TB AMATI STRATEGIC METALS FUND

Batteries 101

By Mark Smith, Fund Manager

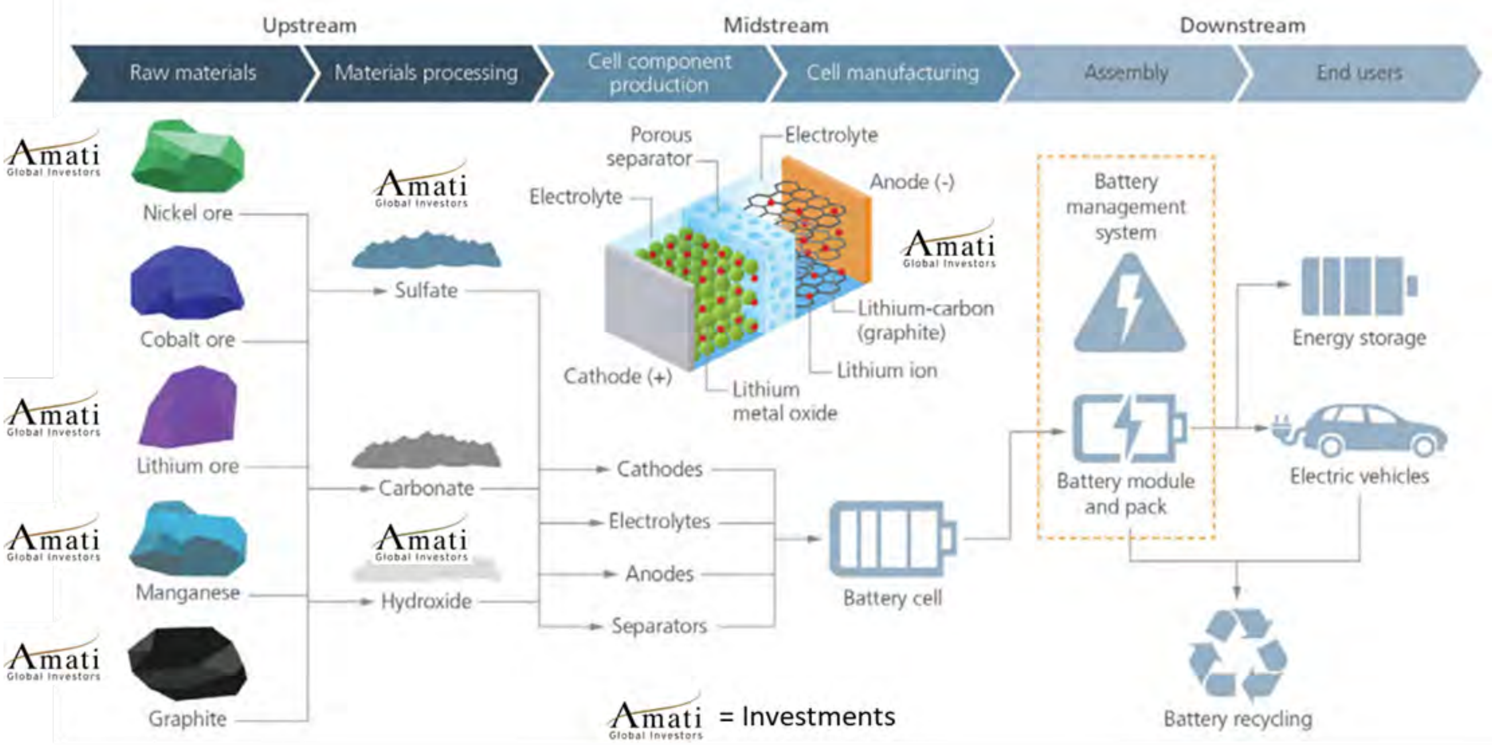
It is clear the energy transition will be metal intensive, and the supply-demand deficit projections vary widely. However, the common denominator will be a supply shortage unless the (mining) industry and governments adapt and change. Worldwide adoption of lithium-ion batteries (LIBs), particularly within portable power applications and electric vehicles (EVs), is generating major concerns.

> *"I need more power Scottie, I just cannae do it, I dinnae have the pooower!"*

The first is a looming lithium and battery metals deficit. S&P has forecast that even if all lithium projects expected to be online by 2030 are perfectly executed, there will still be a 220,000-t deficit in lithium by that year. Indeed, the picture gets worse with over 4 million tonnes of lithium needed by 2035 supplied from over 50 new mines, to meet projected demand. The other concern is a need for a more circular battery economy, with only 5% of LIBs recycled globally. The unprecedented magnitude of LIB consumption also means that without this circular battery economy, current supply chains will further struggle to cope with demand.

But first, to comprehend the challenges you must first understand the battery industry. Outlined in this piece we have simply discussed the basics of the industry, highlighted where the TB Amati Strategic Metals Fund (ASMF) has investment exposure, and explained where we see investment opportunities emerging from the major bottlenecks.

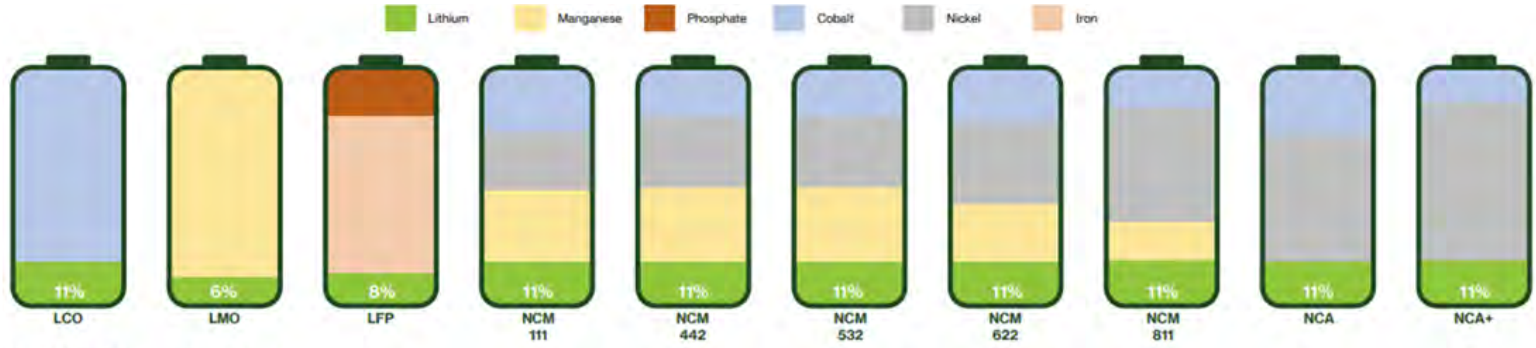
Figure 1 - The basic flow sheet of the battery market from mine to OEM



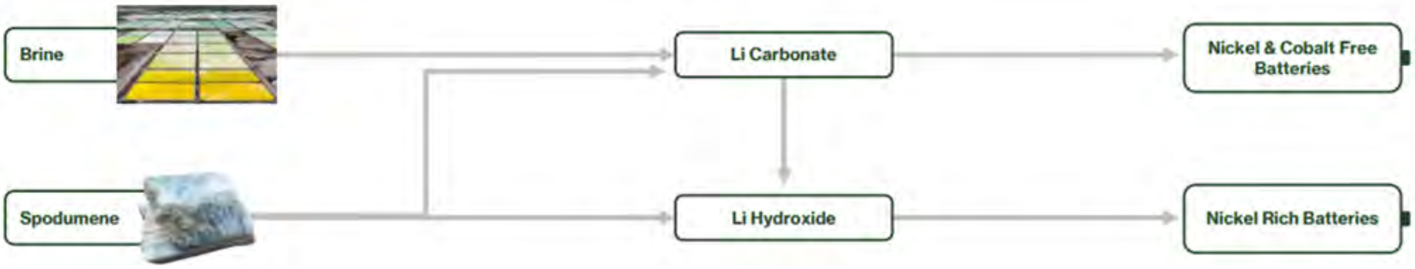
Source: Amati

The chemistry of the batteries will no doubt change according to supply-demand dynamics, but we have purposely invested in companies with assets amenable to supplying different battery types. Figure 2 highlights the different metals used but the common metal is lithium in most battery chemistries, and a constant is graphite for the anode.

Figure 2 - Lithium ion battery chemistries



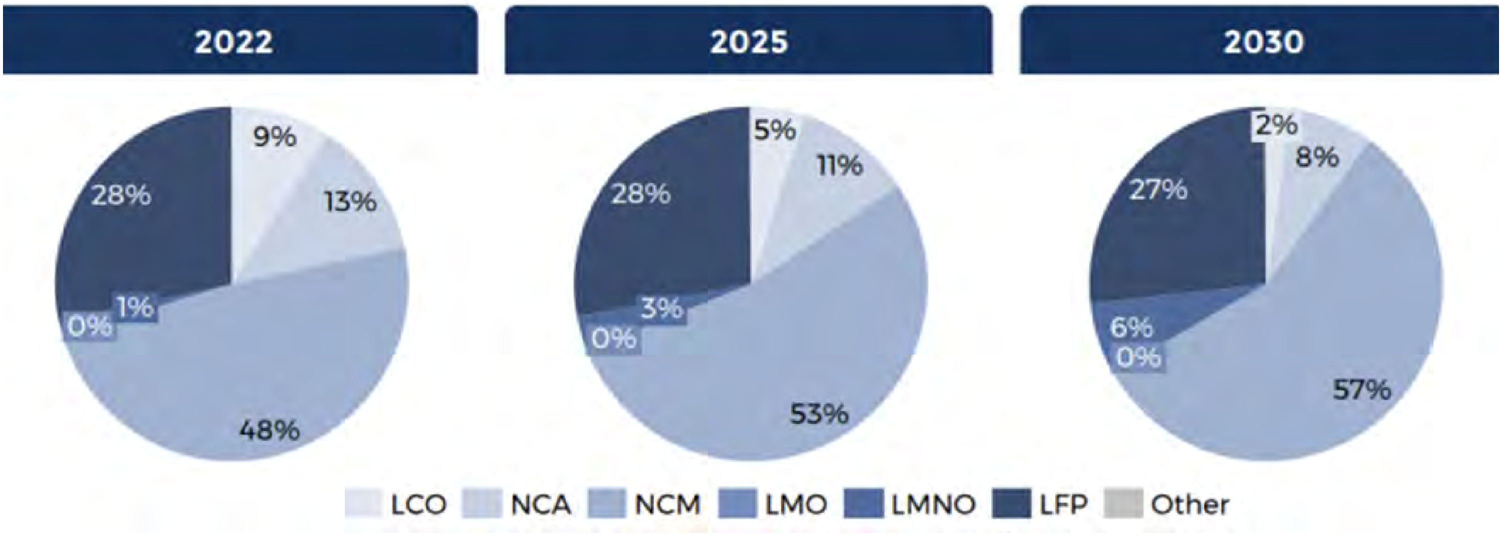
Not All Lithium Are the Same



Source: Sigma Lithium

To highlight this demand for battery metals further, in Figure 3 by 2030, 90% of all batteries will contain at least 11% by weight of lithium, creating a demand over 2.1 million tonnes.

Figure 3 - Market share of batteries

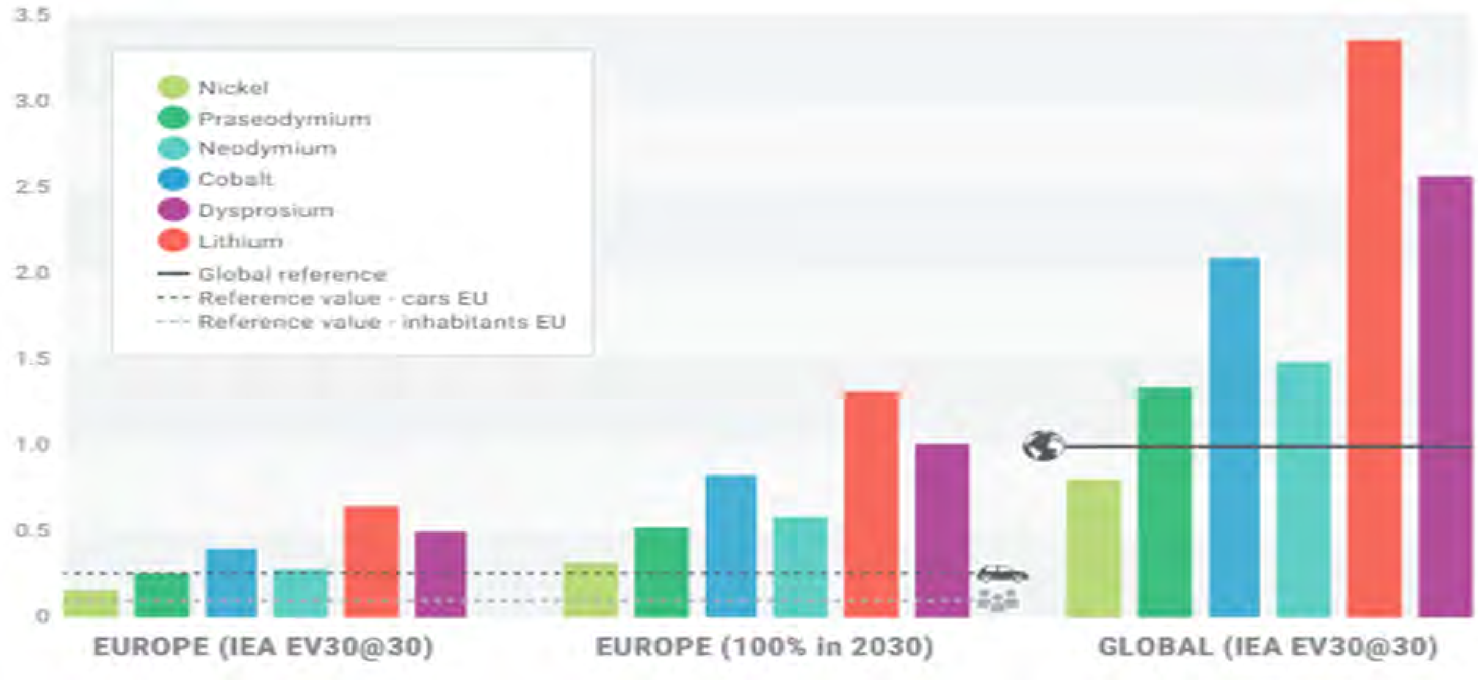


Li demand 540,651 t **1,004,944 t** **2,172,085 t**

Source: Benchmark Intelligence

Presented another way, the International Energy Agency projects that Europe will need between 15% and 70% of the current global production of critical metals in 2030. In its scenario in which all new cars sold in Europe in 2030 are electric, Europe will need as much as 1.5 times current production. Under the global EV30@30 scenario (assuming a 30% EV market penetration), up to three times the current annual global metal production will be needed to produce sufficient electric cars in 2030.

Figure 4 - Factors of global metal production to meet EV demand

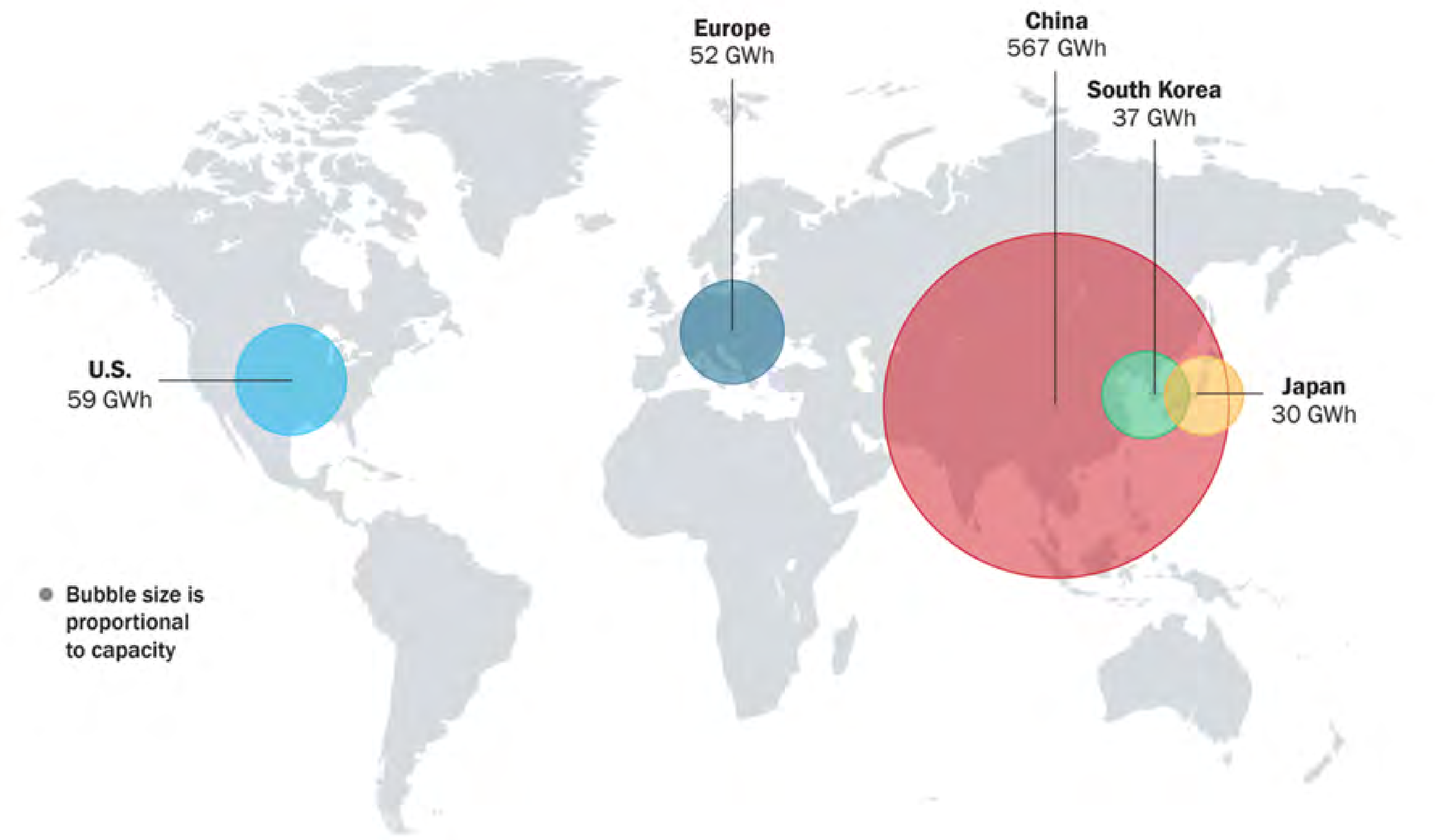


Source: University of Netherlands

The complete transition to an electrified global fleet will require 10 trillion terawatt hours (TWh)of battery production in the next decade, according to Vineet Mehta, director of battery technology and system architecture at Tesla. Furthermore, the report states that if the entire planet totally shifted from fossil fuel consumption, including primary energy utilization, the demand would raise close to 350TWh per year. As shown by the visual below, current global cell manufacturing capacities are nowhere near to rivalling those requirements.

If we were to consider the annual spend on metal procurement at today's prices, Tesla would be spending over US$100 billion for the 11.1 million tonnes of raw materials it needs to build 20m cars. To produce 20m vehicles Tesla alone needs more than the total volume of lithium and natural graphite produced last year, almost a third of the magnet rare earths, 36% of the cobalt. Tesla would consume 1.8m tonnes of copper per year, not even China's state grid uses that much. If every automaker globally went electric, it would amount to US$1 trillion per year metal spend. It then becomes obvious that supply will be a major concern and we haven't even discussed ESG yet!

Figure 5 - Cell manufacturing capacity by country or region 2021



Source:National Blueprint for Lithium Batteries 2021-2030 (energy.gov)

Statistics like this, alongside strained production rates, confirms that battery recycling will need to be drastically increased, and quickly. There are several companies responding to this by innovating a technique which utilizes a hydrometallurgical method to process spent LIBs. Not only does this technique recover nickel, copper, cobalt, and manganese, but most importantly lithium, which the more commonly used pyrometallurgical processing technique, does not. With all new technology the scale up challenges from pilot plant to commercial scale have to be understood.

Figure 6: Benefits of recycling for lithium-ion batteries

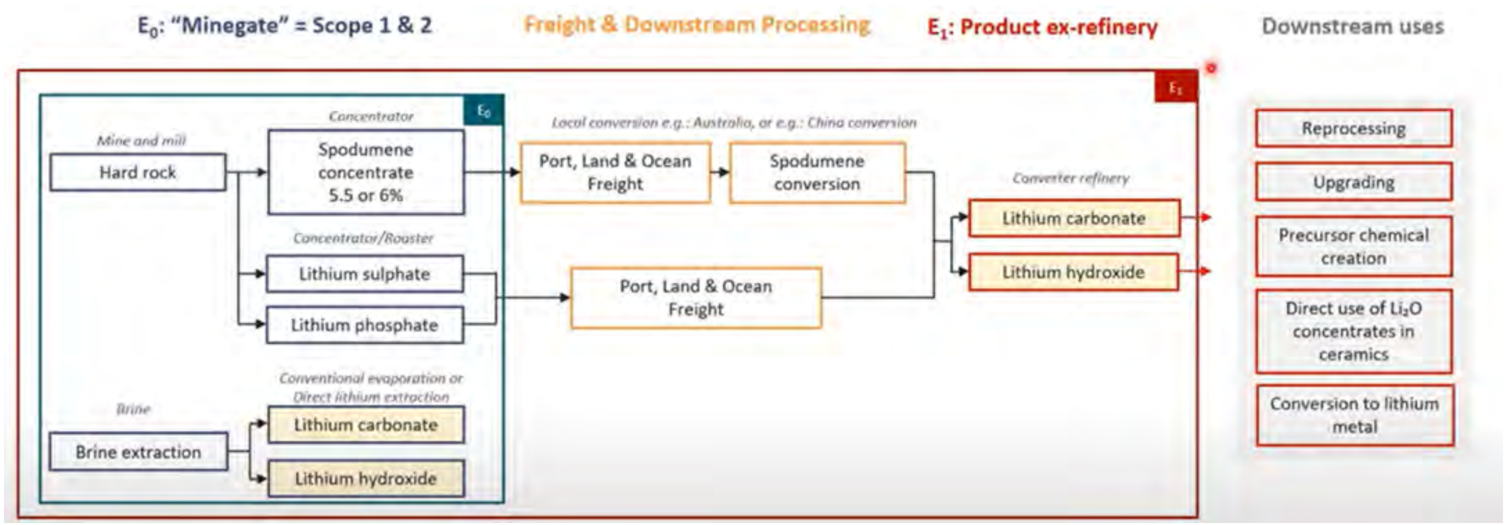
Source: National Blueprint for Lithium Batteries 2021-2030 (energy.gov)

At Amati we are screening several companies to consider investing in, which will complement our investments in the miners, but all our investments are considered within a framework of ESG. Below we have highlighted the somewhat controversial side of the current state of the battery metals sector, but with constant due diligence we have found ways to invest in the sector, whilst reducing the industry's environmental footprint.

Take photos, leave only footprints...carbon or water?

There is a 'Green' paradox in the market currently. The consumer believes the electric vehicle is a green alternative to the internal combustion engine. Skarn Associates have done some great work trying to frame the lithium industry in terms of Scope 1,2 and 3 emission standards. Depending on how the lithium is produced, the belief is one source of lithium carbonate equivalent (LCE) has a lower carbon footprint, however Skarn have managed to level up the industry (hard rock and brines) with E0 and E1 Scope Standards.

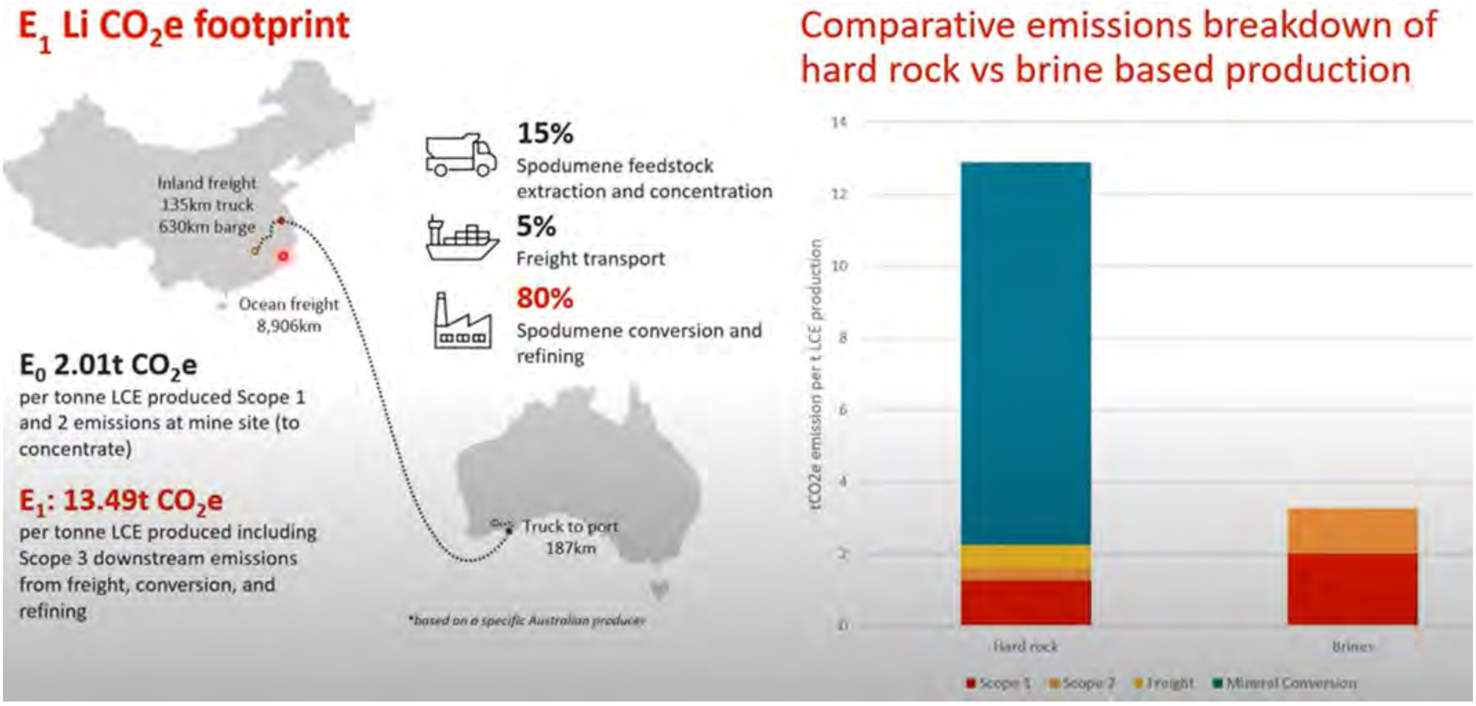
Figure 7: Minegate to Product ex-refinery Scope categories



Source: Skarn Associates

Lithium brines are a very important part of the lithium supply equation, with estimates suggesting brines accounting for ~45% of global LCE supply in 2021, rising to 60% by 2030. Lithium brine deposits are typically characterised by large resource bases/ultra-long mine lives, production costs at the bottom of the global cost curve (i.e. higher margin), and superior sustainability credentials (i.e. significantly lower CO2 intensity based on solar evaporation concentration) compared to converted hard rock sources, as the hard rock processing is carbon intensive.

Figure 8: Emissions of hard rock versus brine production



Source: Skarn Associates

Figure 9: The current environmental footprint of the lithium industry

Spodumene hard rock

Brine ponds - Atacama Desert

Source: Minviro, Amati

To convert spodumene to lithium carbonate the common process route is to leach using sulphuric acid and high temperatures. After the rock is mined, spodumene is heated to 2000 degrees Fahrenheit and then cooled to 149 degrees. It's then crushed and roasted again, this time with concentrated sulfuric acid. Ultimately, sodium carbonate, or soda ash, is added, and the resulting lithium carbonate is crystallized, heated, filtered, and dried.

In order to extract lithium from brines, the salt-rich waters must first be pumped to the surface into a series of large evaporation ponds where solar evaporation occurs over a number of months. Potassium is often first harvested from early ponds, while later ponds have increasingly high concentrations of lithium. Economical lithium-source brines normally contain anywhere from a few hundred parts per million (ppm) of lithium to upwards of 7,000 ppm.

When the lithium chloride in the evaporation ponds reaches an optimum concentration, the solution is pumped to a recovery plant where extraction and filtering remove any unwanted boron or magnesium. It is then treated with sodium carbonate (soda ash), thereby precipitating lithium carbonate. The lithium carbonate is then filtered and dried. Excess residual brines are pumped back into the salar. Evaporation ponds take 18 months to precipitate out other salts and produce a lithium chloride stream which is then converted to lithium carbonate and then from carbonate to lithium hydroxide, however this process is very water intensive.

What is the solution? - Invest smarter

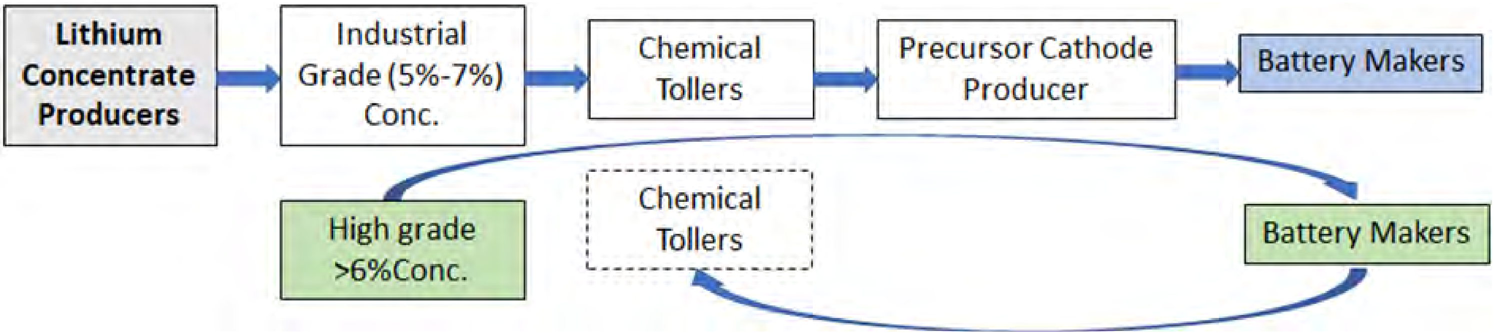
The TB Amati Strategic Metals Fund has a portfolio exposure of 53% to battery metals, with 30% of the fund invested in lithium producers and developers. We have consciously invested in only the best quality companies and orebodies to try and mitigate or reduce some of the above-mentioned issues. The higher the grade of the deposit, the lower the carbon footprint and ability to supply a domestic/regional battery market, rather than shipping concentrate to China. We try to understand the complex chemistry and process engineering to invest in the winners, not the pioneers - select the companies who are second in the queue. New leach technologies will be pivotable in water reduction from brines.

Grade is king

Key to investing in the sector is to identify orebodies and associated companies that can support an integrated 'mine-to-market' business model. This enables the supply chain to shorten and become less fragmented.

- The orebody has to be high grade[1] and of scale with low contaminants[2]
- The battery producer manages the chemical conversion
- Take or pay contracts established with prices linked to hydroxide pricing
- Select battery manufacturers with high credit ratings and project finance facilities

Figure 10 - The lithium supply chain



[1] Conventional DMS premium product >6% Li at a coarse crush with low fines. Low orebody grade variability.
[2] Low contaminant<1% Fe_2O_3, <3% Combined Na_2O/K_2O

Source: Amati Global Investors; Industry reports

Direct Lithium Extraction - *maybe a 'solution' to an environmental problem*

DLE describes a group of technologies that removes lithium from a brine to produce a concentrated lithium solution. The two main processes are:

1. Adsorption – a physical electrostatic process where LiCl molecule in brine is absorbed onto sorbent and removed with a strip solution. Used for geothermal lower concentration brines and there is a trade-off between selectivity and brine concentrations. The concentration of impurities Mg; Na and Ca must be understood.

2. Ionic exchange – a chemical process where the Li+ in the brine is absorbed into solid ion exchange material and swapped for other positive ions (acid). DLE-based processes are typically suited to lithium brine deposits with lower lithium concentrations and/or higher impurity levels. DLE-based methods preferentially extract lithium with impurities remaining in the 'spent' brine and reinjected into the aquifer.

The advantages of DLE include – easy to understand!

- improved economics of exploiting lower grade/higher impurity lithium resources
- lower reagent consumption
- reduced fresh-water consumption
- significantly shorter production lead times (vs typical 12-18 month residence times in evaporation ponds)
- smaller physical footprint (i.e. no evaporation ponds, waste disposal).

Risks to DLE include – harder to appreciate!

- Longer development timelines (in its early stages) due to higher level of test work required given variability of brine chemistries.
- Companies must go from bench scale test work to pilot scale to commercial scale and produce consistent produce in sufficient quantity over a prolonged period.
- Typical scale up factors should be around 10,000x - any less and the project could experience problems.
- Higher energy consumption (higher operating costs), a result of high volumes of brine extracted and reinjected
- Technical risks associated with the reinjection of brine, as the chemistry of the brine has changed which could cause preferential precipitation thus reducing the porosity of the aquifer.
- Understanding the lithium brine cutoff grades; DLE – 100ppb; Pond evaporation 300ppb.

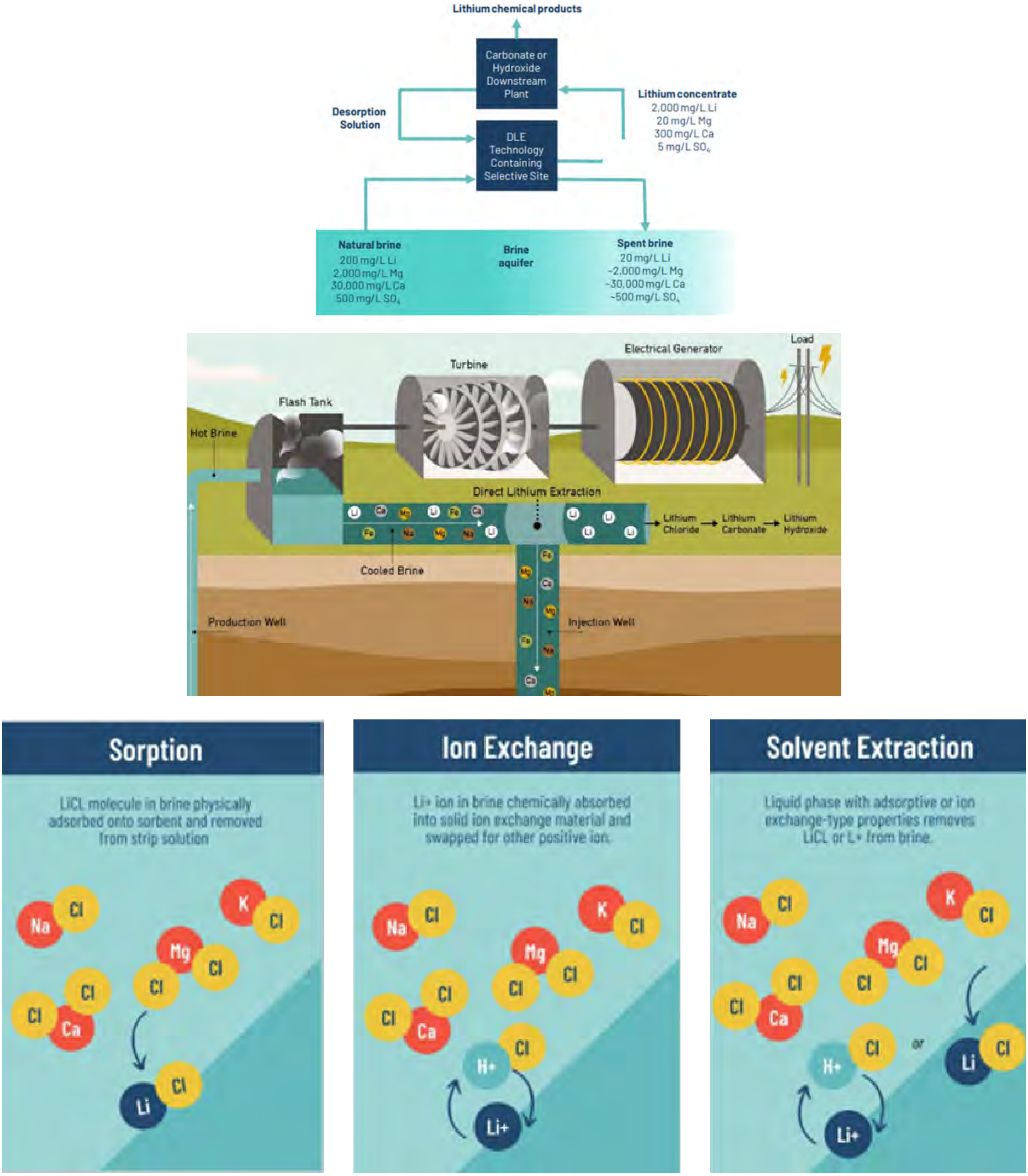
An investment opportunity underpinned by strong demand fundamentals

The decarbonization of the global energy supply will start and end with mining. If you can't grow it, it has to be mined. The ASMF is well positioned to invest in this sector through a concentrated portfolio of 40-45 stocks from explorers to producers. The fund's current metal exposure is:

- Lithium 31%
- Nickel 10%
- Graphite 8%
- Rare Earth Elements 2%
- Lead/Zinc 2%
- Manganese 1%
- Copper 1%
- Uranium 3%
- Gold 24%
- Silver 19%

Over time we expect to transition more into battery and industrial metals, however the investment opportunity in the precious metals sector still remains compelling.

Figure 11: The DLE flowsheet



Sorption

LiCL molecule in brine physically adsorbed onto sorbent and removed from strip solution

Ion Exchange

Li+ ion in brine chemically absorbed into solid ion exchange material and swapped for other positive ion.

Solvent Extraction

Liquid phase with adsorptive or ion exchange-type properties removes LiCL or L+ from brine.

Source: Jade Cove Partners, Amati

Value through the drill bit

"You can't kick the tyres and lick the rocks through a bloomberg screen!"

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Glossary

LCO = Lithium Cobalt Oxide

LMO = Lithium Manganese Oxide

LFP = Lithium Iron Phosphate

NCM = Nickel cobalt manganese oxide

LMNO = Lithium Manganese Nickel Oxide

LCE = Lithium carbonate equivalent

OEM = Original Equipment Manufacturer

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