BENCHMARK

Global Opportunity in Critical Minerals

Workshop on Critical Minerals

Manish Dua, Principal Consultant
Benchmark Mineral Intelligence

Indian National Committee / World Mining Congress
Monday 28th August 2023

Benchmark Mineral Intelligence value chain support

- Manish Dua – Principal Consultant
  - Responsible for battery value chain economics analysis, value chain integration for EV transition growth
  - Developing investment and entry strategies for market players in the battery value chain

PRICE ASSESSMENTS & MARKET DATA	Lithium (8 Carbonate, 6 Hydroxide, 1 Spodumene) Cobalt (Sulphate, Metal, Hydroxide) Natural Graphite (8 Flake, 3 Spherical Graphite) Synthetic Graphite (4 Needle Coke, 2 Pet Coke)	Nickel (2 Sulphate, MHP) Anode and Cathode prices (6 Anode, 7 Cathode) Lithium Ion Battery Cells Gigafactory Assessment Anode & Cathode Market Assessments	WEEKLY / MONTHLY
FORECASTING, CONSULTANCY & ESG	Lithium Cobalt Nickel Natural & Synthetic Graphite Anode and Cathode	Lithium Ion Battery Database Solid State Batteries Recycling ESG Life Cycle Assessments	QUARTERLY
NEWS ANALYSIS, WEBINARS & EVENTS	News & analysis Supply chain commentary Presentation archive	Quarterly Review Magazine Video Archive In-person events in all regions	REGULAR

Financial, industrial and legislative forces are all converging on EVs

POLICY

FP

ARGUMENT *An expert's point of view on a current event.*

The Inflation Reduction Act Is the Start of Reclaiming Critical Mineral Chains

European Commission

Critical Raw Materials Act: securing the new gas & oil at the heart of our economy I Blog of Commissioner Thierry

REUTERS®

Volkswagen, Mercedes-Benz team up with Canada in battery materials push

The New York Times

California E.V. Mandate Finds a Receptive Auto Industry

Ford Supply-Chain Leadership Overhaul Reflects EV Ramp Up

The Washington Post
Democracy Dies in Darkness

The Great Lithium Squeeze

INDUSTRY

yahoo!finance

Electra and LG Energy Solution Sign Three-year Cobalt Supply Agreement

MARKET FORCES

Bloomberg

Lithium Smashes New Record as Supply Struggles to Feed EV Growth

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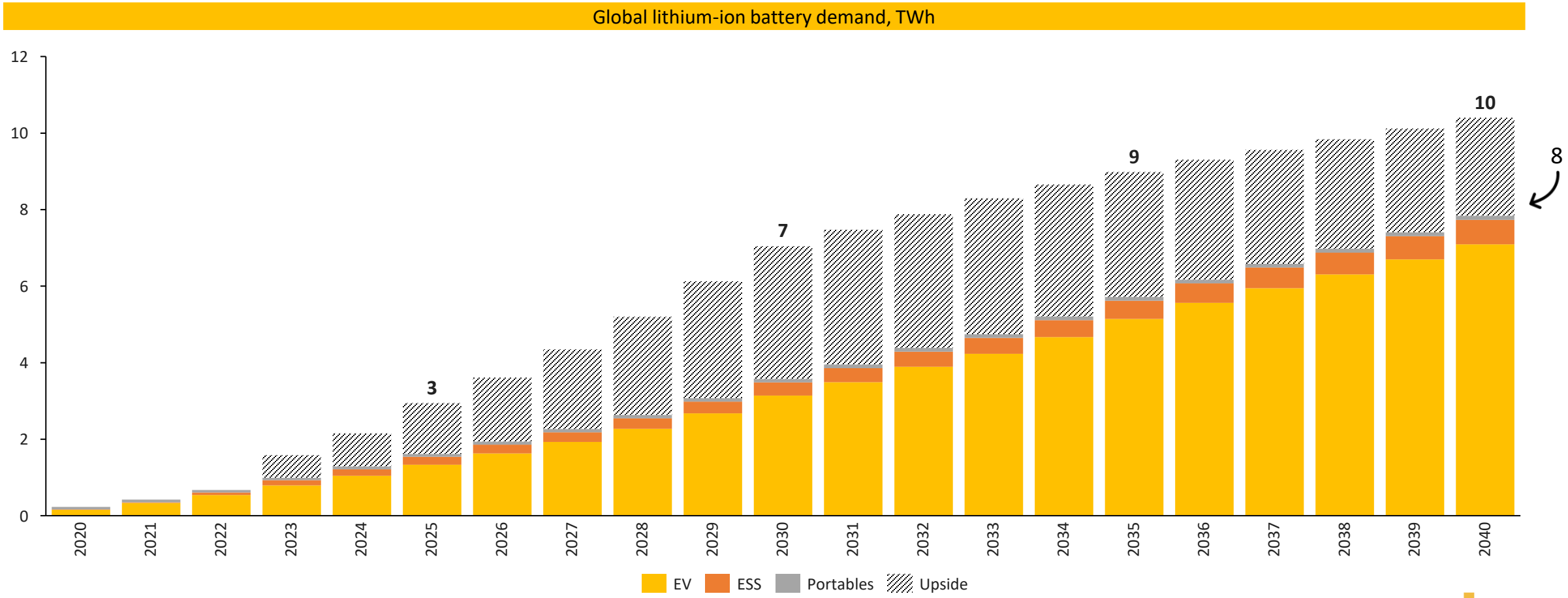
The global battery value chain is entering the Terawatt Era

- The role of renewable battery technology in the low-carbon economy is swelling, moving beyond 1 TWh cumulative installed demand during 2023 and climbing to 8 TWh base case by 2040.
- Lithium-ion battery cell demand is driven by sustainable mobility, rising to >90% market share into the next decade.



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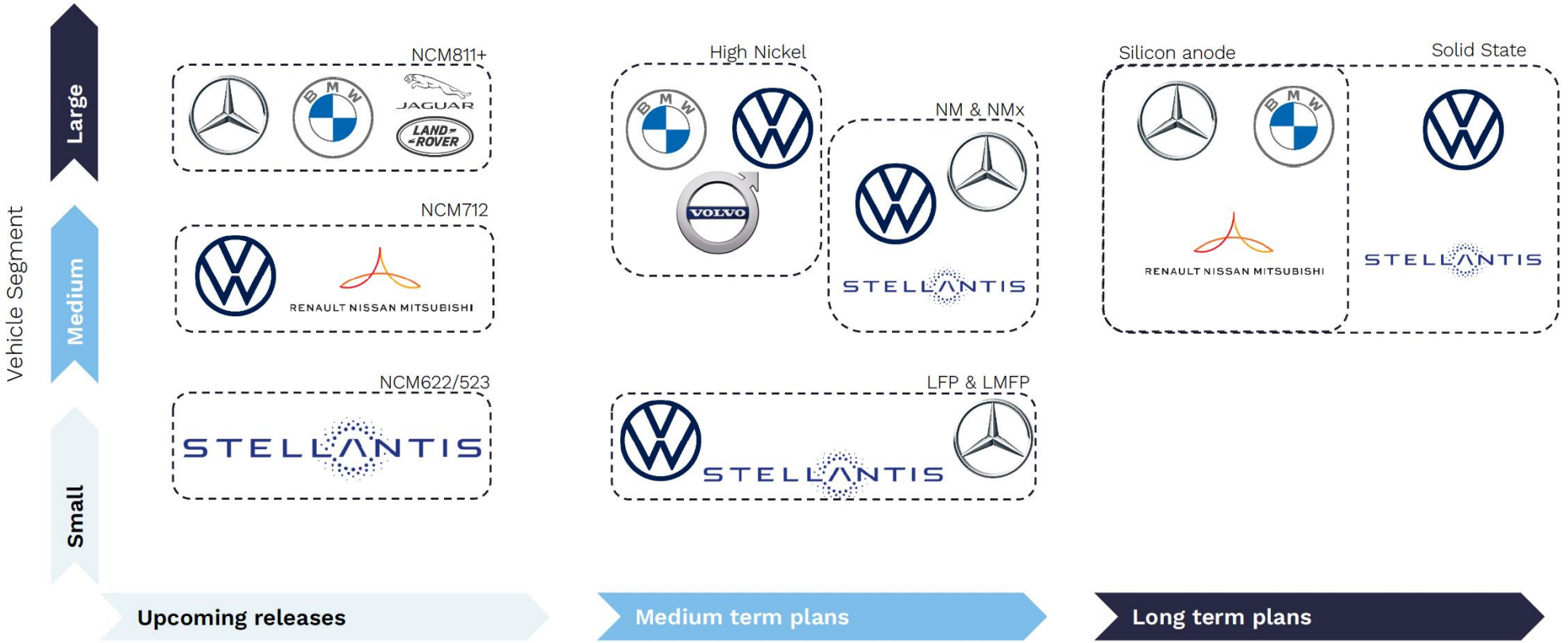
OEM battery roadmaps drive performance from solid state and cost optimisation from LFP/LMFP

- Global automotives are diversifying the technology portfolio to target broad customer requirements centred around the trade-off between performance and price.
- Fundamental to understand regional demands against the role of multiple technologies and critical minerals dynamics.

OEM chemistry roadmap: Europe



rho motion

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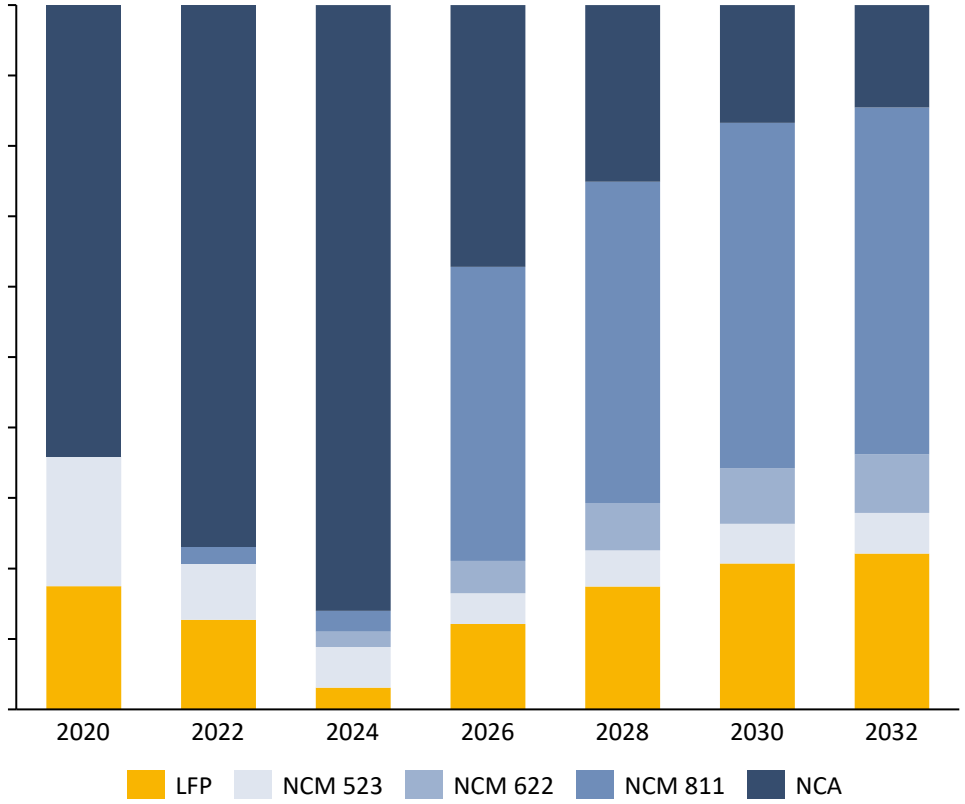
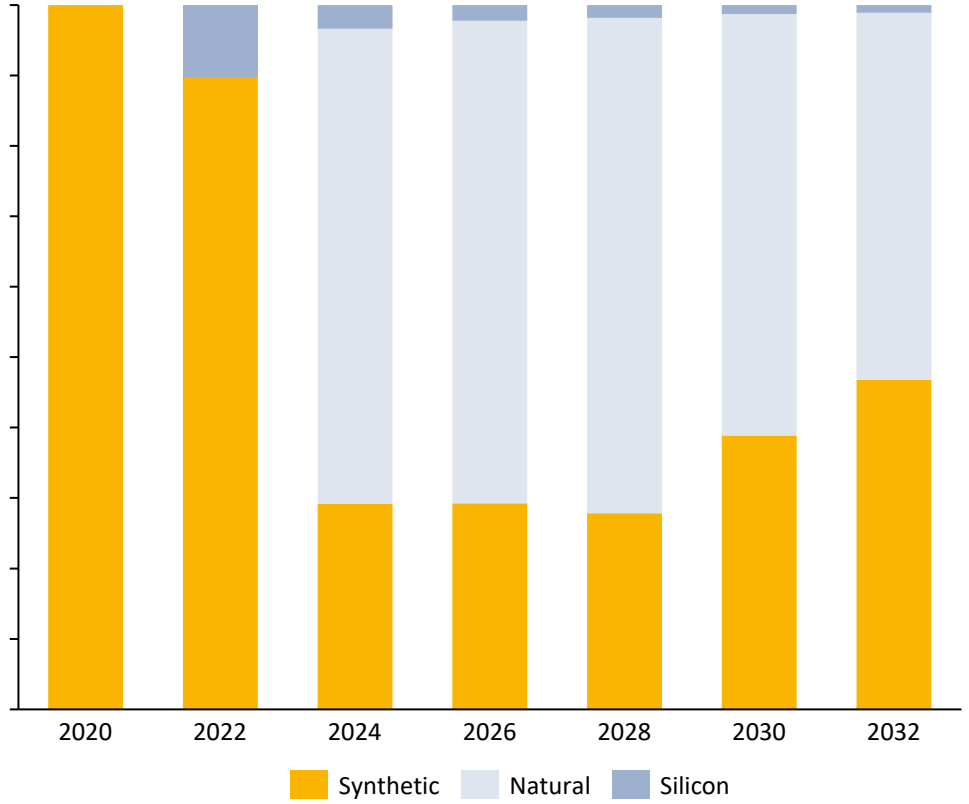
Evolving technology requirements are driving critical minerals demand…

- Cathode and anode roadmaps are yielding rapidly changing requirements for critical minerals.
- The technology mixes need to consider the availability of critical minerals to sustain manufacturing, with legislation pressures e.g., Inflation Reduction Act or EU Critical Minerals Act, driving design and procurement behaviour.

Cathode market share, %



Anode market share, %



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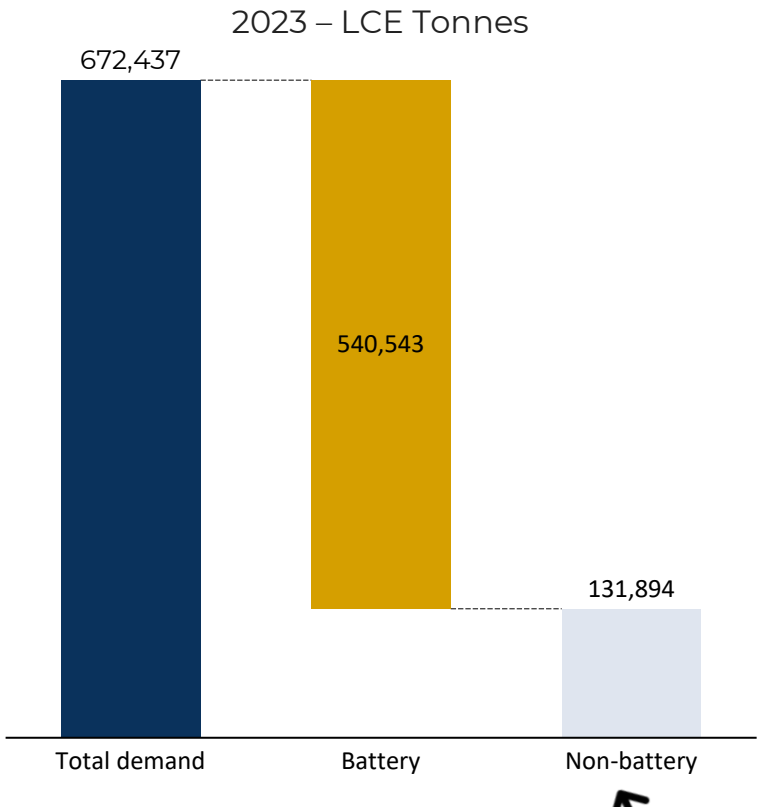
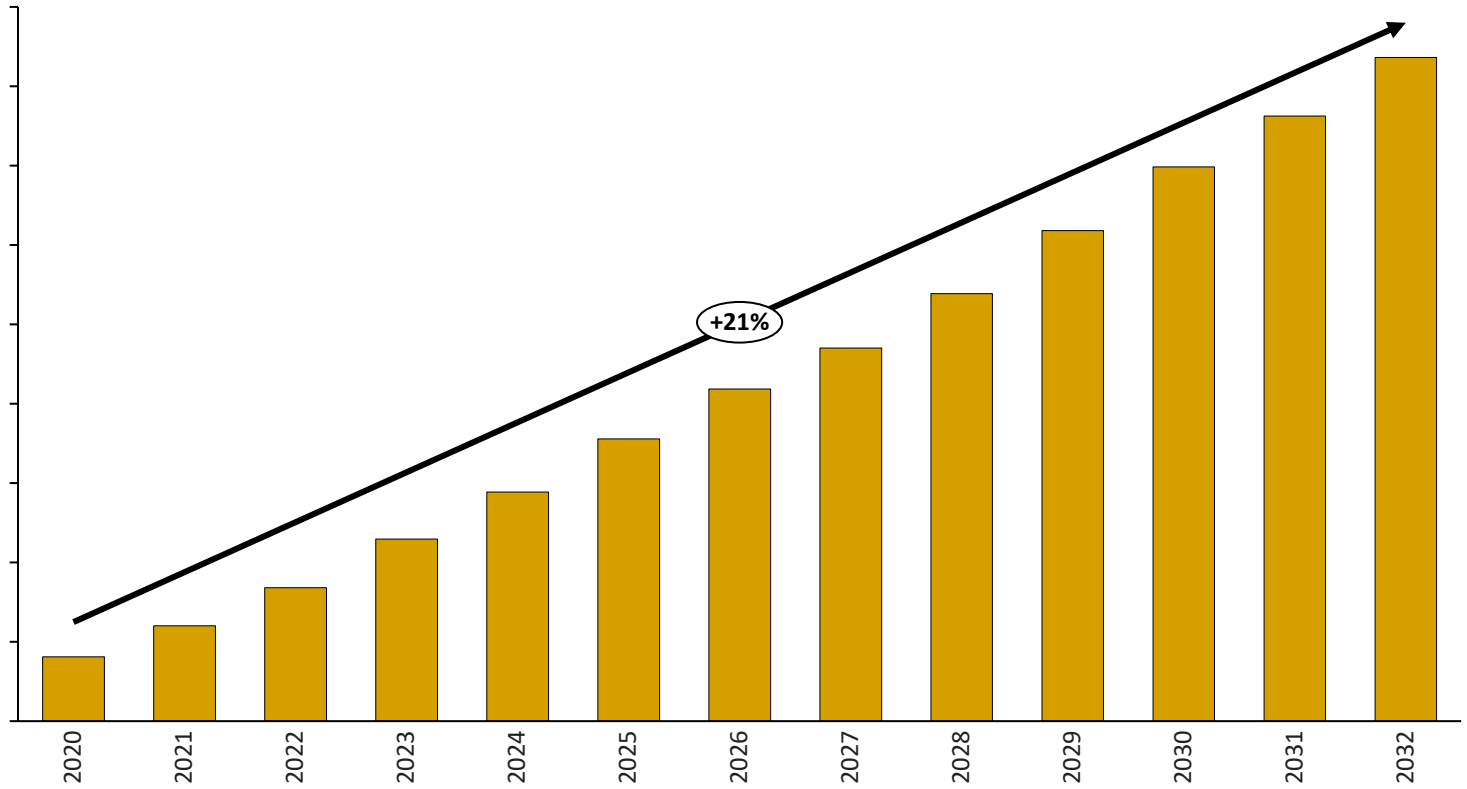
The application of renewable battery technologies are an inflection point in critical mineral demand

- The role of battery technology demand across the critical mineral suite is disrupting traditional industries and placing huge requirements on the rapid evolution and maturity of the scale of supply.
- The lithium industry demand is forecast to grow 16x from 2015 to 2030, challenging the availability of inelastic mining supply.

Lithium chemical demand, base case, LCE tonnes





In 2015 the "other" segment was 60% global demand

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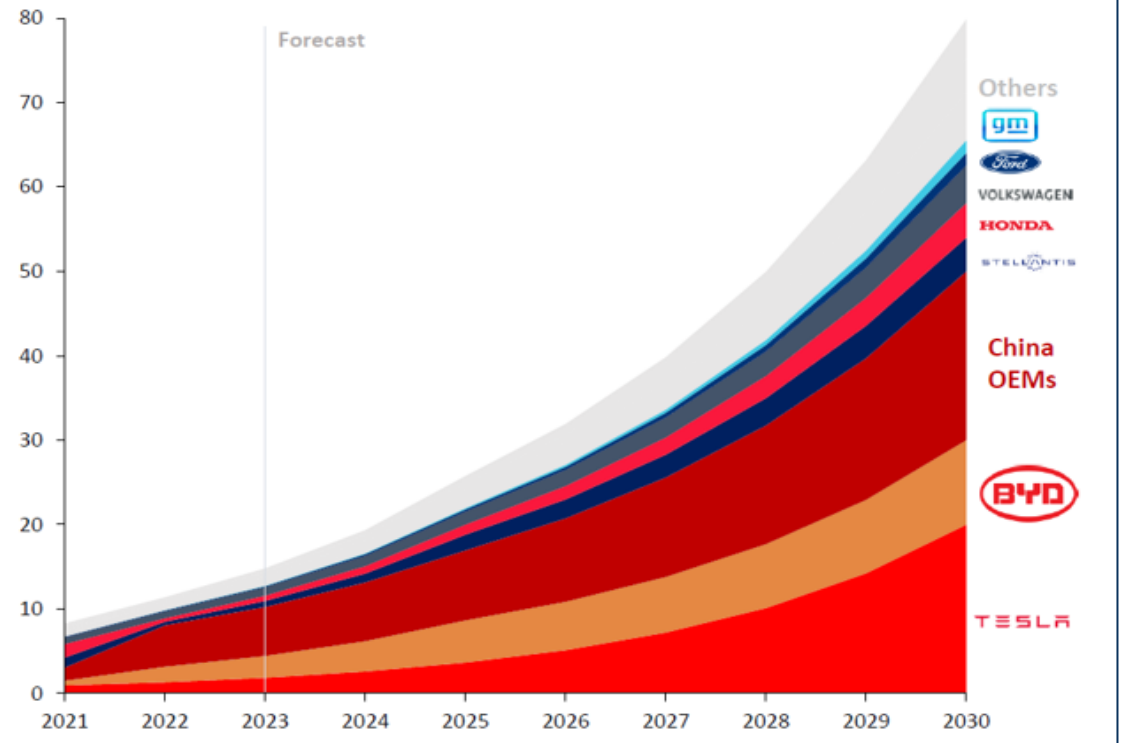
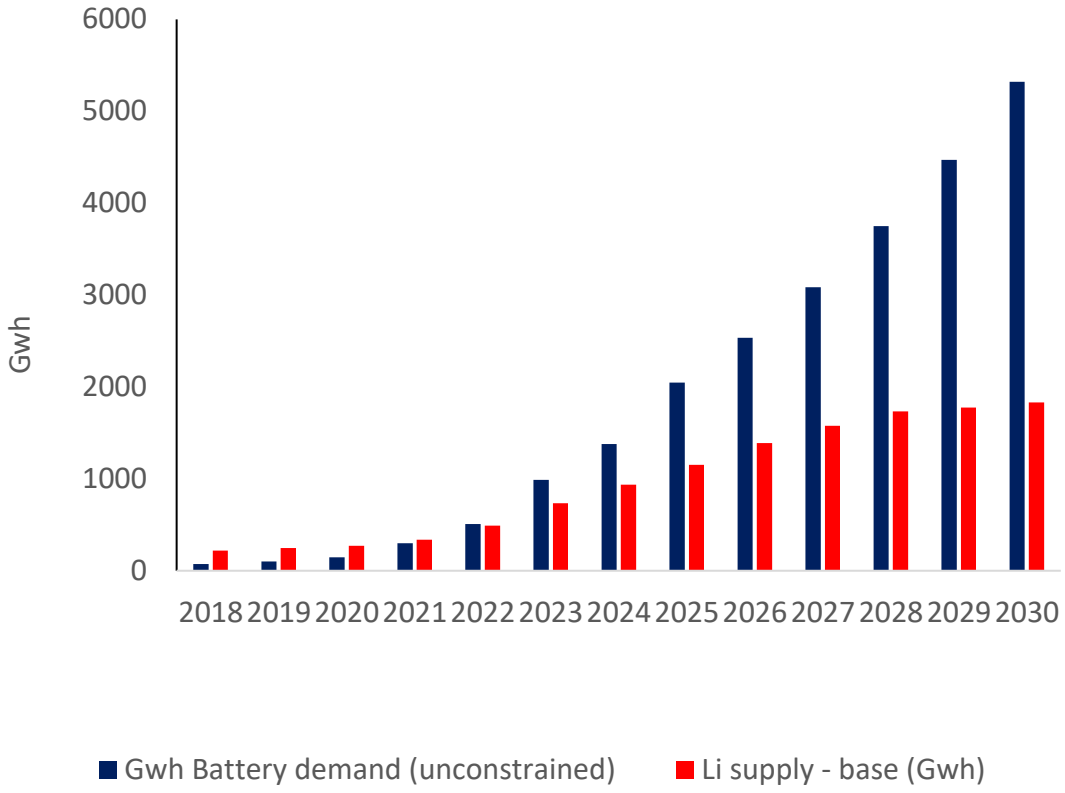
EV and LiB cell deployment: the idealist vs realist perspectives

OEM unconstrained* view (EV ambitions – M units sold)



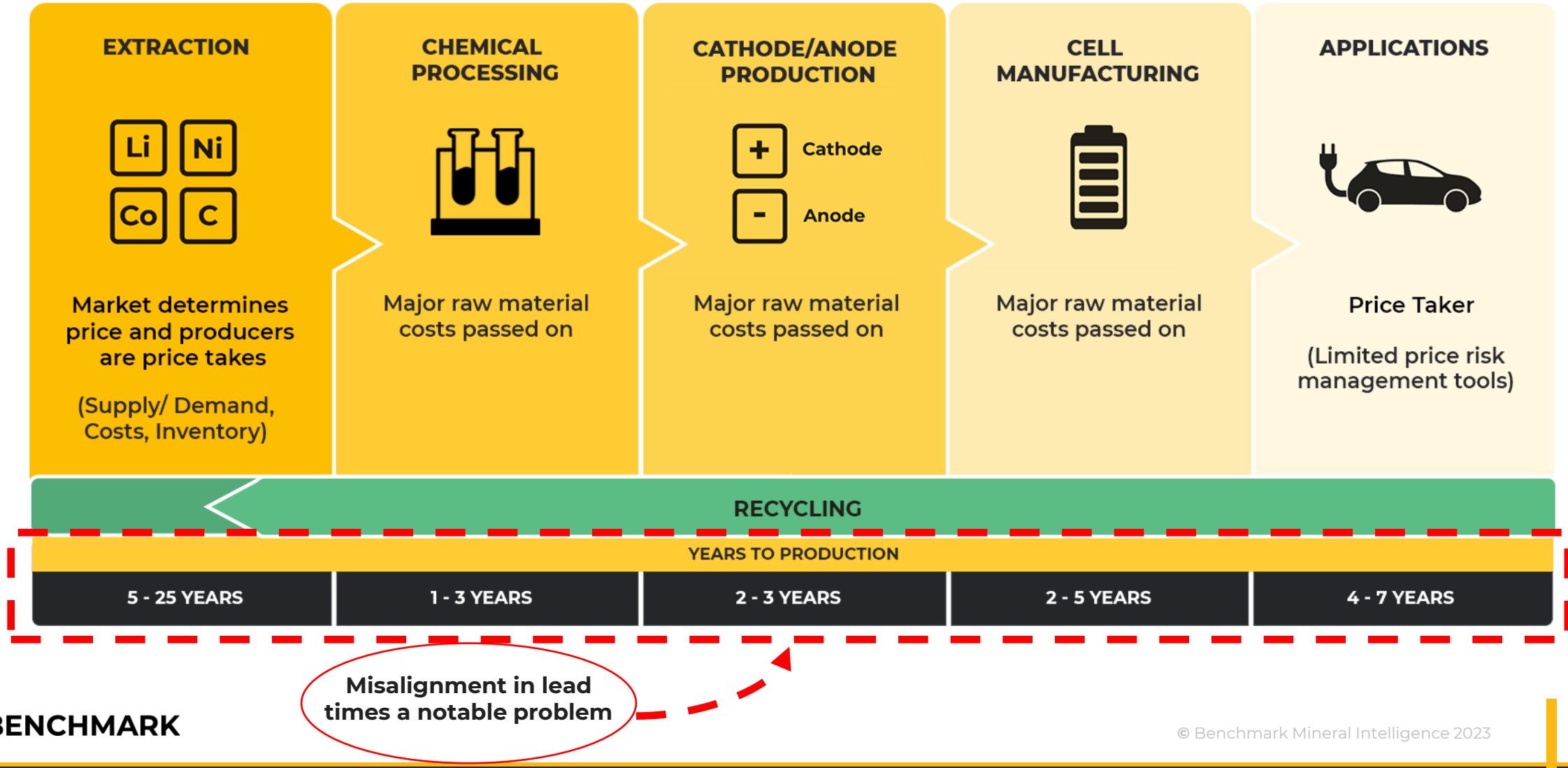
*unrisked view (automakers EV targets)
**Kt LCE converted to Gwh (average chemical conversion ratio). Does not account for major cathode tech yield shifts

OEM unconstrained battery demand (Gwh) v Base-case Li supply**



- OEMs operate in a complex value chain with multiple considerations: LiB cell costs, ESG, geopolitics, stringent qualification (to avoid recall risk)
- Analysis of EV deployment cannot be examined top-down (unconstrained view is unrealistic).

Keeping pace with the downstream trajectory will be difficult for less agile upstream markets



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Other strategic considerations only add hurdles to supply chain success

Location

- Regional supply security of increasing importance to consumers
- Financial incentives to localise from IRA etc

Sustainability

- OEMs' green credentials increasingly tied to supply chain
- Brand/reputational risks

Product specs

- The right type of chemical (delivered in the optimal form) is essential
- VIU will differ across technologies

The Washington Post
Democracy Dies in Darkness

ENERGY
The Great Lithium Squeeze

REUTERS
Reuters

Exclusive: Facing green pressure, Indonesia halts deep-sea mining disposal

Automotive World est. 1992

BMW Group Sustainability through Innovation 2022

FP
ARGUMENT An expert's point of view on a current event.
The Inflation Reduction Act Is the Start of Reclaiming Critical Mineral Chains

The Guardian
Dark matter and lithium water

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Project development timelines are getting longer as we build the wider ecosystem for EV-scale extraction

Machinery

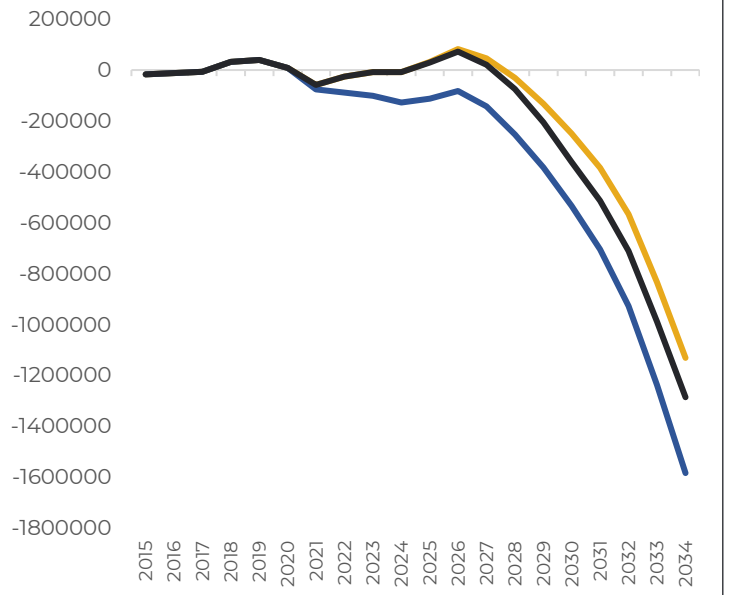
Infrastructure

Workforce

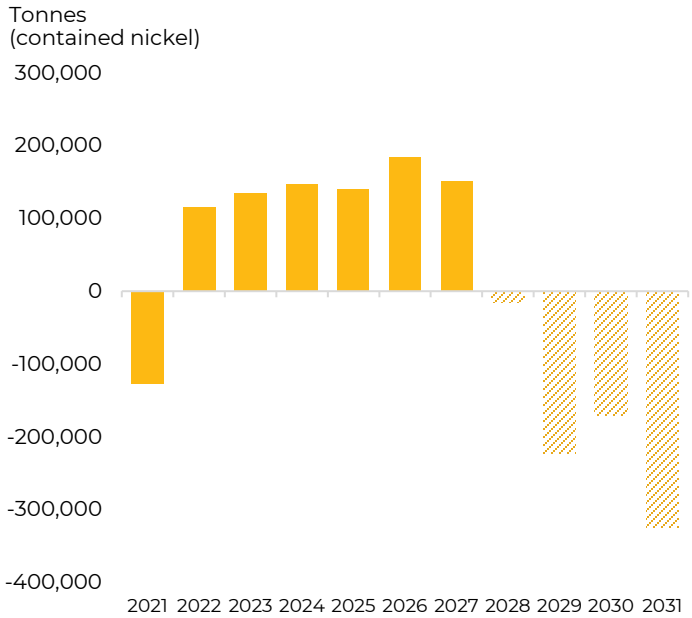
> We are already seeing intensifying shortages in equipment, infrastructure, refining materials and skilled labour. This is having an inflationary impact on project economics....

Critical minerals cliff edge is potentially on the horizon

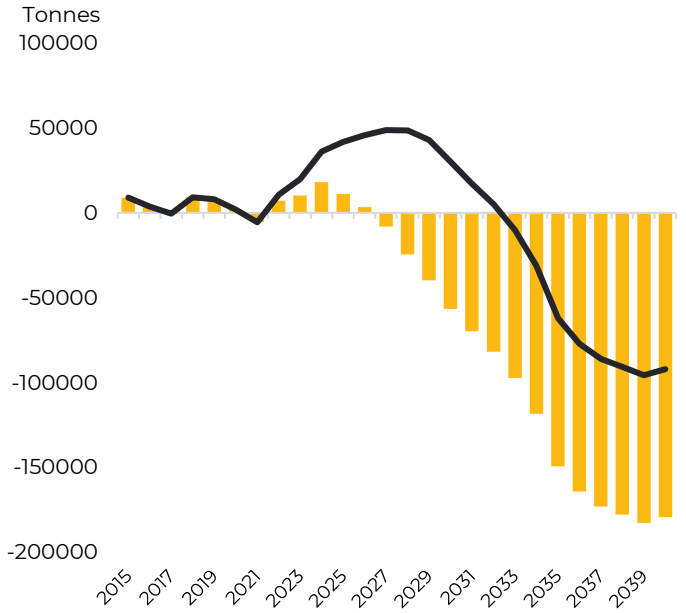
Lithium



Nickel



Cobalt



Capital needs to be deployed today to avoid the challenges of the coming decade

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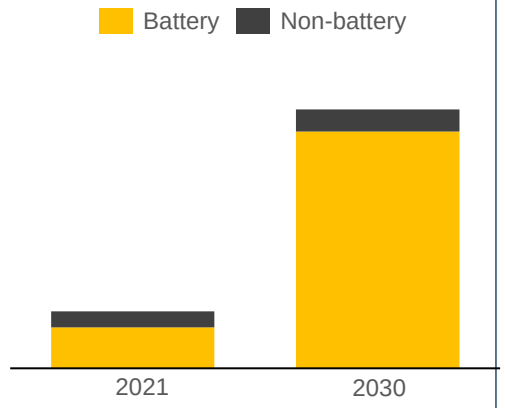
Source: Benchmark Forecasts

Critical minerals supply needs scaling – more challenging, risky than building gigafactories

Lithium demand (LCE basis) 2021-2030 (tonnes)



CAGR
22% 4% (Non-battery) 18-20% (battery)

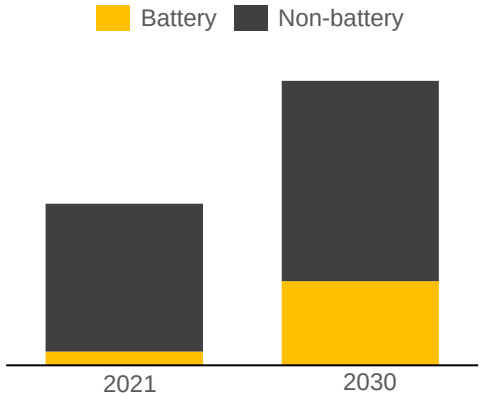
Challenges

- Quality & consistency of product
- Lack of chemical experience
- Lack of a futures price
- Lack of industry standard spec

Locations

- **Latin America**
- **Australia**
- Europe
- North America
- Africa
- China

Primary nickel demand 2021-2030 (tonnes)



CAGR
6% 3% (Non-battery) 22% (battery)

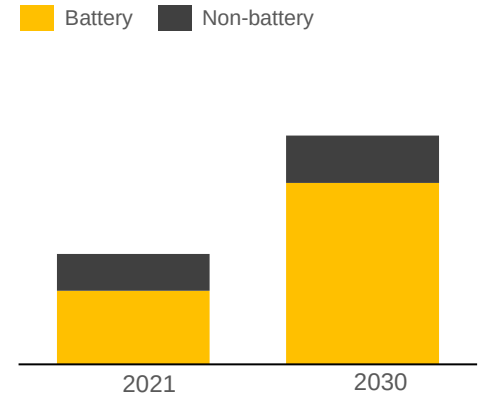
Challenges

- ESG and carbon intensity
- Laterite challenges
- Sulphuric acid supply
- Russia

Locations

- **Indonesia**
- Philippines
- Australia
- PNG

Cobalt demand 2021-2030 (tonnes)



CAGR
8% 2% (Non-battery) 11% (battery)

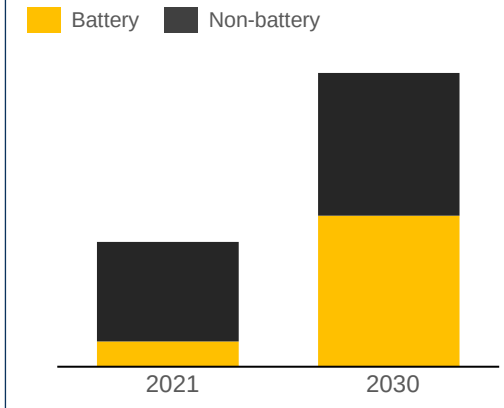
Challenges

- 70% DRC raw material
- (brand image, lack of western investors)
- High cost/substitution
- By-product

Locations

- **DRC**
- North America
- Australia
- Brazil

Needle coke for synthetic 2021-2030 (tonnes)



CAGR
20% (battery)

Challenges

- Competing demand from graphite electrodes market
- Grade quality
- China uncertainty (e.g., role of blending)

Locations

- **US**
- **China**
- **Japan**

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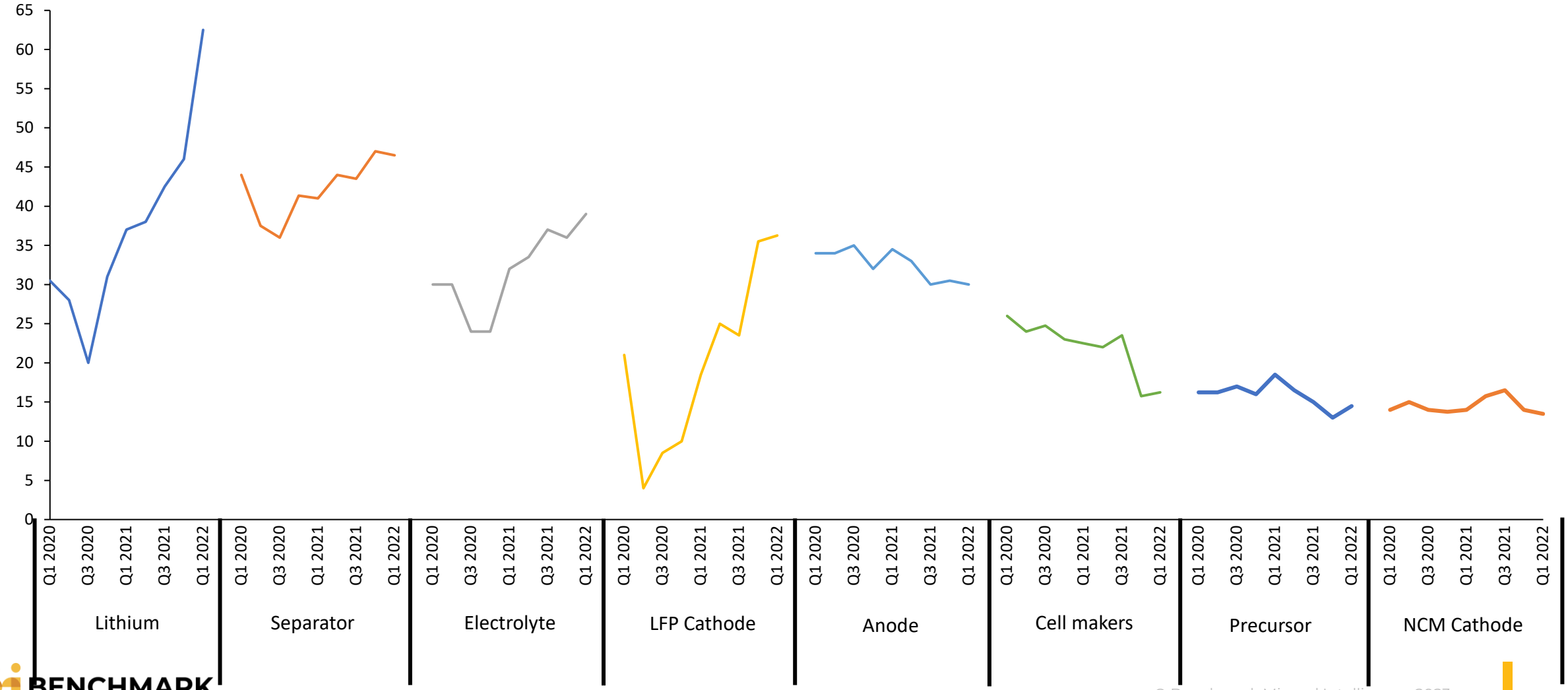
Margins across mining and chemical processing indicative of supply bottlenecks witnessed since 2021

Gross Margin, %



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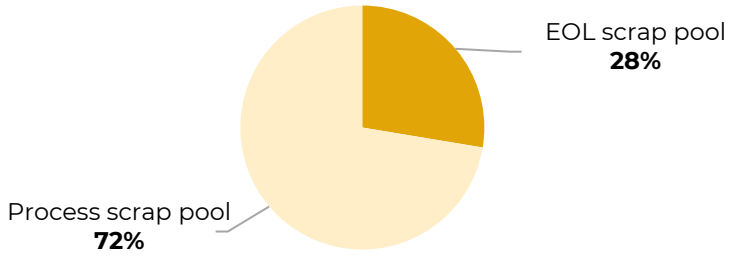
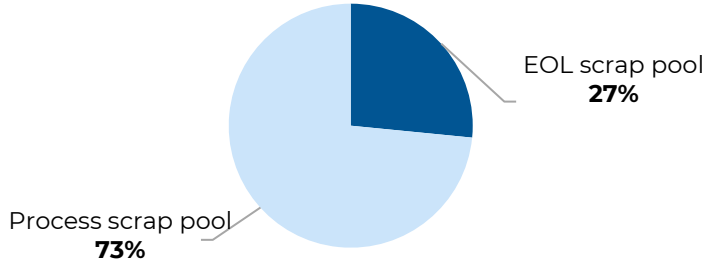
Recycling will play an important role, but cannot fill the void

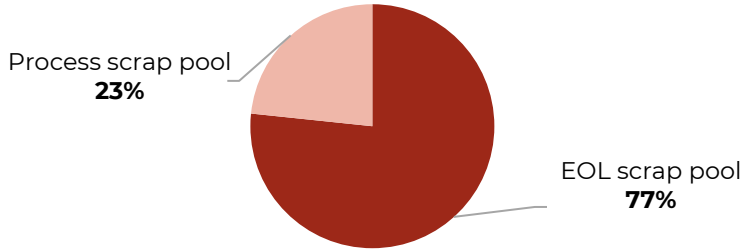
2022



2030



2040



Short-term
Process scrap is the dominant component of the scrap pool, which is generated during cell manufacture. This scrap is ready for recycling with immediate effect, as discharge/ dismantling/ separation steps are not always required (as is the case for EOL batteries). As manufacturers refine their processes, the scrap generated will be reduced.

Intermediate years
Between the short and mid-term case, the process scrap contribution has the potential to fluctuate significantly (in 2025 process scrap will constitute 81% of the total scrap pool). There will be many cell manufacturers coming online over the years, therefore the increased cell capacity will fall in coordination with higher loss rates during ramp up stages.

Mid-term
The increased uptake of electrification of EV and ESS markets across the globe means that demand for LiB manufacture will have increased dramatically by 2030. This increase will mean that the number of LiB manufacturers online will be at an all-time high, and so will the subsequent process scrap.

Long-term
Once cell manufacturers are well-established and have refined their manufacturing process, there will be a general levelling out of process scrap supply. This will be high in volume and provide recycling companies with a consistent and reliable feedstock. As such a high volume of batteries will be reaching EOL at this stage, the requirement for refined and effective discharge/ dismantling/ separation of battery packs, modules and cells will be essential for companies looking to adopt direct recycling processes.

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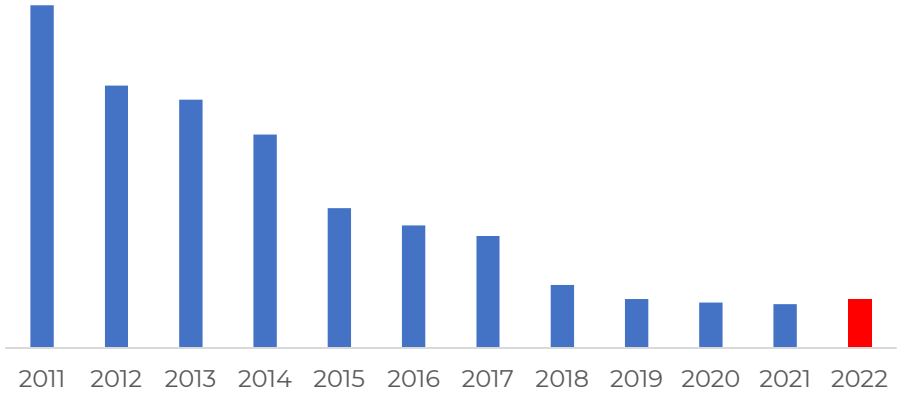
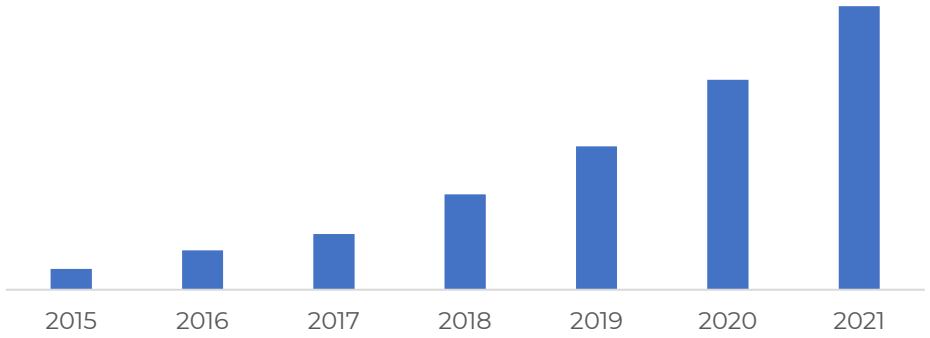
Source: Benchmark Recyc lingReport

The past decade has seen major gains on cost savings and cathode technology, but raw material costs now play an outsized role

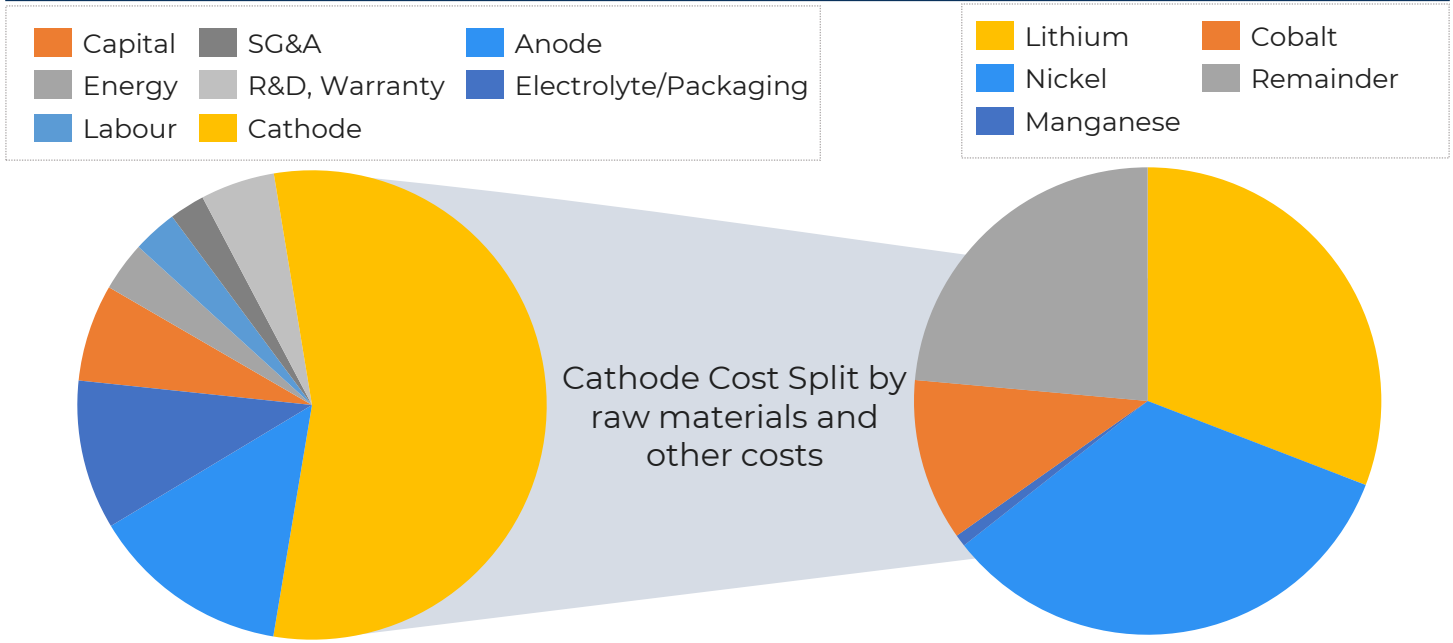
Average battery costs (inc. pack), US$/kwh



Battery cell capacity deployment (Gwh)



NCM 811 cell cost estimate; RHS chart: Cathode split by constituent elements



- Scale and technology improvements (energy density) have helped support declines in li-ion battery and cell costs
- Cathode materials – which include Li, Ni and Co – now account for up to 50-60% of BOM for high-nickel cells. Around 90% of the cathode cost is raw material cost v 50% for anode material (rest is processing cost).

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Critical minerals are now firmly at the heart of EV economics – Attention has now shifted to cathode costs

70% = BOM

Anode

- Natural spherical Graphite
- Synthetic Graphite
- Silicon
- Foils
- Binders

Other

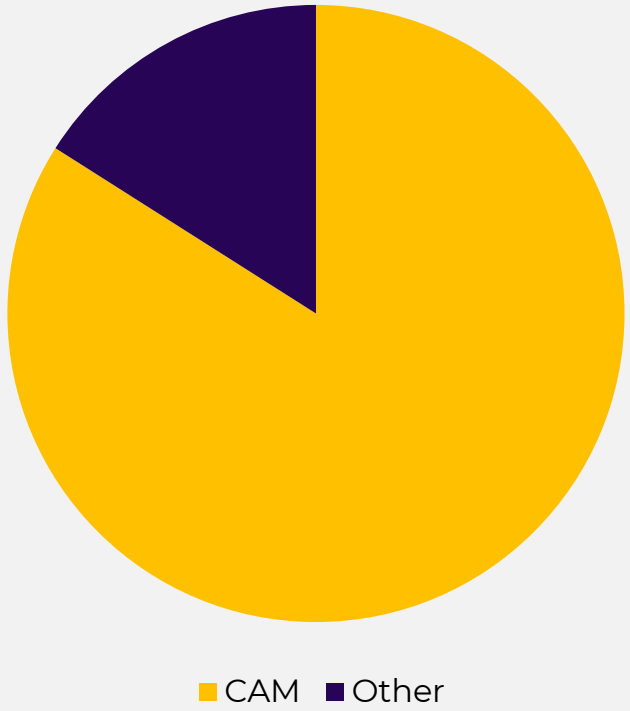
- Separator
- Electrolyte

Cathode

- Lithium
- Cobalt
- Nickel
- Manganese
- Aluminium
- Iron phosphate

Source: Benchmark Battery Cost Model

Cathode Cost Breakdown



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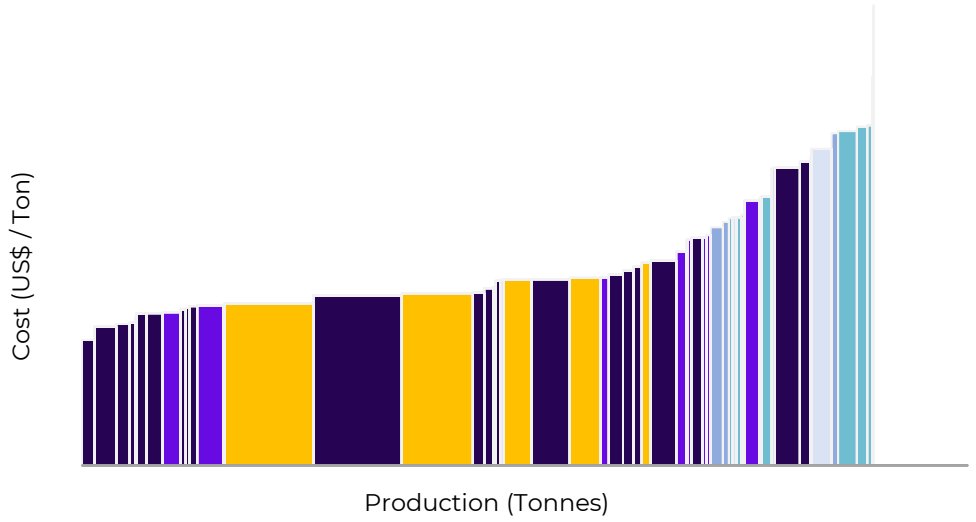
EV economics will ultimately have to absorb higher costs

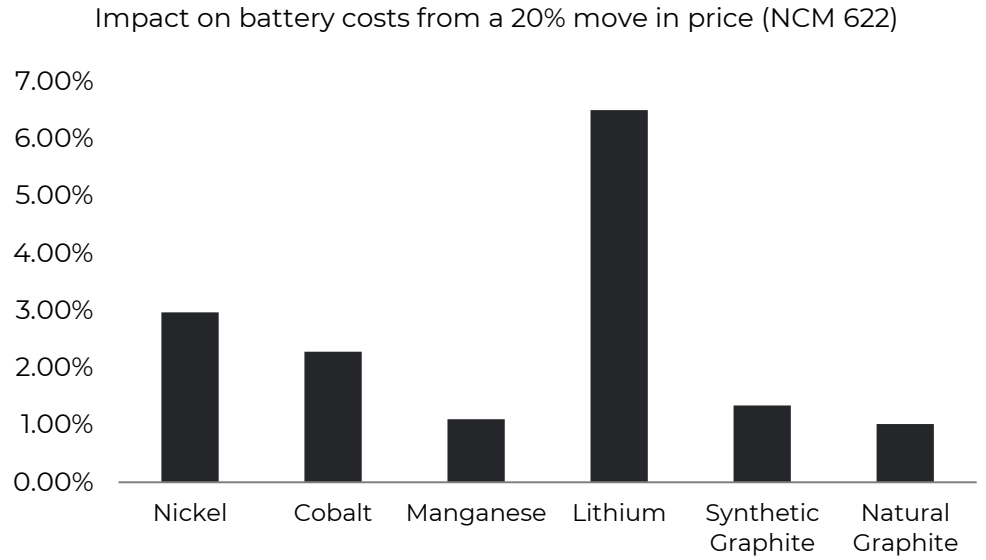
Higher incentive pricing needed to ensure diversified & sustainable supply



New supplies will have to come from higher cost sources of production...

Source: Benchmark Forecasts

This can happen without derailing EV economics



...But if managed correctly this doesn't have to be a disruptive force in battery adoption

Source: Benchmark Battery Cost Model

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This is forcing OEMs to move upstream …

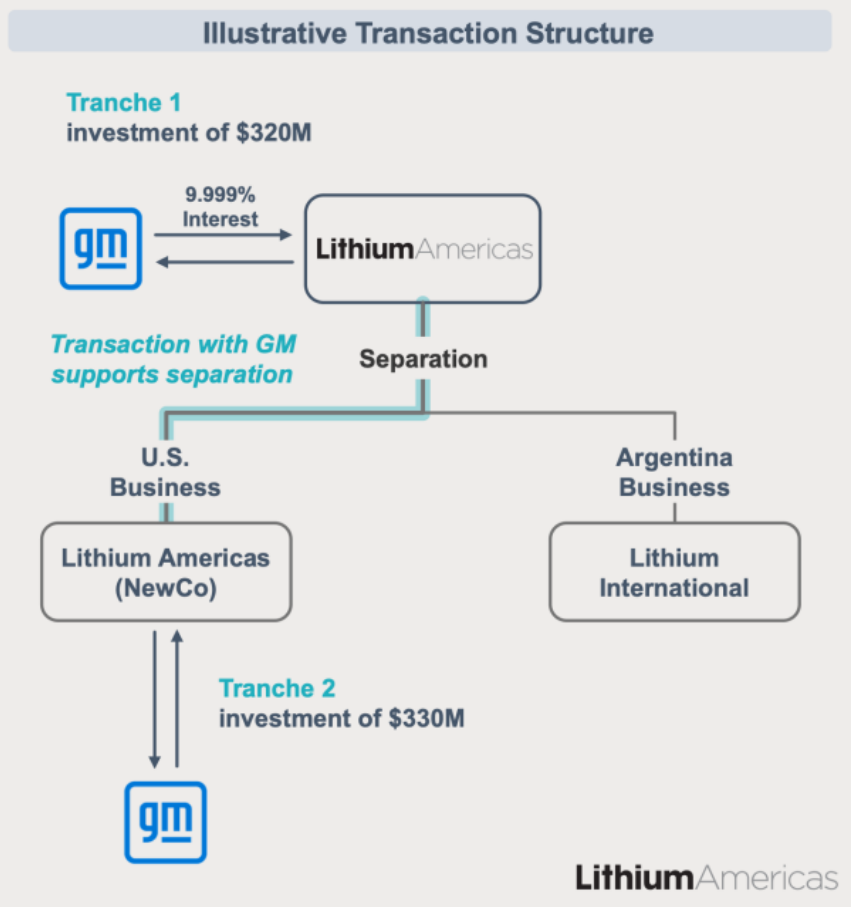
Current supplier | Future supplier | Undisclosed/None

OEM	Mining resources			Battery Materials				Batteries
	Lithium	Nickel	Cobalt	Cathode	Anode	Electrolyte	Separators	
TESLA	Albemarle, Ganfeng, Yahua	Vale BHP Talon metals	Glencore	Sumitomo	BTR, Shanshan, Chinese suppliers Syrah (2024+)	Mitsubishi Chem,Tincl high-Tech	Sumitomo	Panasonic, LGES, CATL
VW	Ganfeng, Vulcan Energy (2026+)	Huayou cobalt Tsingshan	Huayou cobalt Tsingshan	Umicore (2025)				LGES, CATL, SDI
TOYOTA				Sumitomo				PPES
gm	Lithium Americas, Controlled Thermal Resources (2024+)	QPM		POSCO (2024+) BASF	POSCO (2024+)			LGES, CATL
VOLVO								LGES, SDI, CATL
DAIMLER								SK On, AESC, LGES, CATL
STELLANTIS	Vulcan Energy (2026+), Controlled Thermal Resources (2024+)	Terrafame (2025+)						CATL
Ford	Ioneer, Compass, Liontown	Vale, Huayou, BHP						SK On, LGES, CATL
RENAULT NISSAN MITSUBISHI	Vulcan Energy (2026+)	Terrafame						LGES, AESC
BMW	Ganfeng, Livent		Glencore, Managem Group					CATL, SDI, AESC

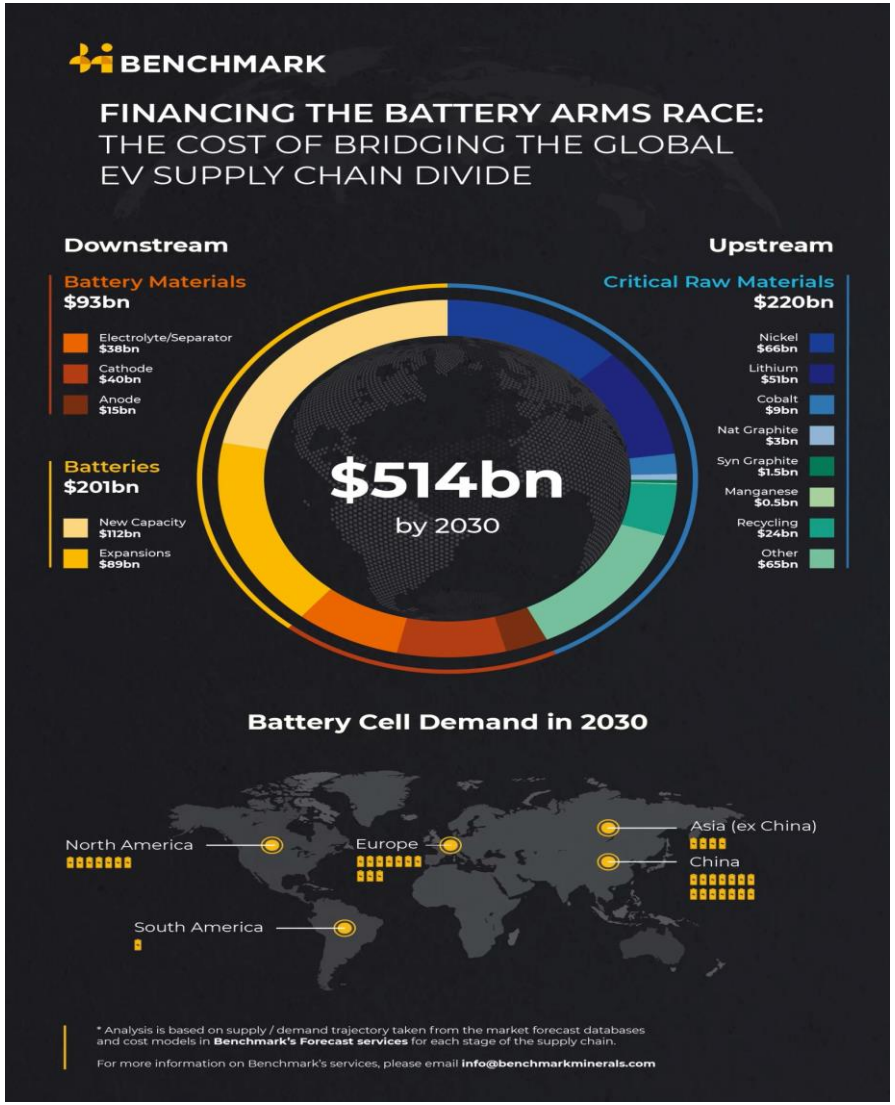
*This table indicates public announcements and is not an exhaustive list. For full details, please contact info@benchmarkminerals.com

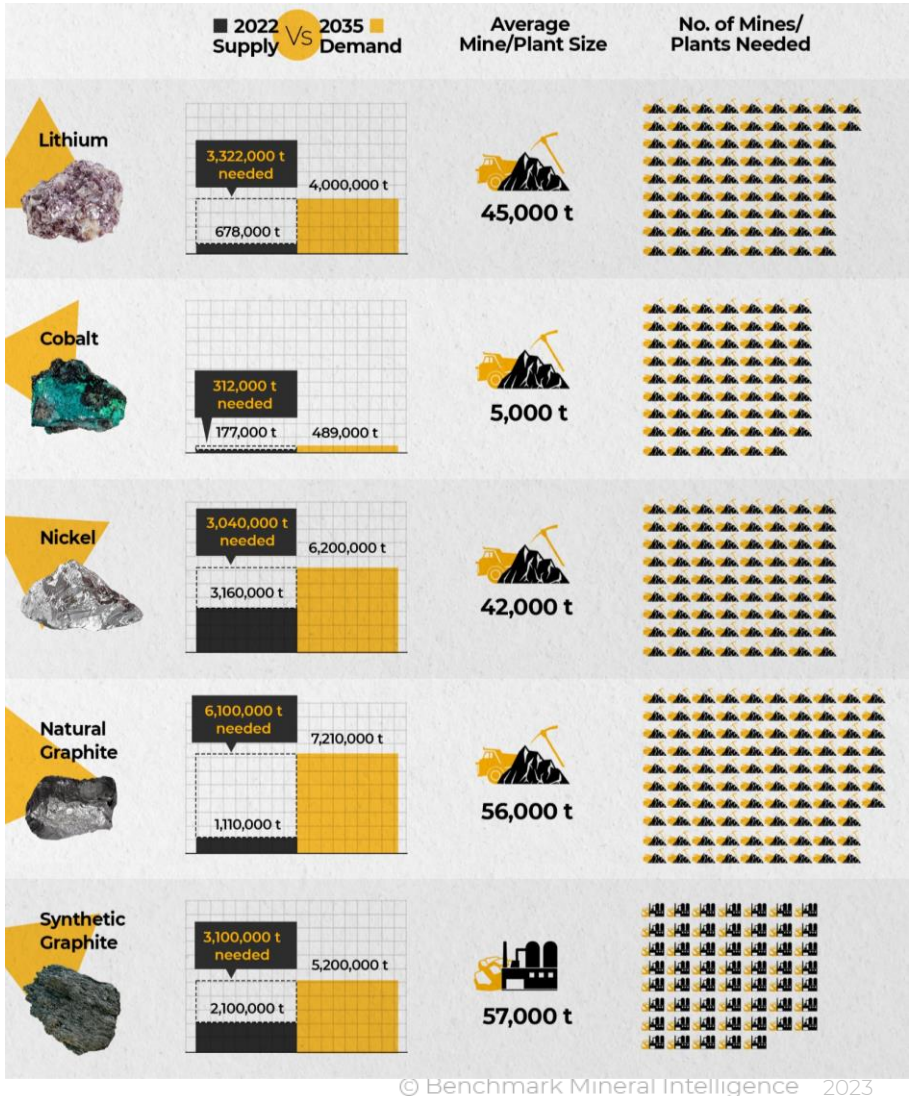
The theme of the decade will be backwards integration as OEMs move to secure supply continuity

- Growing case studies of capital allocation to secure upstream battery material units highlight the maturity of procurement teams and competition for critical minerals.
- Ford and General Motors are leading the market with active strategies, including $650m acceleration capital to support the development of Lithium Americas Thacker Pass project. The investment is associated with binding supply agreement for 100% output from phase 1 with first rights of offer on phase 2 expansion.
- The $ billion cheques needed to sustain the growth of the lithium chemical industry will not originate solely from downstream partners – coordinate capital is required from trading houses, diversified energy suppliers, private and public equity and more.
- Elevated prices limit the pace of the low-carbon transition, targeted capital alleviates supply chain pressures.



Global supply gap opportunity – To sustain accelerating battery demand growth requires 336 new mines to be developed by 2035





The USA's Inflation Reduction Act (IRA) potentially provides 'bank-able' incentives for LiB supply chain development

	Area	Demand- or Supply-related?	Tax credit	Manufacturing, Investment or consumer credit?	Comment
Input materials	Critical minerals[1]	Supply	10% of production costs	Advanced Manufacturing Production Credit (45x [s.13502])	Critical minerals require extraction or processing of the material in the USA to specific purity levels
	Battery electrode active materials	Supply	10% of production costs	Advanced Manufacturing Production Credit (45x [s.13502])	Accessed via CAM or AAM production located in the USA
Batteries	**Battery cells**	**Supply**	**$35/kWh**	**Advanced Manufacturing Production Credit (45x [s.13502])**	**Relates to cell production**
	Battery modules[2]	**Supply**	**$10[1]/kWh**	**Advanced Manufacturing Production Credit (45x, [s.13502])**	**Relates to module production**
Applications	EVs[3]	Demand	Up to $7,500 per vehicle[2]	Consumer credit ('Clean Vehicle Credit' [30d])	Credit paid to the EV buyer, but ultimately incentive value linked to raw material & cell component supply chain
	Critical minerals, Battery electrode active materials, Battery manufacturing and Energy storage[4]	Demand	6% (base credit) Up to 30% + 10%	Advanced Energy Project Credit (48c [s.13501])	Related to the capital cost involved in installing energy storage projects and LiB supply chain capacity (e.g., cell, CAM, AAM, chemical plants, etc)

Section 13502 (45X) – Batteries

1. Critical minerals require mining or refining of the material in the USA at specific purity levels; battery module needs to be made in the USA.
2. Battery module tax credit can go up to $45/kWh for cell and modules system integration;
3. EV credits include additional incentives for used clean vehicles and commercial clean vehicles, which are not directly tied to battery manufacturing in certain locations so have been removed from this table;
4. Energy storage is eligible for additional credits of 10% energy community adder and 10% or 20% environmental justice adder, under specified provisions that will be further clarified by December 31, 2022.

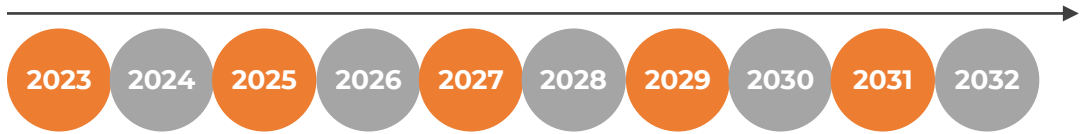
Beyond fundamental supply shortages, IRA tax credits are stimulating ex-Chinese value chains

Automakers are scrambling to evaluate and direct procurement to secure full Clean Vehicle Credits

Tax Credits: Consumer

Applications	Area	Tax credit
	EVs[3]	$3,750
		$3,750

Requirements to access EV credit (Clean vehicle credit: ~$14bn pot without sunset clause)



Critical mineral req. (from North America and FTA countries)

40% 50% 60% 70% **80%**

Battery component req. (from North America only)

50% **60%** 70% 80% 90% **100%**

Note:
1. Critical minerals require mining or refining of the material in the US at specific purity levels;
2. Battery module tax credit can go up to $45/kWh for cell and modules system integration;
3. EV credits include additional incentives for used clean vehicles and commercial clean vehicles, which are not directly tied to battery manufacturing in certain locations so have been removed from this table;
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Assessing critical minerals' supply chains in the light of the IRA's provisions

	Tendency for deficit resilience	US supply potential	FTA supply potential	US refining bottleneck	Value contribution for IRA	Primary constraint	Other Factors
Lithium						Mined-unit level	Primary LiB sector bottleneck.. Technically challenging mining and refining steps, particularly given the CAGR% growth in output required.
Nickel						Mined-unit level	Questions around engagement with Indonesia, ESG concerns
Cobalt						Mined-unit level	Questions around engagement with Indonesia/DRC, ESG concerns
Manganese						Refined-unit level	Current lack of ex-China refining capacity
Nat. Graphite						Refined-unit level	Current lack of ex-China refining capacity

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Most severe/significant

Moderate severity/significance

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Potential opportunities for India

www.benchmarkminerals.com | info@benchmarkminerals.com

HQ: London, UK

Offices: Beijing, Edinburgh, Fort Lauderdale, Melbourne, New Delhi, Porto, San Francisco, Tokyo

Potential options for India to bring utilize its critical mineral deposits offering a route into the value chain

Li

- Lithium deposits have been confirmed in Jammu & Kashmir
- Development of resource key to unlocking value and finding entry into the lithium supply chain
- Leveraging Minerals Security Partnership (MSP) for accessing foreign capital, private expertise and technological knowhow

Mn

Manganese

- Manganese deposits are found in several states, including Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh
- India is among the top 10 producers of manganese ore. Adding a processing layer on top of existing supply chain would provide avenues towards selling high vale Mn sulphate products into battery markets

C

Graphite

- Significant potential for expanding natural flake graphite production for batteries and refractory markets
- Along with doubling down on carbon manufacturing sectors – carbon black, coal tar pitch etc
- India has significant potential for needle coke production through installation of coker units in conjunction with existing oil refineries

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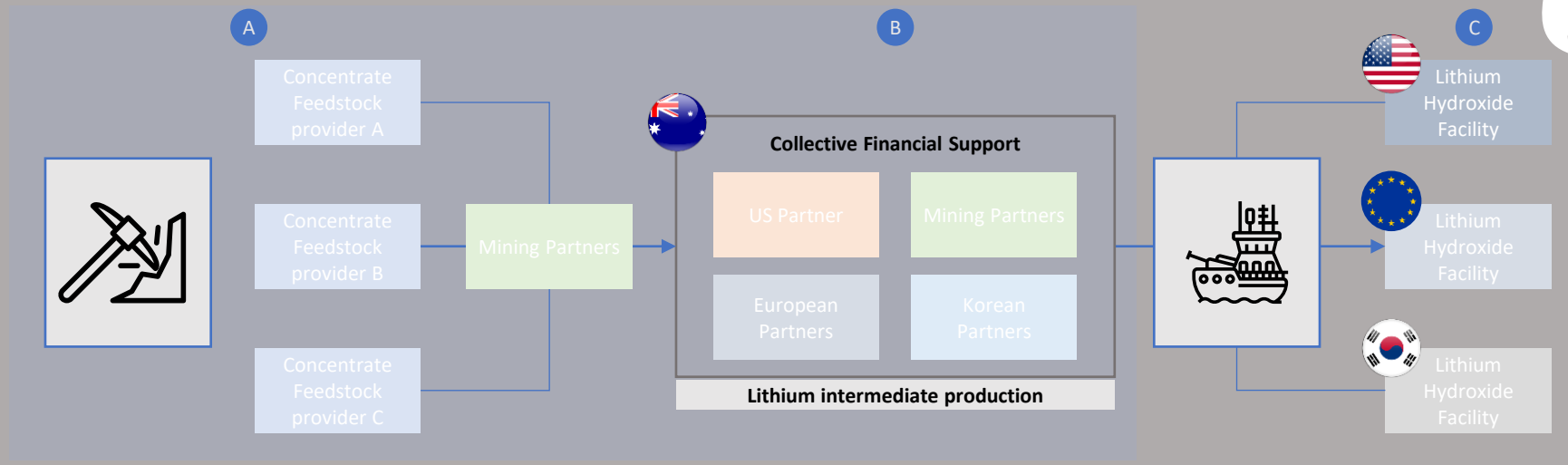
Setting up a Hub & Spoke approach – An illustration

Joining forces to set up joint facilities to produce and sell higher value products

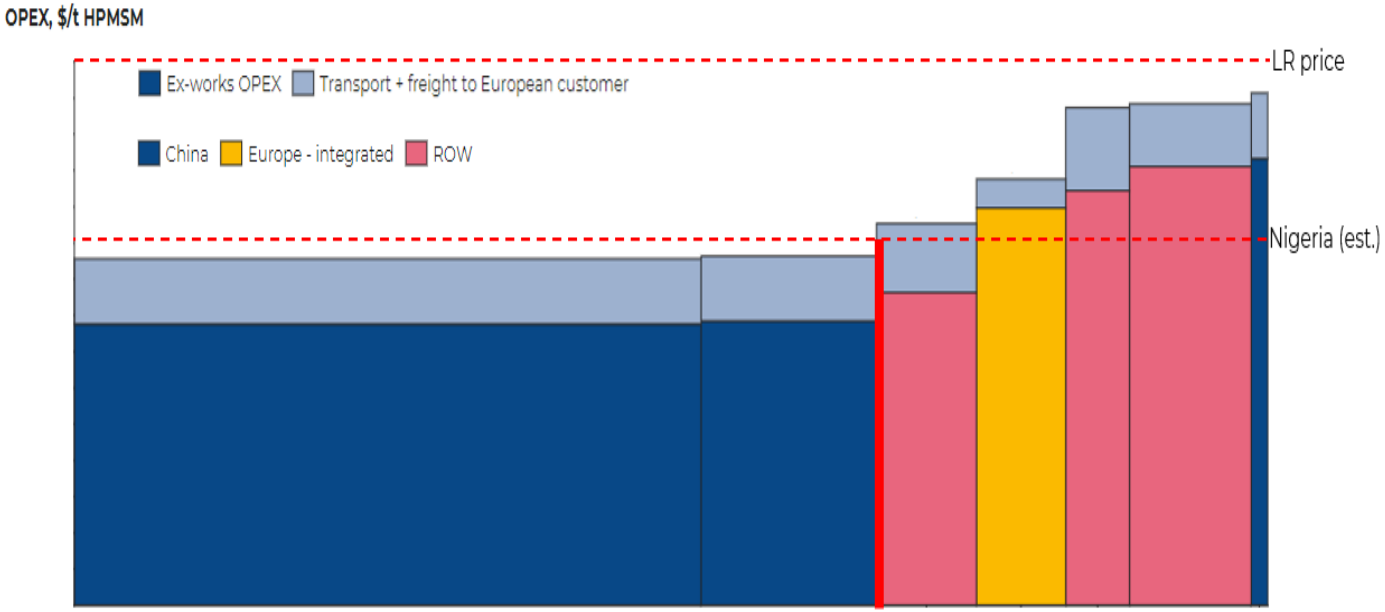


Collective Financial Support

- United loan guarantee (EU members)
- Defence production Act, section III (USA)
- Minerals security pact (USA & partner's)
- K-Sure (Korea)
- Export finance Australia (Australia)

Manganese - High-purity manganese sulphate (HPMSM) could offer value addition to existing manganese production

HPMSM Cost Curve



India currently produces manganese and has deposits in several states

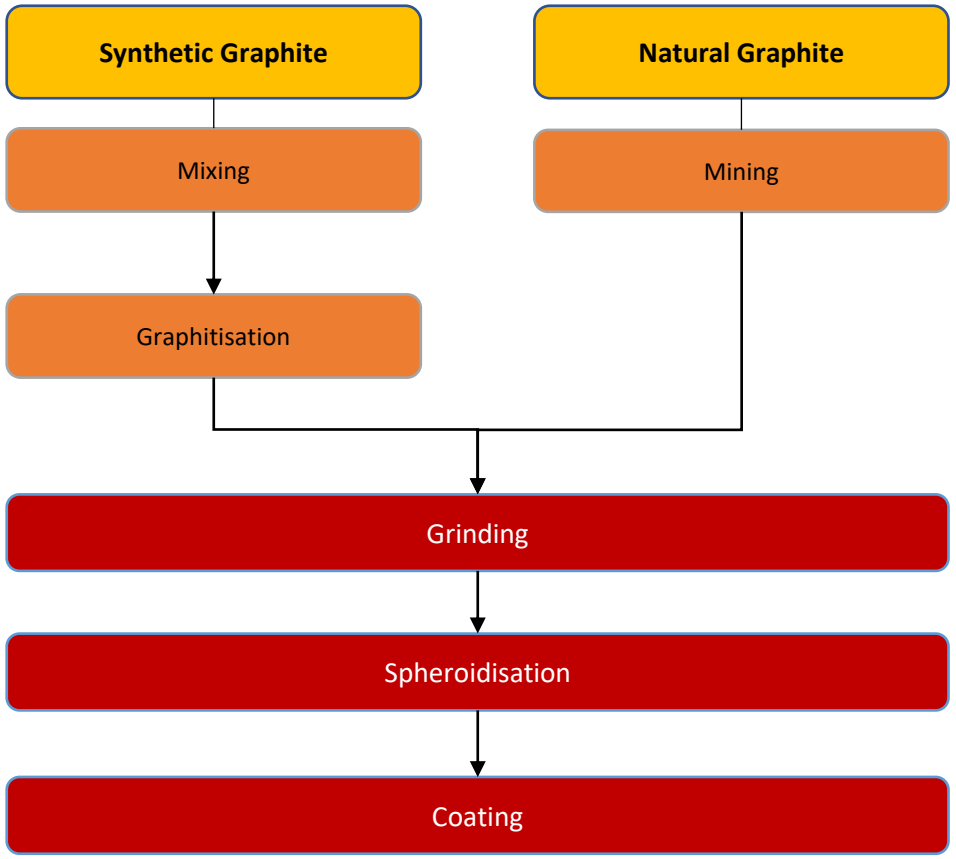
High-purity manganese sulphate monohydrate (HPMSM)

- HPMSM is a key battery material, used in the cathode to add stability to nickel-based chemistries. It is produced by treating manganese ore with sulphuric acid.
- There is potential for existing manganese production in India to be upgraded domestically to HPMSM

India could be one of the lowest-cost providers of HPMSM to Europe and US

Graphite – India could potentially produce needle petroleum coke, used in the production of synthetic graphite

Anode Production Chain



Needle petroleum coke

- Needle petroleum coke is used in the production of synthetic graphite, which is used in anodes of lithium-ion batteries.
- Needle petroleum coke is a by-product of crude oil refining. It can be produced from fluid catalytic cracking (FCC) decant oil.
- FCC units can be installed to existing refineries. However, to produce needle petroleum coke they would need to install coking plants.
- There is potential to produce needle petroleum coke from Indian oil refineries but detailed investigations would be required to assess the suitability of feedstocks and the economic feasibility of any such production.

Benchmark Consulting

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, Volkswagen AG, SQM, Albemarle, BHP Billiton, Glencore and Freeport Cobalt executives**
- Summoned to testify at the **US Senate** in 2017, 2019 & 2020), and briefed the **US White House and Pentagon** on national security implications of battery supply chain geopolitics. Presented to the **G7 Summit** on the Lithium-ion battery supply chain in 2021.
- Leading price reporting agency for battery raw materials, including cobalt sulphate, lithium hydroxide, carbonate, spodumene, flake & spherical graphite, nickel sulphate & MHP.

Where can we support?

- **Research/Consultancy –** Tailored studies to capture value across the global battery supply chain:

- **Market entry studies**
- **Lender's market reports**
- **Procurement strategy definition**
- **Investment Due Diligence**
- **Technical process risk profiling**
- **ESG education –** growing responsibilities and transparency for the supply chain

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