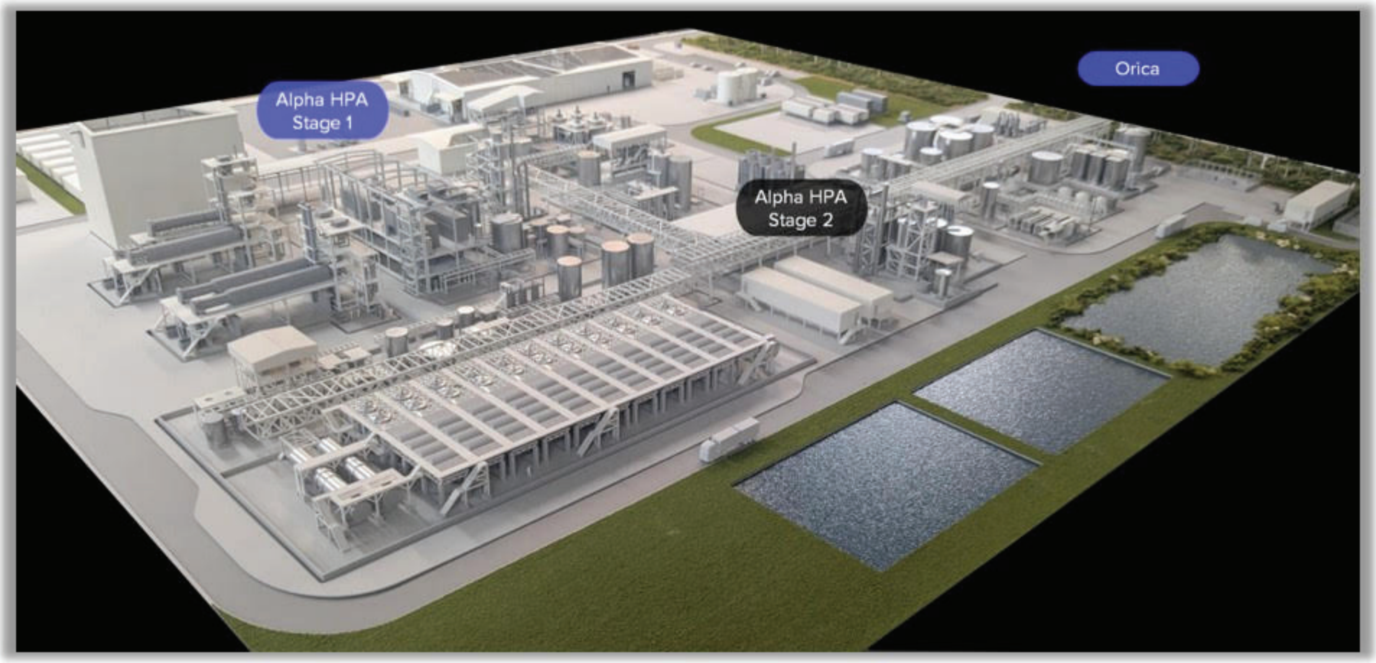
New process for specialty aluminium chemicals

Alpha has fully financed its Stage 2 production facility in Gladstone, which will add ~10ktpa capacity to its operational Stage 1 facility. It will produce speciality aluminium chemicals using a solvent extraction process unique for aluminium chemicals but used in other mineral production (eg copper and zinc). This process yields fewer critical impurities, an attractive production cost and lower environmental footprint compared to traditional HPA production. Its process also yields specialty aluminium chemicals in precursor steps with specifications not commercially available and with emerging high-growth applications. Stage 2 also enables 8-inch sapphire production. Alpha is less likely to displace material supply to the LED market, the traditional use-case for HPA, albeit it has some small LOIs with LED customers. We see Alpha's key opportunities are to grow with and, in some cases, enable growth in high-growth end-markets: semiconductors, lithium-ion batteries and direct lithium extraction. As at 30 June-25, Alpha has letters of intent (LOIs) for >60% of Stage 2 capacity, an indicator of success in product qualification processes. Alpha has a strong pipeline of further potential LOIs, spread across key geographies, and expects to have LOIs covering all Stage 2 production by the end of CY25. The next step is translating these to sales and binding contracts prior to first production in FY27. This will support its value proposition and create barriers to entry across these high-growth end-markets.

Alpha HPA has fully financed Stage 2 of its production in Gladstone

Alpha HPA (Alpha) produces a range of specialty aluminium chemicals using an exclusively licensed solvent extraction, purification and refining process. Its ~A$50m Stage 1 Precursor Production Facility (PPF) in Gladstone (Queensland) produces >300tpa of its full range of such chemicals that can be used for product marketing, testing with potential customers and smaller commercial sales enabling price discovery. Alpha's product mix can be varied to meet demand. In May-24, Alpha announced that it had taken FID (Final Investment Decision) on Stage 2, representing a full commercial deployment of its technology with capacity to produce ~10ktpa of its specialty aluminium chemicals.

Alpha's Stage 1 and Stage 2 schematic



Source: Alpha HPA

Construction has commenced and first production is targeted for 1H27. FID was supported by its Definitive Feasibility Study (DFS) and funding for capex of A$553m (including A$79m contingency) comes from the following:

- Up to A$400m of debt from Northern Australia Infrastructure Facility (NAIF) and Export Finance Australia (EFA), comprising A$320m project debt and a A$80m cost overrun facility;
- ~A$180m of new equity raised;
- Australian government grants of A$45m (90% to Alpha, 10% to Orica); and
- Queensland government grants of ~A$22m.

The photo below shows the location of Alpha's facility in Gladstone – the Stage 1 facility already complete with bulk earthworks complete for Stage 2, across the road from Orica's Yarwun ammonium nitrate plant and with Rio Tinto's Yarwun alumina refinery in the background.

Location of Alpha's Gladstone facility, next to Orica's Yarwun plant

Source: Alpha HPA

A range of specialty aluminium chemicals using a new process

Specialty aluminium chemicals, such as HPA, have a range of properties that make them well-suited for LED and other high-technology electronics applications that we discuss in this report:

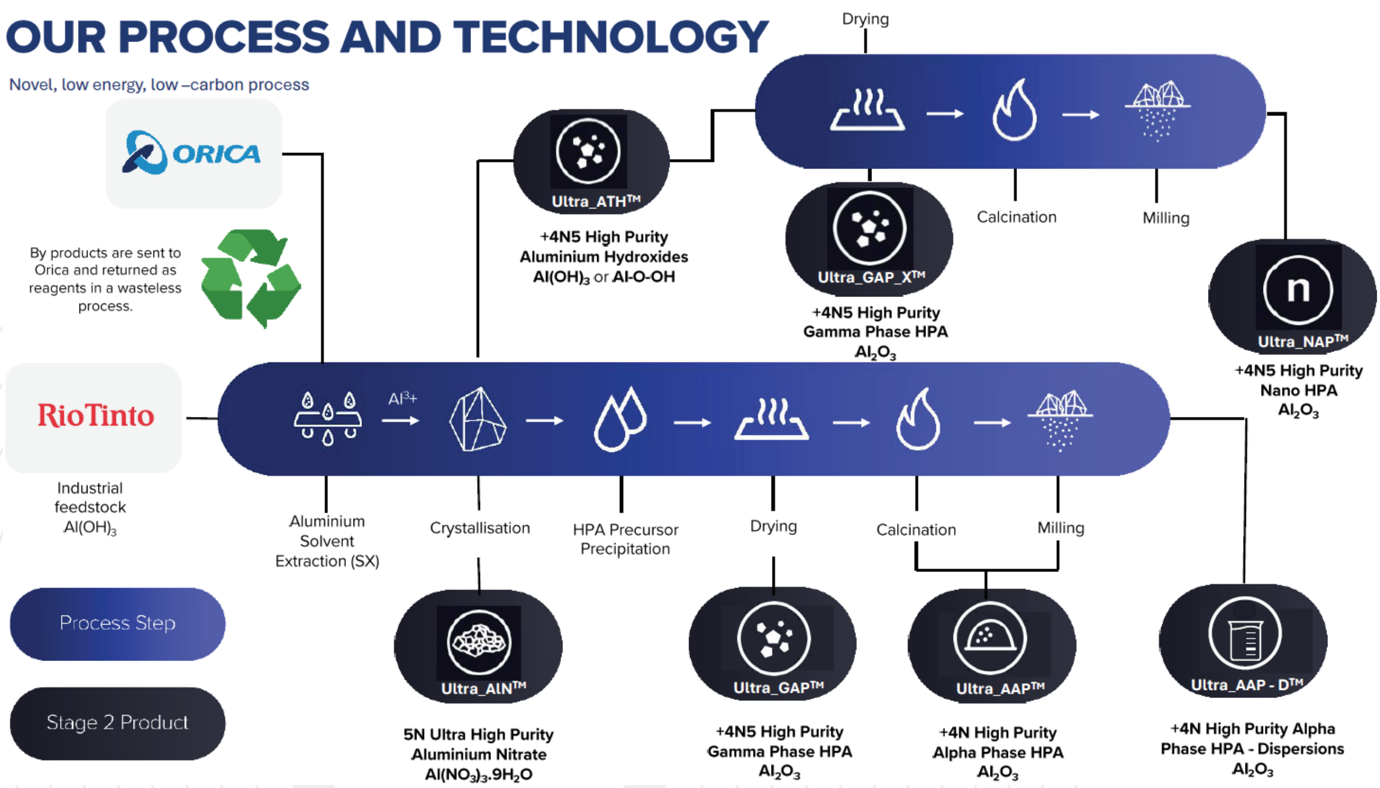
- High hardness, which can be used for abrasive materials or contribute to structural integrity and durability;
- High thermal conductivity, meaning it can be effective in dissipating heat in high-temperature use-cases;
- Good electrical insulation, meaning it can effectively insulate components of devices;
- Optical transparency in crystal form, a key reason for it being used for LEDs;
- Chemically stable, particularly to acids, bases and solvents; and
- Relatively cost-effective compared to alternate materials.

Alpha can produce high-purity specialty aluminium chemicals with product characteristics not commercially available…

The chart below shows the process flow of Alpha's production facility and the products that are produced (there is scope to flex production between products shown and produce new products as it continues to engage with current and potential customers). Key points to note are:

- Alpha receives alumina trihydrate (ATH) from Rio Tinto's nearby Yarwun alumina refinery. This feedstock is an intermediate product for Rio, prior to export, with ~97% purity. This is lower than Alpha's products: in the chart, 4N refers to 99.99% purity, 4N5 refers to 99.995% purity and 5N refers to 99.999% purity.
- Alpha receives some reagents from Orica's Yarwun plant and returns associated by-products to Orica for use in its own manufacturing process. The circular process gives some price protection for Alpha and is key to Alpha's low manufacturing costs.
- Other chemicals used in Alpha's solvent extraction process are sourced from multiple suppliers, with the solvent mixture a key part of its intellectual property. Solvent extraction is widely used in processing other minerals (eg copper and zinc), but Alpha is the first company to use this process in creating specialty aluminium chemicals. Other steps within the production process are self-explanatory.
- This process has a lower environmental footprint and fewer critical impurities compared to HPA from traditional production methods, as described below.
- A further advantage of Alpha's process is the production of high purity aluminium nitrate and ATH in precursor steps. These chemicals, at this purity level, are not commercially available and have emerging applications in high-growth end-markets discussed in more detail below and in the remaining sections of this report. Note we may not cover all demand and use-cases for these chemicals – they may evolve as product testing takes place.

Alpha's process flow and products produced



Source: Alpha HPA

Samples of the product range can be seen below. While difficult to see from a photo, the difference between gamma phase HPA and alpha phase HPA is most surprising when handled – due to additional processing, alpha phase HPA is significantly heavier due to being harder and higher density. These products are then suitable for the different applications discussed below. On the far-right of the photo are the sintered tablets (from alpha phase HPA) that can be used for sapphire production. We have not shown the nano HPA product in the photo, but as the name suggests these are very small particles (sizing down to 50nm). Our feedback from industry contacts is that Alpha's ability to vary the size and shape of its specialty aluminium chemicals to test different applications and optimise performance is an important source of innovation for customers – this is discussed further in each of the following sections of the report.

The products within Alpha's process flow

Source: Rimor Equity Research

… Sapphires an increasingly important part of the offering

In March-23, Alpha announced a collaboration with Ebner-Fametec to utilise its alpha phase HPA (in sintered tablet form) to produce synthetic sapphire boules. Ebner-Fametec first produced sapphire boules (single crystals) in 2012, and its equipment can produce 6 or 8-inch (diameter) products – we believe Alpha is focused on the 8-inch market given 6-inch sapphire boules are widely available in the Asian market. Alpha completed its first production run in May-24. The photos below show sapphire boules, with the Ebner-Fametec machine in the background and an example of a wafer (note that wafers for semiconductors are typically thinner than this).

Sapphire boules from Ebner-Fametec machine

Source: Rimor Equity Research

Synthetic sapphire wafer

Source: Rimor Equity Research

Industry contacts who suggest that the process developed by Ebner-Fametec is cost-competitive with Asian production due to improved yield from its 8-inch boules (i.e. there is less waste during production of wafers). Alpha initially indicated it had interest from customers in the LED and optics markets (consistent with the traditional markets for HPA). In May-25, when Alpha announced it had secured a commercial facility for expanded production of synthetic sapphire near Brisbane, it indicated that the main growth prospects appeared to be in the semiconductor industry. This is consistent with our industry feedback and discussed in the semiconductor section of the report.

Fewer impurities, attractive cost and lower environmental footprint vs traditional HPA production

There are two potential alternate pathways for producing HPA currently. Both use alumina that is produced from bauxite using the Bayer process. The key step beyond the ATH product (that Rio also supplies to Alpha) is a calcination at over 1,000°C to produce smelter-grade alumina (~99.5% purity). From there:

1) Alumina is further processed by electrolysis in an aluminium smelter into finished aluminium metal (this process uses a significant amount of electricity), before HPA is produced using an alkoxide process (reacting aluminium metal with an alcohol in the presence of a catalyst, then reacting this with water, precipitation/washing and a further calcination process at 1,100-1,200°C to yield HPA). There is little opportunity for further purification using this process, meaning the quality of the feedstock metal largely dictates the impurity profile of the HPA.

2) Alumina or ATH from the refinery can be leached, often with hydrochloric acid, to remove impurities (e.g. iron, sodium, silicon and calcium) and the product then undergoes a further calcination process at ~1,200°C to yield HPA. This pathway is less common.

It is clear from these process steps that this process is energy and chemical intensive. Alpha has estimated that its production process can reduce GHG emissions by 60% of more (depending on the source of electricity: source Alpha) and alternative processes have further potential environmental impact from chemicals used. In addition, as discussed in the end-market sections below, there are potentially some impurities from traditional production methods that may mean HPA from these sources is not suitable for some of these high-growth end-markets. CRU has also published research highlighting that Alpha's expected production unit cost of <US$7/kg (from Alpha's May-24 DFS) would be at the bottom of the cost curve, well below incumbents at >US$12/kg.

Enabling high-growth end-markets and diversification of supply…

The traditional market for HPA is LEDs (light emitting diodes), used in lighting (residential, commercial and automotive), display backlighting (in a range of consumer electronics for TVs, smartphones and laptops) and specialty applications. This is consistent for sapphire, which has been used for micro-LED and optical applications such as smartphone cameras and smartwatches. There is clear potential in these markets, particularly if customers want to diversify supply sources – however without such a tailwind it may be difficult for Alpha to displace material supply to these end-markets given current supply chains and vertical integration. Alpha has some smaller LOIs with customers in the LED market.

In our view, Alpha's primary opportunities for its specialty aluminium chemicals are into a range of high-growth markets that require additional supply, require the low impurities Alpha's products offer and/or can utilise the new chemicals offered. For each of Alpha's chemicals to be produced, the table below shows the planned volumes from May-24 (when it announced FID) and potential end-markets. The primary end-markets we discuss are semiconductor manufacturing, lithium-ion battery (LIB) production and direct lithium extraction (DLE). Alpha has the chance to grow with these markets and in some cases enable growth due to product purity, tailoring crystal structures and new chemical offerings.

The volume split could change over time depending on ultimate end-market demand. Alpha continues to provide test samples and product variants (customised size, shape, surface area, etc) to potential customers for use-cases we may not cover. The nature of demand could evolve as product testing takes place, particularly given two products are not commercially available. The most recent example is in the technical ceramics market. On 26 June-25, Alpha indicated had developed "an ultra-high density HPA tablet at 5N purity", made at the request of an end-user, to use as feedstock to "machine high-end machinery parts used in semiconductor fabrication (e.g. electrostatic chucks)". This could change the volume delivered from Stage 2 as aluminium nitrate has a ~7.4x multiple relative to HPA production (i.e. the 3.5ktpa of aluminium nitrate shown in the table below would produce <500tpa of HPA) and ATH has a ~1.5x multiple.

Alpha's products, Stage 2 planned production and high-growth end-markets likely to be serviced

Product	Stage 2 production (tpa)	End-market use case (discussed in specific section of report)
Aluminium nitrate: $Al(NO_3)_3.9H_2O$	3,500	Lithium-ion batteries
Aluminium hydroxides: alumina trihydrate (ATH), $Al(OH)_3$, or Al-O-OH	1,700	Semiconductors Lithium-ion batteries Direct lithium extraction
High purity alumina (HPA), Al_2O_3, gamma phase	2,000	Semiconductors Lithium-ion batteries
High purity alumina (HPA), Al_2O_3, alpha phase	3,200	Semiconductors Lithium-ion batteries
High purity alumina (HPA), Al_2O_3, nano phase	30	Semiconductors Lithium-ion batteries
Sapphire	na	Semiconductors
Total	**10,430**	
HPA equivalent volume	**6,817**	

Source: Alpha HPA, Rimor Equity Research

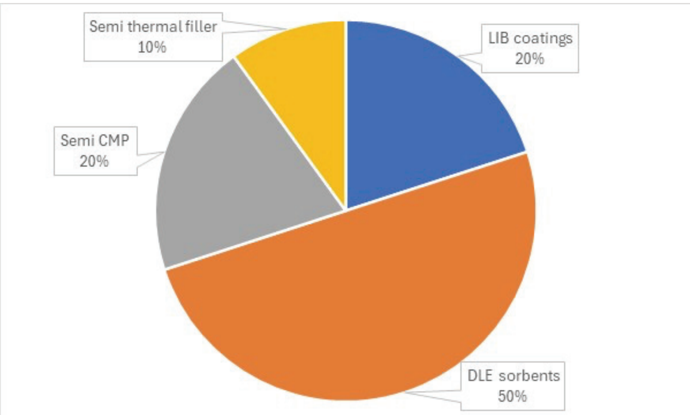
… LOIs >6ktpa so far and a strong pipeline of opportunities

As at 30 June-25, Alpha has executed LOIs (letters of intent) for >60% of Stage 2 capacity. This is indicative of success in product qualification processes with customers. As discussed in each of the end-market sections, these are extensive processes – not only does the product need to meet customer requirements but also requires downstream qualification with end-market manufacturers given the risks associated with product malfunction. Sales/binding contracts tend to follow LOIs with a lag as there is significant detail to finalise with customers and end-market manufacturers.

In breaking down its opportunities further, Alpha released the following information in its 3Q25 activities report:

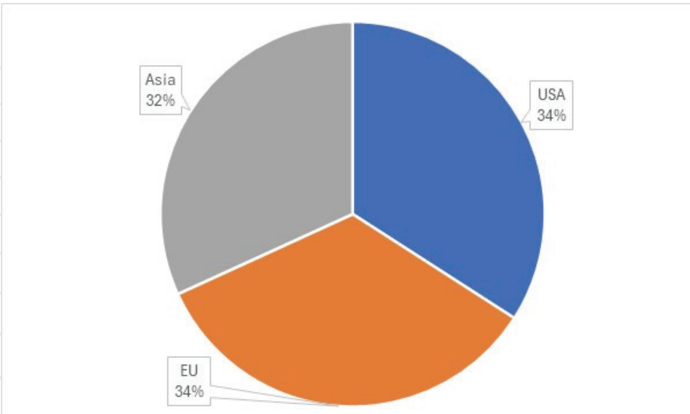
- **LOIs covering >60% of Stage 2 capacity.** Alpha indicated >80% of its LOIs signed to date were for semiconductor end-markets, with ~4ktpa for CMP and ~1.1ktpa for thermal filler applications. The remainder of LOIs are split between LIB, LED and technical ceramics end-markets. In a 26 June-25 release, Alpha stated it had five further LOIs "under draft" and a potential expansion of an existing LOI for semiconductor thermal filler applications. Alpha expects to have covered all Stage 2 production under LOI by the end of CY25.
- We have not analysed the technical ceramics market in detail but note this is for the manufacture of alumina ceramic parts for advanced functional use. Alpha indicated on 26 June-25 it had developed "an ultra-high density HPA tablet at 5N purity" to use as feedstock to "machine high-end machinery parts used in semiconductor fabrication (e.g. electrostatic chucks)" – this is an example of such a use-case.
- **Alpha's estimation of unmet demand ~50ktpa.** This is based on Alpha's own experience in customer negotiations. As can be seen in the left-hand chart below, this is spread across the three main end-markets we have discussed in more detail in the following sections of the report.
- **Alpha's product qualification testing is roughly evenly split between US, Europe and Asia.** Alpha has indicated that its products are undergoing qualification testing for an estimated >40ktpa of product demand (less than unmet demand as Alpha is not qualifying with all potential customers). This has a healthy geographic spread, as well as being across the three end-markets we discuss in more detail as well as the traditional LED market.

Alpha's estimate of unmet demand by end-market



Source: Alpha HPA, Rimor Equity Research

Alpha's product qualification testing by location



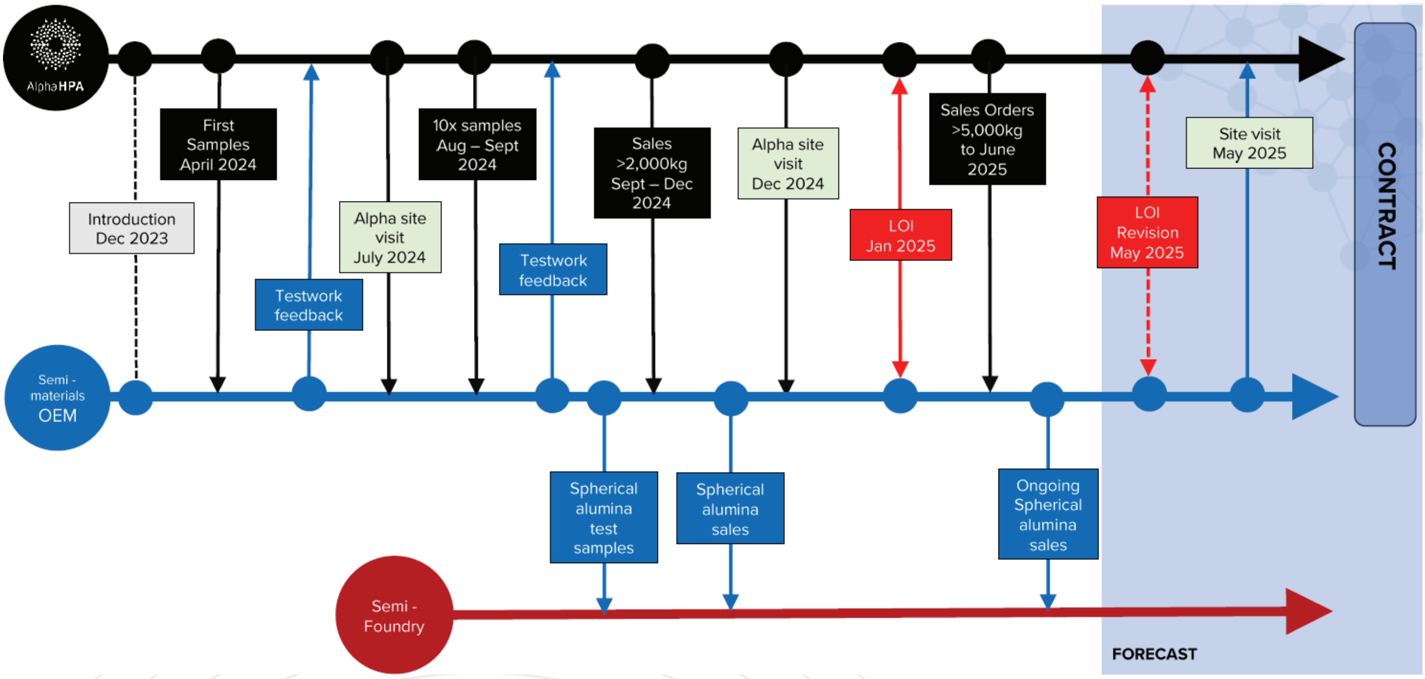
Source: Alpha HPA, Rimor Equity Research

The link between LOIs and sales contracts

At this point it is worthwhile highlighting the link between LOIs and sales/binding contracts. As seen in the chart below:

- LOIs lag the provision of test/qualification samples to potential customers. Customer testing in the three end-markets we discuss in this report are extensive processes – not only does the product need to meet customer requirements, but these customers also require new inputs to achieve downstream qualification with end-market OEMs given the risks associated with product malfunction in high value applications. With multiple steps in the value chain, this can take significantly more time, as seen in the chart below – Alpha commenced testing with a semiconductor materials OEM in Dec-23, but testing with the chip foundry only commenced in Sept-24. Executing an LOI is the first indicator of success in customer product qualification processes.

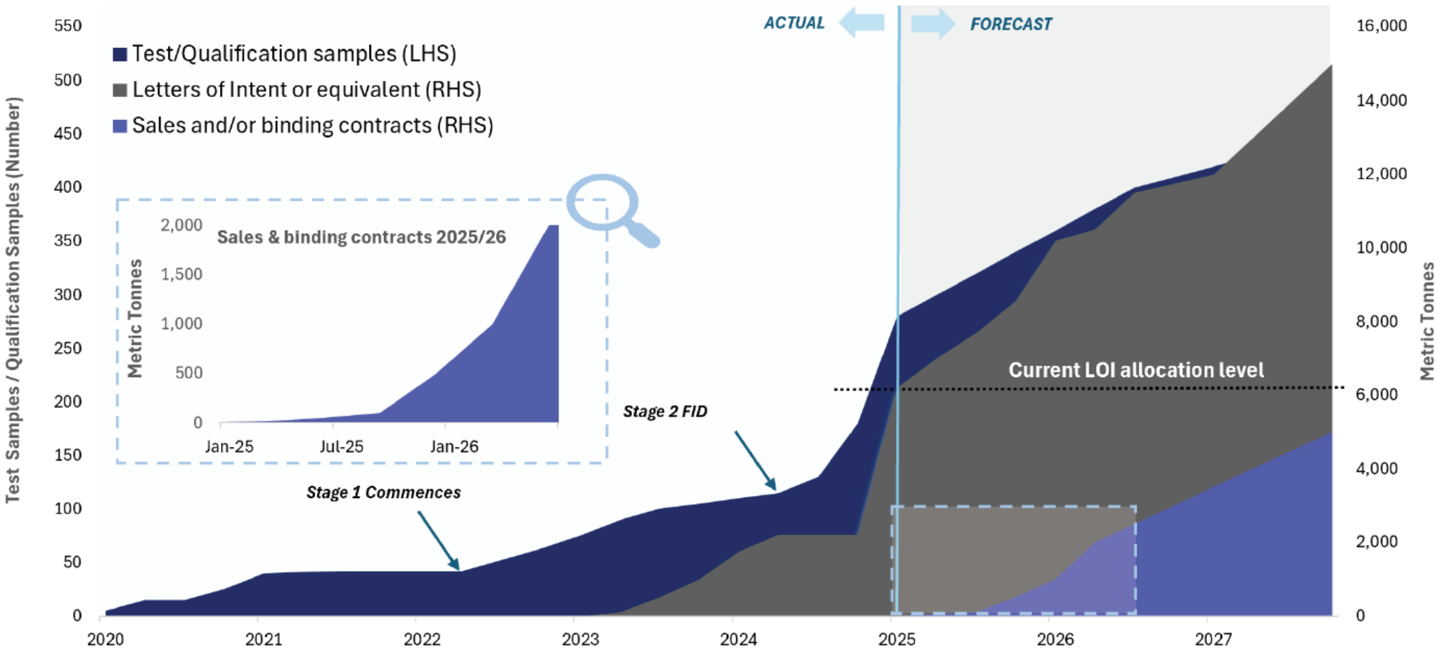
Alpha qualification case study for HPA into thermal fillers



Source: Alpha HPA

- Sales and binding contracts tend to follow LOIs with a lag as there is significant detail to finalise with customers and end-market manufacturers – as shown below, Alpha expects to execute its first sales/binding contracts with customers by the end of 2025. As Alpha progresses in the customer qualification process, this becomes a significant barrier to entry, as discussed below.
- The availability of product, and particularly its fully financed Stage 2 commercial production, has been a clear accelerant to customer testing and LOIs given it offers supply chain certainty with customers.

Alpha's product marketing progression



Source: Alpha HPA

Building a value proposition and barriers to entry in high-growth end-markets

The remaining three sections of this report cover the high-growth end-markets that we believe offer significant opportunity for Alpha, as a supplier of high-purity specialty aluminium chemicals: semiconductors, lithium-ion batteries (LIBs) and direct lithium extraction (DLE). Within each of these sections, we discuss the following:

- **The strong forecast growth for each end-market.**
- **The uses for Alpha's specialty aluminium chemicals in the end-market supply chain.** For semiconductors we cover the CMP process, packaging/thermal management and sapphire wafers. For LIBs we look at separator coatings and anode/cathode coatings. For DLE we focus on adsorption materials.
- **The importance of high-purity chemicals within the end-market production process.**
- **The importance of Alpha's ability to vary the size and shape of its specialty aluminium chemicals to test different applications and optimise performance with customers.** This is part of delivering specialty aluminium chemicals with morphology (physical properties) for high performance in the use-case. Morphology can impact packing density, coating performance, porousness, reactivity, light transmission, heat dissipation, electrical conductivity. One reason we highlight the physical difference between gamma phase HPA and alpha phase HPA above is that this is driven by morphology, making the two phases appropriate for different use-cases.
- **The rigorous qualification process for supplying into each end-market and why this creates a significant barrier to entry.** The LED market, the traditional end-market for HPA, is a useful guide to such barriers to entry once supply chains are established. While there is potential in these markets if customers want to diversify supply sources, without a push for supplier diversification it may be difficult for Alpha to displace supply to these end-markets given current supply chains and vertical integration.
- **The value proposition offered by high-purity specialty aluminium chemicals.** Price discovery reported by Alpha appears reasonable – the speciality chemicals offered by Alpha generally represent <5% of the cost of production (the exception is the potential use of sapphire wafers in semiconductor manufacturing). There are a range of factors other than price that are critical to customer decision making. In addition, it is worth noting that pricing of these specialty chemicals are not linked to aluminium or alumina commodity prices.

Alpha continues to provide test samples and product variants (customised size, shape, surface area, etc) to potential customers for use-cases we may not cover. The nature of demand could evolve as product testing takes place, particularly given two of its products are not currently commercially available. The most recent example is in the technical ceramics market. On 26 June-25, Alpha indicated had developed “an ultra-high density HPA tablet at 5N purity”, made at the request of an end-user, to use as feedstock to “machine high-end machinery parts used in semiconductor fabrication (e.g. electrostatic chucks)”.

… With product technical advantages for these high-growth end-markets

Within the remaining three sections of this report (semiconductors, lithium-ion batteries (LIBs) and direct lithium extraction (DLE)), we discuss the importance of high-purity specialty aluminium chemicals and of Alpha’s ability to vary the characteristics of its chemicals to Alpha achieving a product advantage for these high-growth end-markets. Alpha has the chance to grow with these markets and in some cases enable growth due to product purity, tailoring crystal structures and new chemical offerings. There are potentially some impurities from traditional production methods that may mean HPA from these sources is not suitable for some of these high-growth end-markets.

Alpha continues to provide test samples and product variants (size and shape) to potential customers for use-cases we may not cover. The nature of demand could evolve as product testing takes place, particularly given two of its products are not currently commercially available.

Technical advantages of Alpha’s products

Use-case	Products	Primary product advantage
Semiconductor thermal fillers	HPA, ATH	Eliminated radioactive material (uranium and thorium), below industry threshold levels of <1ppb
Semiconductor CMP	HPA	Tailored morphology
Direct lithium extraction sorbents	ATH	Amorphous crystal structure New chemical
Lithium-ion battery coatings	HPA, Aluminium nitrate	5N purity New chemical offering at these purity levels

Source: Alpha HPA

Semiconductors

The semiconductor sector has taken on increased geopolitical importance in recent years and is a key enabler of electrification and digitisation. The semiconductor industry is changing to enable new technologies for new markets – continued innovation will likely require new materials to improve capabilities. Alpha can produce a number of specialty aluminium chemicals that appear well suited to high-growth segments within the evolving semiconductor market: ATH, HPA and sapphire. The semiconductor end-market accounts for >80% of customer LOIs signed to date (~5.1ktpa), validating Alpha's reported performance advantages and reflecting the innovation-driven need for new materials. High performance semiconductors have the potential to increase demand for HPA due to the need for higher performance packaging and thermal management. High-power semiconductors, such as silicon carbide and gallium nitride, could use Alpha's products for chemical mechanical polishing (CMP), packaging and thermal management and wafer substrate material. Industry contacts suggest Alpha is well-placed given its aluminium chemicals are high-purity and low contamination levels (radioactive or other impurities), can be provided with varying product characteristics (which it has done for CMP applications) and have reported performance advantages. HPA in CMP and packaging typically accounts for <5% of the cost of a high performance or high-power semiconductors; more if sapphire is used.

Alpha's products appear well suited to high-growth segments within the evolving semiconductor market given high-purity products with performance advantages…

Alpha's process flow (see Section 1) will produce a number of specialty aluminium chemicals that could be used in the semiconductor market: ATH (which can be used directly or can be decomposed to form HPA), HPA and sapphire. It may be more difficult for Alpha to displace product supply into the traditional silicon semiconductor market unless customers want to diversify supply sources. However, the semiconductor market is rapidly evolving to enable future-facing applications – this will likely require new materials to improve capabilities. We see significant potential for Alpha's products to be suitable to, and in some cases enabling, high-growth segments such as:

- **High-performance semiconductors,** such as those enabling increased processing power required due to proliferation of data centres from growth in cloud computing, IoT and, more recently, AI. In these end-markets, we expect to see innovation in design and the use of new materials, such as higher performance packaging and thermal management. HPA appears to be steadily increasing its share of higher performance packaging and thermal management solutions, given its relatively high thermal conductivity and high electrical insulation, combined with being cost-effective relative to alternatives.
- **High-power semiconductors, such as silicon carbide (SiC) and gallium nitride (GaN).** These can increase the energy efficiency of semiconductors in larger electrical devices and provide superior heat management relative to current chip designs. These are relatively new markets and Alpha's products can be used for chemical mechanical polishing (CMP, both ATH and HPA), packaging and thermal management (similar to advanced semiconductors, using HPA) and wafer substrate material (sapphire, for GaN semiconductors). The benefits of HPA are similar to those discussed for advanced semiconductors.

Industry contacts suggest Alpha has a strong prospect of supplying into these markets given its ability to supply high-purity specialty aluminium chemicals with low contamination levels from radioactive or other impurities, of varying product characteristics to test different applications, and have reported performance advantages. We expand on the importance of these advantages in the remainder of this section, in brief:

- **CMP process.** Alpha has stated that customer testing is indicating "+50% removal rate improvement in both wafer and package polishing" due to its morphology – Alpha can change the morphology of its chemicals in precursor steps. Alpha's products also contain low levels of alkali metals (e.g. sodium and potassium), which can lead to semiconductor performance issues if used in the CMP process.
- **Packaging and thermal management.** Alpha has reported that its product has "non-detect levels of uranium and thorium" and qualifies as a 'low-alpha' feedstock as a result (as below, 'low-alpha' product has no detectable alpha radiation). Alpha has stated that its novel purification process (discussed in Section 1) has eliminated radioactive impurities (source: Alpha's 3Q25 activities report).

… The largest source of Alpha's LOIs to date

As at 30 June-25, Alpha indicated >80% of customer LOIs signed were for semiconductor end-markets, with ~4ktpa for CMP and ~1.1ktpa for thermal filler applications. The semiconductor market makes up ~30% of Alpha's estimate of unmet demand – this estimate for the semiconductor sector is greater than the capacity of Alpha's Stage 2 facility.

Semiconductors – essential for an electric world; increased focus and growth globally

Semiconductors are used in the production of electronic devices, enabling the function of various components by controlling electrical currents. They are used in small devices (e.g. smartphones, TVs, robotics and medical devices) or larger devices (e.g. EVs, telecommunication networks, renewable energy systems, power grids and industrial motors) and are essential for the manufacture and function of these devices.

While known as enablers for some time, semiconductors have entered broader consciousness in recent years due to:

- Supply chain constraints after the impact of COVID-19;
- Geopolitical concerns around concentration of supply;
- Trade restrictions such as tariffs and export controls;
- Increased demand due to an increasing shift towards electrification;
- Increased demand due to increased processing power requirements of data centres; and
- Increased demand due to increased data centre processing requirements, particularly to support AI capability.

The combination of these factors has led to an increased focus on semiconductor production by corporates and governments alike. One industry contact recently stated 'the secret sauce of the semiconductor supply chain is quality control at every stage of the manufacturing process' and awareness around the number and complexity of steps to producing semiconductors has become more apparent to a wider audience in recent years.

The US has been the most active in incentivising semiconductor investment; with other countries following

The highest profile government action had been the US CHIPS and Science Act (CHIPS Act), signed into law in Aug-22, that provided US$52.7bn for "American semiconductor research, development, manufacturing, and workforce development". In 1990, the US accounted for ~40% of global semiconductor manufacturing – at the time of the legislation, this had reduced to ~10% (and none in advanced areas). This was seen as a significant strategic risk for defence and other sectors deemed critical for future economic growth and national security. The CHIPS Act also prohibits funding recipients from expanding semiconductor manufacturing in China and other "countries of concern".

In Aug-24, the White House stated that companies have announced >US$395bn of investments in semiconductors and electronics, backed by US$30bn of direct funding and US$25bn of loans for semiconductor manufacturing projects. The White House release stated it expected the US to produce nearly 30% of "leading-edge chips" by 2032, from none previously (source: White House). Further funding awards were made over the course of 2024.

While there were some concerns that the Trump administration would seek to repeal the CHIPS Act, it appears that its focus is renegotiating existing grants and other changes. Its most meaningful success in this area was to increase the investment to be made by TSMC from US$65bn to US$165bn. So while changes to the mechanism of incentivising investment in the semiconductor industry may change, the desire of the US to drive increased investment in the semiconductor industry cannot be doubted.

Similar to a number of major US industrial policies from recent years, there have been policy reactions from the EU and Asian countries. Two of the more meaningful have been:

- **South Korea**. In March-23, Korea announced that it would aim to incentivise more than US$400bn of investment in silicon chip, EV and battery manufacturing domestically in a multi-year investment plan. This is backed by a number of companies also active in the US such as LG Energy, Samsung and SK On.
- **Europe**. In Sept-23, The EU approved the European Chips Act to "bolster Europe's competitiveness and resilience in semiconductor technologies and applications, and help achieve both the digital and green transition". The EU highlighted that European demand for semiconductors was expected to double by 2030 and that its action was at least partly to address the recent "semiconductor supply crisis". The EU expects more than €43bn of policy-driven investment under the act, to be broadly matched by the private sector.

It is beyond the scope of this report to analyse which countries are likely to be the most successful in building a resilient semiconductor industry – our main takeaway is that governments in major jurisdictions see this industry as highly strategic and are actively supporting production growth to enable other industries deemed strategic.

The needs of the semiconductor industry are changing to enable new technologies for new markets, also requiring new materials

Although there are differences in the composition of traditional silicon semiconductors, most comprise of:

- **Silicon wafer**. Made from high purity silicon that has been grown into a large single crystal (a boule).
- **Dopants**. Trace impurities are added to enable conductivity.
- **Dielectric layers**. To insulate different regions of the chip.
- **Conductive materials**. These enable circuits and interconnections to be formed.
- **Packaging materials**. To protect the chip and allow heat dissipation.

At the same time as semiconductor industry is coming into increased focus (as explained above), it is also seeing rapid change and innovation due to a combination of the following:

- Demand for increased processing power due to proliferation of data centres from growth in cloud computing, IoT and, more recently, AI.
- Increased electrification.
- Geopolitical competition, driving significant investment and movement in supply chains.
- A shift of manufacturer strategy from a focus on cost optimisation to a more balanced strategy that increases the importance of resilience. Key ways to do so include diversification of suppliers, long-term supply agreements and dual sourcing for key components.

We expect to see ongoing improvements to semiconductor design in response to such changes and to enable increased semiconductor use for future-facing applications. Based on industry feedback we expect to see innovation in the use of new materials in semiconductor design in addition to mitigate some of the constraints with current materials as designs are changed. We view this as a key opportunity for Alpha, i.e. enable high-growth markets rather than attempt to displace supply to current end-markets. We discuss two specific high-growth markets within semiconductor production.

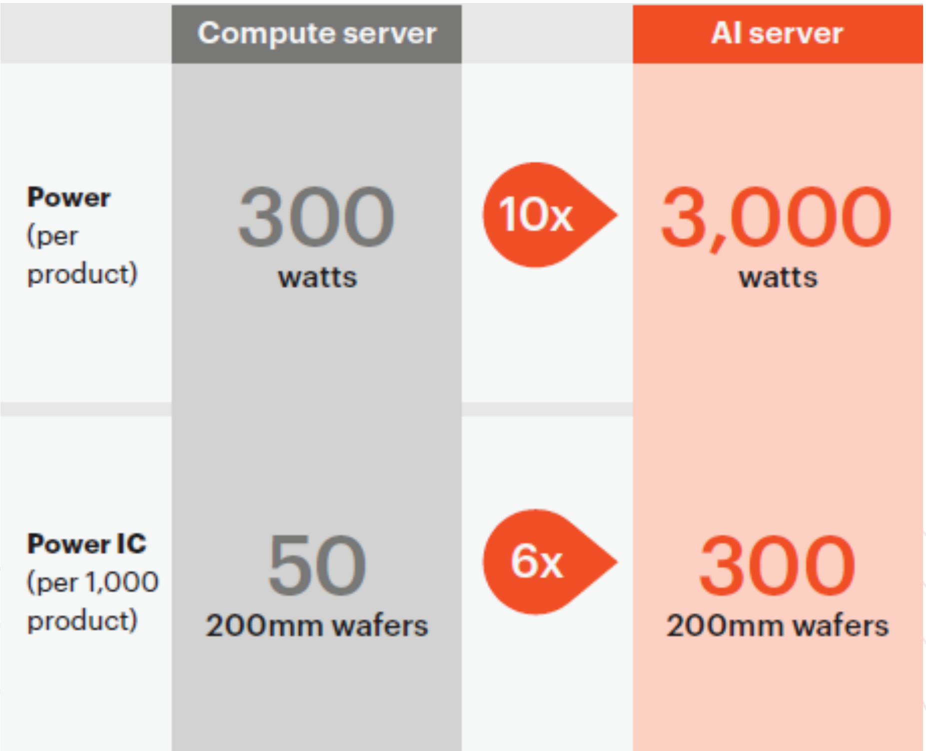
1. **High performance semiconductors for high performance processing.** Applications such as AI, high quality graphics and high-performance computing in scientific applications require high performance processing that enables speed and energy efficiency that is not possible using traditional semiconductors.
2. **Silicon carbide and gallium nitride semiconductors for high power applications.** These can increase energy efficiency of semiconductors in larger electrical devices and provide superior heat management relative to current chip designs.

1. High performance semiconductors are critical for high performance processing

There are a range of emerging applications that require speed and energy efficiency that is not possible using traditional semiconductors. The demand for high performance processing in these applications is driving demand for HBM (high bandwidth memory) chips, to be used in high performance parallel processors. Examples of these applications include:

- **AI.** This is one of the most important drivers of high-processing demand and hence the demand for high performance semiconductors. Kearney's PERLab recently forecast AI server volumes to grow by 40-50%pa CAGR between 2024 and 2027. AI servers are a subset of total services but, given increased power requirements, are a key driver of high-performance semiconductor demand (see chart below, source: Kearney).
- **High quality graphics.** This is relevant for both consumer (e.g. gaming) and commercial (e.g. media production) applications. Frame speed and other such improvements require significant and fast processing capacity.
- **High-performance computing.** This is particularly relevant for scientific applications – simulation, modelling and other tasks require significant and fast processing capacity.
- **Data centres and telco network equipment.** Telco infrastructure requires more rapid processing and routing to enable use-cases that are being provided to consumer and commercial customers.

Power comparison between compute and AI server



Source: Kearney PERLab

Moore's Law has been a guiding principle for semiconductor innovation…

Moore's Law has been a guiding principle for semiconductor industry innovation since Intel co-founder George Moore published his seminal paper in 1965 – it was revised in 1975 to a prediction that "the number of transistors on an integrated circuit will double every two years with minimal rise in cost" (source: Intel). Over this timeframe, a key way of keeping pace with Moore's Law was to reduce the size of the transistor – the most advanced are now 2nm and below (supplied by TSMC as market leader), down from 90nm in 2003/04.

Industry contacts suggest that 2nm transistors are approaching theoretical size limitations, but the drivers of change above are leading to ongoing innovation in semiconductor design and manufacturing to further improve performance. Innovations such as 3D packaging/stacking, chiplets, EUV (extreme ultraviolet) lithography and GAAFETs (Gate-All-Around FETs) are mostly beyond the scope of this report, but the goals are broadly consistent:

- Boosting and optimising data throughput;
- Increased memory bandwidth; and
- Improved energy efficiency.

… Constraints to further developments are leading to innovation in use of new materials

As further advances in semiconductor manufacturing are made, there are some key constraints to keep in mind:

- **Growing energy requirements.** Industry contacts have confirmed the energy intensity of data centres is increasingly in focus, particularly from industry players and regulators. This is amplified by the transition towards AI and other workloads that require rapid interconnects between chips, which is more energy intensive than traditional use-cases. To illustrate this, Texas Tech University System and Fermi announced in June-25 a partnership to build an AI campus near Amarillo, Texas, powered by up to 11GW of electricity. One focus for innovation is improving semiconductor energy efficiency, i.e. maximising performance per unit of energy.
- **Heat management more important.** As transistors are added to each integrated circuit and chips become more complex, heat is more of an issue for the semiconductor. Higher temperatures can impact semiconductor speed, reliability and longevity. Up to 40% of electrical demand for new AI data centres is for cooling, using the traditional method of air-cooling. While liquid cooling can reduce this meaningfully, heat management remains a large driver of energy demand. Thermal management of AI chips is increasingly a critical area of focus – each AI integrated circuit is made up of multiple HBM chips and high-performance parallel processors. As above, with transistor size falling below 5nm in many cases, ensuring that heat is dissipated effectively and efficiently with high quality packaging becomes more important (and expensive) as the chip becomes more complex.
- **Error tolerance within chips reduces, increased focus on impurities.** One industry contact recently stated 'the secret sauce of the semiconductor supply chain is quality control at every stage of the manufacturing process'. As transistors become smaller, there can be more interaction between components and therefore less margin for error in the operation of the chip. With error tolerance within chips reducing as transistors become smaller, the importance of reducing impurities in the manufacturing process increases. Materials that can enable such advances are critical, as are the absence of impurities such as radioactive material that can cause greater issues as error tolerance within chips reduces (discussed in more detail below).

While there is potential to improve semiconductor design to mitigate these constraints, based on industry feedback we expect to see innovation in the use of new materials in semiconductor design as well. We believe the need for higher performance packaging and thermal management and the increased focus on impurities has the potential to create an opportunity for Alpha's various HPA offerings.

Potential increased demand for HPA in packaging and thermal management for high performance chips…

Packaging and thermal management are used in semiconductors to insulate currents and manage thermal conductivity (the latter is effectively managing heat dissipation). If the semiconductor overheats this can reduce chip performance or cause device failure. This is critical for high performance parallel processors (e.g. Nvidia) and high bandwidth memory (HBM) chips given these operate at higher temperatures than traditional silicon semiconductors. The thermal packaging is critical to ensure that devices perform optimally:

- If the semiconductor overheats, this can cause degraded performance (which may be throttled down) or data integrity/functionality errors; and
- In the medium-term could result in accelerated damage to circuits and reliability failure.

There are a range of materials used for packaging and thermal management currently – HPA is used in some silicon chips. Kearney's PERLab report identified advanced packaging capacity as a potential bottleneck to high performance semiconductor manufacturing in coming years. We expect the demand for higher performance materials to increase the market size for HPA, particularly with morphology that is well-suited for the use-case, along with some other products.

The choice of materials for packaging and thermal management is the outcome of a trade-off between thermal conductivity, affordability and mechanical strength. HPA is well suited for use in higher performance packaging and thermal management solutions for high performance semiconductors due to the following advantages:

- It has relatively high thermal conductivity (20-30x more thermally conductive than silica), meaning it can be effective in dissipating heat from high-power components.
- It has high electrical insulation, meaning it can effectively separate and insulate components in semiconductors.
- It is cost-effective compared to alternate materials (mentioned below).
- Its relative mechanical strength means it performs strongly in environments where devices could face stress.

To contrast, aluminium nitride has higher thermal conductivity, but it significantly more expensive and does not have the same mechanical strength – it is used in niche ultra high-performance applications as a result. HPA is an input to the production of aluminium nitride, so Alpha has some leverage to this growth (providers still need low-alpha material, see below) – Alpha reports that it is in qualification with at least one manufacturer of aluminium nitride. Some advanced carbon-based materials (e.g. graphene) appear attractive however, they are not widely available and significantly more expensive at present.

… Alpha's HPA has zero radioactive impurities…

As above, as transitors become smaller, the error tolerance within chips reduces, elevating the importance of reducing impurities in the manufacturing process. Bauxite, the raw material to produce HPA, can contain trace amounts of radioactive elements including uranium and thorium, with concentrations varying depending on the deposit. The radioactive decay of these materials produces alpha particle radiation, particularly when heated. Even trace radioactive impurities can cause errors, degrade performance or cause data corruption in semiconductors. While this is less critical in consumer electronics, this is clearly sub-optimal for high-performance semiconductors used in aerospace, defence, data centre and AI applications.

PW Consulting has highlighted tightening standards for high performance semiconductor packaging in Japan, South Korea, US and the EU. It also indicated price premiums for low-alpha HPA (no detectable alpha radiation) in Japan can be 40-60% over conventional HPA, offsetting "downstream product reliability improvements exceeding 30% in critical failure metrics" (source: PW Consulting). More broadly PW Consulting highlighted a 22% premium for certified low-alpha HPA compared to standard grades.

There are suppliers of low-alpha certified HPA material currently: PW Consulting highlights the leading suppliers of low-alpha spherical HPA are from Japan and Korea (Sumitomo Chemical, Nippon Light Metal and Daehan Ceramic), with China's Zibo Sinoshine emerging as a supplier certified by NASA and attracting premium pricing of US$58/kg – this is materially higher than Alpha's published pricing market discovery. However, to reduce radioactive impurities within HPA currently available is an energy intensive process and tolerance levels for such material could reduce over time as requirements for semiconductors evolve. Alpha's novel purification process (discussed in Section 1) has eliminated radioactive impurities (source: Alpha's 3Q25 activities report), below industry threshold levels of <1ppb, hence appears well positioned to deliver for future needs as requirements evolve.

… And Alpha can vary product characteristics and the range of its offerings

Our feedback from industry contacts is that Alpha's ability to vary the morphology and product characteristics (physical properties such as size, shape, surface area, etc) of its specialty aluminium chemicals to test different applications and optimise performance is an important source of innovation for customers. HPA that is used in higher performance semiconductor packaging and thermal management needs to have small particles (which Alpha can provide) and are often different shapes to improve packing density (e.g. spherical and flake shaped particles often pack well together). Increased packing density reduces thermal resistance that can exist if there are air pockets between particles.

2. Silicon carbide and gallium nitride semiconductors enabling high power applications…

As the name suggests, high power semiconductors are used for larger electrical devices (e.g. EVs, telecommunication networks, renewable energy systems, power grids and industrial motors) that have larger electrical currents/voltages, higher resultant temperatures and may also require power conversion. At the same time as many of these end markets have been growing, in recent years silicon carbide (SiC) and gallium nitride (GaN) semiconductors have emerged as superior alternatives to traditional silicon semiconductors to enable such high power applications. Both SiC and GaN semiconductors use increased volumes of specialty aluminium chemicals compared to traditional silicon semiconductors (discussed below). The key advantages of SiC and GaN semiconductors are (we compare them next):

- **Can operate at higher temperatures and voltages.** Both SiC and GaN semiconductors have a larger bandgap, meaning electrons need to absorb more energy before they can conduct electricity through the semiconductor. This means they can operate at higher temperatures and voltages that are necessary for high power use-cases, particularly when needed for harsh environments.
- **Higher efficiency.** Lower resistance and higher thermal conductivity result in lower energy losses, resulting in reduced power consumption and therefore higher efficiency.
- **More compact and simpler systems.** The use of SiC and GaN semiconductors can result in more compact and simpler system design with less materials required. As an example, expensive cooling systems can be simplified and, in some cases, eliminated. This is due to:
    - Higher thermal conductivity, meaning heat can be dispersed more effectively;
    - Higher power density, due to operating at higher temperatures/voltages; and
    - Higher switching frequency operation, reducing the requirement for inductors and transformers.
- **Improved reliability and longevity.** Due to properties of thermal conductitiy and higher power density, SiC and GaN devices are better able to operate in harsh environments without degradation. This improves both their reliability and product lifetime, as well as improving performance in such harsh environments.

Across the various high-power applications, we note the following advantages:

- **EVs.** SiC and GaN devices improve power inverter and converter efficiency, managing power flow between battery and electric motor. They can handle higher voltages and, as a result, reduce system size and weight.
- **Renewable energy systems.** They can be used in solar inverters and wind turbine systems where efficiency and high voltage performance is critical.
- **Power grids.** They can improve the efficiency and stability of this critical infrastructure, especially high-voltage networks.
- **Telecommunications infrastructure.** The deployment of 5G networks and data centres globally is driving increased demand for high-performance and energy-efficient power electronics. SiC and GaN technologies allow for more compact and reliable power systems that can handle the requirements of such infrastructure.
- **Industrial motors.** SiC and GaN semiconductors can improve energy efficiency and reduce heat dissipation.

… SiC and GaN semiconductors have some different characteristics and likely use-cases

While SiC and GaN have emerged as superior alternatives to traditional silicon semiconductors for high power applications, they have different characteristics that means each may have differing use-cases (subject to other factors such as cost) and a number of industry contacts see them as complementary. The key differences between SiC and GaN semiconductors are as follows – we focus on characteristics for high power use-cases, where both are superior to traditional silicon semiconductors (as discussed above):

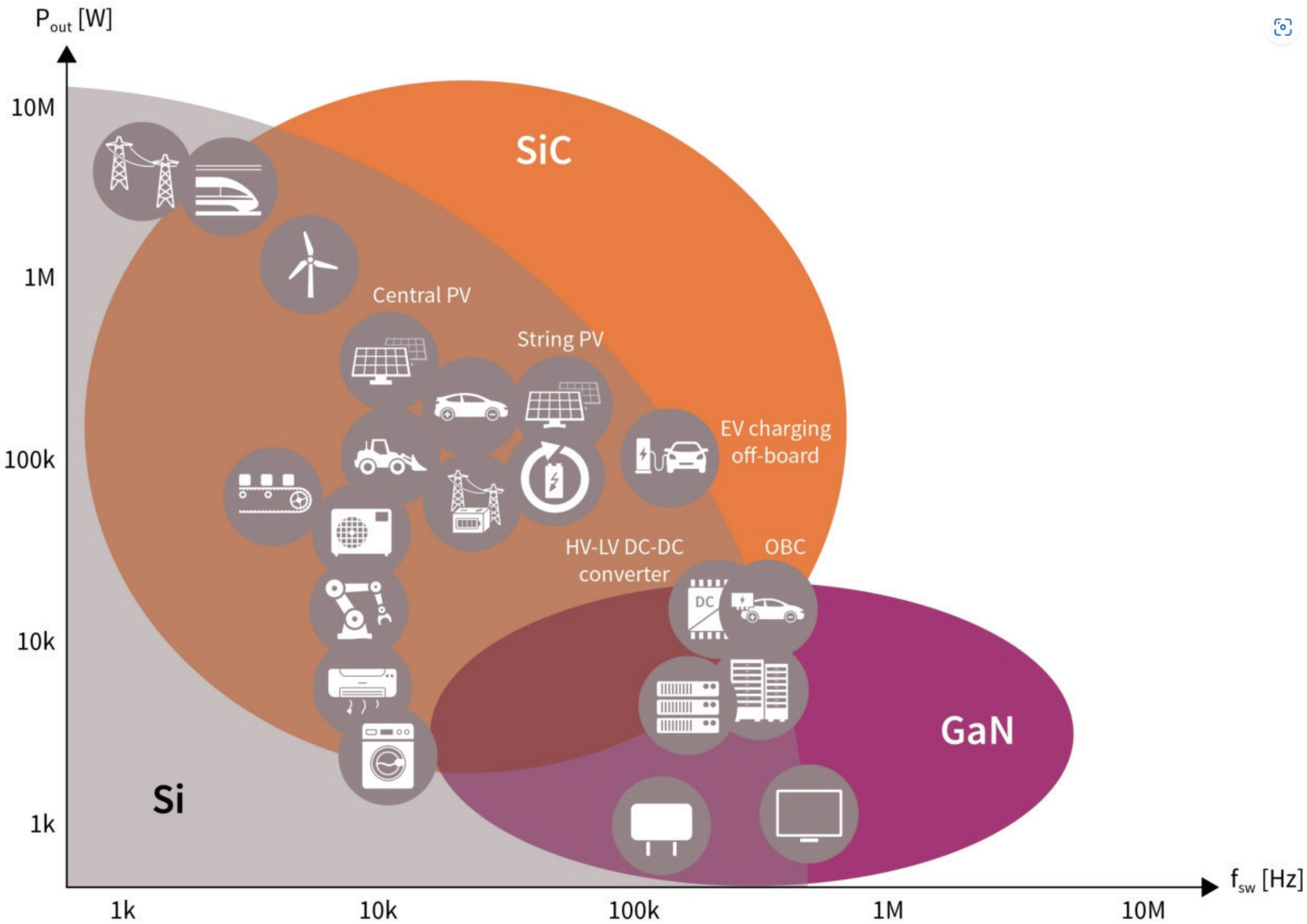
- **GaN has a wider bandgap than SiC.** This is important for operating at higher temperatures and voltages, with GaN semiconductors having an advantage in this area.
- **SiC offers a higher breakdown voltage than GaN.** Despite a slightly narrower bandgap, this means SiC devices can withstand higher voltages than GaN devices.
- **SiC has higher thermal conductivity than GaN.** Both are superior to traditional semiconductors, with SiC having a further advantage for use-cases where heat management is important.
- **GaN has higher electron switching speed than SiC.** Electron mobility is higher in a GaN chip, enabling faster switching speeds and higher frequency operation.
- **SiC is generally more expensive than GaN.** The production process for producing high-quality SiC wafers (from crystal) requires higher temperatures and additional handling, hence tends to be more expensive than GaN production, which can be grown on a range of substrates (including sapphire, which we discuss below).

As a result of this, there are some applications that are likely to be better suited to one or the other of SiC/GaN, albeit there is some interchangeability:

- **SiC favoured in high-power, high-temperature applications.** This is due to the durability and thermal conductivity of SiC compared to GaN semiconductors, which can be needed in harsh environments. Examples of such use-cases are EVs, solar inverters and power grids.
- **GaN favoured in high-frequency, high-speed applications.** This is due to the faster power switching speed and efficiency of GaN compared to SiC semiconductors. Examples of use-cases are 5G base stations, satellite communications, other radio frequency applications and consumer power applications such as fast chargers and robotics (lower cost assists with the latter).

Infineon Technologies has graphically represented the opportunity for SiC and GaN applications (it produces both) to show the complementarity. Future Market Insights estimates that SiC semiconductors have ~80% share of the high-power semiconductor market and is expected to remain dominant, despite the rapid growth of both (it forecasts a CAGR to 2034 of 25-30%pa for both, source: Future Market Insights).

Mapping of power applications as a function of technology



Source: Infineon Technologies

SiC and GaN markets are expected to grow strongly over this decade

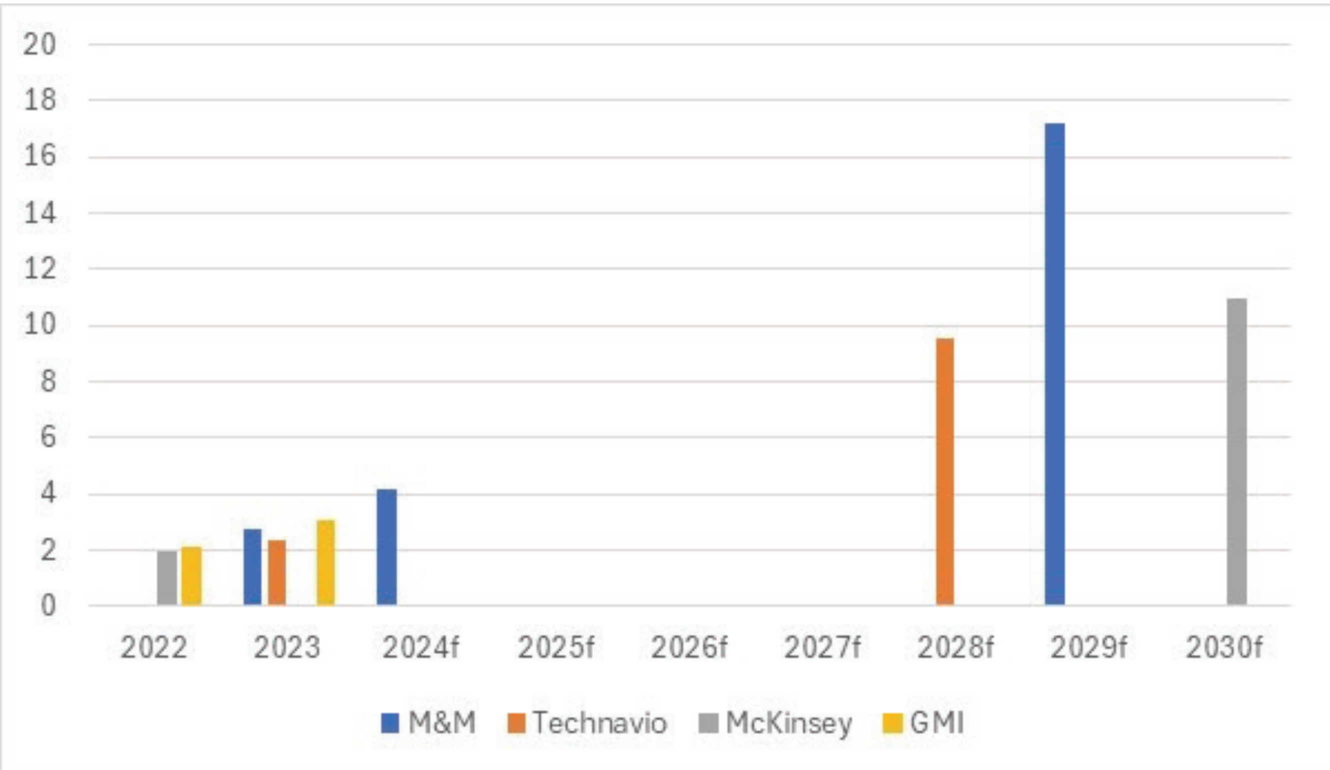
We summarise a range of publicly available industry growth forecasts for SiC and GaN semiconductors below. We note that this could duplicate growth forecasts if there is an underlying assumption from one source that one technology is more likely to be adopted. Either way, due to the advantages of SiC and GaN over traditional semiconductors and the growth of the end-markets that require high-power semiconductors, the market for both SiC and GaN semiconductors is forecast to grow strongly over the remainder of this decade. This should lead to increased demand for specialty aluminium chemicals given both SiC and GaN semiconductors use increased volumes of such chemicals compared to traditional silicon semiconductors (note that SiC appears to have higher HPA intensity – see below).

The SiC industry size is forecast to grow by >25%pa over the remainder of this decade…

We summarise a range of publicly-available industry growth forecasts for SiC semiconductors in the chart. Key points:

- While definitions of the 'SiC industry' differ between sources, the SiC industry was sized at ~US$2bn in 2022 and US$2.5-3.0bn in 2023, similar to the GaN market discussed below.
- Growth forecasts differ, but the consensus is for the industry to grow to >US$10bn by 2030.
- We show the McKinsey low case from its Oct-23 forecasts (market size was estimated at US$11-14bn, source: McKinsey). EV growth was a material driver of the McKinsey forecasts and over the course of 2024, it has recognised that near-term growth forecasts were likely too high. Even at the lower end of its forecasts, this still represents a Cagr of 24%pa to 2030.
- Growth forecasts from the other three sources are 32-35%pa over the remainder of the decade (from a 2023 base). We have not shown the GMI forecast for 2032 of a US$40bn market size (source: GMI) due to its impact on the scale of the chart. Interestingly, its Cagr is only marginally above Technavio (source: Technavio), although GMI's 2023 market sizing starts at a higher level. The upper end of the forecast growth rate range is the forecast of Markets & Markets, which forecasts the market size to reach US$17bn in 2029 (source: Markets & Markets).
- These growth forecasts appear to take into account the near-term slowdown in EV demand in western markets in particular. As recently as June-25, Yole Group reiterated its forecast of 24%pa CAGR for the SiC device market, from US$2.7bn in 2023 to ~US$10bn in 2029 (source: Yole Group). As in the specific examples below, expansion plans are being managed carefully but still appear to be progressing.
- While western markets have offered attractive support for the development of the industry, given the end-markets that are ideal for SiC semiconductors, it is not surprising that China and the broader Asian market (particularly Japan, Korea and Taiwan) are the largest globally. Given the growth in EVs and production of other equipment expected in coming years, these countries are also expected to see the most growth over this decade. Technavio estimates ~44% of growth in its forecast period will come from Asia-Pacific (including China).

SiC industry revenue growth forecasts (US$bn)



Source: Markets & Markets, Technavio, McKinsey, Global Market Insights, Rimor Equity Research

… Specific use-cases highlight advantages of SiC and growth potential

We believe the following are examples of SiC market development that highlight the advantages of SiC semiconductors and the potential for medium/long-term growth:

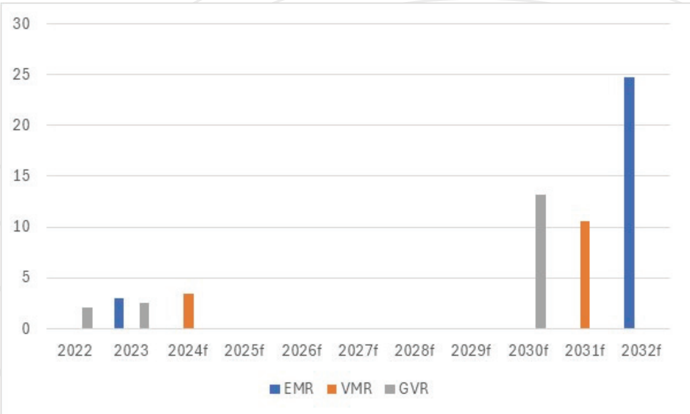
- **Wolfspeed, despite restructuring, has built significant SiC capacity**. Wolfspeed opened the world's largest SiC fabrication plant in Marcy, NY in Apr-22. In Sept-22 it announced plans to build a larger ~US$5bn facility in Chatham County, NC – this facility opened in March-24 and was due to ramp-up over time. A material part of Wolfspeed's business plan was based on EV roll-out and it signed stategic partnerships with Jaguar Land Rover in Oct-22 and Mercedes-Benz in Jan-23 for long-term supply of SiC semiconductors. These are to be used in the inverter (managing the transfer of power from battery to the electric motor) for next generation EV powertrains to improve range and power. The slowdown of EV growth and its debt load has seen Wolfspeed shelve plans to build capacity in Germany and, most recently, agree to restructure its capital structure under Chapter 11 to allow it to focus on cashflow generation and long-term growth.
- **Nexperia and Mitsubishi Electric**. The companies announced a strategic partnership in Nov-23 to jointly develop SiC MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors, used for power management, signal processing or switching electronic signals). The goal of the partnership is to continue to improve the energy efficiency and performance of SiC semiconductors as well as responding to the "rapidly growing demand for high efficiency discrete power semiconductors". The companies also stressed the importance of being a supplier of reliable power semiconductors and the track record of delivering products that qualify with customers.
- **Mitsubishi Electric and DENSO investment in Coherent SiC business.** In Dec-23, the two businesses announced a combined investment of US$1bn to acquire a 25% stake in Coherent's SiC semiconductor business. At the same time, both companies signed long-term supply contracts for SiC devices and Coherent funded further manufacturing expansion of the SiC business. In the March-25 quarter, Coherent discontinued the development of SiC devices and modules, where it did not see that it had a competitive advantage. However, this does not indicate a lack of growth – it refocused efforts towards SiC substrate and epiwafers, where it considered it had a competitive advantage and highlighted improving customer demand.
- **STMicroelectronics building capacity in Italy**. In May-24, STMicroelectronics Catania announced plans to build a ~€5bn vertically integrated SiC manufacturing facility in Catania, Italy. The site will be a centre of manufacturing as well as further product development. It is targeted to open in 2026 and ramp-up capacity by 2033.
- **ROHM launches EcoSiC brand**. The launch of its SiC branding in June-24 was to highlight superior performance of SiC devices, allowing more efficient and compact systems, and sustainability of its products, leading to reduced energy consumption in EVs and renewable energy systems. It is worth noting that ROHM has a similar branding for gallium nitride devices. ROHM announced the adoption of its 4^{th} generation SiC chips in three EV brands from Geely in Aug-24 and a long-term supply agreement with UAES in Sept-24.
- **onsemi launches EliteSiC brand**. The July-24 launch of onsemi's most recent generation of SiC technology, EliteSiC M3e MOSFETs, came with a promise to improve performance and reliability of next-generation electrical systems at a lower cost per kW, hence driving adoption across EV, solar, energy storage and data centre markets. onsemi also announced plans to release additional generations of the technology in the years to 2030. It believes each generation of SiC cells will allow increased power density and reduced package size. In Oct-23, onsemi completed the expansion of its SiC wafer fabrication facility in Bucheon (Korea), which it claimed to be the largest at the time, with capacity to produce >1m 200mm SiC wafers at full capacity.

The GaN industry size is forecast to grow by >20%pa over the remainder of this decade…

We summarise a range of publicly-available industry growth forecasts for GaN semiconductors in the chart. Key points:

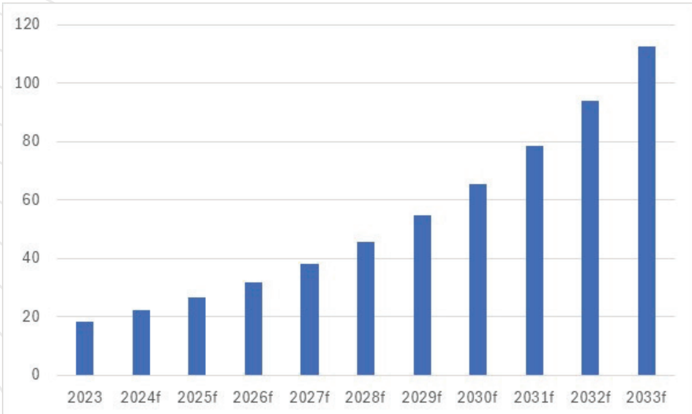
- While definitions of the 'GaN industry' differ between sources, the GaN industry was sized at ~US$2bn in 2022 and US$2.5-3.0bn in 2023, similar to the SiC market discussed above. Growth forecasts differ, but the consensus shown in the left-hand chart is for the industry to grow to >US$10bn by 2030.
- Growth forecasts from the three sources shown are 20-25%pa over the remainder of the decade (from a 2023 base). The upper end of the forecast growth rate range is the forecast of Expert Market Research, which forecasts the market size to reach almost US$25bn in 2032 (source: Expert Market Research). The forecast from Grand View Research has a similar 26%pa CAGR over its forecast period to 2030 (source: Grand View Research). The low end of the forecast growth rate range is the forecast of Verified Market Research, which forecasts the market size to reach ~US$10.5bn in 2031 (source: Verified Market Research).
- The right-hand chart shows the forecast growth of the GaN semiconductore device market of Market.us (source: Market.us), a Cagr of ~20%pa for the 10yrs to 2033. This is made up of opto semiconductors, power semiconductors and RF semiconductors. Opto semiconductors are the largest share of GaN devices, comprising 'advanced display technologies and high-efficiency lighting', used in consumer electronics and automotive lighting applications in particular. RF applications are particularly 5G related.
- Similar to SiC semiconductors, while western markets have offered support for the industry, China and the broader Asian market (particularly Japan and Korea) are the largest regional end-markets. Market.us estimates Asia-Pacific accounts for ~40% of the GaN semiconductor device market. VMR cites government data highlighting Chinese GaN device production grew by 45% between 2021 and 2023 and Japanese GaN semiconductor exports grew 38% between 2020 and 2024. TSMC (Taiwan) and Samsung Electronics (Korea) have also indicated they will grow GaN production, albeit some of this capacity looks set to be built in the US and Europe due to government incentives (discussed above). Growth in Asia is driven by its consumer electronics manufacturing base, the rapid expansion of 5G technology and EV adoption.
- The North American and European GaN markets are also expected to grow rapidly due to the use-cases discussed. VMR expects the GaN semiconductor market to grow by ~22%pa between 2021 and 2026.

GaN industry revenue growth forecasts (US$bn)



Source: EMR, VMR, GVR, Rimor Equity Research

Global GaN semiconductor device market (US$bn)



Source: Market.us, Rimor Equity Research

… Specific use-cases highlight advantages of GaN and growth potential

We believe the following are examples of GaN market development that highlight the advantages of GaN semiconductors and the potential for medium/long-term growth:

- **Infineon driving growth of its CoolGaN offering.** In March-23, Infineon acquired GaN Systems for US$830m to accelerate its product development in this area (it also has made significant investments in SiC technology development). Since this time, Infineon has invested in its manufacturing scale, as well as R&D activities. In Sept-24 it announced the production of the first 300mm GaN wafer, made using its existing 300mm silicon wafer production line at its facility in Villach, Austria. This larger wafer can fit 2.3x as many chips as a 200mm wafer and Infineon stated this would be a key driver in contributing to GaN cost parity with traditional silicon semiconductors – this would clearly be a key driver of takeup.
- **Navitas and SHINRY.** In Jan-24, the companies announced the opening of a joint R&D laboratory to accelerate the development of EV power systems enabled by Navitas' GaN technology. The goal of the laboratory is to accelerate projects from development to market that that result in faster charging and extended range. SHINRY is a supplier of on-board power supply to Honda, Hyundai, BYD, Geely, XPENG, BAIC and other OEMs.
- **Texas Instruments (TI) quadrupling GaN capacity.** TI began production of GaN semiconductors in Aizu (Japan) in Oct-24. Building on its capacity in Dallas (Texas), once its new facility has ramped up, TI will have the capacity to manufacture 4x more GaN semiconductors than was previously possible.
- **Developments supporting GaN usage in 5G infrastructure.** VMR cites both industry and government data to highlight the importance of GaN semiconductors for this sector. The Global Mobile Suppliers Association reported GaN-based RF power amplifiers were used in ~60% of 5G base stations deployed in 2023. While from government data, ~70% of 5G base stations deployed in China in 2023 contained GaN-based RF devices, India increased GaN-based device imports for wireless infrastructure by 55% between 2022 and 2024 and the US saw a ~40% increase in GaN RF device shipments for wireless infrastructure from 2021 to 2023. Companies such as Sumitomo Electric, Mitsubishi Electric, Qorvo, NXP Semiconductors and Wolfspeed have each made GaN-based product announcements for the 5G infrastructure market in the last 12-18 months.
- **Developments supporting GaN usage in EVs.** VMR also cites government data to highlight the growth of GaN usage by the EV sector. In China, there has been a ~50% increase in GaN semiconductors in EVs from 2022 to 2024. In the US, GaN devices are now estimated to be used in ~30% of new EVs, while in Europe there has been a ~55% increase in GaN-based devices in EVs between 2022 and 2024. In addition to Navitas (above), companies such as ON Semi and Infineon have each made GaN-based product announcements for the EV market in the last 12-18 months due to GaN's ability to improve power conversion efficiency and reduce overall system size.
- **Developments supporting GaN usage in power.** The IEA has highlighted that GaN-based solar inverters achieved a market share of ~25% in 2023, up from ~10% in 2020, while VMR reports that the US DoE estimates that power devices accounted for ~45% of the total GaN semiconductor market in 2023. Companies such as SK Key Foundry, Guerrilla RF and Transphorm have each made GaN-based product announcements for the power sector in the last 12-18 months.

Specialty aluminium chemicals are used at critical stages of SiC and GaN production

Specialty aluminium chemicals are used in two critical stages of SiC and GaN semiconductor production – chemical mechanical polishing (CMP) and packaging and thermal management. In both cases, SiC semiconductors typically use more such chemicals than GaN semiconductors (with both using more than traditional silicon semiconductors). GaN semiconductors can also use sapphire as the substrate material for its wafers. These are discussed in turn:

Chemical mechanical polishing (CMP)

In simple terms, the CMP process uses an abrasive slurry in both mechanical polishing and chemical steps to achieve a smooth, uniform and defect-free surface on SiC or GaN wafers. It is critical for subsequent steps in production, particularly for the steps that involve photolithography and deposition of materials onto the wafer in complex multiple layers that create the features of the semiconductor itself. Achieving the balance between material removal and polishing means that the composition of the slurry is critical – if inappropriate, it can cause defects to the surface such as scratching. This means slurries and other consumables are regularly fine-tuned or replaced – this can be costly.

HPA can be used as an abrasive material in the slurry. In the mechanical polishing, HPA within the slurry removes surface imperfections and other material from SiC or GaN wafers. In the chemical process, it assists with softening materials to be removed with the polishing process. The primary advantages of HPA are:

- HPA, with Mohs hardness score of up to 9 (depending on the phase) is substantially harder than traditional CMP abrasive materials, silica and ceria. This makes it more effective in the CMP slurry on harder substrates that are used in SiC or GaN chips. Increased hardness also assists with durability of its use within the CMP process.
- It removes material from the wafer efficiently, allowing for a faster polishing process.
- It is cost-effective compared to alternate abrasives (mentioned below).
- It is chemically stable and allows flexibility to use a range of chemicals within the slurries that are in turn used for producing specific use-cases of the SiC semiconductor.

There are other materials that can be used as the abrasive in a CMP process. Silica is softer than HPA and can reduce the risk of scratching, however it tends to have lower removal rates and can have an all-in cost greater than HPA – this means it is less efficient for harder substrates that are used in SiC or GaN chips (traditional silicon semiconductors are not as hard). Diamond can also be used in CMP slurries and offers higher removal rates than HPA on wafers, however its cost means that it can be significantly more expensive than using HPA.

Alpha has stated that customer testing is indicating “+50% removal rate improvement in both wafer and package polishing” due to its novel morphology and contains low levels of alkali metals (in particular sodium and potassium, the risks of such contamination are discussed below).

Packaging and thermal management

Each semiconductor chip is covered with a protective packaging to insulate high currents and manage thermal conductivity (the latter is effectively managing heat dissipation). As discussed for high performance semiconductors (see above), this is critical for SiC and GaN semiconductors given they operate at higher voltages and temperatures than traditional silicon semiconductors. The packaging is critical to ensure that devices perform optimally:

- If the semiconductor overheats, this can cause degraded performance over time, stress on product integrity (cracking or warping) or complete device failure; and
- If the electrical insulation is insufficient, this can result in current leakage (impacting efficiency and/or reliability), short circuits or breakdown of the device.

HPA is well suited for use within the packaging of SiC and GaN semiconductors due to the following advantages:

- It has relatively high thermal conductivity (20-30x more thermally conductive than silica), meaning it can be effective in dissipating heat from high-power components.
- Its thermal expansion is compatible with SiC and GaN, reducing the likelihood of failure due to thermal stress.
- It has high electrical insulation, meaning it can effectively separate and insulate components in semiconductors.
- It is cost-effective compared to alternate materials (mentioned below).
- Its high hardness means it performs strongly in environments where devices could face stress.
- ATH has an added benefit of acting as a flame retardant by releasing water vapour when heated (ATH decomposes with heat to form HPA and water).

The shortcoming of using HPA is for more extreme applications – those that result in extreme temperatures, high-power or high-frequency. In such cases, more advanced materials such as aluminium nitride or beryllium oxide – these are both more expensive than HPA so are likely to be only used where there is material added value to the device. Beryllium oxide can also lead to toxicity concerns, so there are added safety requirements. Alpha has some redundancy in this area – aluminiuim nitride can be made from HPA in a carbothermal reaction and nitridation process, albeit this is a different process to that undertaken at its facility currently.

SiC semiconductors typically require more HPA for CMP process and packaging & thermal management

In both of the above use-cases, SiC semiconductors typically use more HPA than GaN semiconductors (with both using more than traditional silicon semiconductors) due to:

- **CMP process is more intense for SiC production.** SiC's hardness typically results in the need for a longer and more intense CMP process relative to GaN production – this results in increased HPA intensity given the need for more abrasive material and/or more consumption of materials within the CMP slurry.
- **The use-cases favoured for SiC devices require higher quality packaging and thermal management.** As above, SiC is favoured in high-power, high-temperature applications such as EVs, solar inverters and power grids. These require packaging that can ensure thermal management and structural integrity due to generation of substantial heat – this tends to require increased use of HPA.

GaN semiconductors can also use HPA, in the form of sapphire, as the substrate material for its wafers

The substrate material is the base material used to make semiconductor wafers. The wafer itself is a thin slice of a larger crystal that has been grown for this purpose. It is the foundational layer of the semiconductor circuit – it provides mechanical support and is the platform onto which photolithography and deposition of materials occurs in complex multiple layers that create the features of the semiconductor itself. Silicon is the most commonly used substrate for traditional semiconductors such as memory chips. The substrate material influences the performance, efficiency and thermal management capabilities of the semiconductor.

As above, in high power applications, SiC and GaN semiconductors are now gaining market share. However, these names can be misleading – SiC semiconductors most often use silicon carbide as the substrate, however GaN semiconductors typically use a different substrate for wafers (it is difficult to grow GaN crystals), with GaN itself grown on the wafer. The substrates for GaN semiconductors are most often silicon or silicon carbide, with sapphire increasingly being used (from a low base). Silicon carbide has higher thermal conductivity, better lattice matching to GaN (resulting in fewer defects) and conducts electricity. It tends to be used for applications that are high-power and high-temperature – these are similar use-cases that are favoured for SiC semiconductors and there may be some overlap in application. Sapphire tends to be used due to its attractive cost (relative to SiC) and are used in lower-power applications in particular (e.g. LEDs or low-power radio frequency applications) – for these applications, sapphire has higher thermal conductivity and better lattice matching than silicon. As a result, GaN semiconductor growth may result in sapphire demand growth due to these advantages and value proposition. As discussed in Section 1, Alpha is in the process of a significant increase in sapphire manufacturing capacity.

Quality of semiconductor is critical in high performance and high-power applications given downside risks…

The nature and value of the end-markets for emerging, high-end semiconductor platforms including high performance (AI processors, HBM chips) and high-power semiconductors (SiC, GaN) gives a sense of the importance of the quality of the semiconductor itself. The high-power semiconductor production line typically involves testing of all chips for stress associated with high temperature, high voltage and efficiency. Chips that do not meet quality standards are not sold – this is clearly costly for the manufacturer given the technical complexity of the production process. The high manufacturing and processing costs of high performance and high-power semiconductors remains a challenge.

There are some issues with high performance and high-power semiconductors that are difficult to detect. There are further issues that come due to the technical complexity of design and integration of such semiconductors into existing systems and production infrastructure that can result in longer development times and higher costs. If any of these processes are not followed properly, this can result in risk to the device from:

- **Overheating.** This is the most common cause of faults and results from insufficient cooling, which can degrade materials over time and potentially lead to 'thermal runaway', where power is dissipated beyond design limits, leading to ultimate device failure.
- **Material defects and impurities.** Due to the high-stress conditions under which they operate, high-power semiconductors are susceptible to 1) relatively minor defects such as cracking and voids that can occur in the manufacturing process; or 2) contamination from material impurities that can create weak points. The quality of both the manufacturing process and materials used is therefore critical for reducing such risks.
- **Other breakdowns.** There are a range of other events that can cause quality degradation or failure of high-power semiconductors due to the high temperature and voltage environment in which they operate.

These risks are potentially costly to each of the chip manufacturer, device manufacturer and consumer. Such faults can result in one or more of the following:

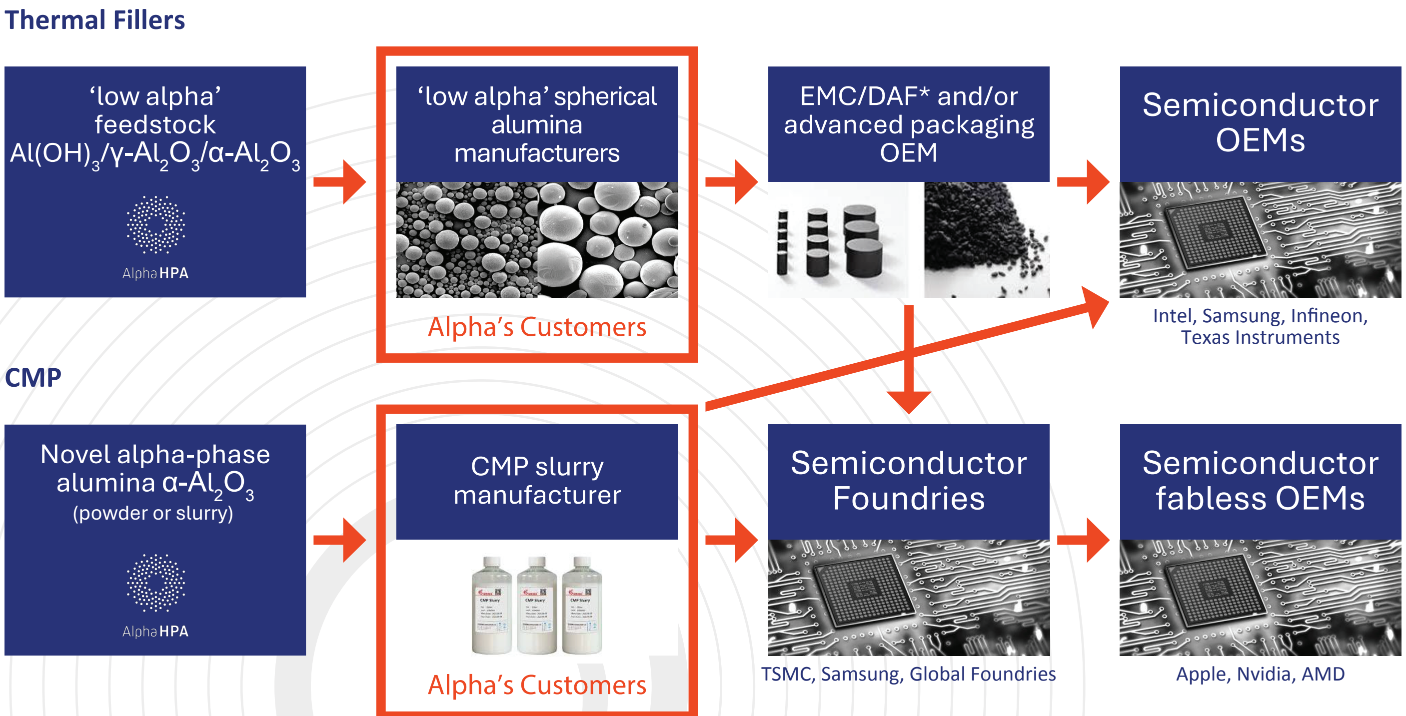
- Reduced efficiency, performance and device life;
- Reduced reliability and operational instability; and/or
- Device failure.

Given the nature of the devices and the operating environment, device failure is the worst-case outcome that can result from a fault. If the device fails due to overheating, the thermal runaway can cause melting of the device or fires within the device, which can lead to larger risks in certain locations. If the device failure allows high voltage electricity to escape, this can damage equipment beyond the device or compromise safety in certain circumstances.

As a result, qualification processes are rigorous, LOIs are the first indicator of success

As is clear above, faults in each of the emerging, high-end semiconductor platforms are costly for the manufacturer and could be a risk to safety. Given the technical complexity of the production process, customers throughout the supply chain need assurance they are receiving high quality inputs to their own processes. One industry contact recently stated ‘the secret sauce of the semiconductor supply chain is quality control at every stage of the manufacturing process’. To supply to a high performance or high-power semiconductor manufacturer, suppliers undergo a comprehensive product qualification process to ensure materials supplied meet quality specifications. Not only does the product need to meet customer requirements, but these customers also require downstream qualification with end-market manufacturers given the risks associated with product malfunction. As can be seen in the chart below, there are multiple steps in the semiconductor value chain that may need to be tested. Executing an LOI is the first indicator of success in customer product qualification processes.

Semiconductor value chain for providing CMP and thermal packaging specialty chemicals



* EMC = Epoxy Molding Compound
* DAF = Die Attach Form

Source: Alpha HPA, various, Rimor Equity Research

A typical qualification process for suppliers of specialty aluminium chemicals would involve the following:

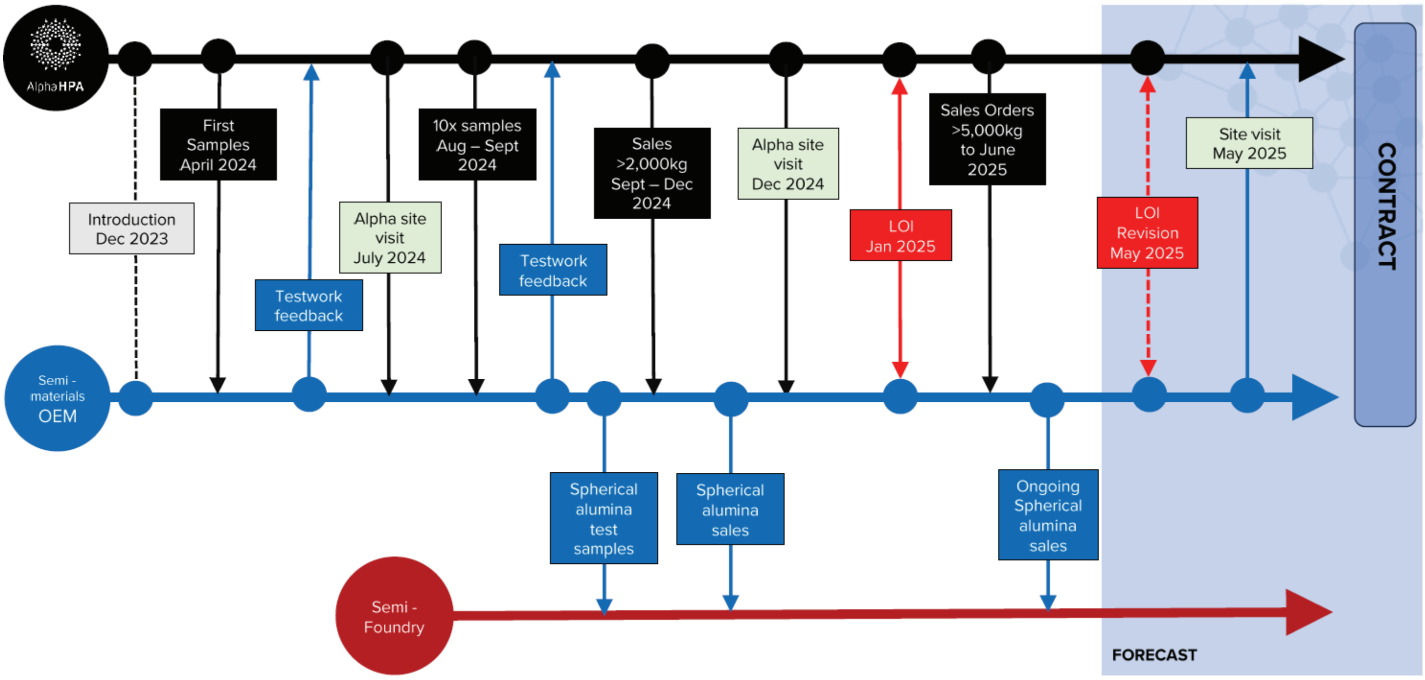
- **Material compliance and compatibility, particularly for CMP process.** As discussed in section 1, Alpha is particularly focused on 4N (99.99%), 4N5 (99.995%) and 5N (99.999%) purity products – ensuring sufficient purity for the semiconductor market is a critical, but only first, step. Semiconductor manufacturers will also consider contaminants, chemical compatibility and particle shape, size, surface area and distribution. Contaminants can impact performance and reliability of the semiconductor (discussed below). Chemical compatibility is related, but more concerned with the potential for adverse reactions with chemicals used in the CMP or wafer cleaning stages of production. Particle properties can impact performance of HPA in the CMP process in particular – uniformity of wafer surface and not leading to defects in the chip is critical. Alpha's ability to vary the product characteristics of its chemicals appears attractive in this context. Physical properties are also critical if HPA is used to produce a sapphire wafer used for GaN semiconductor production.
- **CMP performance testing.** In addition to compliance/compatibility, the HPA will be tested in the CMP process to determine material removal, surface roughness after the process and defect rates. Morphology of the HPA is an important driver of CMP performance. Alpha has stated that customer testing is indicating "+50% removal rate improvement in wafer polishing" due to its morphology. Alpha has also reported end-users seeking ultra-low levels of alkali metals (sodium/potassium) as a key quality requirement for CMP. Light, positively charged metal ions like sodium and potassium can cause issues with cleaning of the final polished substrate.
- **Material properties, particularly for packaging.** HPA provided will be tested for electrical insulation, thermal conductivity and strength. This is to ensure it will meet the needs required for operating high-power semiconductors, particularly in harsh environments (as described above). Testing will take place on the HPA material itself as well as simulation to assess likely performance over time.
- **Material properties and quality, particularly for sapphire wafers in GaN semiconductor production.** Sapphire wafers must be high purity, and the single crystal needs specific crystal orientation in order to deliver high performance (allowing high-quality polishing and avoiding defects and lack of uniform thickness). Testing for thermal conductivity and strength are also important to ensure operation in harsh environments.
- **Quality management systems and reproducibility.** This is relevant to the specialty aluminium chemical producer's own operations and is to ensure the process is robust, ensuring documentation of raw materials and processes, in addition to consistency of final product to ensure it can continue to meet performance specifications, which is critical to semiconductor production itself being uniform in quality.
- **Environmental and safety compliance.** This is particularly relevant for handling and disposal of hazardous chemicals. Increasingly we expect this to consider the emissions profile of and waste generated from production. Given an increasing global focus on embedded emissions in production, we expect Scope 3 emissions for the semiconductor manufacturer to be increasingly relevant.
- **On-site audits.** Semiconductor manufacturers will typically visit the site of HPA production to evaluate the manufacturing process, quality control systems and environmental compliance systems.

… And can take more than 12 months, a significant barrier to entry

The product qualification process can take >12 months. The following timeline is indicative:

- **Initial supplier evaluation.** This is to assess the supplier's suitability, before assessing product quality. It focuses on quality management systems, environmental and safety compliance and likely involves an on-site audit. Depending on logistics and complexity, this can take up to 3 months.
- **Material testing.** This is to assess material compliance and compatibility. For HPA, this will take into account the range of factors we identified above for the CMP process, packaging and wafer production. These typically involve small-scale trials to evaluate performance. This can take up to 6 months.
- **Qualification trials.** After initial material testing, larger-scale trials are undertaken to determine performance across the semiconductor production process. This will analyse yield, defect rates and reliability testing. This can take up to 6 months.
- **Testing with downstream customers.** As above, not only does the product need to meet customer requirements, but these customers also require downstream qualification with end-market manufacturers given the risks associated with product malfunction. If the process has multiple steps in the value chain, then this can take significantly more time. This is illustrated in the chart below – Alpha commenced testing with a semiconductor materials OEM in Dec-23, but testing with the foundry only commenced in Sept-24.

Alpha qualification case study for HPA into thermal packaging



Source: Alpha HPA

Once a supplier is qualified, the material is then used in production. Even after this qualification, suppliers are typically monitored to assess ongoing quality of material. Once a supplier has been qualified, this constitutes a significant barrier to entry for a new supplier. This is particularly true if the end-market for the customer is relatively low growth – unless there is an incentive for a customer to change supplier, it is difficult for new suppliers to replace current suppliers. Although this may appear to make it difficult for Alpha, it is worthwhile noting that the semiconductor end-market that we have discussed above is expected to grow strongly over coming years. This means there is an opportunity for new suppliers who can deliver the quality of product required. In addition, there is an opportunity for Alpha to deliver products for new applications (e.g. sapphires) that we discuss above.

HPA quality and performance, not price, is primary decision-point for semiconductor manufacturers

Due to the risks discussed above, all of which can have significant downside risk to profitability, semiconductor manufacturers need to ensure they have access to high quality materials while limiting supply chain vulnerabilities. Based on our discussions with industry contacts the price of HPA, while a factor, is not the most important factor for their decision-making on sourcing such products – it is the broader value proposition that is most critical. The key decision-points are as follows:

HPA, with few contaminants, to minimise risk to quality of semiconductor

Contaminants can cause all the risks we mention above (performance, reliability and failure). As above, semiconductor manufacturers typically require at least 4N (99.99%) HPA to minimise the risk around contaminants and have rigorous qualification processes to mitigate risk. Alpha's products score well in this area. Key contaminants to consider are:

- **Metallic impurities.** Trace amounts of iron, nickel and copper are among the most problematic contaminants given the potential for electrical leakage, wafer defect formation and device failure. Semiconductor manufacturers give particular attention to such impurities and also seek to mitigate such risks with other process controls in the CMP process in particular.

- **Radioactive impurities.** As we discuss above, this can come from materials such as HPA and quartz used in semiconductor production. The radioactive decay of materials such as uranium, thorium or radium produces alpha particle radiation, particularly when heated, that can disrupt the operation or reduce the reliability of the semiconductor. This is increasingly important as semiconductor technology advances are made. Alpha has reported that its product has "non-detect levels of uranium and thorium" and qualifies as a low-alpha feedstock as a result. Alpha has stated that its novel purification process (discussed in Section 1) has eliminated radioactive impurities (source: Alpha's 3Q25 activities report).
- **Alkali metal impurities.** The CMP process is particularly sensitive to small, positive charged ionic impurities such as the alkali metals, sodium and potassium. Alkali metal impurities are very difficult to clean from the polished wafer surface. This is problematic due to the potential for sodium and potassium ions to move, leading to potential electrical instability and device failure, and/or react with other materials in the process, leading to performance issues due to corrosion or changes to the surface of wafers. Ultra-pure HPA mitigates this risk, in addition to other materials used, such as the use of deionised water. Alpha's process is capable of manufacturing aluminium chemicals that are low in alkali metal impurities.
- **Calcium and magnesium.** These are common impurities in HPA and can lead to semiconductor performance issues, particularly in high-voltage applications.
- **Carbon.** Such impurities can cause performance issues in particular.

HPA size, shape, surface area and distribution is also a quality consideration for semiconductor manufacturers

Consistency of particle size, shape, surface area and distribution is important for semiconductor manufacturing due to quality control during the manufacturing process. This is particularly the case in the CMP process given the importance of uniformity of the surface and material removal to wafer quality – consistent abrasion is more likely from HPA with uniform particle size and distribution. This is also critical for avoiding defects in the wafer surface that can come from larger particles. Particle size and distribution is also important for the use of HPA in packaging – uniformity (and in some cases a mix of shapes) can maximise density of the packaging and thermal conductivity, improving performance and structural integrity of the semiconductor. Feedback from industry contacts suggests that Alpha's ability to vary the size and shape of its specialty aluminium chemicals to test different applications and optimise performance with customers is an important driver of its progress with semiconductor suppliers and manufacturers to date.

Material properties for appropriate functionality

We described the initial phases of the qualification process above. In the early stages of this process, there is a range of testing, focused on material quality and properties. As described, these are clear decision-points for semiconductor manufacturers determining whether the HPA is appropriate for the CMP process, packaging and sapphire wafers.

Supplier processes for quality management and ongoing support

We also described the assessment of quality of management systems above. This is relevant to the HPA producer's own operations and to ensure the process is robust, ensuring documentation of raw materials and processes. In addition, consistency of final product is critical to semiconductor production to ensure performance specifications can continue to be met, increasing the potential for semiconductor production itself to be uniform in quality. On-site audits can be used for this assessment. There is also the potential for a stronger relationship between suppliers and customers if the supplier can offer some technical support that is relevant to the semiconductor manufacturing process.

Supply chain reliability and resilience

On-time and in-full product delivery is critically important for most manufacturing processes and semiconductor manufactuing is no different. The importance of this has increased in recent years, with supply chain constraints after the impact of COVID-19 and geopolitical concerns around concentration of supply being material issues for semiconductor manufacturers (as an example, in mid-2023 China's Ministry of Commerce announced export controls on gallium). Given Australia is not a large global supplier of HPA products already, we believe this is an opportunity for suppliers from Australia, such as Alpha.

Environmental and safety compliance

This is particularly relevant for handling and disposal of hazardous chemicals. Increasingly we expect this to consider the emissions profile of and waste generated from production. Given an increasing global focus on embedded emissions in production, we expect Scope 3 emissions for the semiconductor manufacturer to be increasingly relevant.

Pricing is part of the broader value proposition

For semiconductor manufacturers, quality, reliability and resilience of the supply chain are paramount concerns. While price is typically secondary to these considerations, it will still form a part of the supplier value proposition that balances price with material performance and productivity. As we discuss next, HPA in CMP and packaging typically accounts for <5% of the cost of a high performance or high-power semiconductor – this is high enough to be visible to semiconductor manufacturers, but low enough that the overall value proposition is the primary consideration. If sapphire wafers are used (for GaN semiconductors), then the proportion of total cost of manufacturing is significantly higher – however once again, this is likely to be part of a broader value proposition that has driven the use of sapphire over competing wafer substrates.

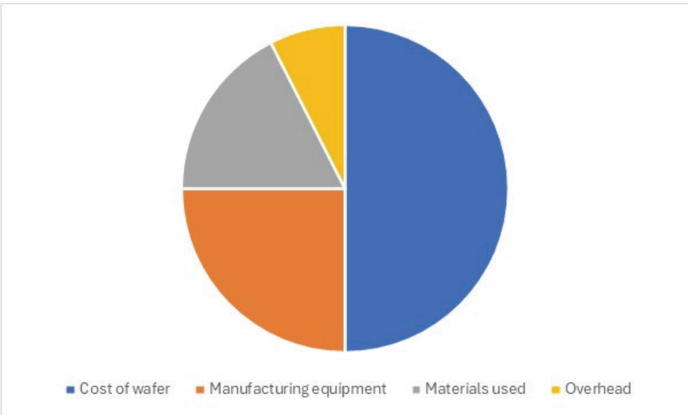
HPA in CMP and packaging accounts for <5% of the cost of a high performance or high-power semiconductor; more if sapphire wafers are used

We have estimated the contribution of HPA to the cost of a high performance or high-power semiconductor from speaking to industry contacts – we believe this supports our view that the value proposition for a semiconductor manufacturer is based on product quality and performance, not price. Key points:

- **For high-performance semiconductors, HPA in high performance packaging and thermal management accounts for <5% of semiconductor cost.** Industry contacts have estimated that HPA being used in high performance packaging would make up 1-3% of the cost of a high-performance semiconductor. The range will depend on the performance specifications - when compared to SiC and GaN semiconductors (below), the cost of wafer fabrication is the main cost of a high-performance semiconductor and will be the primary cost driver.
- The charts below show our estimates of the breakdown of costs for manufacturing SiC and GaN semiconductors, using information gleaned from speaking to industry contacts. We speak to ranges in the specific discussion points however, we show the midpoints in these charts – the splits are indicative and will not correspond with all SiC and GaN production costs.
- **SiC semiconductors are more expensive to manufacture than GaN semiconductors.** As above, SiC semiconductors are favoured in high-power, high-temperature applications – these tend to be use-cases where the higher cost is justified due to the performance benefits delivered. GaN semiconductors are favoured in high-frequency, high-speed applications that are often less expensive than the use-cases for SiC semiconductors – in this case they are more cost-effective.
- **The cost of the wafer is the largest cost driver for both SiC and GaN semiconductors.** This is also the largest driver of the cost differential between SiC and GaN semiconductors. SiC wafers are more expensive than sapphire or silicon substrates that can be used for GaN wafers, while thicker epitaxial layers (material grown on the substrate to give the properties needed for the end-use device) are also required for SiC semiconductors given the high-power applications for which they are made.
- **Manufacturing equipment and overhead a slightly higher relative cost for GaN semiconductors, but off a low overall base.** Manufacturing equipment is cheaper for GaN semiconductors given it can leverage established techniques and machines used in silicon semiconductor manufacturing. However, it still represents a meaningful fixed cost given it is a high-tech application and for this reason tends to represent a higher proportion of costs for GaN semiconductor manufacturing, compared to SiC manufacturing. Note this includes testing and quality control, which is typically part of the semiconductor production line, and the resultant cost of identifying defects. In a similar vein, overhead is also slightly higher as a proportion of GaN semiconductor costs due to their fixed cost nature.

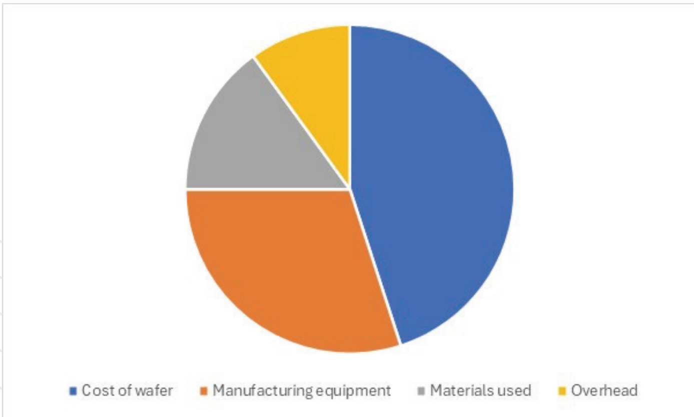
- **The SiC manufacturing process is more materials intensive than GaN manufacturing.** This is due to both the higher cost of materials for the CMP process and a higher cost for packaging in SiC semiconductor manufacturing. SiC semiconductor manufacturing typically involves a more extensive CMP process due to the hardness of SiC (compared to other substrates used for GaN semiconductors) – this takes longer and consumes more of the CMP slurries compared to GaN semiconductor manufacturing. In addition, the use of SiC semiconductors in high-power and high-temperature applications means that increased thermal management and packaging is required.
- **Assuming HPA is used in both CMP and packaging, it would account for an estimated 5-8% of SiC semiconductor costs and an estimated 4-7% of GaN semiconductor costs.** Assuming HPA is used in both the CMP process and for packaging, this represents 33-40% of the cost of materials used in the production of both SiC and GaN semiconductors. The range depends on the use-case for the semiconductor – a higher performance semiconductor, used in a harsher environment, will typically use a higher proportion of HPA. In addition, if HPA is able to be recycled for longer use in the CMP process, this cost could reduce.
- **If a GaN semiconductor uses a sapphire wafer, then the proportion of cost related to HPA could increase by and additional 15-25% of production cost.** If sapphire wafers are used (for GaN semiconductors), then the proportion of total cost of manufacturing is significantly higher – it is worth noting that one of the drivers for the use of sapphire as a substrate, compared to SiC, is the lower cost so the relative cost is clearly important. Industry contacts estimate the cost of using sapphire for a GaN semiconductor substrate us 30-50% of the cost of wafer – this could result in specialty aluminium chemicals costing an additional 15-25% of the cost of a GaN semiconductor.

Cost drivers for SiC semiconductors



Source: Industry contacts, Rimor Equity Research

Cost drivers for GaN semiconductors



Source: Industry contacts, Rimor Equity Research

Lithium-ion batteries

Despite recent geopolitical changes, we expect the global trend towards electrification to continue. Lithium-ion batteries (LIBs) are a critical enabler and strong production growth is expected to continue this decade and beyond. As LIBs proliferate, we expect increased focus on battery safety, given risks are more widely recognised. LIB manufacturers have been mitigating risks with cooling and battery management systems, however these add weight and cost. There is a clear focus on risk prevention where possible. HPA is already used for LIB separator coating, albeit this is unlikely to be Alpha's primary opportunity. HPA for coating cathodes is an opportunity given supply to the Asian market is only just ramping up. However coating anodes or cell casings using aluminium nitrate, a precursor chemical in Alpha's process, is most interesting because this specialty chemical is not commercially available. Alpha has achieved technical approval from an anode OEM and is reporting good test results from cell casings coated with its UltraCoat product. Industry contacts suggest Alpha is well-placed given its specialty aluminium chemicals are high-purity, can be provided with varying particle size/shape and with low contamination levels. If used in any of these applications, HPA would account for <5% of LIB cost. At 30 June-25, the LIB market accounted for ~5% of Alpha's LOIs.

Alpha's products appear well suited to high-growth segments within the LIB market…

Alpha's process flow (see Section 1) will produce specialty aluminium chemicals that could be used in the LIB market: particularly aluminium nitrate and various phases of HPA. It may be more difficult for Alpha to displace product supply into the current LIB market unless customers want to diversify supply sources. However, LIB manufacturers are looking to prevent risk and will continue to innovate with new materials. This appears to be the market opportunity for Alpha given an increased focus on battery safety, particularly aluminium nitrate which is not commercially available.

HPA is already used for LIB separator coating, albeit this is unlikely to be the primary opportunity for Alpha as there is a gradual trend towards lower purity. HPA for coating cathodes is an opportunity given supply to the key Asian market is only just ramping up. However, the potential for coating anodes or cell casings using aluminium nitrate, a precursor chemical in Alpha's process, is most interesting – this would be a unique opportunity for Alpha because this specialty chemical is not commercially available. Alpha has achieved technical approval from an anode OEM and is reporting good test results from cell casings coated with its UltraCoat product. Industry contacts suggest that Alpha has a strong prospect of supplying into the LIB market given its ability to supply high-purity specialty aluminium chemicals, of varying size/shape to test different applications and with low contamination levels that could jeopardise the LIB operation.

… An important source of Alpha's LOIs due to unique product offerings

As at 30 June-25, Alpha has customer LOIs of ~300tpa for the LIB market, ~5% of Alpha's total LOIs, for cathode coating and doping applications. The LIB market makes up ~20% of Alpha's estimate of unmet demand – we note its estimate of unmet demand for the LIB sector alone is roughly the same as the capacity of Alpha's Stage 2 production facility.

Lithium-ion batteries (LIBs) – essential for electrification

Despite recent geopolitical changes in western and developing countries, we think it is reasonable to suggest that the global trend towards electrification will continue given there are a number of drivers of such change:

- **Greenhouse gas emission reduction.** This is primarily relevant to use-cases with an energy source that is currently a fossil fuel – if the energy source can be changed to be electric, it may be easier to reduce emissions given there is a clear pathway for the decarbonisation of electricity system. This is primarily through the roll-out of renewable energy and battery to help manage intermittency in renewable energy sources.
- **Energy efficiency and technological improvements.** The cost of batteries dropping significantly and technological advancements over the last decade has enabled the use of electric motors for an expanded range of applications. These tend to be materially more efficient than fossil fuel-based systems.
- **Energy security.** The Russian invasion of Ukraine has been one of a number of geopolitical factors that has heightened focus on energy security. Electrification, if powered by locally produced energy, can reduce reliance on imported fossil fuels, making an economy less susceptible to geopolitical shocks.

Lithium-ion batteries are a critical enabler of electrification

The trend towards electrification has in turn drawn attention to the importance of energy storage – the leading enabling energy storage technology at the moment is the lithium-ion battery (LIB). We use the term LIB as a catch-all for a range of battery types that are enabled by lithium chemistry that we describe in more detail below – the two most common are lithium nickel manganese cobalt (NMC) and lithium iron phosphate (LFP). There are a range of applications for which LIBs are important for ongoing growth:

- **Electric vehicles and other transport.** There is a growing shift towards increasing electrification of transport. There is a debate about the trajectory of change, however the change itself appears clear due to stricter emissions regulation (not limited to GHGs), falling battery costs and government incentives. A key limitation to growth appears to be the expansion of charging infrastructure. LIBs can be used to power electric vehicles such as cars, vans, buses and trucks, as well as other industrial transport applications such as forklifts, logistics equipment and mining trucks.
- **Consumer electronics.** LIBs are used in a range of consumer electronics such as laptops, smartphones and power tools, with increasing applications for e-bikes and e-scooters.
- **Industrial applications.** These are growing in sectors such as robotics, medical devices, drones and some military equipment.
- **Renewable energy storage.** LIBs enable the storage of solar and wind power to be used at a time when renewable energy is not being generated. We will spend more time on mobile battery applications, rather than these stationary energy storage applications, as these appear more likely to drive demand growth for HPA and derivative products that we discuss in this report.

Government support for electrification remains strong

Despite recent geopolitical changes in western and developing countries, strong government support still exists for incentivising electrification. The highest profile areas of support are in the US, through the Inflation Reduction Act (IRA), and Europe, through the European Green Deal – there are several areas where support is through other mechanisms. The key areas of support are:

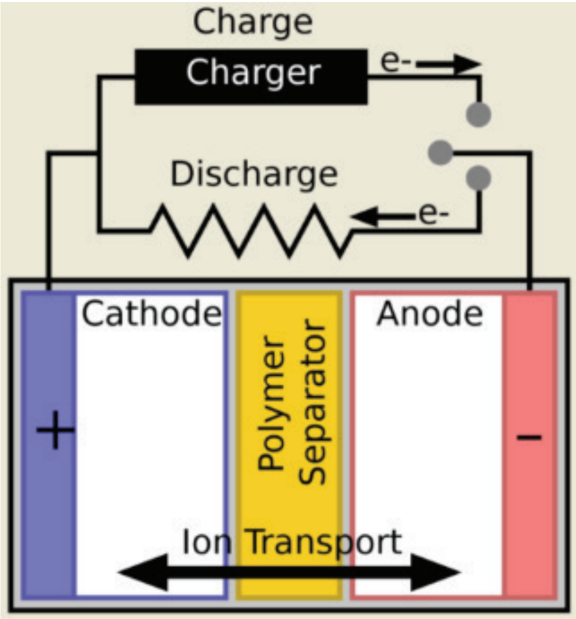
- **EV purchase incentives and tax credits.** This is to lower the upfront cost of EVs. US incentives under the IRA have not survived under changes made by the Trump administration, however a range of European countries have such incentives.
- **Emission and fuel economy standards.** These incentivise OEMs to produce more EVs, with some markets imposing minimum levels of EV sales. Fuel standards exist in the US (state-based standards will likely survive any federal changes), Europe and Australia. Europe and California have mandated 100% of new car sales to be zero-emission by 2035. While these targets are also subject to change, both these governments also have government procurement directives to support the uptake of EVs.
- **Charging infrastructure investment.** This supports the deployment of fast-charging infrastructure in particular. The Bipartisan Infrastructure Law provided significant support for EV charging, while Europe has mandated fast charges to be available on major highways in coming years.
- **Manufacturing incentives.** Both the US, through the IRA, and Europe, through the European Battery Alliance, have introduced tax credits and subsidies for local production of LIBs and EVs. While support in the US carries some risk, we such manufacturing incentives as the most likely to survive within a Trump administration given the nature of the industries that are being supported. Similar to semiconductor industry incentives discussed in the previous section, increased manufacturing and sovereign capability remains bipartisan.

NMC and LFP batteries are the most common LIBs at present

The two most commonly-discussed LIBs are NMC and LFP – the names refer to the makeup of the cathode. There are other, more niche, types of LIBs including lithium nickel cobalt aluminium oxide (NCA), lithium cobalt oxide (LCO) and lithium tianate (LTO). A LIB works in the following way:

- Both the anode and cathode of a LIB can store lithium – typically as a compound given elemental lithium is highly reactive (lithium-carbon compounds in the anode, lithium-metal oxides in the cathode);
- The salt-based electrolyte carries positively charged lithium ions between the anode and cathode – from anode to cathode when discharging, the opposite direction when charging;
- The polymer separator between the anode and cathode allows the lithium ions to flow through it, but does not allow the electrons that are freed up to do so – the separator also prevents anode and cathode reacting; and
- The electrons flow through an external circuit between the anode and cathode (in the same direction as lithium ions) – this creates the electrical current, with ions and electrons recombining at the anode or cathode (depending on the direction of flow, discharge or charge).

Simple representation of a LIB



Source: UPS

Comparing NMC and LFP batteries

Although there is some overlap in the use-cases, NMC and LFP batteries have some important differences which result in each having optimal applications. We compare the technologies in the table below:

Comparing NMC and LFP lithium-ion batteries

	NMC	LFP
Chemistry	Cathode: nickel, manganese, cobalt Anode: carbon	Cathode: lithium iron phosphate Anode: carbon
Thermal stability	NMC batteries are not as stable, hence thermal management systems are essential to prevent over-heating	Chemical structure is more stable, less prone to thermal runaway – better suited to applications where safety is critical or harsh environments
Energy density	Higher energy density, hence can store same energy in a smaller, lighter package – better suited to applications where space and weight is critical	Lower energy density, hence bulkier for the same energy storage capacity
Cycle life	Shorter cycle life (although still sufficient for EV applications)	Longer cycle life – better suited for use where durability and lifespan is crucial
Cost	Raw materials more expensive; cost effective where space and weight constraints are critical	Raw materials more abundant and cheaper; cost effective on a per cycle basis where long-term cost efficiency is essential
Applications	EVs (particularly with longer range), portable electronics	Stationary energy storage, EVs (particularly for low-cost vehicles)

Source: Aichelin, Mayfield, Rimor Equity Research

We are watching changes in battery chemistry for potential changes to HPA markets…

There are a range of emerging technologies such as solid-state or sodium-ion batteries that aim to deliver higher energy density, longer lifespan, improved safety (from reduced risk of thermal runaway) and reduced cost of production (given the replacement of some of the more expensive commodities within a NMC battery). At present, these technologies remain in development. As we discuss below, there appears likely to continue to be a role for HPA in solid state batteries. While HPA has characteristics that are likely to be attractive for future battery chemistries, we consider the broader risk to consider for the market for HPA products is the potential for changes to the battery technology, rather than the relative share of LIB production between NMC and LFP batteries. This is due to HPA's core properties of thermal and electrical conductivity, chemical stability and purity (the latter being discussed below as is critical). It should be noted that a NMCA (nickel manganese cobalt aluminium) battery is an evolution of the NMC battery and appears to have similar use-cases for HPA.

… Solid state batteries appear most prospective

Solid state batteries (SSBs) use a solid electrolyte instead of a liquid electrolyte used in a LIB. SSB technology is still in development and aims to deliver higher energy density, longer lifespan and improved safety. There are a wide range of companies pursuing developments in this area, so we consider this is the most likely technology to consider. A few considerations that are relevant for this report:

- **Similar cathode materials can be used.** NMC and LFP can still be used in a SSB, although there are other potential cathode materials being explored given a SSB allows for the more energy-dense materials to be used.
- **Electolyte material is not yet standardised.** There appear to be three primary categories of solid electrolyte material at present (obviously subject to change): 1) sulfide-based (ion conductivity approaching liquid electrolytes, able to be processed at room temperature, but need a cathode protective layer given it can be chemically unstable next to high-voltage cathode materials and can react to moisture); 2) oxide-based (more stable and compatible with high-voltage cathodes, non-toxic, but lower ionic conductivity and can be brittle in manufacturing); and 3) polymer-based electrolytes (easy to manufacture, compatibility with LFP cathodes, but lower ionic conductivity and not suited to high voltages).
- **Electrolyte compatibility with cathode is important.** Solid electrolytes need to enable ion conductivity and at the same time must be stable with the cathode. As we discuss below, this is the essence of the potential role of HPA within a SSB – enabling conductivity of the electrolyte and surface coating for the cathode.

As discussed below, HPA is likely to retain an important role in SSB technology due to its chemical properties.

LIBs markets are expected to grow strongly over this decade

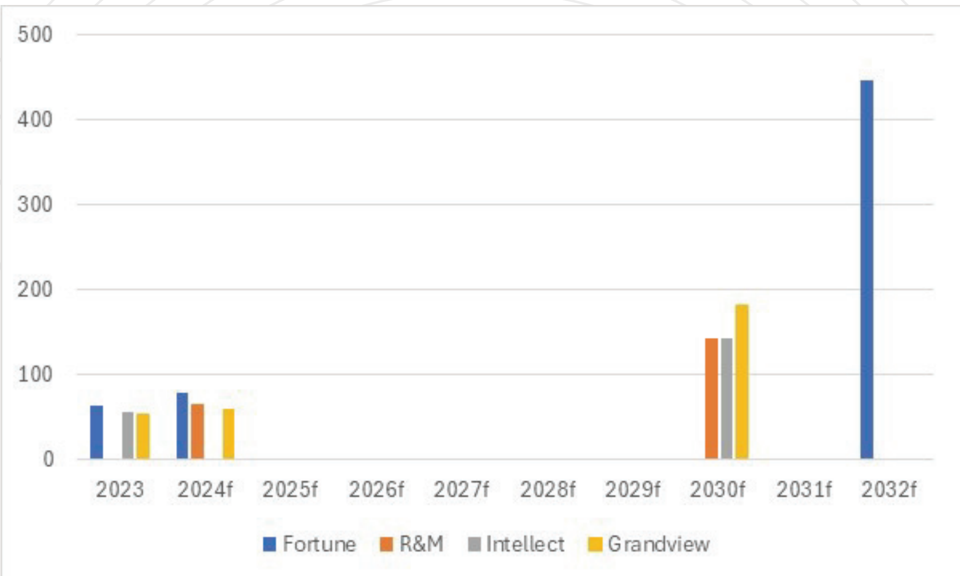
We summarise a range of publicly available industry growth forecasts for LIBs below. We also note the relative growth forecasts for NMC and LFP batteries where available. Due to the trend towards electrification and the importance of LIBs to enabling electrification, the market is expected to grow strongly over the remainder of this decade. Continuous improvement in energy density, charging times and safety features are expected to continue to drive growth in LIBs from these uses and potentially a broader range of applications. Consumer demand for portable and high-functionality electronic devices and industrial demand should further add to growth. In turn this should lead to increased demand for specialty aluminium chemicals that are used in LIBs or will be used as innovation in LIB technology is delivered.

LIB industry revenue is forecast to grow by 15-20%pa over the remainder of this decade…

We summarise a range of publicly-available industry revenue growth forecasts for LIBs in the chart below. Key points:

- Market sizings differ between sources, with estimates for the LIB industry being sized at US$55-65bn in 2023 and US$65-80bn in 2024.
- Growth forecasts differ, but the consensus is for the industry to grow to at least US$150-200bn by 2030.
- The low end of forecast range is from both Research & Markets (Research & Markets) and Intellect Markets (Intellect Markets), who both forecast a CAGR of ~14%pa, with a market size ~US$150bn in 2030.
- Grandview (Grandview) and Fortune (Fortune) are the two more bullish outlooks, with a forecast CAGR of ~20%pa and ~24%pa respectively. Grandview's 2030 forecast is the top end of the range we have quoted, i.e. ~US$200bn. Fortune forecasts a market size of almost US$450bn in 2032 – this implies a market size of almost US$300bn in 2030, well ahead of all other forecasts.
- While western markets have offered attractive support for the development of the industry, it is not surprising that the Asia Pacific market is the largest globally. Fortune and Grandview estimate that almost 50% of the current LIB market is in Asia Pacific and that it will continue to dominate over this decade. China, Japan and Korea are seen as likely the largest markets for EV manufacturing, while strong demand for consumer electronics is likely to also drive growth in the Chinese, Indian, Japanese and Singaporean markets.
- Research & Markets estimates China to be ~18% of the current market and increase share to ~22% by 2030. Statista (Statista) estimated that China produced ~70% of batteries that entered the global market in 2023 (clearly the full value chain is not in China, corresponding to the revenue market sizing).

LIB industry revenue growth forecasts (US$bn)



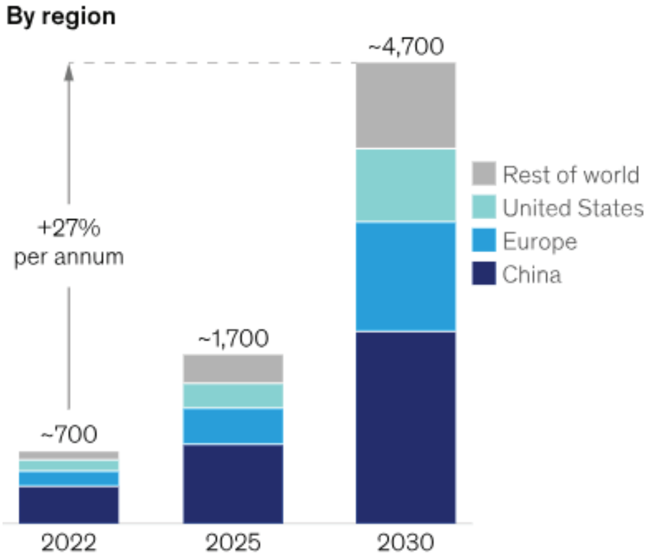
Source: Fortune Business Insights, Research & Markets, Intellect Markets, Grandview, Rimor Equity Research

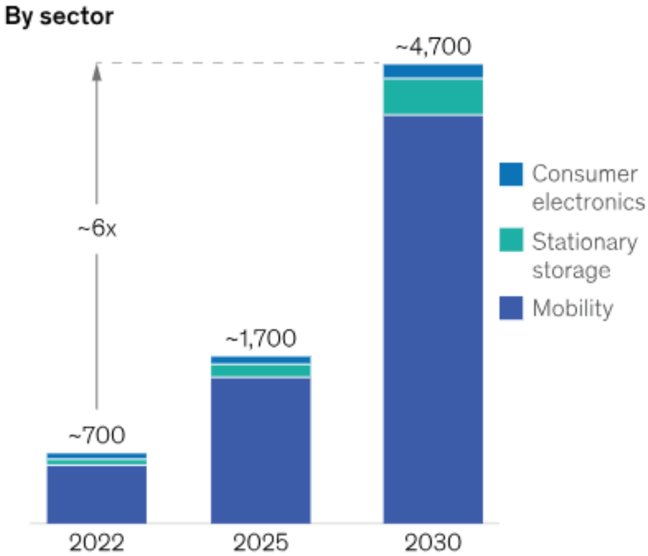
… With LIB capacity forecast to grow by 20-25%pa, faster than revenue due to falling prices

Some industry forecasts are provided in capacity terms rather than market value. These are also instructive for demand forecasts for specialty aluminium chemicals that are used in LIBs. Key points:

- Although LIB capacity growth forecasts are from different sources to those of industry revenue growth forecasts, it is not surprising that capacity growth is forecast to be higher than revenue growth in an industry which is expected to deliver ongoing unit cost reductions as innovations continue to advance the technology.
- Statista expects global demand for LIBs to increase ~7x between 2022 and 2030, reaching 4.7TWh by 2030, a CAGR of >25%pa. It estimated that EVs accounted for >80% of global demand for LIBs in 2024.
- McKinsey (McKinsey) released similar forecasts in Jan-23, seen in the chart below – a similar end-point in 2030 and a CAGR of ~27%pa. As can be seen, it forecasts China to continue to be the largest source of demand, at ~40% of global demand for LIBs by 2030, and mobility to account for ~90% of global demand by 2030. Given a lower EV growth trajectory in the last two years, McKinsey has reduced its forecast 2030 global LIB cell demand to ~4TWh, still implying a ~20%pa CAGR – the market splits in the chart below remain relevant, we discuss its updated forecasts in the context of NMC and LFP below.

McKinsey base-case (Jan-23) global LIB cell demand (GWh)





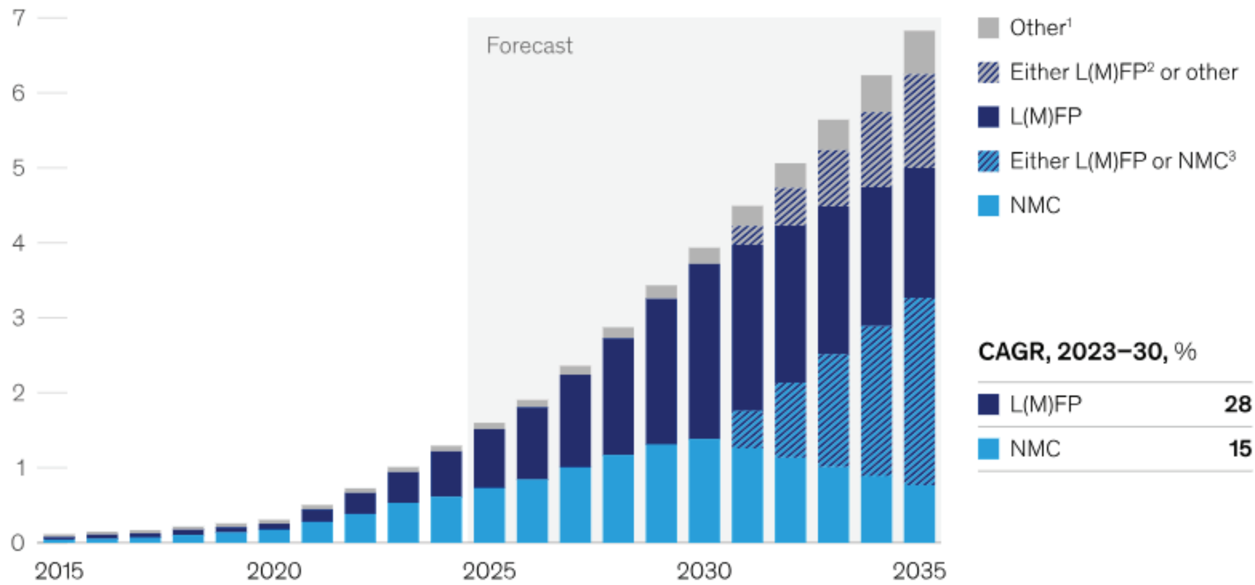
Source: McKinsey

With mixed forecasts around the relative growth of NMC and LFP batteries

Market estimates around the relative growth of NMC and LFP batteries differ. EVs have been and will likely to continue to be the primary market for LIBs. Over the last 10 years, automotive OEMs have preferred NMC batteries due to higher energy density that allows for a longer range (to address consumer 'range-anxiety'). LFP batteries have historically been used in lower cost EVs, however technological improvements driven by Chinese EV manufacturers have reduced the gap in performance. This has led to OEMs considering increasing LFP use, albeit current supply chains for western EV manufacturers provide some challenges to rapidly doing so. At this stage it is unclear whether LFP battery improvements will continue to outpace improvements to NMC batteries. Some of the different views include:

- Research & Markets forecasts that the share of NMC batteries in the market increases from 47% now to 54% by 2030, growing at a CAGR of 16.5%pa compared to LFP batteries growing at ~12%pa.
- Fortune highlights LFP batteries as the fastest-growing segment of the market due to the qualities we list above.
- McKinsey forecasts LFP batteries to grow at ~28%pa between 2023 and 2030, faster than NMC batteries at ~15% CAGR. However, in the forecasts shown below (from Dec-24 – as above, moderating medium-term growth in LIB demand) it highlights uncertainty from 2030 based on the potential for divergence in LFP and NMC battery improvements and the potential for other technological developments such as solid-state batteries (SSBs). For determining demand for specialty aluminium chemicals, we discuss the implications of this below.

McKinsey (Dec-24) global LIB cell demand by source (TWh)



¹Including sodium-ion and other lithium-ion chemistries.

Source: McKinsey

HPA has a current role in LIB production; coating cathodes/anodes are key opportunities

At present, HPA is used principally as a coating material for LIB separators (shown in the diagram near the start of this section). This is not to be confused with aluminium, which is also used in LIBs (and also needs to be high-purity) as the cathode current collector. Looking forward, we believe Alpha's opportunities for its high-purity specialty aluminium chemicals to be for cathode coating, anode coating and, in solid state batteries, be used for advanced ceramic components, particularly the electrolyte. We discuss these in turn.

HPA currently predominantly used for LIB separator coating, however purity has been reducing over time

In many LIBs, HPA is coated on the separator to enhance its thermal stability, mechanical strength and safety. Given LIBs have high energy density, the separator can be subject to significant thermal and chemical stress. At the same time, it must allow for lithium-ion transit and offer mechanical strength. The HPA coating can enhance the operation of the separator. It prevents shrinkage or melting, reducing the risk of thermal runaway, and protects against the formation of dendrite, which can cause short circuits. HPA also allows lithium-ions to pass and is strong, hence having a role in ensuring performance, durability and safety. LFP batteries typically use less HPA for separator coating than in NMC batteries given they have greater thermal stability due to their chemistry.

Earlier versions of LIBs used HPA that was 4N purity and above. However with the focus on reducing cost of batteries, a number of manufacturers have gradually reduced the purity of the HPA being used – some of the market has moved to 3N purity. There is potential for Alpha to provide its HPA products for this use-case if customers want to use 4N products, particularly if they want to diversify supply sources. However without a push for supplier diversification it may be difficult for Alpha to displace supply to these end-markets given current supply chains and vertical integration. We view Alpha's primary opportunities for its specialty aluminium chemicals are into the use-cases that are potentially higher growth and that we discuss next: cathode coating, anode coating and to SSB manufacturers.

HPA can also be used for coating cathodes

One of the key safety risks for LIBs is thermal runaway. We discuss the cause of this in more detail below (see discussion below on LIB quality). To manage this risk, LIBs have internal cooling systems and battery management capability. Both add material volume/weight and cost to the battery. One area of current interest to LIB manufacturers appears to be prevention of the causes of thermal runaway (as opposed to managing them if they occur). Chemical reactions between cathode/anode and electrolyte are risks that can be managed through coating of cathodes or anodes.

Cathode materials, particularly those with high proportions of nickel, can react with the electrolyte resulting in excess heat or gases that add to pressure. This risk is greater at higher voltages, which is particularly important for EV charging applications. Alpha appears to have had some customer traction with its different phase HPA products and ATH. HPA can be used for cathode coating (typically at <1% of cathode weight) or ATH can be used for cathode doping (where HPA is introduced into the cathode at the time of production) to:

- Reduce the potential for such chemical reactions between cathode and electrolyte;
- Improve thermal performance;
- Enhance structural stability; and
- Extend the life of the LIB due to reduced capacity loss over time.

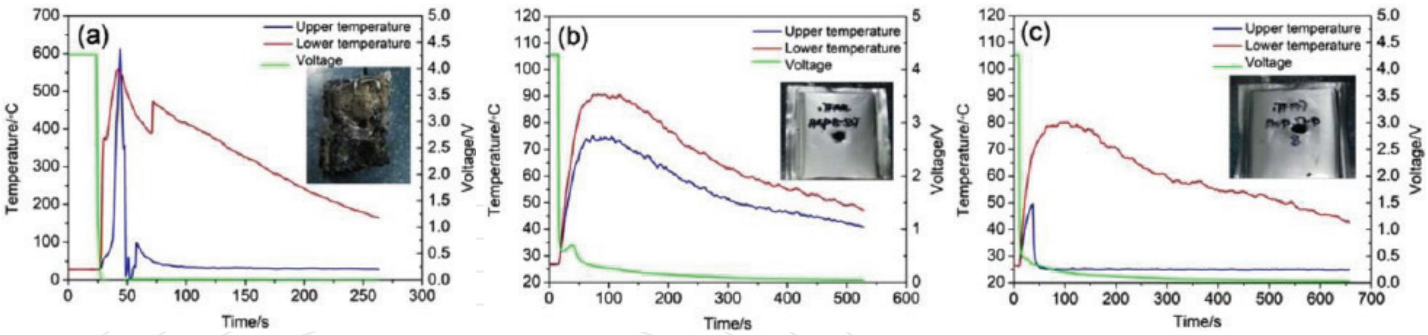
The leading player globally appears to be Evonik (a German specialty chemicals company), with its AEROXIDE product – this is a fumed alumina made up of very small particles (~100nm) produced when aluminium chloride is subjected to flame hydrolysis. Evonik has stated that its product increases the service life of a LIB by ~50% (source: AEROXIDE). Interestingly, Evonik will only produce this product in Asia towards the end of 2025 (currently it is produced in Germany only) – in March-23 it announced that it would produce this product from its Yokkaichi plant in Japan in order to be "closer to customers". At its May-25 investor day, it noted "demand for this specific market is growing" and "continued positive momentum" in Asia, indicating this is not an established product in this market and therefore offers Alpha the prospect of growing with the market rather than replacing incumbent providers.

Potential use-case for aluminium nitrate is for coating anodes

There have been two studies published by Chinese academics that assess the potential to use HPA to coat graphite anodes to manage the risk of reaction with electrolyte (effectively becoming an artificial solid electrolyte interphase, which is typically formed on the anode in the first few charge/discharge cycles but does reduce the capacity of the battery and can degrade over time):

- In 2016, Feng et al published a study through the American Chemical Society (ACS) demonstrating that coating natural graphite (the anode) with HPA could improve Coulombic efficiency (a measure of efficiency of charge transferred within the battery – a higher score means longer battery life and lower risk of side reactions that could cause thermal runaway), cycling stability and rate performance (a measure of a battery maintaining capacity and efficiency when charged/discharged at different rates).
- In 2019, Xu et al published a study in the Chinese Journal of Chemistry (CJC) demonstrating that coating natural graphite (the anode) with HPA could limit side reactions, improve cycle stability and prevent thermal runaway when the battery is physically damaged (using a nail penetration test). The safety testing was the most dramatic conclusion – we show the untreated and treated results that were published below (note two treated samples were presented, with a mass ratio of 1% HPA and 3% HPA relative to the natural graphite). The temperature scale is particularly noteworthy – the untreated graphite anode reaches temperatures of >500°C as a result of chemical reactions that lead to the melting of the separators (at ~130°C) and consequent thermal runaway, while the HPA-treated batteries do not reach over 100°C. All untreated cells ignited, while all treated cells did not ignite.

Xu et al (2019) nail penetration tests for (a) untreated graphite, (b) 1% HPA coating and (c) 3% HPA coating



Source: Chinese Journal of Chemistry

Both the reports discussed above applied the HPA to the natural graphite anode using the sol-gel method. This is one of a number of methods that can be used – consistent with the discussion by Xu et al, the sol-gel method is seen by industry contacts as simpler and lower-cost, hence being more appropriate for scaling in the mass-market. The sol-gel method uses an HPA precursor, typically aluminium nitrate or an aluminium alkoxide, to form an alumina sol (a collodial suspension) that is then coated on the graphite. Some further points to note:

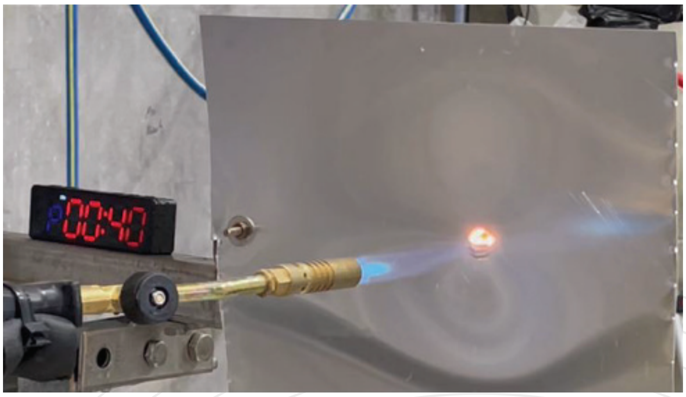
- The advantage of using aluminium nitrate as a precursor is that it can be dissolved in water in the first stage (the alkoxide needs an alochol-based solvent) and is more stable at room temperature. The alkoxide pathway can provide a denser coating with better uniformity, but is more difficult to produce.
- The sol can be applied using dip-coating (the graphite anode is dipped in the sol and withdrawn at a controlled speed), spin-coating (the sol is placed on the anode and spun at high-speed for coverage) or spray-coating (the sol is sprayed on the anode).
- In 2025, Zhao et al published a study through the Royal Society of Chemistry (RSC) demonstrating the viability of spray-coating of the HPA sol as the application technique. It highlighted the scalability and cost-efficiency of spray-coating, used in numerous other industries for paints and specialised coatings, as particularly important for mass manufacturing in LIBs.

As discussed in Section 1, aluminium nitrate is produced in a precursor step of Alpha's manufacturing process. Other HPA production pathways do not produce aluminium nitrate, meaning it has been more complex and expensive to produce at high purity levels. The research from Xu et al is particularly noteworthy given the researchers worked for BTR New Energy Materials, which has been the leading global provider of anode materials for more than a decade. Alpha has indicated it is in discussions with a number of anode manufacturers and in Dec-24 reported it reached technical acceptance (qualification) for the use of its aluminium nitrate for anode coatings with a leading anode OEM. It has not named this OEM and would likely only do so if it received a material LOI for this product. Similar to the semiconductor market, as described below, further qualification testing will likely need to be undertaken with other downstream participants in the supply chain.

… Alpha is also seeing early interest in testing aluminium nitrate for coating cell casings

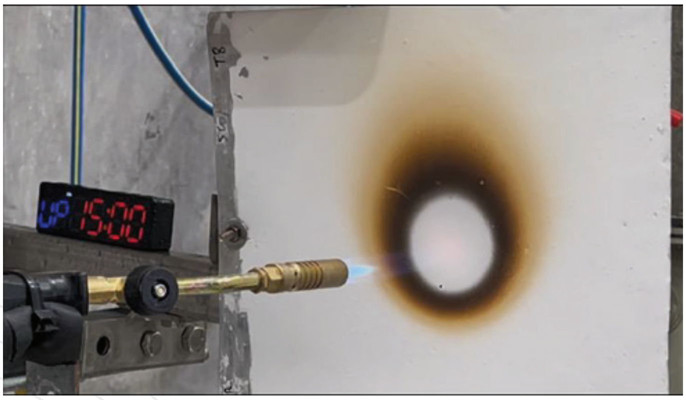
Alpha has recently reported interest from automotive OEMs in testing cell coating applications for its aluminium nitrate chemical. Based on our discussions with industry contacts, this has likely come following progress around anode coating and highlights the opportunity for innovation when bringing new specialty aluminium chemicals to market (as Alpha has done with aluminium nitrate). Citing modelling from P3 Group, Alpha indicates that there is a neutral cost impact for using its UltraCoat product (which uses its aluminium nitrate chemical) given the ability to remove other materials used for cooling and battery management systems. It has also released these photos highlighting the benefits of the UltraCoat coating on an aluminium LIB cell casing – a butane flame burns through an uncoated cell in 40secs, meaning it is susceptible to thermal runaway, while a UltraCoat coated cell is still intact after 15mins.

Uncoated aluminium cell case after 40secs



Source: Alpha HPA

Aluminium cell case with 0.3mm UltraCoat after 15mins



Source: Alpha HPA

A potential role for HPA and aluminium nitrate in solid state batteries

As above, SSBs differ from LIBs due to the liquid electrolyte in a LIB being replaced by a solid electrolyte. It appears likely that HPA would retain an important role in SSBs due to its chemical properties, however the function is likely to change. Rather than being used for separator coatings, as is currently the case in NMC and LFP batteries, there are two primary potential roles for HPA that are critical for electrolyte stability and electrode protection:

- **Interface protection and cathode coating.** In an SSB, the solid electrolyte is often reactive with the cathode materials. HPA coatings can be used to stablise the interface between the two, resulting in longer battery life.
- **Electrolyte layers.** Some SSB designs use ceramic electrolytes that use thin layers of HPA to improve conductivity and protect the battery from lithium dendrites. LATP (Lithium Aluminum Titanium Phosphate) is an example of such a solid electrolyte – the contribution of aluminium typically comes from HPA.

We also note recent literature highlighting a potential role for aluminium nitrate as a sintering agent in the manufacture of solid state electrolytes (source: ScienceDirect). This research was published in Dec-24 and therefore is relatively new – wider scale adoption could lead to a dramatic increase in high purity aluminium nitrate use in a SSB. This is an example of a chemical, at this purity level, that is not commercially available and may have an emerging application in a high-growth end-market such as SSBs. This will evolve as product testing takes place.

Whether or not more HPA is used in a SSB than in one of the primary LIB categories remains to be seen and will to some extent depend on the resultant industry standard. Oxide-based SSBs may use more HPA given it is a key stabiliser within the electrolyte, while in sulfide-based SSBs the HPA use may reduce due to it being used less in the electrolyte material.

Quality of battery is critical given risks that can occur

LIBs that do not meet quality standards are not sold – this is clearly costly for the manufacturer. Testing failure rates can be more than 20% in new battery manufacturing facilities or when manufacturing with new materials – clearly this is a focus area for battery manufacturers given the potential impact on profitability. LIBs are typically tested for safety, performance and logevity risks at various points in the manufacturing cycle:

- **Cell level**. Before further assembly, cells are typically subject to electrochemical testing (for capacity, efficiency), safety testing (to assess risk around short circuits and further risks) and impurity detection (that could cause battery life reduction or operational risks).
- **Module level**. After cells are assembled into modules, they are subject to electrical balancing (to ensure even discharge and reduce risks of vulnerabilities), vibration (simulation of shocks) and stress testing (particularly for electrical stress and water ingress).
- **Pack level**. Once the pack is assembled and the BMS is installed, the battery itself undergoes further testing. The BMS itself is tested to ensure accuracy and proper controls are in place. The battery is also tested for crash safety (particularly for EV applications), water resistance and other environmental factors (humidity, altitude).

There are some issues with LIBs that are either not detected or occur in-use. The primary risks that can happen while a LIB is in operation are:

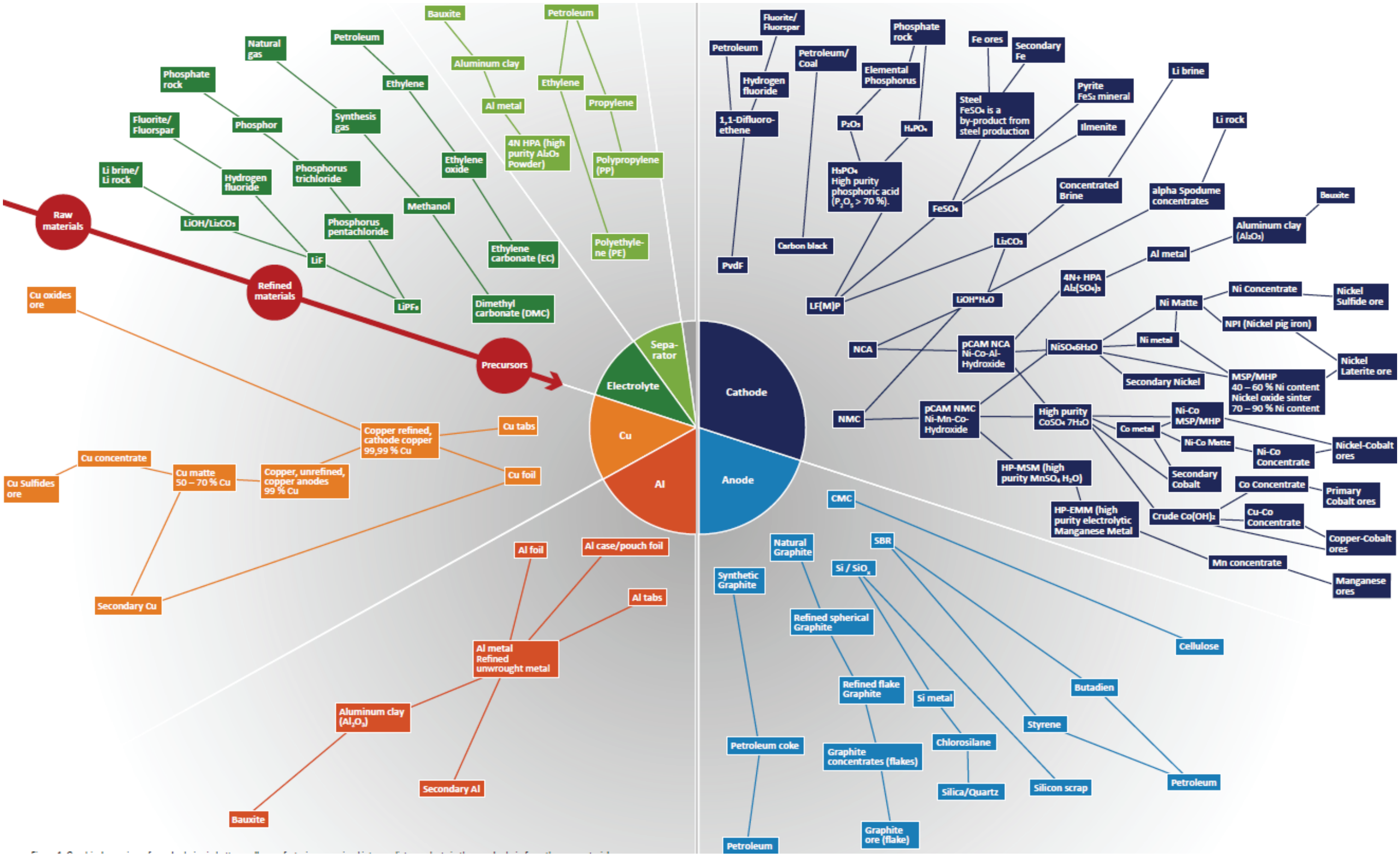
- **Deterioration in performance**. The LIB can lose charge capacity over time, due to a range of issues. This has an impact on battery life and the efficiency of the battery.
- **Short circuits**. This occurs when there is a direct electrical pathway between anode and cathode. This can lead to a number of more serious risks.
- **Thermal runaway**. This is the key safety risk for LIBs and occurs when heat generated inside the battery exceeds the rate of dissipation, resulting in further increases in temperature and a build up of pressure as the electrolyte produces gases. Once this occurs, the temperature inside the LIB continues to increase and can lead to failure, fire or explosion. Thermal runaway can be caused by overcharging or overdischarging (this can lead to lithium plating or dendrite growth), physical damage to the LIB, chemical reactions between cathode/anode materials and electrolyte, high external temperatures or manufacturing defects.
- **Gas build-up**. If a LIB fails, it will release a range of gases. These can cause a build-up in pressure and potentially an explosion. However, if the gases escape, they can be toxic – carbon monoxide is an example, although there are others that can cause damage to human health.
- **Disposal risks**. LIB disposal remains a critical challenge given the risks around treatment of LIBs in the general waste stream (risk of damage leading to thermal runaway and contamination) and the lack of recycling infrastructure. This has a more limited impact on users currently however, we anticipate tighter restrictions on disposal in the future that should drive change in this area.

The risk of thermal runaway is the worst-case scenario for LIBs given it can lead to fires and explosions, beyond device failure. To help manage this risk, LIBs have internal cooling systems and battery management capability – these add material volume/weight and cost to the battery, hence there is a large focus on prevention rather than mitigation.

As a result, qualification processes are rigorous…

As is clear from above, all faults in LIBs are costly for the manufacturer and could be a risk to safety. The supply chain is complex (as seen in the graphic below). Given the complexity of the supply chain and technical complexity involved in the production process, customers throughout the supply chain need assurance that they are receiving high quality inputs to their own process. To supply to a LIB manufacturer, or even a supplier to a LIB manufacturer, suppliers undergo a comprehensive product qualification process to ensure materials supplied meet the quality specifications needed for the production process. LIB manufacturers undergo their own product qualification process with their customers across the various industries we discuss above. In the chart below, note that HPA is shown in light green – as we explain above, not to be confused with the use of aluminium as shown in dark orange.

Graphical overview of supply chains in battery cell manufacturing (HPA shown in light green)



Source: German Federal Ministry for Economic Affairs and Climate Action

A typical qualification process for suppliers of HPA would involve the following:

- **Supplier qualification and material compliance.** This will involve determining the purity of the HPA products, regulatory compliance and supply chain capability (both production capacity and on-time delivery). As discussed in section 1, Alpha is focused on 4N (99.99%) and above purity products. LIB manufacturers will also consider contaminants as these can impact performance and reliability of the LIB.
- **Material certification.** In addition to purity, this will investigate chemical compatability and particle shape, size and distribution to ensure the HPA meets the requirements for the LIB.
- **Pilot testing.** This is the first evaluation of how the HPA performs in a LIB production line. The primary tests would involve adhesion to the separator/cathode/anode (as relevant), thermal stability, Coulombic efficiency, cycling stability, rate performance and electrochemical performance.
- **Quality management systems and reproducability.** This is relevant to the HPA producer's own operations and is to ensure the process is robust, ensuring documentation of raw materials and processes, in addition to consistency of final product to ensure it can continue to meet performance specifications, which is critical to LIB production itself being uniform in quality.
- **Full-scale production and process testing.** This will go beyond pilot testing and introduce the HPA to the LIB production line – critical testing at this stage is for consistency of batches, compatibility with the LIB production line and stability testing over extended cycles.
- **Ongoing supplier audits.** LIB manufacturers will typically visit the site of HPA production to evaluate the manufacturing process, quality control and supply chain security systems and environmental compliance systems. In addition, manufacturers will conduct ongoing audits to ensure long-term consistency.

… And can take more than 12 months, a significant barrier to entry

The product qualification process for LIB manufacturers can take more than 12 months (it can be shorter for existing suppliers, hence Alpha is targeting some of these suppliers directly – however the qualification process with those suppliers is likely to take >12 months). The following timeline is indicative:

- **Initial supplier evaluation**. This is to assess the supplier's suitability, before assessing product quality. It focuses on quality management systems, environmental and safety compliance and likely involves an on-site audit. Depending on logistics and complexity, this can take up to 3 months.
- **Material testing**. This is to assess material compliance and compatability. For HPA, this will take into account purity, chemical compatibility and particle shape, size and distribution. In addition to the pilot testing to to evaluate performance, this can 6-9 months.
- **Qualification trials**. After initial material testing, larger-scale trials are undertaken to determine performance across the full-scale LIB production line. This will analyse consistency of performance and battery stability testing over extended cycles. This can 6-9 months.
- **Testing with downstream customers.** As above, not only does the product need to meet customer requirements, but these customers also require downstream qualification with end-market manufacturers given the risks associated with product malfunction. If the process has multiple steps in the value chain, then this can take significantly more time.

Once a supplier is qualified, the material is then used in production. Even after this qualification, suppliers are typically monitored to assess ongoing quality of material. Once a supplier has been qualified, this constitutes a significant barrier to entry for a new supplier. This is particularly true if the end-market for the customer is relatively low growth – unless there is an incentive for a customer to change supplier, it is difficult for new suppliers to gain material market share. Although this may appear to make it difficult for Alpha, it is worthwhile noting that the LIB end-market that we have discussed above is expected to grow strongly over coming years. This means there is an opportunity for new suppliers who can deliver the quality of product required. In addition, there is an opportunity for Alpha to deliver products for new applications (e.g. cathode/anode/cell case coatings, solid-state batteries) that we discuss above.

HPA quality is a key decision-point for LIB manufacturers

Due to the risks discussed above, all of which can have significant downside risk to profitability, LIB manufacturers need to ensure they have access to high quality materials while limiting supply chain vulnerabilities. Based on our discussions with industry contacts, the price of HPA is more important for LIB manufacturers than for semiconductor manufacturers – this is particularly the case for consumer devices and entry-level EVs, where price sensitivity exits. However, given the risks to safety, battery life and the cost of defects, these industry contacts suggest quality is normally prioritised over price, meaning the broader value proposition is most critical. The key decision-points are:

HPA, with few contaminants, to minimise risk to LIB performance

Contaminants can cause all the risks we mention above (performance, reliability and failure). LIB manufacturers tend to require at least 4N (99.99%) HPA to minimise the risks around contaminants, although some lower quality batteries can use lower purity HPA due to the price differential. Key contaminants to consider are:

- **Sodium and iron**. These are the most critical contaminants for LIB manufacturing – even trace levels can cause significant issues around unwanted side reactions. Sodium can result in the formation of dendrite, which can cause short circuits and reduce cycle life. Iron can cause short circuits and accelerate degradation of the battery.
- **Chlorine and sulfur**. The presence of these contaminants can result in corrosion of battery components or unwanted side reactions that can reduce battery life and safety.
- **Silicon, calcium and magnesium**. These are common impurities in HPA and can impact coating uniformity, hence potentially impacting the performance of the separator and anode. If the coating is not uniform, this can result in unwanted side reactions.
- **Heavy metals (e.g. lead, nickel, copper)**. The presence of such contaminants can result in toxic gases forming and potential electrochemical instability.

HPA particle shape, size and distribution is a quality consideration for LIB manufacturers

Consistency of particle shape, size and distribution is important for LIB manufacturing, reflected in the qualification testing criteria above. This is influenced by quality control during the manufacturing process and is critical for uniformity of separator, cathode or anode coating. Uniformity can maximise density of the coating, improving the performance and adding to the structural integrity of the LIB. If the coating is uneven, this can impact stability and shorten the cycle life of the LIB.

Moisture content can lead to suboptimal coating performance

An increased level of moisture content can cause agglomeration (small particles forming clusters due to the particles being stuck together). Such clusters can lead to manufacturing defects due to the impact on highly tuned equipment. It can also result in coatings not being uniform, which creates risk around stability and cycle life as above.

Material properties for appropriate functionality

We described the initial phases of the qualification process above. In the early stages of this process, there is a range of testing, focused on material quality and properties. As described, these are clear decision-points for LIB manufacturers determining whether the HPA is appropriate for the use-cases described above.

Supplier processes for quality management and ongoing support

We also described the assessment of quality of management systems above. This is relevant to the HPA producer's own operations and to ensure the process is robust, ensuring documentation of raw materials and processes. Consistency of final product is critical to LIB production to ensure performance specifications can continue to be met. On-site audits can be used for this assessment. There is also the potential for a stronger relationship between suppliers and customers if the HPA supplier can offer technical support that is relevant to the LIB manufacturing process.

Supply chain reliability and resilience

On-time and in-full product delivery is critically important for most manufacturing processes and LIB manufactung is no different. The importance of this has increased in recent years, with supply chain constraints after the impact of COVID-19 and geopolitical concerns around concentration of supply being material issues for LIB manufacturers. Given Australia is not a large global supplier of HPA products already, we believe this is is an opportunity for suppliers from Australia, such as Alpha.

Environmental and safety compliance

This is particularly relevant for handling and disposal of hazardous chemicals to ensure compliance with environmental regulations. Increasingly we expect this to consider the emissions profile of and waste generated from production. Given an increasing global focus on embedded emissions in production, we expect Scope 3 emissions for the LIB manufacturer to be increasingly relevant.

Pricing is part of the broader value proposition

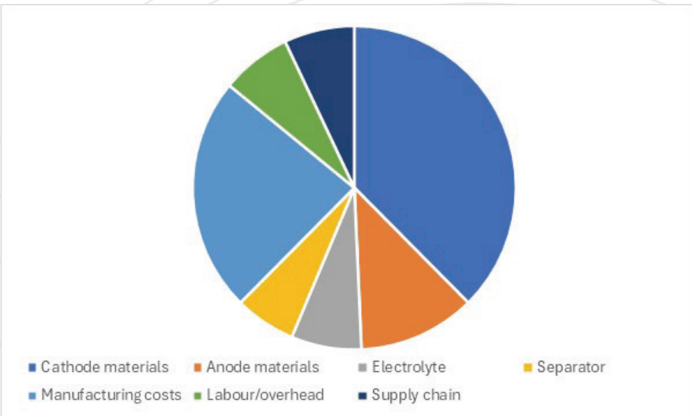
For LIB manufacturers, quality and resilience of the supply chain are paramount concerns. While price is typically secondary to these considerations, it will still form a part of the supplier value proposition that balances price with material performance and productivity. As we discuss next, HPA typically accounts for <5% of the cost of a LIB – while meaningful, the overall value proposition (particularly cycle life, thermal stability and durability) is the primary consideration. Poor quality HPA can lead to higher defect rates and lower yields, reducing manufacturer profitability.

HPA accounts for <5% of the cost of a LIB

The charts below show estimates of the breakdown of costs for LIB manufacturing, using information from BloombergNEF and confirmed by industry contacts. We speak to ranges in the specific discussion points, however we show the midpoints in these charts – the splits are indicative and will not correspond with all LIB production costs, particularly given movements in commodity prices. Key points:

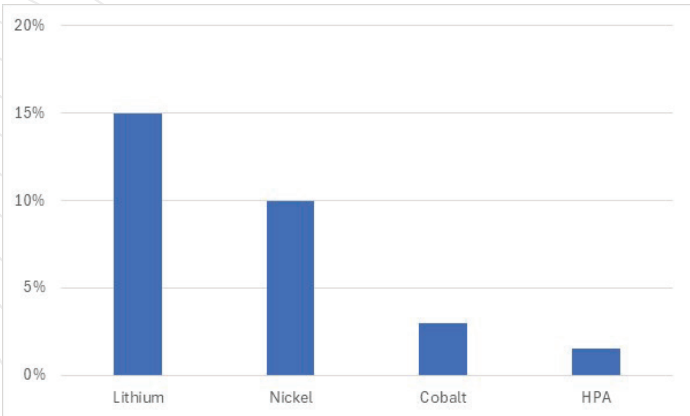
- **Commodity prices can drive significant differences in cost drivers**. The charts below are indicative and based on a range of sources. Some cost splits we have seen do not account for manufacturing costs and labour/overhead, but we believe these are important to consider for the cost sensitivity of LIB manufacturers. While battery costs have reduced over the last 10-15yrs, this is not a straight-line trend. Commodity price variations can drive significant change in the cost of the battery pack from year-to-year.
- **We have shown cost splits for NMC batteries, LFP batteries are lower cost**. The charts below show cost splits for NMC batteries. LFP batteries are lower cost, driven primarily by the lower cost of cathode materials relative to nickel and cobalt.
- **The cathode is the largest driver of cost, with commodity prices the largest driver of cathode cost**. This is clear from the left-hand chart. The cathode materials are the largest driver of cost variations – an indicative split of the cost of lithium, nickel and cobalt is shown in the right-hand chart. These account for more than half of the cost of the cathode. The dramatic increase in the price of lithium, seen in 2021/2022, increased the price of LIB manufacturing for the first time since 2010. We discuss this further in the DLE section of the report next.
- **HPA accounts for <5% of the cost of a LIB, value proposition more important than price**. Unlike the cost of cathode materials, HPA is a relatively low proportion of the cost of a LIB for each of the applications we discuss above (coating of separators, cathodes or anodes). Based on discussions with industry contacts, we estimate the cost for each of these applications to be 1-2% of the cost of a LIB – even for a LFP battery (with lower cost of cathode materials), this is still <5% of total cost. For a cathode coating, the loading of HPA is typically <1% of the weight of the cathode. The loading may be higher for an anode coating, but the anode is a far lower proportion of total LIB cost. We believe this supports our contention that LIB manufacturers will focus on the value proposition rather than the cost alone.

Cost drivers for LIB manufacturing



Source: Industry contacts, Rimor Equity Research

Comparison of key cost components (% of battery cost)



Source: Future Battery Industries CRC, Rimor Equity Research

Direct lithium extraction

Lithium is clearly essential for the production of LIBs, as discussed in the previous section. Cheaper extraction at scale appears the most critical challenge given the ongoing push to reduce the cost of LIBs. DLE (direct lithium extraction), the extraction of lithium from lithium-salt bearing groundwater (brines) using a combination of technologies, is potentially transformative for brine extraction relative to the cost and environmental footprint of traditional extraction via evaporation. There is no one-size-fits-all given varying brine chemistries, however adsorption is the only DLE technology currently in use and appears set for strong growth in delivering a flatter lithium cost curve. Specialty aluminium chemicals are an important enabler of adsorption and given the investment activity from a wide-range of players, this is a large potential market. High purity amorphous ATH, a precursor chemical in Alpha's process, appears the most interesting opportunity for Alpha given it is not commercially available. Industry contacts suggest Alpha is well-placed given its specialty aluminium chemicals are high-purity and can be provided in an amorphous structure to improve lithium reactivity and therefore extraction. At 30 June-25, Alpha had not executed any customer LOIs in the DLE market although it is testing with >14 counterparties and Alpha has reported its amorphous ATH product gives >1.5x longer life and up to 2x higher extraction rates than current products in use. The contribution of ATH to the cost of DLE is not readily available, however we calculate this to be <5% of the cost of producing lithium chemicals if sorbent material can be reused over 1,000 cycles.

Alpha's products appear well suited to the high-growth DLE market…

Alpha's process flow (see Section 1) will produce ATH in a precursor step, a specialty aluminium chemical that could be used in the DLE market. Although there are some suppliers into the current DLE market that could be difficult to displace, the market is relatively nascent with the potential for strong growth over the medium-term.

This potential use-case for ATH, Alpha's precursor chemical, is most interesting because it is a unique opportunity for Alpha – high purity ATH in the amorphous crystal structure is not commercially available. Industry contacts suggest that Alpha has a strong prospect of supplying into this market given its ability to supply high-purity ATH with an amorphous structure to improve lithium reactivity and therefore extraction efficiency. Alpha has reported that lithium aluminium layered double hydroxide (LDH, the most common DLE sorbent) manufactured using its amorphous ATH product gives >1.5x longer life and up to 2x higher extraction rates than current products in use. There is an alternative pathway for the production of LDH – this requires aluminium chloride, which is produced with HPA/ATH and hydrochloric acid, hence having additional cost and potential for greater environmental impact.

… An important source of Alpha's LOIs due to unique product offerings

As at 30 June-25, Alpha has not executed any customer LOIs in the DLE market, although it is testing with >14 counterparties. The DLE market makes up ~50% of Alpha's estimate of unmet demand – we note its estimate of unmet demand for the DLE sector alone is greater than the capacity of Alpha's Stage 2 production facility.

Lithium – essential for LIBs…

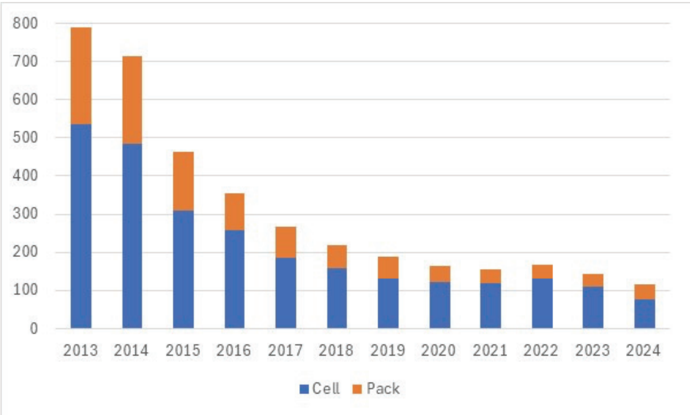
The previous section discussed the importance of LIBs to the ongoing move towards electrification. Clearly lithium is necessary for producing a LIB, so it appears logical that there will be strong growth in demand for lithium as the production of LIBs is increased over the next decade and beyond. This is irrespective of the relative share of LIB production between NMC and LFP batteries. The primary risk is a change in battery chemistry. As discussed above, there are a range of emerging technologies such as solid-state or sodium-ion batteries that aim to deliver higher energy density, longer lifespan, improved safety and reduced cost of production. The commercialisation of new battery technologies could increase or reduce the demand for lithium – at present these technologies remain in development, hence it appears reasonable to expect strong lithium demand growth over the next decade.

… Cheaper extraction at scale appears the most critical challenge

The left-hand chart shows weighted average LIB battery pack and cell prices since 2013 (this is the average assessed by BloombergNEF across a range of end-market uses). Battery costs have reduced significantly over this time. Initially this was driven by the benefits of scaling-up production and innovation. As the price reduced, the commodity prices became a larger cost driver – in the previous section we highlighted lithium was the greatest commodity cost within the cost of an LIB and is a large cost driver of cathode materials (the largest proportion of LIB manufacturing cost).

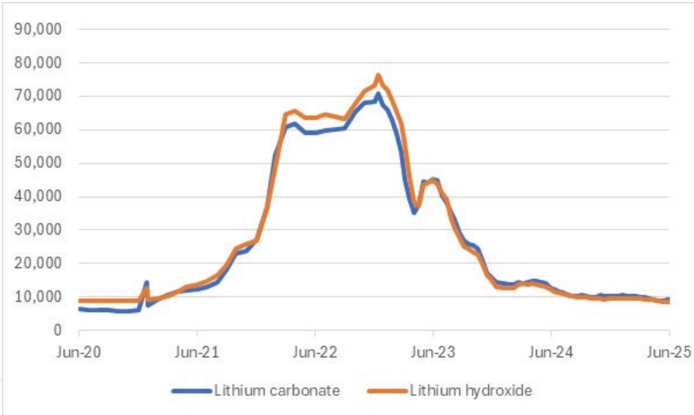
The right-hand chart shows the global weighted average price of lithium carbonate and lithium hydroxide over the last five years – the dramatic increase due to demand-supply imbalance over 2022 is clear. Although it is difficult to see in the left-hand chart, in 2022 the average cost of a LIB battery cell increased by 11% as lithium prices increased. This is an average across the full year – Benchmark estimated cell prices increased by more than 50% from the start of 2021 to the end of 2022. With a dramatic fall in the lithium price as new supply entered the market and demand forecasts fell short of expectations, the cell price fell in 2023 and 2024 once again. BloombergNEF estimates that the average cell price for a LFP battery fell below US$100/kWh for the first time in 2023, and were ~30% cheaper than NMC battery cells in the same year. The shift towards LFP batteries is an important driver of the average price reduction seen in the chart.

Average LIB pack & cell price split (real 2024 US$/kWh)



Source: BloombergNEF, Rimor Equity Research

Lithium price, global weighted average (US$/t)



Source: Benchmark, Rimor Equity Research

BloombergNEF estimates that the total cost of a LIB battery will reach US$80/kWh in 2030 (BloombergNEF), down ~40% from 2023, due to further "technological innovation and manufacturing improvement". Most commentators suggest that such ongoing cost reductions are critical to drive demand, which in turn will drive scale benefits and further cost reductions. There are two risks to such ongoing reductions:

- The likely expansion of production in markets such as the US and Europe, incentivised by government actions, that could increase average battery costs for a period of time as these industries scale and due to higher local costs than in Asia (including energy, equipment, land and labour), where most LIBs are currently produced.
- Commodity price fluctuations in the event of a supply-demand imbalance, as was seen in 2022.

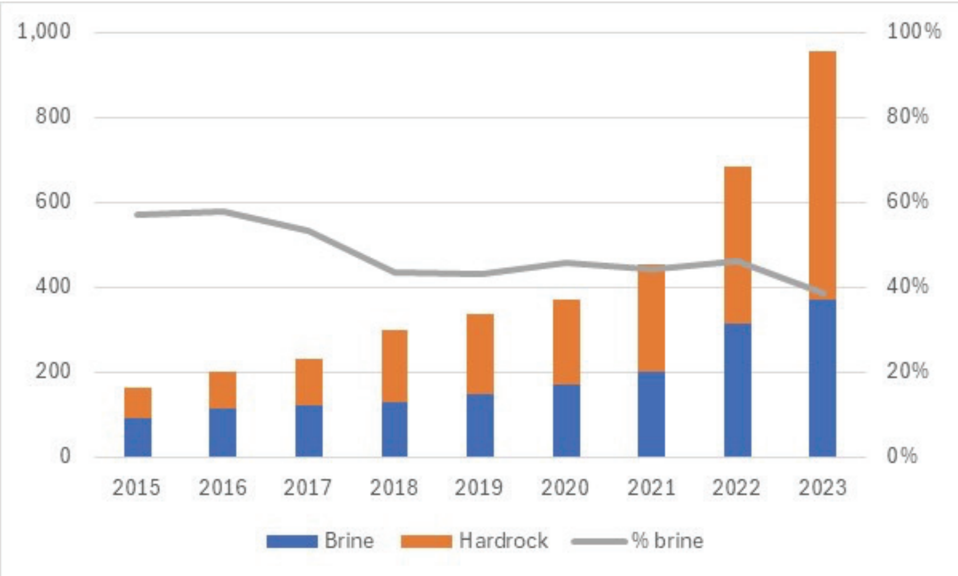
As above, lithium is the most important commodity for LIB manufacturing given its contribution to cost and difficulty in replacing it with other chemicals in new battery technologies. This has led to significant R&D effort to develop methods of cheaper extraction at scale – prior to 2020, lithium was more referred to as a specialty chemical. As was seen in 2022, scaling lithium production rapidly has limitations and can cause significant price volatility. DLE (Direct Lithium Extraction) technologies have the potential to be transformative in this respect (discussed in more detail below). It is worth noting that nickel (the second largest commodity cost driver in an NMC battery) has seen transformative supply-side developments that have significantly reduced production costs in recent years – this has significantly reduced the cost risk associated with nickel.

A brief history of hard-rock vs brine lithium mining…

The chart below shows the production of lithium from brine and hardrock since 2015. As can be seen:

- Brine was the source of almost 60% of lithium in 2015 and 2016 (and prior).
- As industry demand grew, brine production was unable to scale rapidly and hardrock became the source of more than 50% of lithium by 2018 and ~60% in 2023.
- Most of the hardrock lithium production has come on from Australian mines (accounting for >50% of mining), with processing being scaled rapidly in China (accounting for >50% of processing): source IEA. As is often the case with Chinese processing, the scale and cost-base has so far enabled production to ramp-up while the lithium price has remained subdued. As above, the risk comes from processing to enable further demand.

Brine and hardrock lithium production since 2015 (kt of LCE)



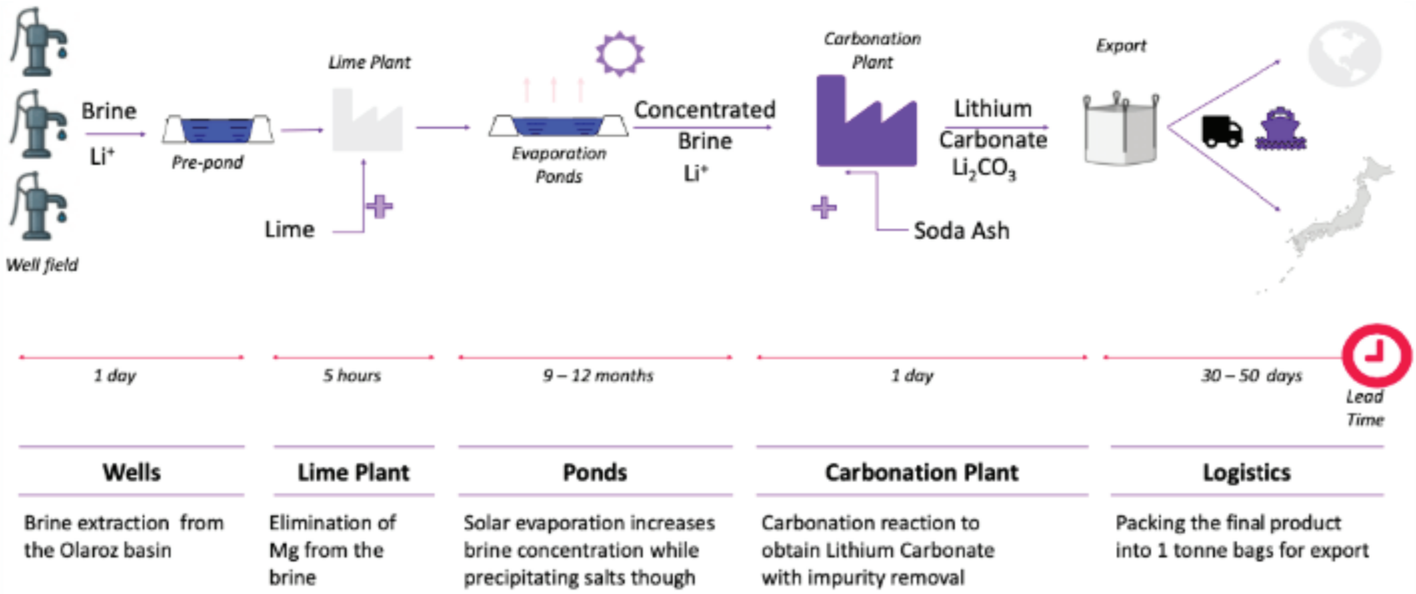
Source: Benchmark, Rimor Equity Research

… Traditional brine extraction has not offered flexibility to scale with demand

One of the key reasons for brine production being unable to scale rapidly is the inherent flexibility of the production process. Key points to note are:

- **Brine extraction has mostly been by evaporation, which is slow to built and to extract**. Most brine extraction has used evaporation ponds, as illustrated below. Brine is pumped to the surface and, using reagents to assist in removing other ions, water is evaporated, leaving a concentrated lithium chloride solution that is then converted to lithium carbonate. This can take up to 24 months to extract lithium, limiting the ability to materially change production in response to price signals. Development timelines are also lengthy, given the scale of such projects and the potential for environmental issues.
- **Low yields**. Benchmark has stated that extraction yields using evaporation ponds in South America have typically been <50%. This also limits scaleability of the process.

Traditional brine extraction process through evaporation



Source: Allkem, Rimor Equity Research

DLE technologies are potentially transformative for brine extraction, but no one-size-fits-all

DLE refers to a number of technologies, of varying commercial readiness (albeit some are already used in extraction of other commodities), that are aimed at more efficiently extracting lithium from brine. The advantages over the traditional evaporation process are:

- **Speed**. The extraction of lithium from the brine can be between several hours and a few days. This is much faster than evaporation ponds, which can take 12-24 months.
- **Higher yields**. Testing of DLE technologies has so far yielded lithium recovery rates of >80% (source: Benchmark). This is far higher than evaporation ponds, reducing unit costs and potentially unlocking resources that have previously been considered uneconomic.
- **Less environmental impact and weather dependence**. DLE technologies typically have lower water usage than evaporation ponds and also require a far smaller footprint (this is also a positive for receiving operational permitting). In addition, evaporation ponds clearly rely on supportive weather conditions, whereas DLE is a chemical process that does not rely on weather.

DLE technologies are attracting new players to lithium extraction…

The advantages of DLE technologies and the geographic spread of brine resources are attracting a range of new players to the market. Most noticeable is the interest of oil & gas companies, such as ExxonMobil, who see the DLE process as similar to their core skill base of drill-based reservoir management, upstream oil extraction and refining. In addition, chemical companies are entering the market given the need for reagents and other chemicals in each of the processes below. These new players can offer expertise from other processes as well as significant capital to invest in development of these technologies. We discuss this in more detail below, in the section that looks at the range of companies developing adsorption DLE technology.

… But it appears there is no one-size fits all DLE technology solution

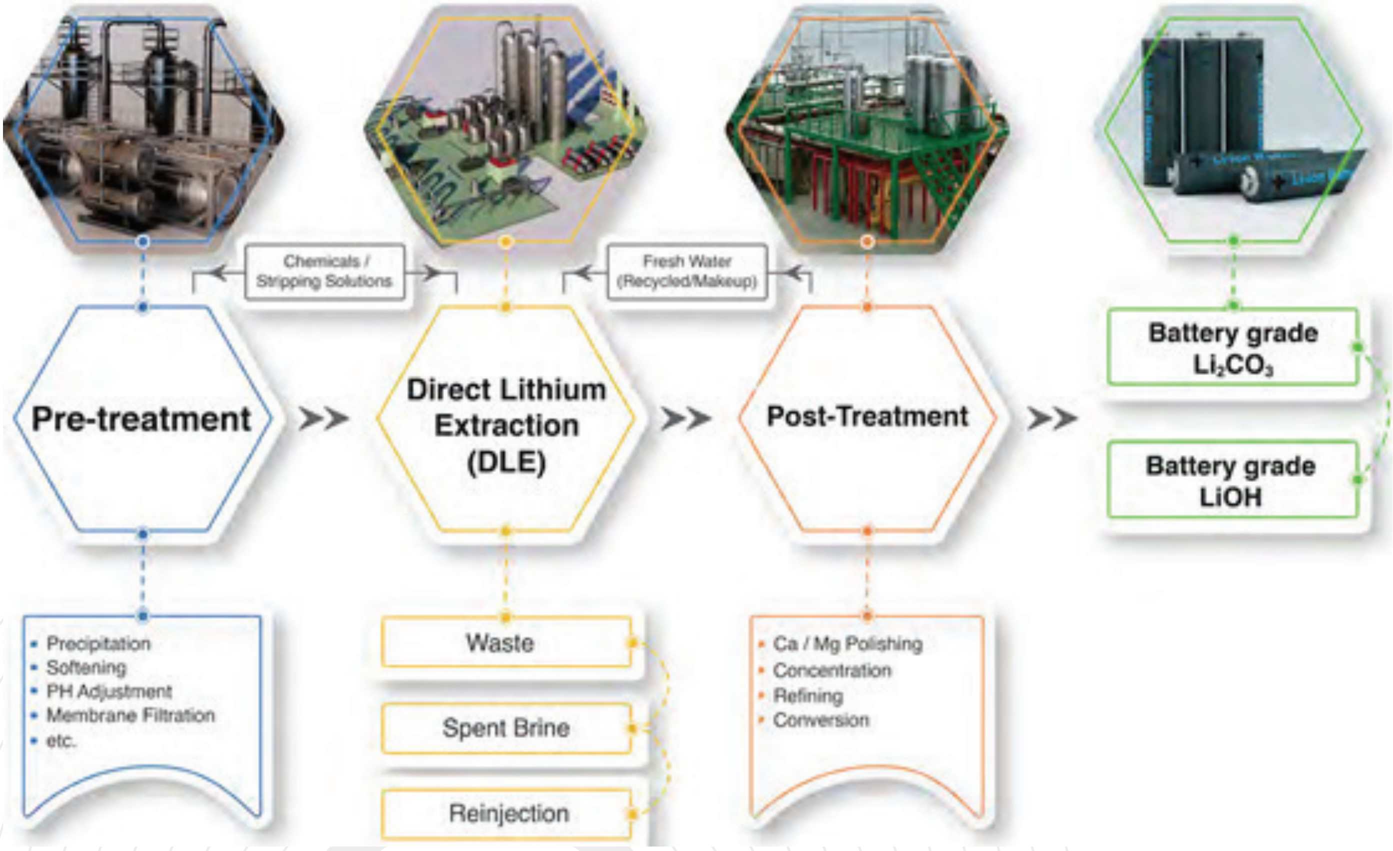
It is critical to recognise that there may be no single technology solution that can optimise lithium extraction across all brine resources. The most obvious reason for this is the brine source can differ: from conventional salar resources, to the emerging use of oilfield and geothermal resources. Even within similar sources, the chemistry of the brine resource can differ, meaning the DLE technology may be standard but the materials used may be different.

Five groupings of DLE technologies, adsorption the only technology currently in use…

As above, DLE refers to a number of technologies, of varying commercial readiness, that are aimed at more efficiently extracting lithium from brine. There are five technology groupings that come under the DLE technology 'umbrella'. Each DLE technology has different cost and extraction efficiency, and other relative pros/cons, which we discuss separately below. Each of the technologies involves these main steps (also shown in the diagram):

- **Pre-treatment** of brine to optimise lithium extraction – by reducing impurities and modifying pH;
- A processing unit that extracts lithium using the specific **DLE technology** discussed below – this allows for the remaining brine to be reinjected into the source;
- **Post-treatment** of lithium extracted to concentrate and purify the lithium product; and
- **Production** of either lithium carbonate or lithium hydroxide on-site for commercial use – this is a key advantage of DLE when compared to the processing of hard-rock resources that require significant processing (using significant energy and chemicals) in order to produce such products for commercial use.

DLE extraction process

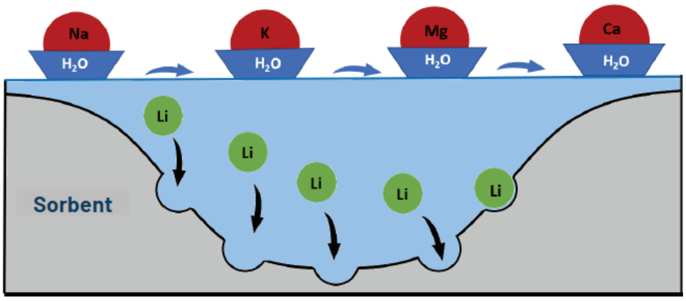


Source: International Lithium Association

Adsorption – the DLE technology currently in use

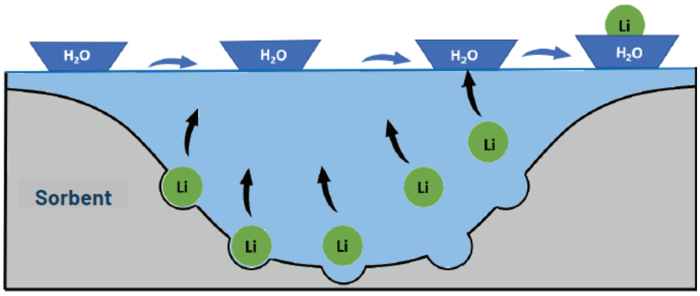
The typical lithium brine contains a range of saline ions such as sodium, potassium, magnesium and calcium (as shown in the left-hand diagram). Lithium ions within the brine require a number of water molecules to surround them in order to stabilise their electric charge – however the saline ions compete for such water molecules. This allows a specifically-designed adsorbent material to be used to capture the lithium ions, as shown in step 1 – the adsorbent material can be based on aluminium, manganese or titanium compounds. Once loaded with lithium ions, the adsorbent material is washed with water, releasing the lithium ions. This allows the adsorbent to be reused and also results in the water having a high concentration of lithium, enabling conversion to the the product for commercial use.

Adsorption step 1



Source: Vulcan Energy

Adsorption step 2



Source: Vulcan Energy

Adsorption is the only DLE technology currently in commercial operation and is also the DLE technology that uses specialty aluminium chemicals. We discuss this below. Pros/cons relative to other DLE technologies include:

- **Advantages**. 1) Recovery rates can be >90%; 2) Already commercially operational; 3) Produces high-quality lithium carbonate; 4) Does not require reagents like ion exchange and solvent extraction processes, water is used to recover lithium; 5) Suitable for low concentration brines and less impacted by brine composition.
- **Disadvantages**. 1) Adsorption equipment can lead to a high upfront cost; 2) Requires elevated temperatures; 3) Risk around contamination of brine; 4) Resultant lithium concentration in water can be lower than ion exchange, requiring further steps to purify lithium and water.

Ion exchange

Ion exchange technologies separate ions within a solution by exchanging them for other ions with an equivalent charge. In the case of lithium extraction, the brine is passed through a vessel with an ion-exchange resin or membrane – the resin/membrane captures the lithium ions and allows other ions to pass through, effectively acting like a sieve. The resin/membrane is then washed with acid – this switches lithium and hydrogen ions to form lithium chloride.

Pros/cons relative to other DLE technologies include:

- **Advantages**. 1) Recovery rates can be ~90%; 2) Reduced risk of impurity contamination in the product stream due to high selectivity of lithium; 3) High capacity, meaning it is appropriate for both low-grade and high-grade brines; 4) Low energy/water usage; 5) Can be carried out at ambient temperature/pressure.
- **Disadvantages**. 1) Ion exchange equipment can lead to a high upfront cost; 2) Significant reagent volumes are required, resulting in higher ongoing opex; 3) Materials can degrade given the use of acid in the process.

Solvent extraction

Solvent extraction technologies use an organic solvent (often kerosene) containing an extractant to separate lithium from brine. The extractant is designed to selectively extract lithium, leaving behind saline ions, by forming a metal ion. Lithium is then recovered using an aqueous solution. Solvent extraction can also be used in combination with one of the other DLE technologies to increase purity of lithium, which is critical for battery applications.

Pros/cons relative to other DLE technologies include:

- **Advantages**. 1) Solvents for extraction processes are readily available outside the lithium industry, meaning the process has relatively low operating costs (indeed this is the process Alpha uses to produce its specialty aluminium chemicals in the first instance); 2) A high recovery rate (>95%) can produce high-purity lithium without an additional concentration step.
- **Disadvantages**. 1) Organic solvents can have supply chain and handling challenges, including potential fire hazards and equipment damage; 2) Residual brine may require treatment if it contains the solvent; 3) Upfront capex costs can be higher than other DLE technologies; 4) Operating costs can escalate if the solvent is not able to be recycled.

Membrane-based separation

Membrane-based separation technologies use a porous membrane that allows lithium ions to pass through, while capturing other ions (particularly saline ions). A variety of processes can be used – nanofiltration (using pressure) and electrodialysis (using an electric field) are the two most commonly considered. Similar to solvent extraction, this can be used in combination with other DLE technologies to increase purity of lithium, which is critical for battery applications.

Pros/cons relative to other DLE technologies include:

- **Advantages**. 1) A high recovery rate (>95%) can produce high-purity lithium without an additional concentration step; 2) Offers a potential modular design that allows for easier scaleability.
- **Disadvantages**. 1) Requires high pressure to work effectively; 2) Operating costs can be escalated if membrane is permanently degraded; 3) Can be water intensive.

Electrochemical processes – less developed

This technology uses electrodes to extract lithium from brine, which is then deposited onto the electrode itself. This is an early stage technology, along with some others, and we will not discuss as much detail as for other technologies.

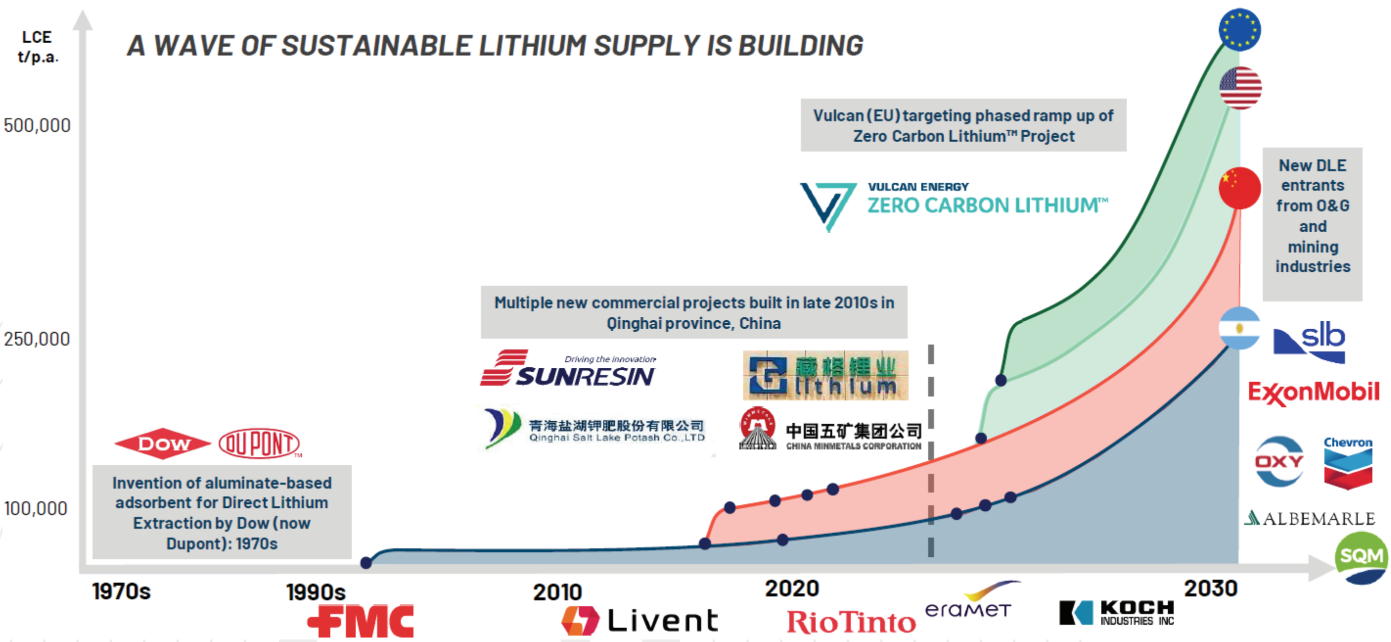
… Adsorption the only technology currently in use and set to grow rapidly

Adsorption was first used by FMC at its Hombre Muerto project in 1996 – FMC became Livent, then merged with Allkem in early 2024 to become Arcadium and was ultimately acquired by Rio Tinto in 2025. Over the last 10 years, a number of Chinese producers have also used adsorption DLE technology to increase lithium production – this was over the same time period as it became the leader in processing spodumene. These Chinese companies continue to innovate, but appear to have more proprietary DLE technologies – it is unclear that they will meaningfully impact production in western countries. Over the next decade and beyond, lithium production using adsorption DLE technology is expected to ramp-up rapidly, based on activity from a wide-range of players (in alphabetical order):

- **Albemarle** has indicated that it is investigating the use of adsorption DLE technologies at its Arkansas facility, complementing its bromine operations. Over time it is expected to also look at developing DLE technology for use at its Chilean operations (also in the Salar de Atacama region).
- **Chevron** has indicated it is considering opportunities to produce lithium, given it fits with the core capabilities of an oil & gas producer, and may licence a DLE technology (unlike many of its peers who are developing their own DLE technologies, as discussed in this section).
- **Eramet** commenced production of lithium from its plant in Argentina in Dec-24, aiming to produce ~24ktpa of lithium annually once ramped up, with further expansion possible.
- **ExxonMobil** has stated an intention to produce lithium from brine from a reservoir in Arkansas. Although it is actively assessing DLE technology options, with adsorption considered. It announced the success of its first lithium well in Jan-24 and has highlighted an interest in expanding into lithium production due to the geoscience, engineering and chemical processing being similar to those in its production and refining operations. It has signed MOUs for offtake with battery makers SK On and LG Chem.
- **Koch Industries**, through its Koch Technology Solutions (KTS) subsidiary, has developed its Li-Pro lithium selective sorption technology and is looking to use its range of capabilities (including EPC and trading) to assist mining companies with lithium separation. Its project with Compass Minerals in Utah was suspended by Compass In Nov-23 due to an uncertain regulatory climate. It has also signed agreements with Standard Lithium and Arizona Lithium to advance its technology.
- **Lithium de France**, a subsidiary of Arverne Group, has indicated it will use adsorption at its project in Alsace, France. This is the same lithium brine field as that being developed by Vulcan Energy, which is operating across the border, within Germany (see below). The project has received €20m of funding from BPI France and the EU's Next Generation Fund and has financial backing from Equinor and Hydro. It is targeting ~27ktpa of lithium carbonate equivalent by 2031.

- **Occidental Petroleum**, through its wholly owned subsidiary TerraLithium, has developed an adsorbent technology that it states has a "99%+ capture efficiency" at its pilot plant in California. In June-24, it announced a JV with BHE Renewables (owned by Berkshire Hathaway) to demonstrate and deploy its technology on the brine that is processed at BHE's geothermal power plants in California's Imperial Valley.
- **Rio Tinto** has indicated an intention to increase production through Arcadium's assets significantly over coming years, as well as drive the development of its Rincon project (acquired in 2022), using adsorption technology.
- **Saudi Aramco** is investigating opportunities to expand into lithium production in JV with Ma'aden using DLE technologies. It is investigating a range of technologies, including adsorption. Like ExxonMobil, Saudi Aramco has highlighted opportunities using its operational expertise, existing infrastructure, drilling operations and extensive geological data in the area.
- **SLB** (formerly Schlumberger) has developed an adsorption-based technology that it has tested in Nevada to achieve a "recovery rate of 96%" (it quotes 85-95% for the majority of brine sources). It has also stated that it can undertake subsurfect modelling to understand resource potential and project economics for third parties.
- **SQM** indicated in mid-2024 that it would choose one or more DLE technologies during 2025 to expand its production in the Salar de Atacama region of Chile. This is further to its JV with the Codelco, the Chilean state-controlled miner that was introduced to lithium projects by Chile's National Lithium Strategy (see below). Given the size and complexity of the Atacama region, SQM is expected to partner with more than one DLE technology provider – further support for the face that there is no one-size-fits-all approach.
- **Vulcan Energy** has indicated that it will use adsorption at its project in the Upper Rhine Valley brine field that is due to ramp-up during 2026. Vulcan refers to its project as zero carbon lithium and has highlighted the fact that adsorption has "multi-decade commercial precedent" and offers low opereating cost, reduced environmental impact and high quality lithium output.

History of and future use of adsorption technology for DLE extraction



Source: Vulcan Energy

DLE has advantages over hard-rock mining in producing battery-grade lithium

In addition to advantages over traditional evaporation processes for extracting lithium from brine, DLE also has important potential advantages over processing lithium from hard-rock resources. These are:

Final conversion to lithium chemicals for end-market is easier after DLE than for hard-rock resources…

As described above, once lithium has been extracted using a DLE process it exists as lithium ions in a solution. This solution can be used to directly convert to lithium hydroxide or lithium carbonate (the two chemicals that are then used to make LIBs) through a relatively simple chemical reaction. On the other hand, once lithium is mined in hard-rock form, it still needs to be extracted from the hard-rock – this is a more complex process that requires significant energy and cost before lithium hydroxide or lithium carbonate are produced:

- The hard-rock ore is crushed and then separated both mechanically and via floatation to concentrate the ore;
- Once concentrated, it must be converted to a more reactive phase, requiring calcination/roasting at 1,000-1,100°C – clearly this is an energy-intensive process;
- After calcination/roasting, the lithium is leached with acid to produce a lithium solution (often this is sulfuric acid to form lithium sulfate); and
- Once the lithium is in a solution, a simple chemical reaction produces lithium hydroxide or lithium carbonate.

This yields a number of advantages for DLE over hard-rock mining:

- A simpler and faster process due to having fewer steps;
- Lower energy costs given no need for the high-temperature calcination/roasting process;
- Fewer chemical steps (and costs) required to produce lithium hydroxide or lithium carbonate;
- Lower environmental impact due to the above points;
- The production of lithium hydroxide or lithium carbonate is typically integrated with the DLE process, allowing cost synergies and optimising the DLE process for the production of lithium hydroxide or lithium carbonate so as to tailor the output for the specifications of the battery producer.

… DLE also enables geographic diversification of LIB supply chains away from China

It appears clear that there is escalating geopolitical tension due to the recognition of risk of supply chain concentration in critical industries being through China. While ~80% of lithium production is spread between Australia, South America and China, most of the lithium hydroxide and lithium carbonate production is in China (it dominates production of hard-rock resources from Australia and is a major player in production from its own brine resources). As is the case in a number of industries, this extends further downstream, with China also dominating LIB production and having cost advantages in doing so that include labour and other costs, construction timelines and its ability to act quickly across its vertically integrated supply chain. As above, the expansion of the use of DLE technologies should also enable the production of lithium hydroxide and lithium carbonate in a wider range of locations that can then go through the qualification processes with buyers of battery-grade lithium.

Chilean government policy has signalled a drive for DLE technology development

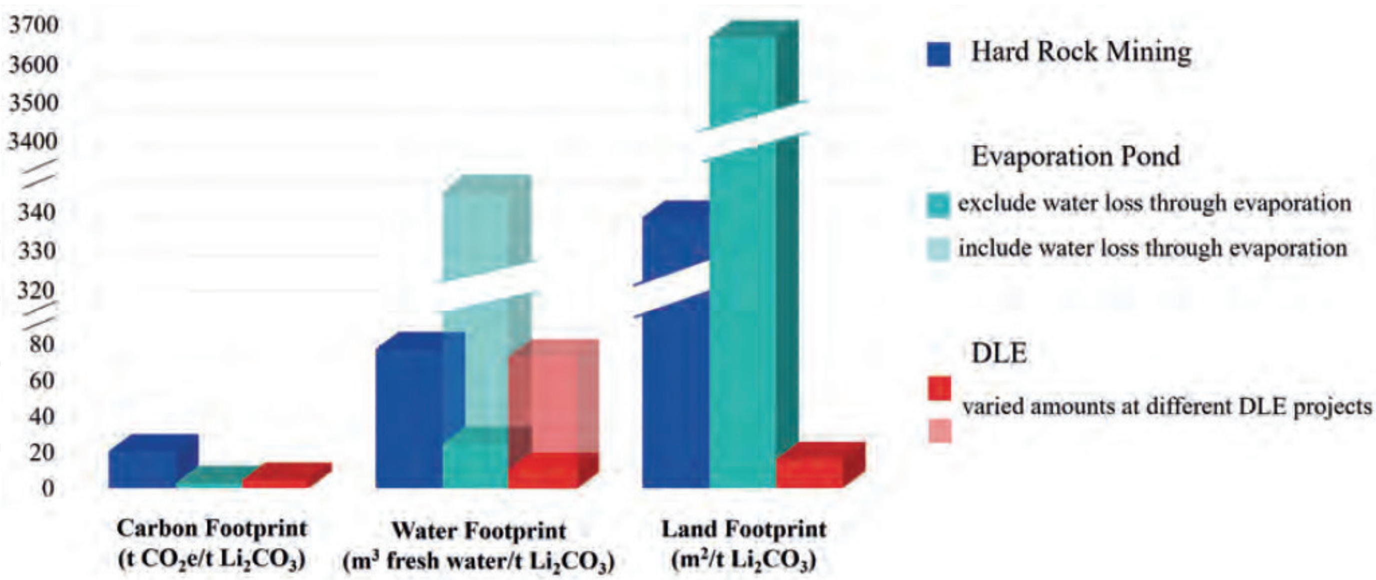
In April-23, the Chilean government released its National Lithium Strategy. Although widely reported as nationalisation on release, it has since become clear that it aims to increase the country's role in the global lithium market, and at the same time drive DLE technology development in response to the loss of leadership that we described above. The key components of the strategy include:

- **Creation of a state-owned enterprise to oversee lithium operations in Chile.** The government would then hold a controlling interest in strategic projects. This is to be done through Codelco.
- **Public-private partnerships** to encourage collaboration with the private sector to boost lithium production.
- **Environmental sustainability.** The strategy emphasised technologies to minimise environmental impact, particularly on water-sensitive areas such as the Atacama Desert. This favoured DLE technology adoption.
- **Technology development.** Chile established a research institute to drive innovation and add value to the lithium production chain. Again, this has focused on DLE technology adoption.
- **Community engagement.**

DLE appears set to flatten the lithium supply cost curve

There are a range of factors that will determine the position on the lithium supply cost curve for a particular project: the brine source (conventional salar, oilfield, geothermal), scale, enabling infrastructure, DLE technology selection and energy costs. As above, DLE is in relative infancy but the technology does appear likely to flatten the cost curve, particularly given the investment taking place from a wide range of large companies and advantages of this type of mining. These advantages extend to the carbon, water and land footprint of DLE – as can be seen below, this is favourable for DLE technologies when compared to hard-rock mining and evaporation of brines. This in turn could result in the delivery of additional supply at costs that are not prohibitive for the end-markets serviced (and as we discuss in the previous section, the cost of LIBs is likely to be a key driver of demand).

Comparison of carbon, water and land footprints for DLE with hard-rock mining and evaporation



Source: International Lithium Association

ATH is an important component of adsorption technology

The adsorbent materials primarily in commercial use are:

- **Lithium aluminium layered double hydroxide (LDH)**. This is considered the most chemically stable option and is used by Livent in the Hombre Muerto project (now owned by Rio Tinto), Rio Tinto (in Rincon in addition to its ownership of Livent), Eramet and Vulcan. Other technology proponents from above are generally silent as to the nature of their adsorbent materials.
- **Lithium titanate**. This is the most commonly used adsorbent in Chinese operations and appears effective with lithium brines that have a high pH.
- **Lithium manganese oxides (LMO)**. These are in development. There is some progress, although chemical stability is a key challenge for such adsorbent materials.

LDH is made from ATH, $Al(OH)_3$, that is reacted with lithium chloride, or from aluminium chloride that is reacted with lithium hydroxide. The latter requires alumium chloride to be produced from HPA and hydrochloric acid, hence having additional cost and potential for greater environmental impact. The LDH enables the ion exchange explained above. It is worth noting that ATH can also form composite adsorbent materials (with those listed above) to improve durability and enhance distribution of adsorbent materials.

High-purity ATH and other characteristics needed to maximise lithium recovery rates

Based on discussions with industry contacts, the key characteristics of the ATH that optimises performance are:

- **High-purity ATH** (minimum 4N) is typically used to avoid interference from contaminants that could reduce the stability of the process and ensure consistency of ion exchange. Iron, silicon and sodium can significantly reduce lithium recovery rates and adsorbent longevity, two of the critical cost drivers of the DLE process.
- **Amorphous structure** that maximises surface area and are more reactive. An amorphous material has atoms or molecules arranged randomly, rather than being well ordered as in a crystalline structure. This means the molecules have a higher surface area and are therefore more reactive, hence attracting more lithium ions. This results in a higher recovery rate and enables higher final product purity. Alpha's process enables the production of completely amorphous ATH. In Apr-24, Oak Ridge National Laboratory published findings that amorphous aluminium hydroxide significantly improves the lithium extraction yield (source: Oak Ridge).
- **Hydrophilic**, allowing relatively easy interaction with the aqueous brines that are used.
- **Greater durability**. This enables multiple cycles using the same adsorbent materials, i.e. reducing waste. As below, this can dramatically improve the economics of DLE.

Alpha has reported its amorphous ATH product gives >1.5x longer life and up to 2x higher extraction rates than current products in use. The benefit of longer life is explored in more detail below.

Qualification processes with customers are rigorous

Despite DLE receiving increased focus in recent years, the qualification processes for suppliers are rigorous given it is one of the most important parts of the DLE functionality. This process can take 12-24 months, depending on the scope of qualification. The following timeline is indicative:

- **Material specification and initial testing**. In this stage, potential customers undertake lab-scale testing on samples, particularly focused on purity (and lack of contaminants) and the structure of the material. This can take 2-3 months.
- **Compatibility testing**. Once material specifications are confirmed, prototype adsorbents are produced and testing takes place for capacity, lithium capture rates, lithium release and chemical stability. This can take 2-4 months.
- **Pilot-scale testing**. In this phase, adsorbents are scaled and tested on brine to determine lithium selectivity (i.e. letting sodium, potassium, magnesium and calcium pass), resusability across cycles and resistance to fouling from the brine. This can take 3-9 months.
- **Industrial trials**. The process is further scaled to determine integration with plant systems and long-term chemical stability. This can take 3-6 months.
- **Supplier approval**. At this point, the supplier undergoes technical audits across quality assurance, traceability, consistency and logistics. Commercial terms and offtake are agreed at this point. This can take 1-2 months.

There are a few complexities associated with the DLE process that can extend timelines beyond these typical timelines:

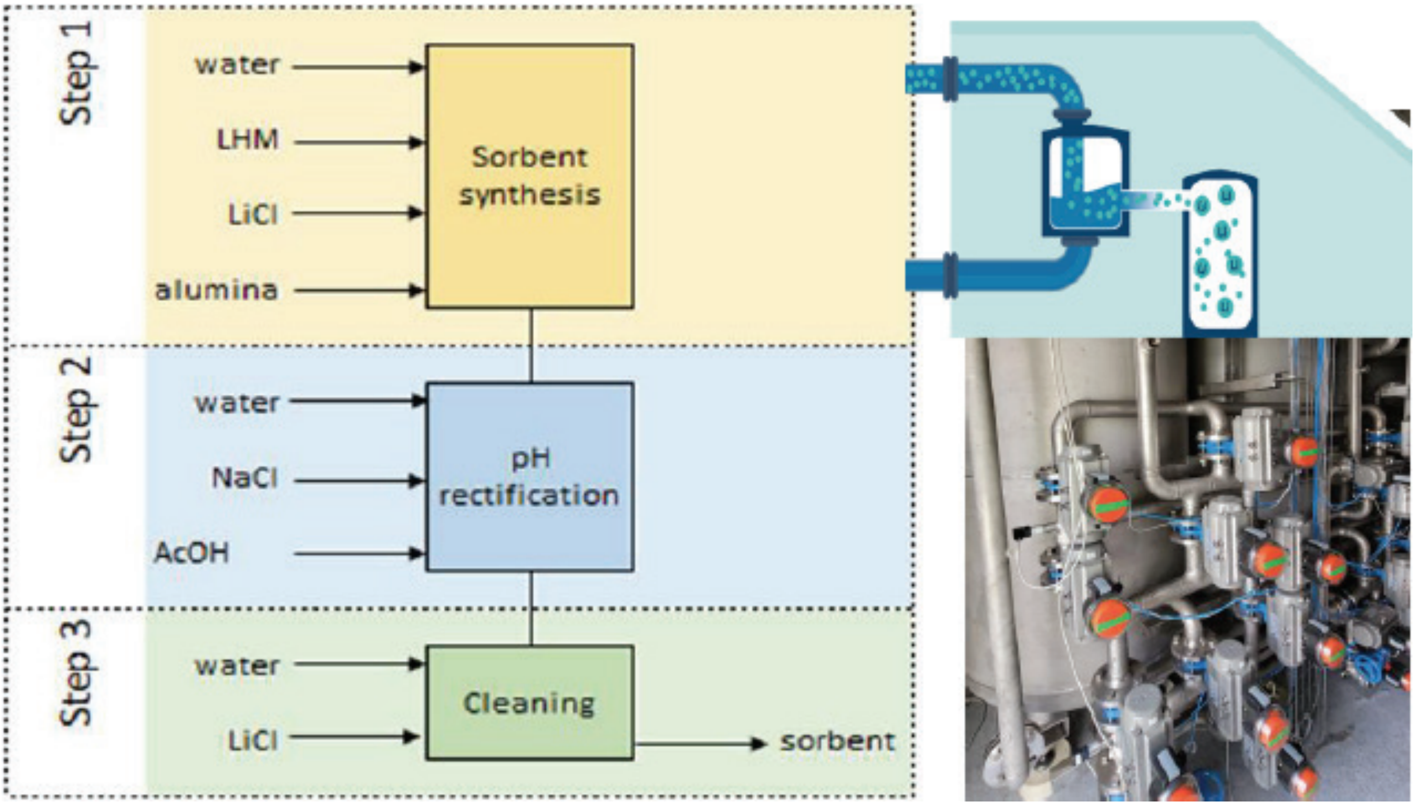
- **Complex or new brine chemistries**. As above, due to brine sources differing (from conventional salar resources, to the emerging use of oilfield and geothermal resources), there may be no no single adsorbent that is optimal, even for the brine resources of a single lithium producer. This could require testing of different adsorbents with complex or new brine chemistries.
- **Third-party validation**. The nature of the demand for lithium (driven by LIBs) is such that different battery producers have different specifications and/or supply chain requirements that dictate different requirements for suppliers of HPA and therefore a more complex qualification process.
- **Government involvement**. Government-backed projects will tend to have longer internal procurement or contracting cycles that could also impact on the qualification timeline.

ATH is an important input, but reuse over multiple cycles dramatically reduces the cost

HPA, produced from ATH, is an important driver of the cost of adsorbents, and therefore the cost of the DLE process. However there are a number of other costs to the DLE process such as other raw materials, equipment depreciation, labour, energy and other operational costs. The exact proportion of the cost of ATH is difficult to quantify given the lack of information available from operational DLE producers and the complexity around the following:

- **As above, there is no one-size fits all DLE technology**. This applies to both the use of DLE technologies as well as the composition of the adsorbent. The materials used may be different in different use-cases. The cost can vary based on the application used, production methods and market conditions.
- **To illustrate, some global patents give an indicative 7-11kg of ATH needed to extract 1kg of lithium**. Even with the potential for different adsorbents to be used we hesitate to rely on this figure as much as use it to highlight the potential use of HPA. Industry contacts have suggested there are a range of global patents that indicate the lithium to aluminium mole ratio can be up to 0.5:1. Taking into account respective molecular masses and the make-up of ATH ($Al(OH)_3$), this gives an indication of the significant need for HPA in DLE processes using adsorbents. Ask us for more information on such patents.
- **7-11kg of ATH would cost US$105-220, however this is dramatically reduced over multiple cycles**. The US$105-220 cost of 7-11kg of ATH uses using Alpha's product pricing discovery of US$15-20/kg. However it is critical to recognise that the adsorbent process recycles sorbent over multiple cycles, i.e. it is not consumed as part of the lithium extraction process. In its Nov-23 release of its bridging engineering study results, Vulcan Energy has stated that its two pilot plants have operated >5k and >2k cycles over 2.5yrs and 1yr respectively at different pressures and temperatures, with no meaningful degradation of its sorbents. Data from the Hombre Muerto project does not appear available.

Recycling of sorbent materials



Source: Vulcan Energy

- **If the sorbent material can be reused over 1,000 cycles, then the cost of ATH is US$0.10-0.22 for 1kg of lithium**. Clearly this is a significant reduction and would represent <5% of the cost of producing lithium hydroxide or lithium carbonate. It highlights the importance of multiple cycles using the same adsorbent materials in dramatically improving the economics of DLE. Key drivers of reusability are the sorbent type (composite LMO and HPA sorbents appear to have displayed higher levels of reusability than LDH), structural stability, process conditions (temperature and pH) and contamination.

Disclosures

Rimor Equity Research Pty Ltd (ACN: 620 265 778) (Rimor) is the holder of an Australian Financial Services Licence (AFSL: 501971).

This research report is for information purposes only and should not be construed as an offer, solicitation or recommendation to acquire a financial product. The information in this research report is directed and available to clients deemed to be Wholesale Clients under Section 761G of the Corporations Act of 2001. This information is intended to be general in nature and is not personal financial product advice. It is designed to provide Rimor's view of the quality of the financial product as an investment option. Rimor's remuneration is not linked to the views expressed in this research report and Rimor is not remunerated by any financial product provider.

Any advice contained in this document is general advice only and has been prepared without considering your objectives, financial situation or needs. Before acting on any information, you should consider the appropriateness of the information provided and the nature of the relevant financial product having regard to your objectives, financial situation and needs.

You should seek independent financial advice and read the relevant disclosure statements or other offer document prior to making an investment decision (including a decision about whether to acquire or continue to hold) about a financial product. Past performance is not a reliable indicator of future performance.

Although all reasonable care has been taken to ensure that the information contained in this document is accurate, neither Rimor nor its respective officers, advisers or agents makes any representation or warranty, express or implied as to the accuracy, completeness, currency or reliability of such information or any other information provided whether in writing or orally to any recipient or its officers, advisers or agents.

To the fullest extent permitted by law, we expressly exclude, and accept no liability for any loss or damage which may be suffered by the recipient, or any third party, and/or which may arise any reliance placed on, any information contained on this research report, including, but not limited to direct, indirect, consequential or other loss or damage, loss of data, loss of income, profits, contracts or opportunity, loss of goodwill or claims by third parties and whether caused by tort (including negligence), breach of contract or otherwise, even if such loss or damage was reasonably foreseeable by us.

Recipients of this research report agree to respect the confidential and proprietary nature of Rimor's published research. The recipient agrees not to copy, sell, rent, sub-license or otherwise make the research report available, in whole or part, to any third party; or to post the report, in whole or part, on a website visible to anyone other than an employee of the recipient. Rimor owns, and reserves all rights in relation to, the research report produced and receiving this report does not assign or transfer ownership in those materials to the recipient.

It should be assumed that, from time to time, Rimor and its employees, officers or partners will hold investments in financial products which are the subject of its research, from which they will benefit if the forecasts and judgments presented in this research report prove to be accurate. Rimor considers that such holdings are not sufficiently material to compromise the research provided in this report.

Further, Rimor employees, officers or agents may hold non-executive director positions in corporate entities which have interests and investments in similar industries to those entities which are the subject of Rimor's research. Specifically, Mr Scott Ryall, the sole director of Rimor, holds a non-executive directorship at Infragreen Group Ltd (ACN 668 228 742) (Infragreen). Any conflicts (actual or perceived) are managed in accordance with Rimor's Conflicts of Interest Policy.

Rimor Equity Research
In-depth • Long-term • Different

Scott Ryall
scott.ryall@rimorequityresearch.com.au
+61 459 110 791