Benchmark Mineral Intelligence

Metal Market Supply Squeezes and the Rising Cost of LiBs

Mark Beveridge

TXF Global Commodity Finance 2022: Amsterdam

11 May 2022

mbev@benchmarkminerals.com

BENCHMARK MINERAL INTELLIGENCE

TXF

Benchmark Mineral Intelligence is a world leader in understanding the lithium-ion battery industry and battery materials supply chain

Who we are

- Benchmark is a lithium-ion battery supply chain specialist organization
- Leading international team of experts dedicated to the lithium ion battery supply chain – including former **Tesla, Albemarle, BHP Billiton, EY, Glencore and Freeport Cobalt executives**
- Summoned to testify at the **US Senate** (2017, 2019 and 2020), and brief the **G7**, **US White House** and **Pentagon** on opportunities in the battery supply chain
- Leading **IOSCO-certified** price reporting agency for battery raw materials, including cobalt sulphate, lithium hydroxide and spherical graphite pricing

What we do

- **Research/Consultancy –** Off the shelf models for supply/demand, pricing/costs in lithium, cobalt chemicals, nickel sulphate, anode graphite material
- **Reliance –** Commissioned by major Export Credit Agencies, investment banks and corporates to develop strategy and investment planning
- **Events / Webinars –** 20+ events per year in 6 continents, with combined total attendance of 25,000+ in the last 5 years
- **Field Trips –** Regular client tours to key parts of the Chinese supply chain

LiB reaching cost/scale requirements of mass market EV adoption—but raw material inputs difficult to control

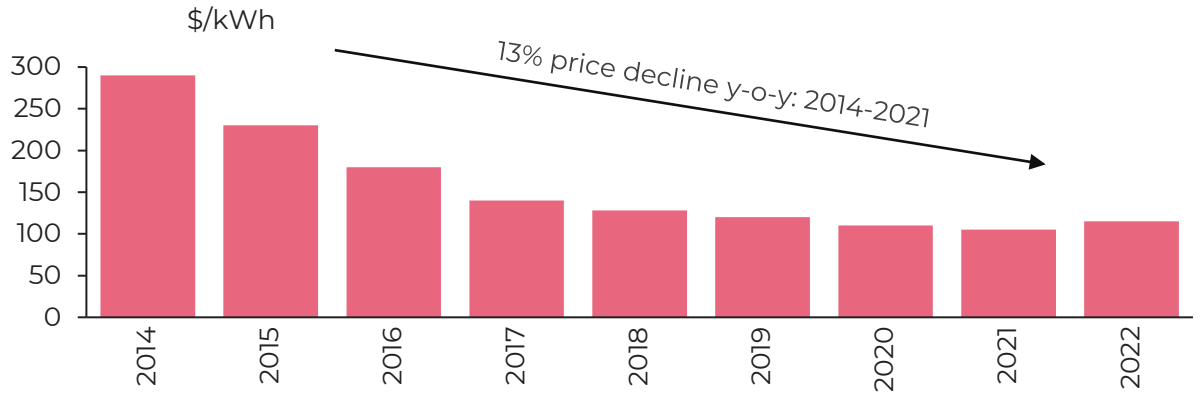
Overview

- Traditional Li-ion has been commercially available for 30 years and proven in many different applications. Some automakers have committed roadmaps that rely on known technologies rather than new potential.

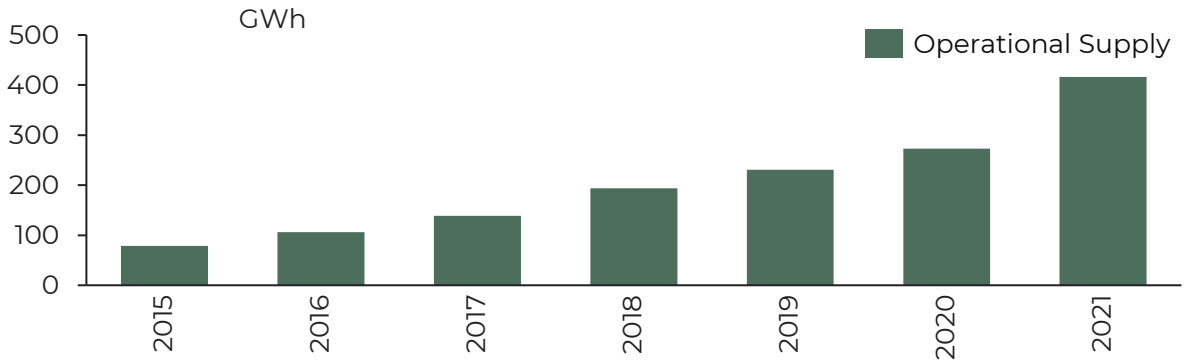
Cell Cost Trends

- Economies of scale have reduced manufacturing element in cell costs
- Cell technology largely focused on the cathode
- 'Bill of material' elements, such as cathode metals, can't be optimized via scale, hence reversal of trend in average cell costs for 2022.
- Indicatively, +$10/KWh in cell costs = circa +$500 at the cell level within an EV.

Cost for lithium-ion battery cells, in $/kWh



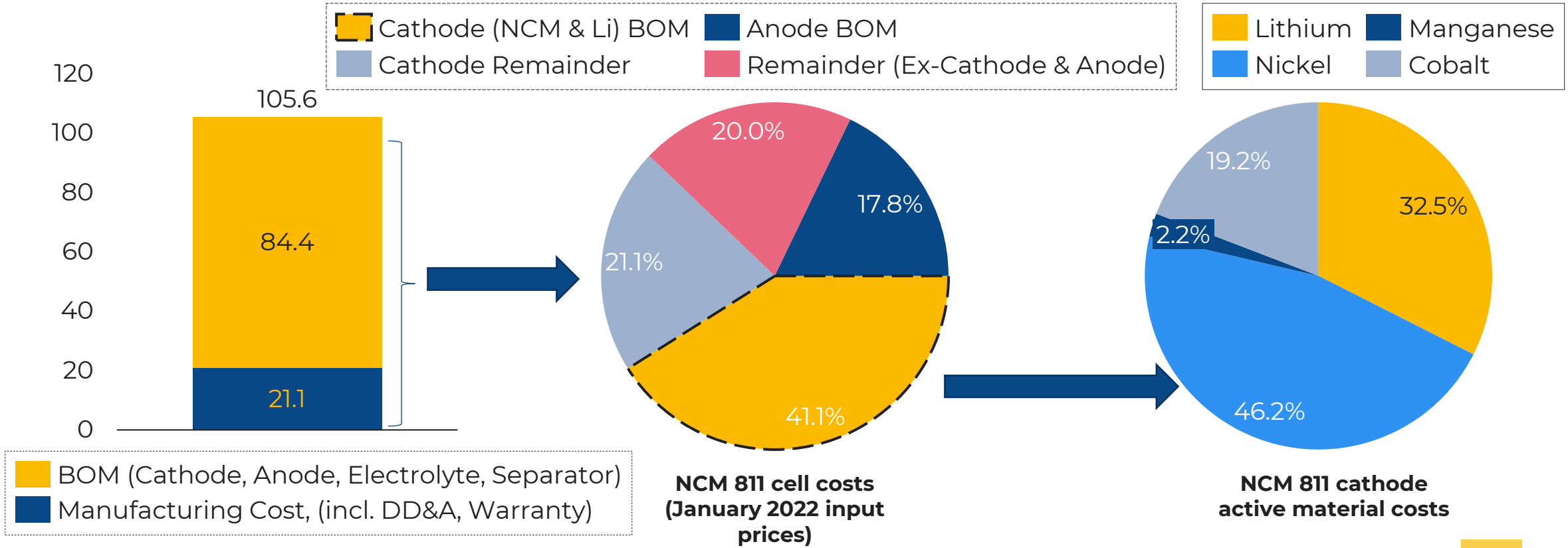
GWh deployed for lithium-ion batteries



High Ni-cathode cells are sensitive to a range of input prices—Ni, primarily, but also Li and Co

- Recent increases in metal prices have pushed cell production costs back above $100/KWh (ex-margin) for Ni-rich chemistries like NCM 811 (the developmental impetus for which came from its high-energy characteristics and Co-thrifting).

NCM 811 battery cell cost estimate: $/KWh (LHS), % splits (RHS)



NCM 811 cell costs (January 2022 input prices)

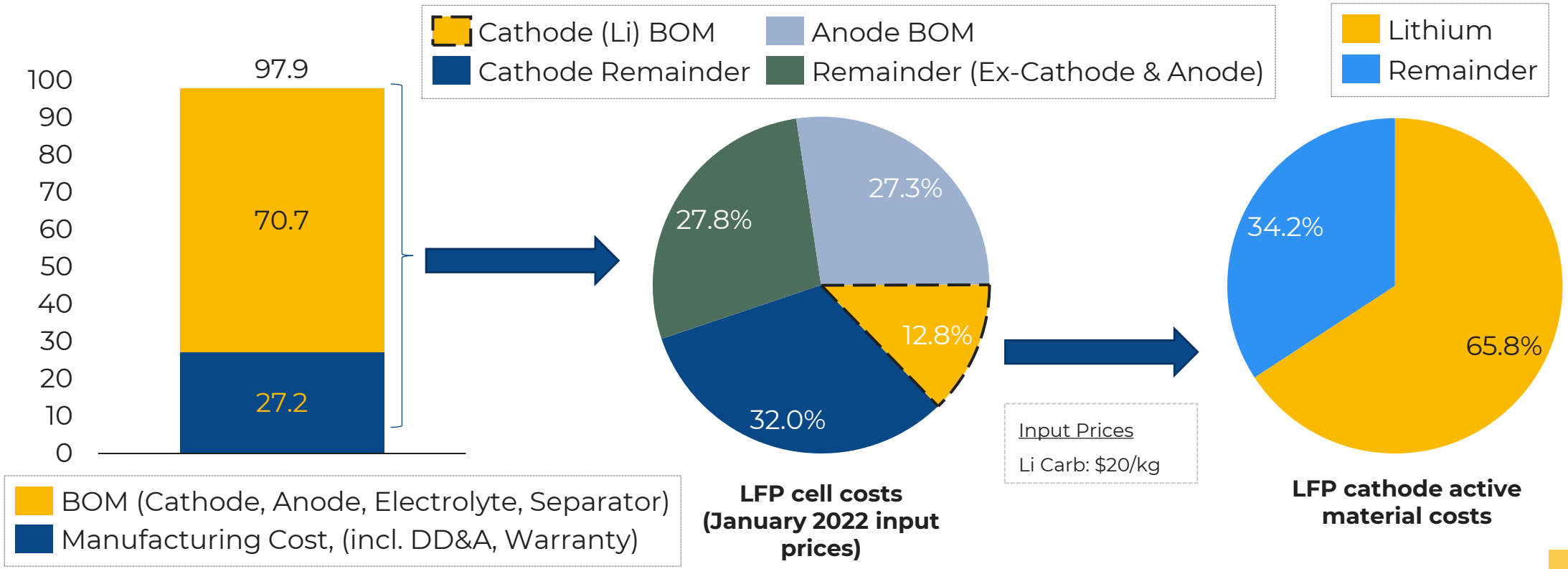
NCM 811 cathode active material costs

Source: Benchmark Mineral Intelligence

Headline LFP cell costs also rose through 2021; they are primarily sensitive to Li above all else

- NCM 811 $/KWh cell costs were edging lower than those for LFP in 2020, due to the higher specific energy of the former. Rising metals prices have led to that gap closing and subsequently opening in favour of LFP through 2021.
- LFP cell costs in 2022 dependent on lithium input price

LFP battery cell cost estimate; RHS chart is the cathode split out by its components

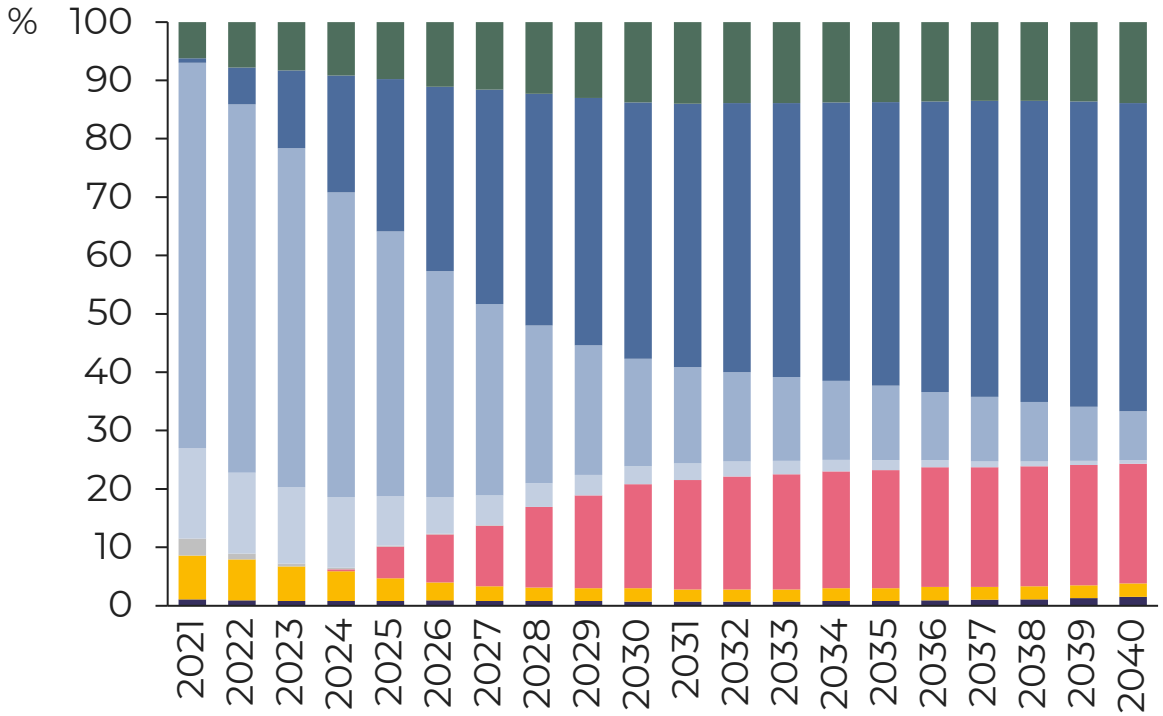


Source: Benchmark Mineral Intelligence

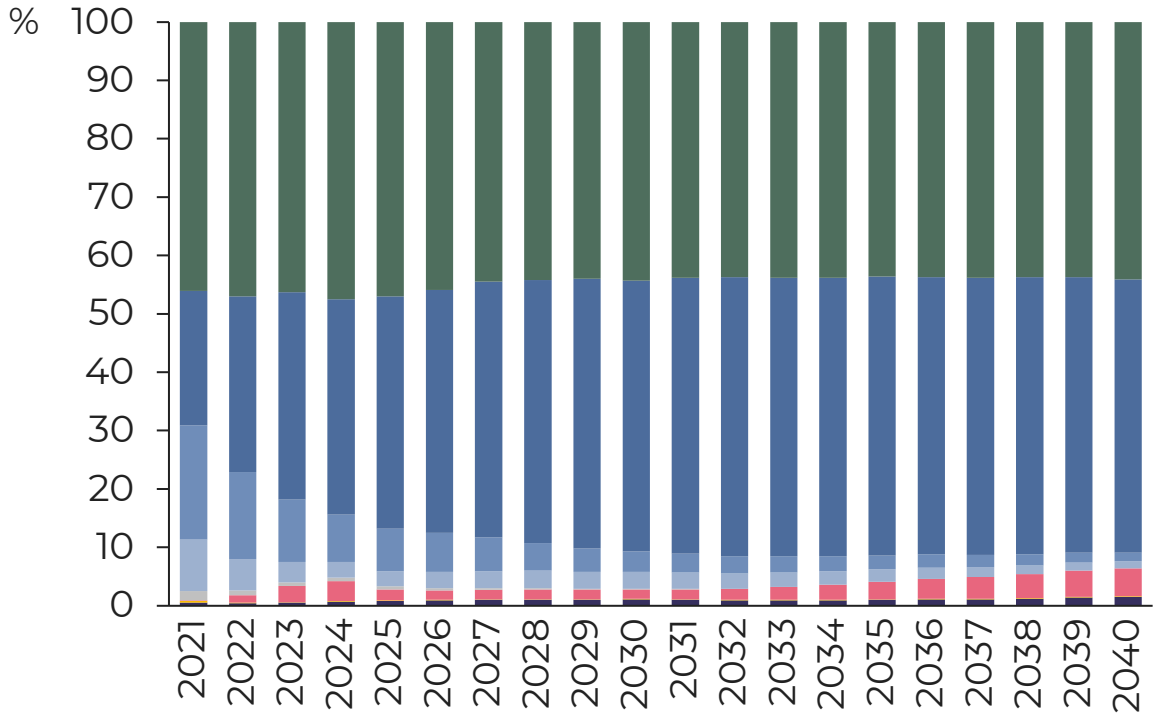
NCM vs LFP: Not simply a zero sum game—room for both depending on OEM's product offerings

- LFP incumbency in China; Western OEMs have planned for NCM
- Why incumbency of investment over the next 3 years matters for the industry?

Europe Cathode Chemistry Market Share



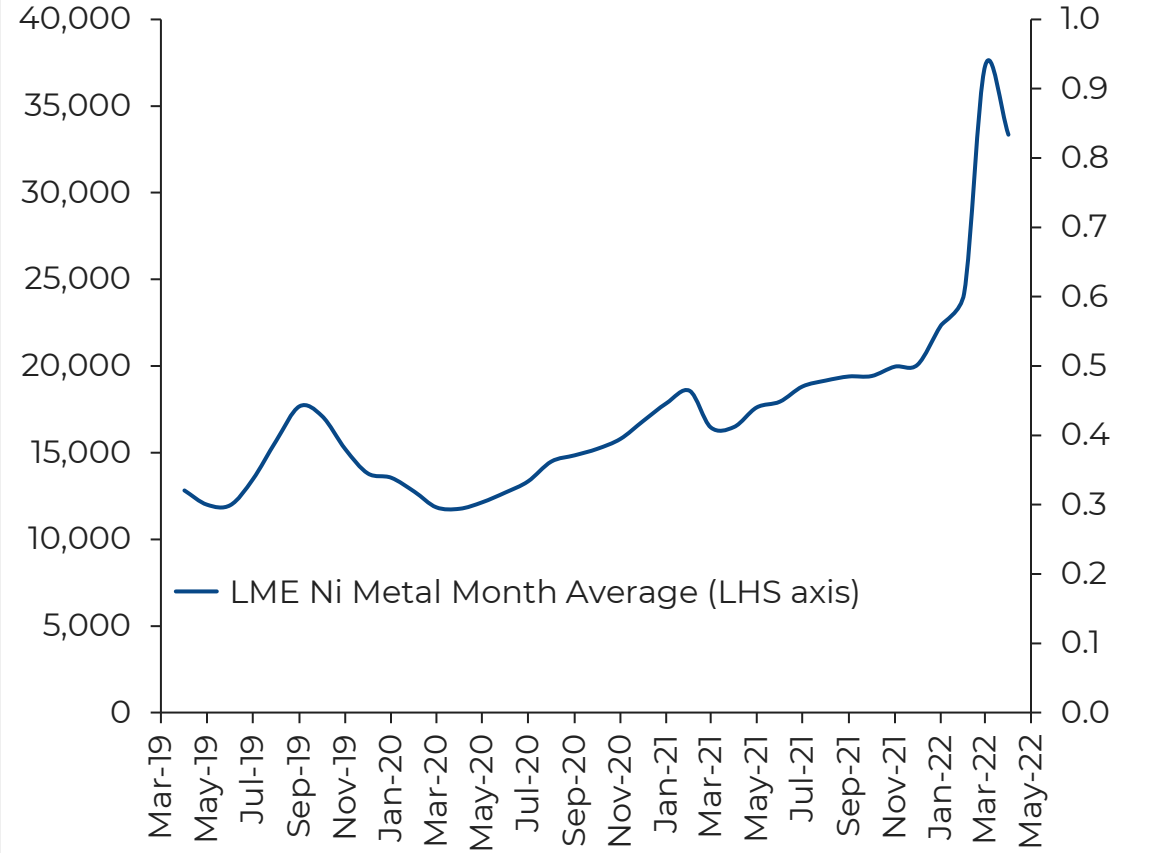
China Cathode Chemistry Market Share



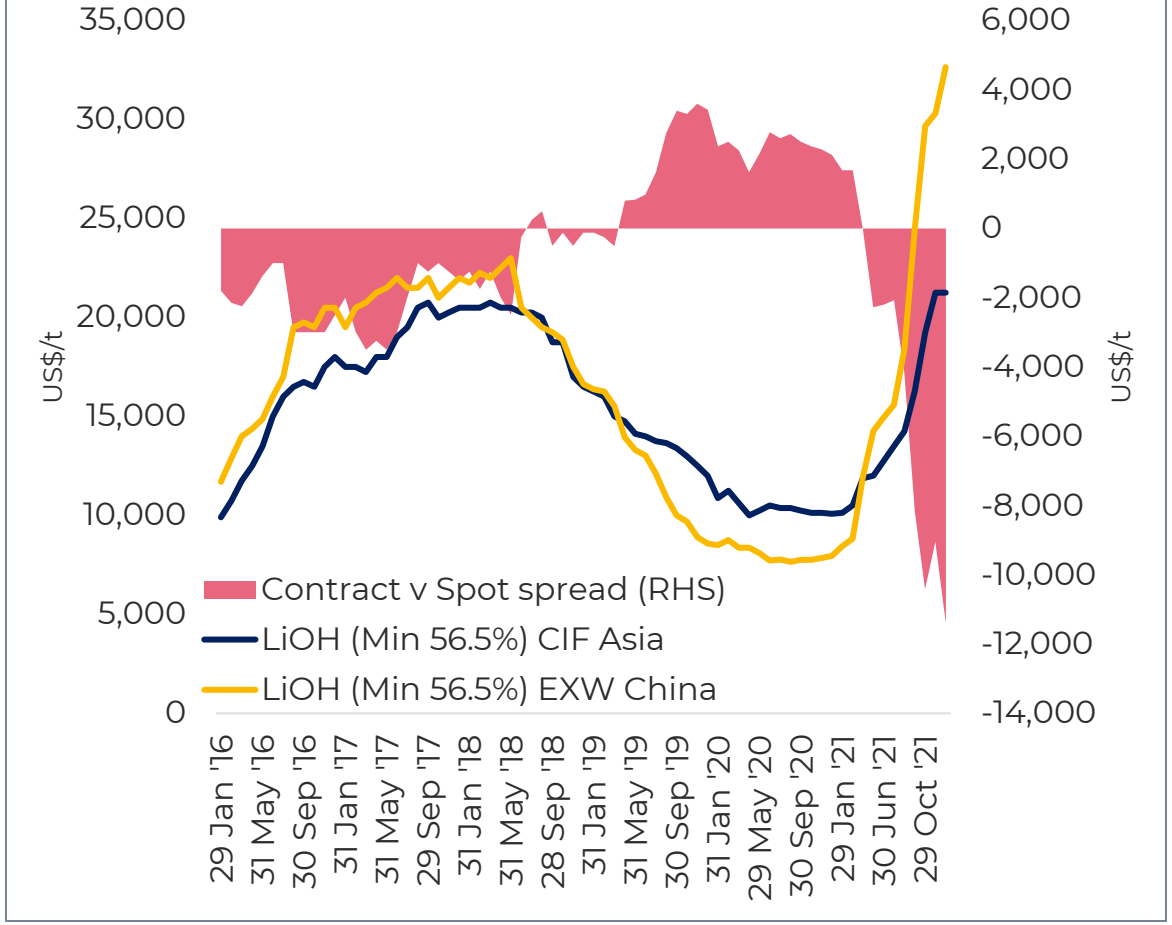
LFP NCM811+ NCM622 NCM523 NCM111 LMNO NCA Other

Nickel and Lithium prices have demonstrated extreme volatility of late, although for different reasons

Monthly LME nickel prices, (US$/tonne)



Lithium Contract v spot pricing and spread (US$/tonne)



Refined nickel is produced in many forms, each one typically suited to particular applications

Nickel Sulfate

Nickel Powder

Nickel Briquettes

Electrolytic Nickel Cathode

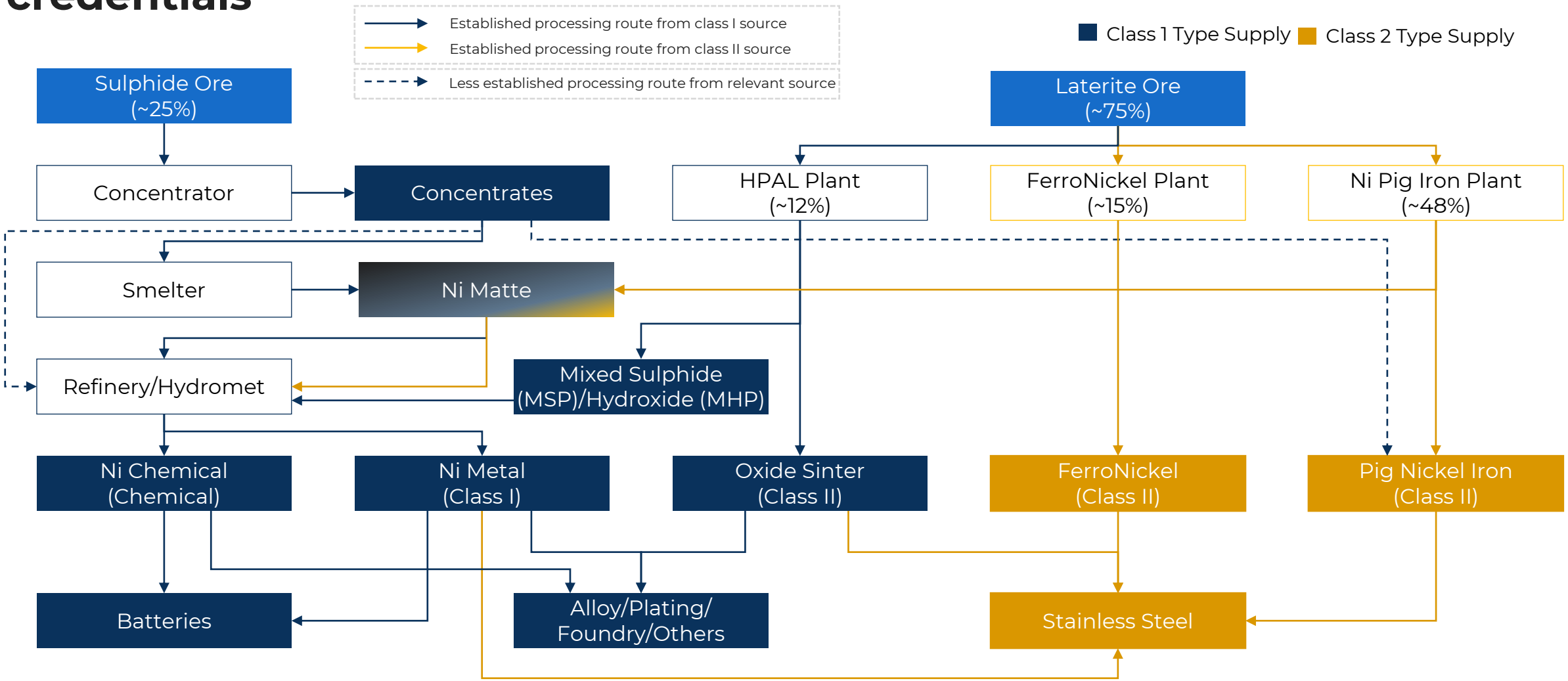
Nickel Pig Iron

Ferro Nickel

Intended application for a Ni product typically determines how it is refined

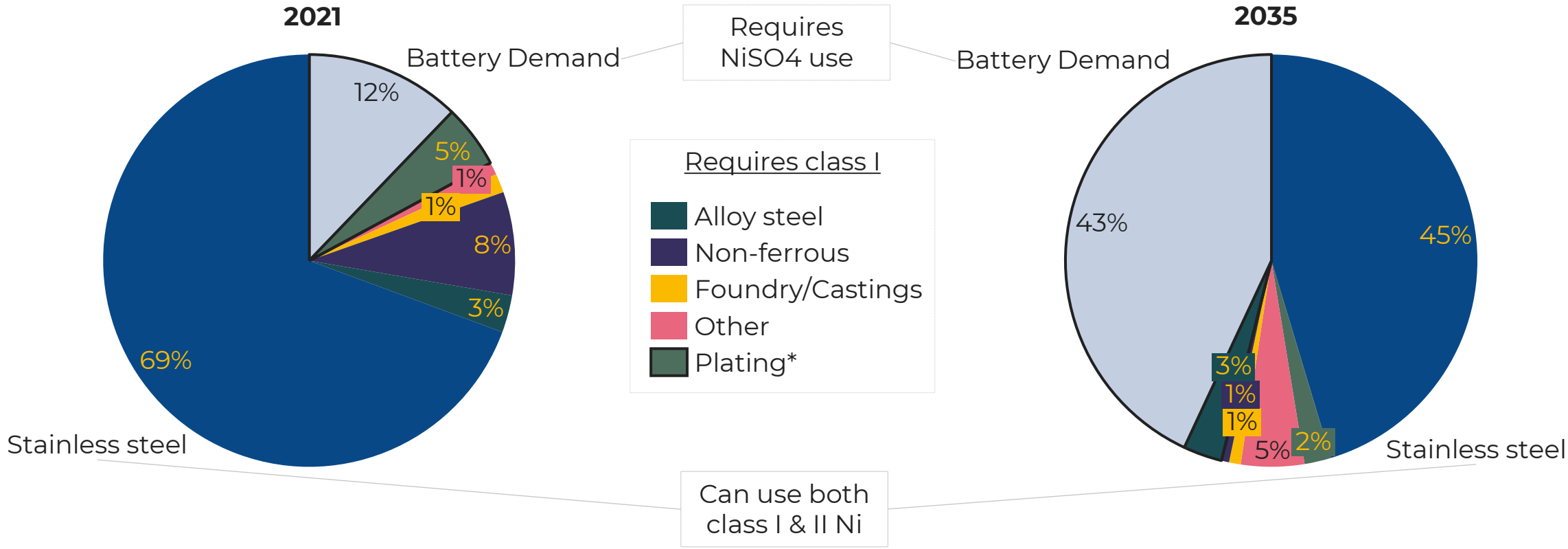
- There are many forms of refined nickel but not all of them are nominally intended for a battery
- Nickel sulphate ($NiSO_4$) is the end product used in a NCM LiB.
- There are also many processing routes that can be followed in order to reach a battery grade product.
- Nickel metal (briquettes, powders, cathode)—categorised as Class I material—can be leached with sulphuric acid to yield $NiSO_4$.
- Nickel pig iron (NPI), ferro-nickel (FeNi) and nickel oxide—all categorised as Class II material—are more typically supplied to the stainless steel industry.

Two distinct supply chains to NiSO4, each with pros and, in some cases, significant cons—notably, laterite routes have weaker ESG credentials



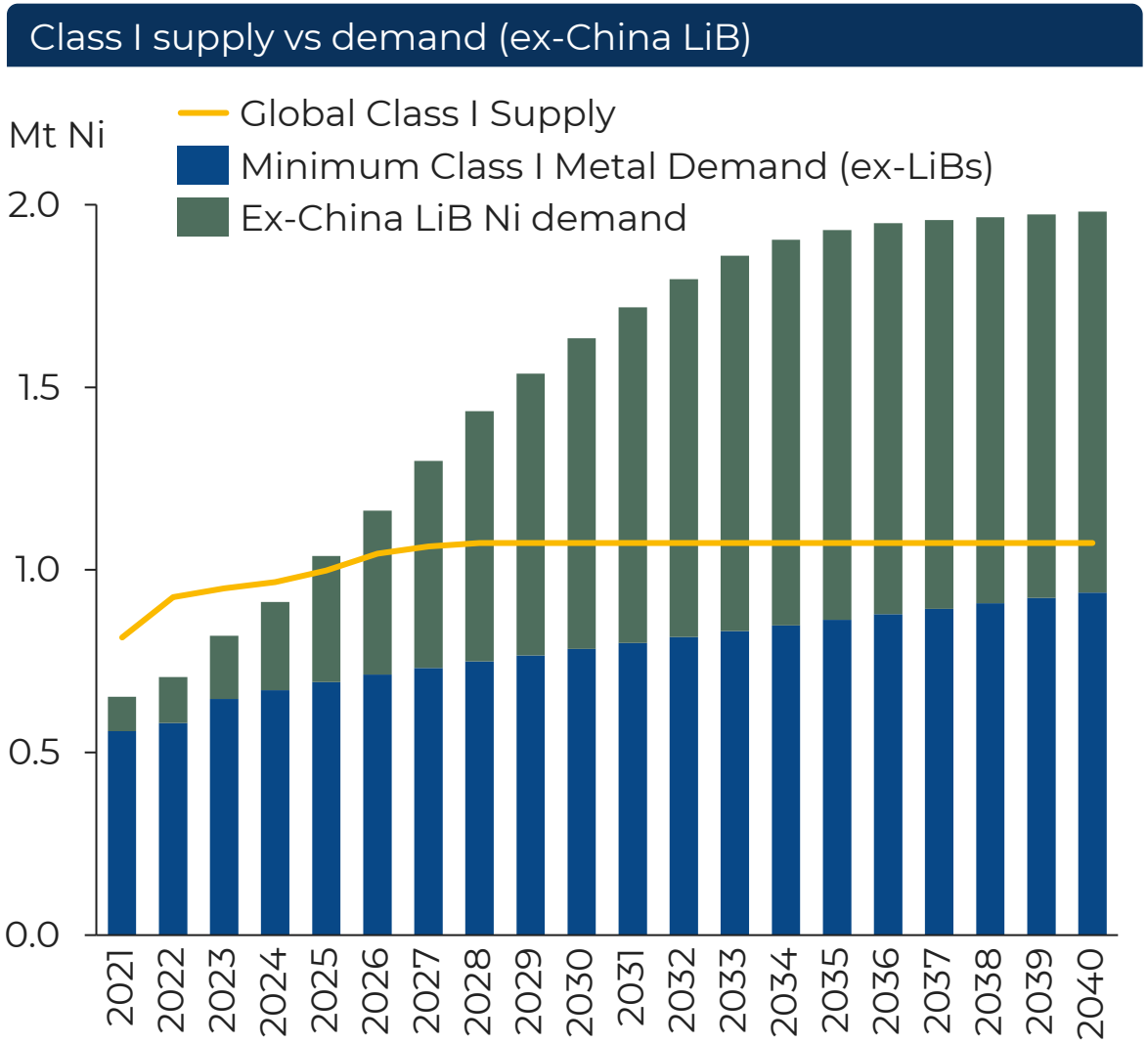
Nickel sulphate will account for more than 43% of overall demand by 2035, as the LiB sector grows

Global nickel market demand structure, 2021 vs 2035



* Plating can use either class I or nickel sulphate

There is a looming shortage of class I units—the LiB supply chain will have to consider laterite alternatives to address growing demand



- Scope for substitution of class I units in non-LiB applications is limited

- Quite clear that class I supply cannot be relied upon to provide the nickel units required by LiB demand growth over the coming decade (even if we assume that the Chinese market exclusively uses non-class I feedstocks)

The options that present themselves in the light of this are::

- **New, as-yet undiscovered sulphide deposits will need to be developed.** But the timelines involved to build new mines and associated smelting/refining capacity outside of China, or commercialise untried processing approaches (pOX), mean this is not a practical response to a deficit forecast by 2025.

- **Nickel sulphate production will increasingly have to rely on laterite sources in future**. ESG issues linked with laterite conversion will have to be ameliorated.

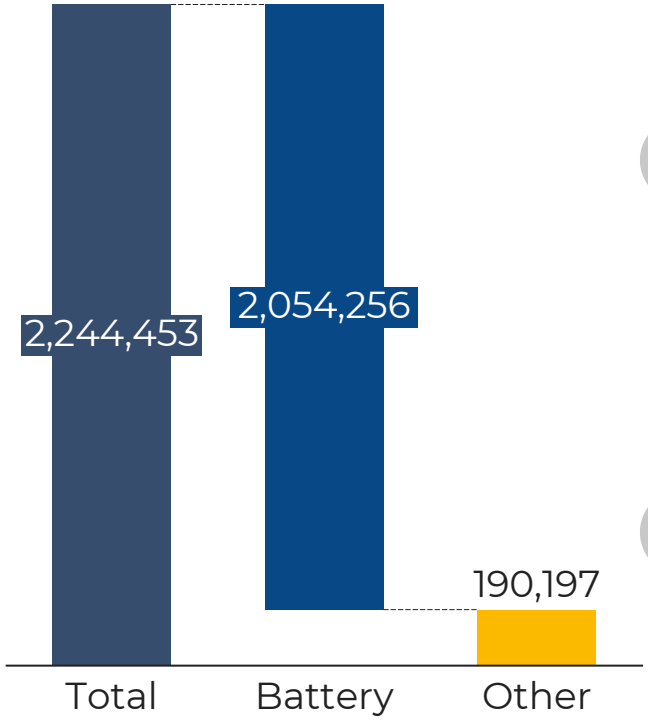
To date, NiSO4 producers have relied on class I units for marginal supply. MHP is emerging as a viable alternative; NPI-to-matte conversion seems increasingly likely to supply Chinese markets

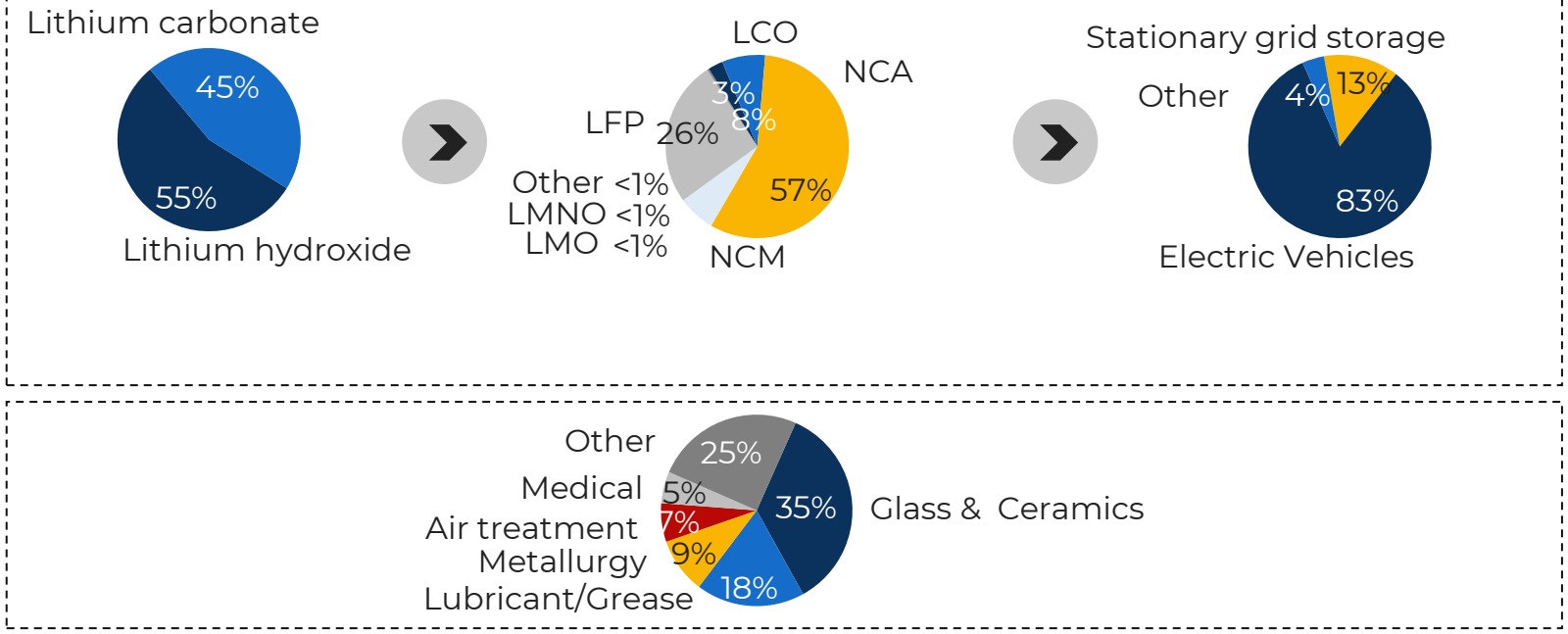
	Availability	Ease of processing to battery grade nickel	ESG profile
MHP	Not resource nor capital constrained for growth in Indonesia	Low complexity and refinery likely to be able to receive multiple sources of MHP. MHP also provides highest levels of Co byproduct credits	CO2 emissions manageable if sulphate refinery is next to MHP source. Tailings in Indonesia still an issue.
Laterite Matte (NPI-to-Matte conversion)	Vast potential for NPI capacity in China and Indonesia to switch to Matte	Direct processing appears straightforward but still to be developed	Very high CO2 emissions from NPI produced with coal fired energy
Sulphide Matte	Resource constrained	Direct processing appears straightforward but still to be developed	Inherently lower CO2 and may benefit from green power.
Sulphide Concentrate	Resource constrained, but high prices may induce a few projects	Direct processing would be complex. Alternative is to produce pig iron in China	Transport costs to processing centers likely to push CO2 emissions high
Class 1 metal	Limited addition of refining capacity for Class 1 and strong competition from both SS and EV markets	The easiest and cheaper cost route	Low CO2 from sulphide sources

Most Optimal Least Optimal

In contrast to nickel, there is little in the way of a legacy lithium sector that can be expanded to meet growing LiB demand

Global Lithium Supply vs Demand, '000 LCE tonnes, 2030



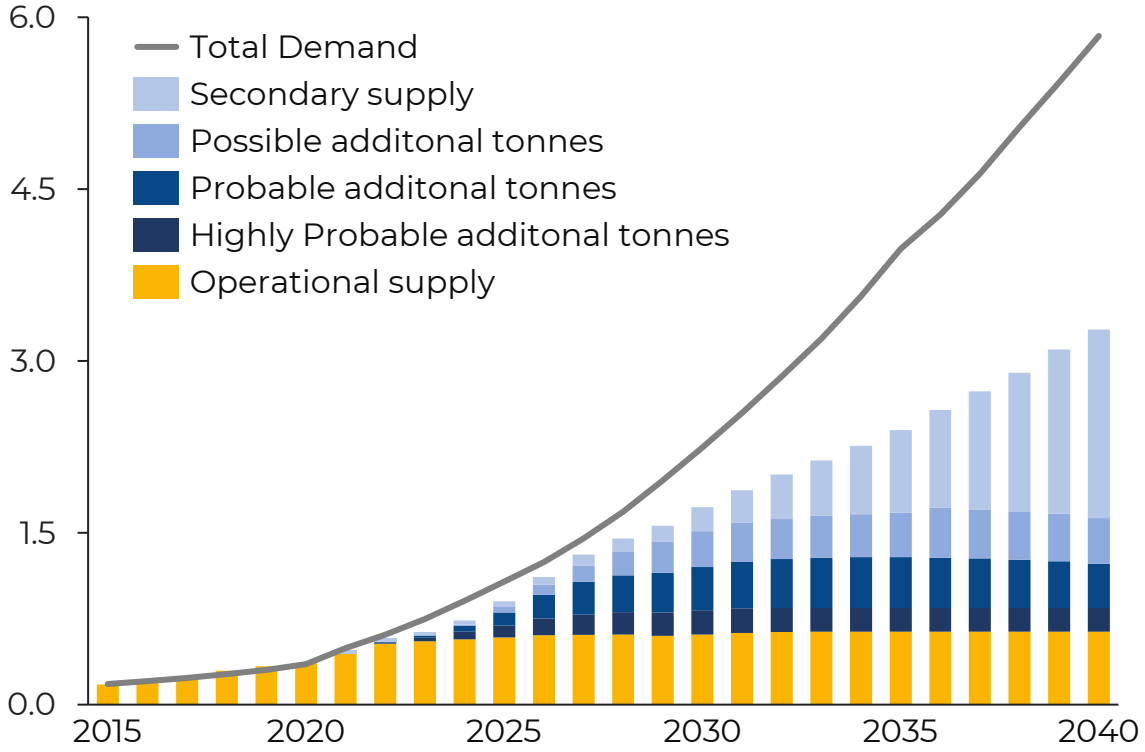


Note: LFP - Lithium iron phosphate, LMNO – Lithium Manganese Nickel Oxide, LMO - Lithium Manganese Oxide , NMC - Lithium Nickel Manganese Cobalt Oxide, NCA - Lithium Nickel Cobalt Aluminium Oxide, LCO - Lithium Cobalt Oxide

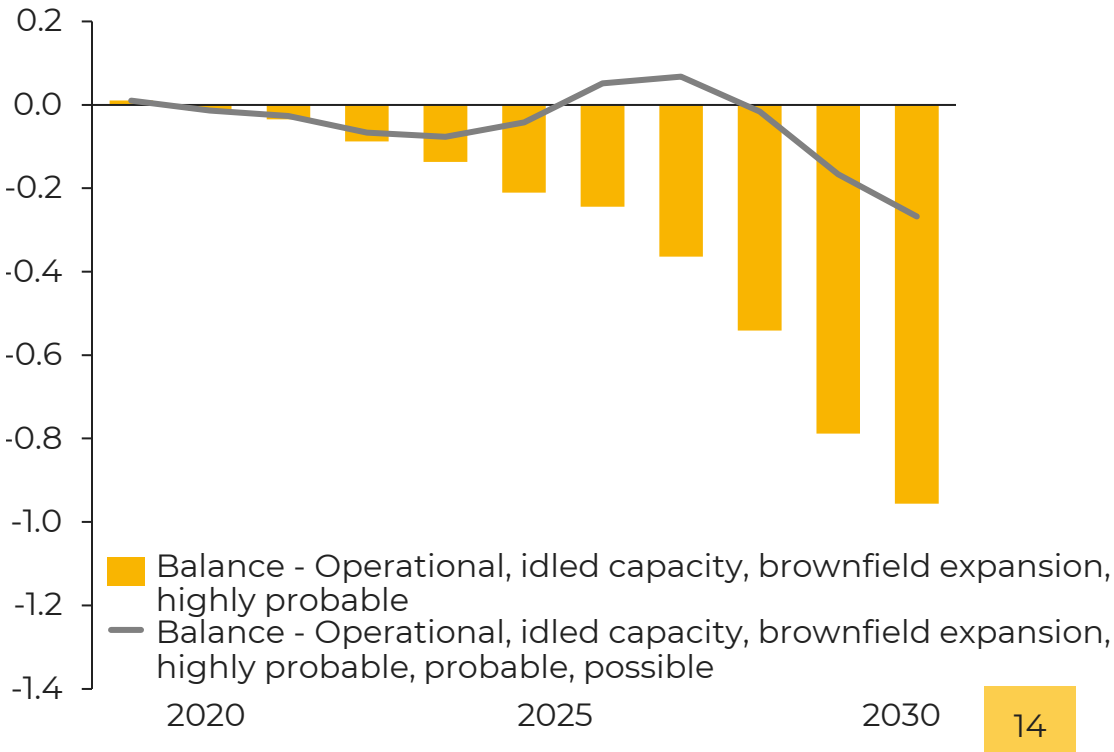
Lithium supply will struggle to keep pace with demand—as-yet unannounced projects will have to be brought into production to resolve market deficit

- There is significant investment, both planned and under way, in new greenfield and brownfield lithium capacity.
- In the medium term this could see a surplus of material that will correct prices downward from current highs. However, there will be an ongoing need for new investment to meet demand in the longer term.
- Note on forecast capacity – BMI tracks existing and announced plans to build new capacity. The capacity forecasts below are not exhaustive and Benchmark expects there to be significant additional unannounced capacity built within the next 5 to 10 years

Lithium Supply Demand Balance to 2040 (million tonnes LCE)

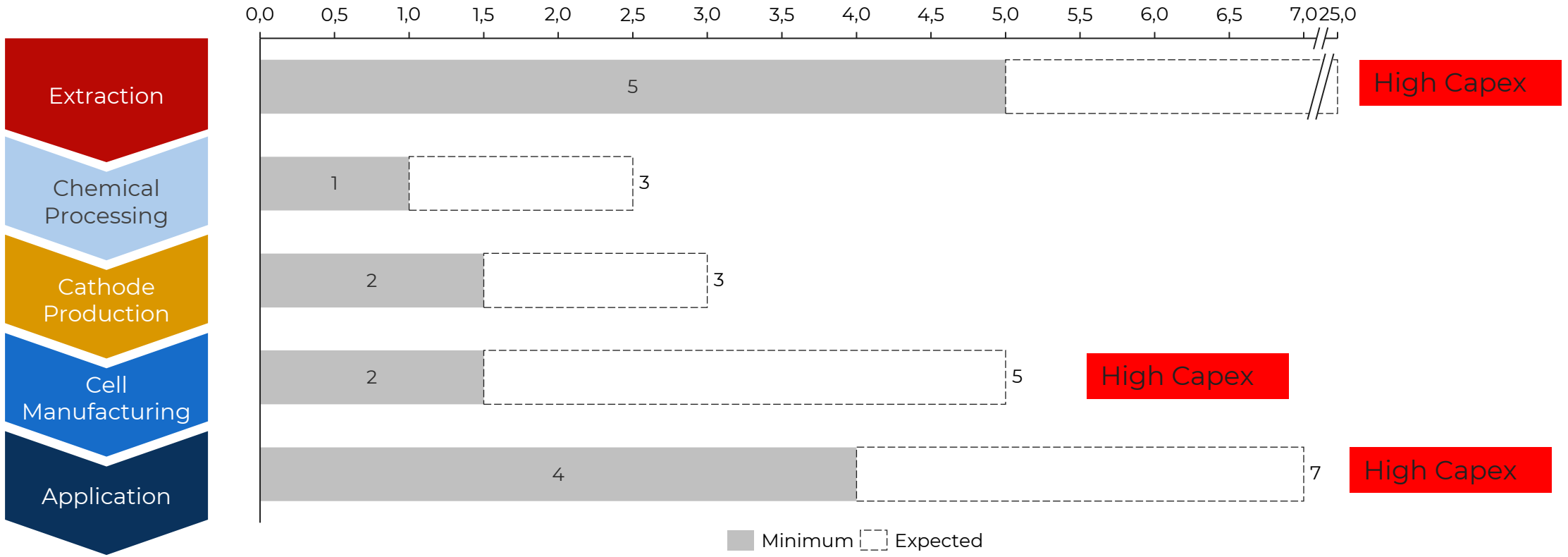


Lithium LCE million tonnes, market balance



Extraction of raw materials is the longest part of the supply chain to develop – it is also location-constrained by geology

Approximate timeline to progress major supply steps (years)



Source: Benchmark - Indicative

LiB Supply Chain: interdependent stages that respond to different incentives yet need conjunctional development