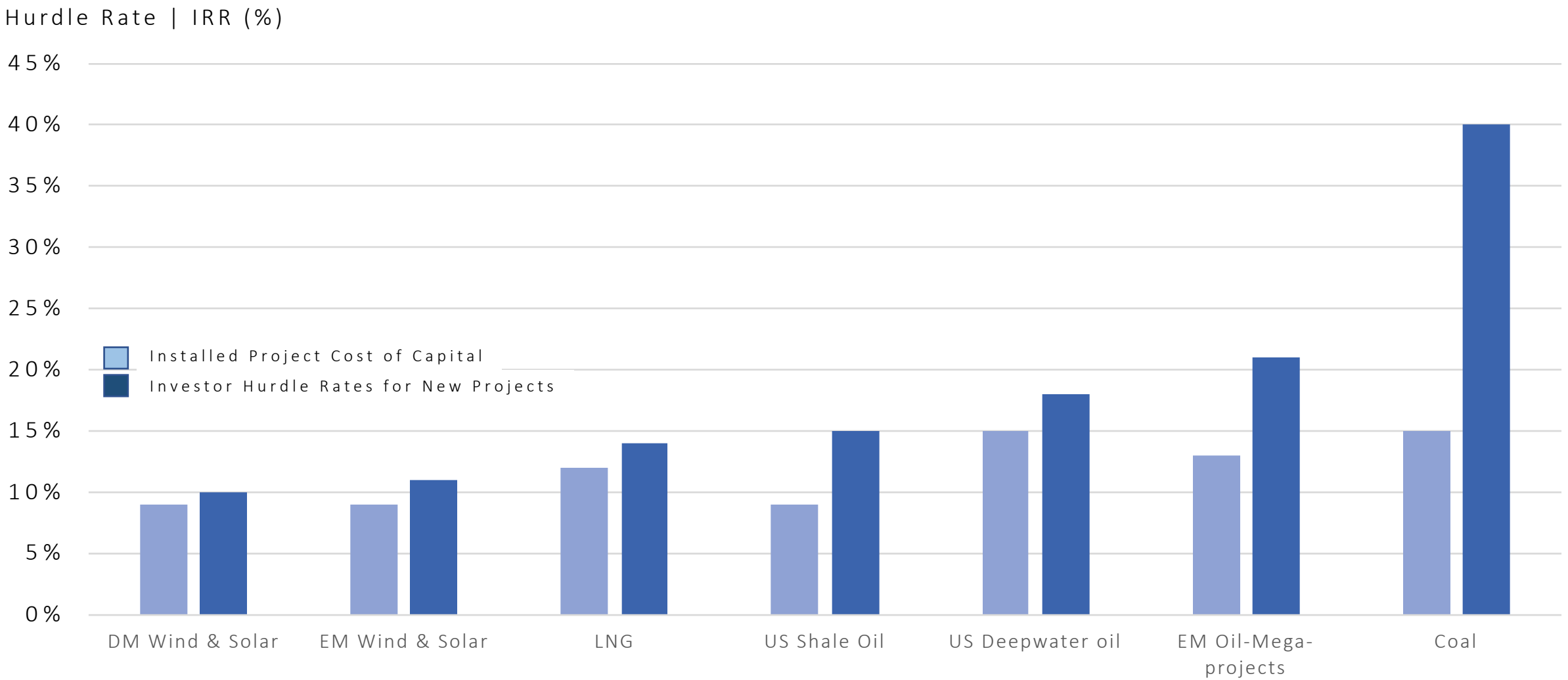
RISKS & OPPORTUNITIES IN THE BATTERY SUPPLY CHAIN

MASSIFCAPITAL

ENERGY TRANSITION

HURDLE RATES

Uncertainty in the energy transition is increasing hurdle rates.

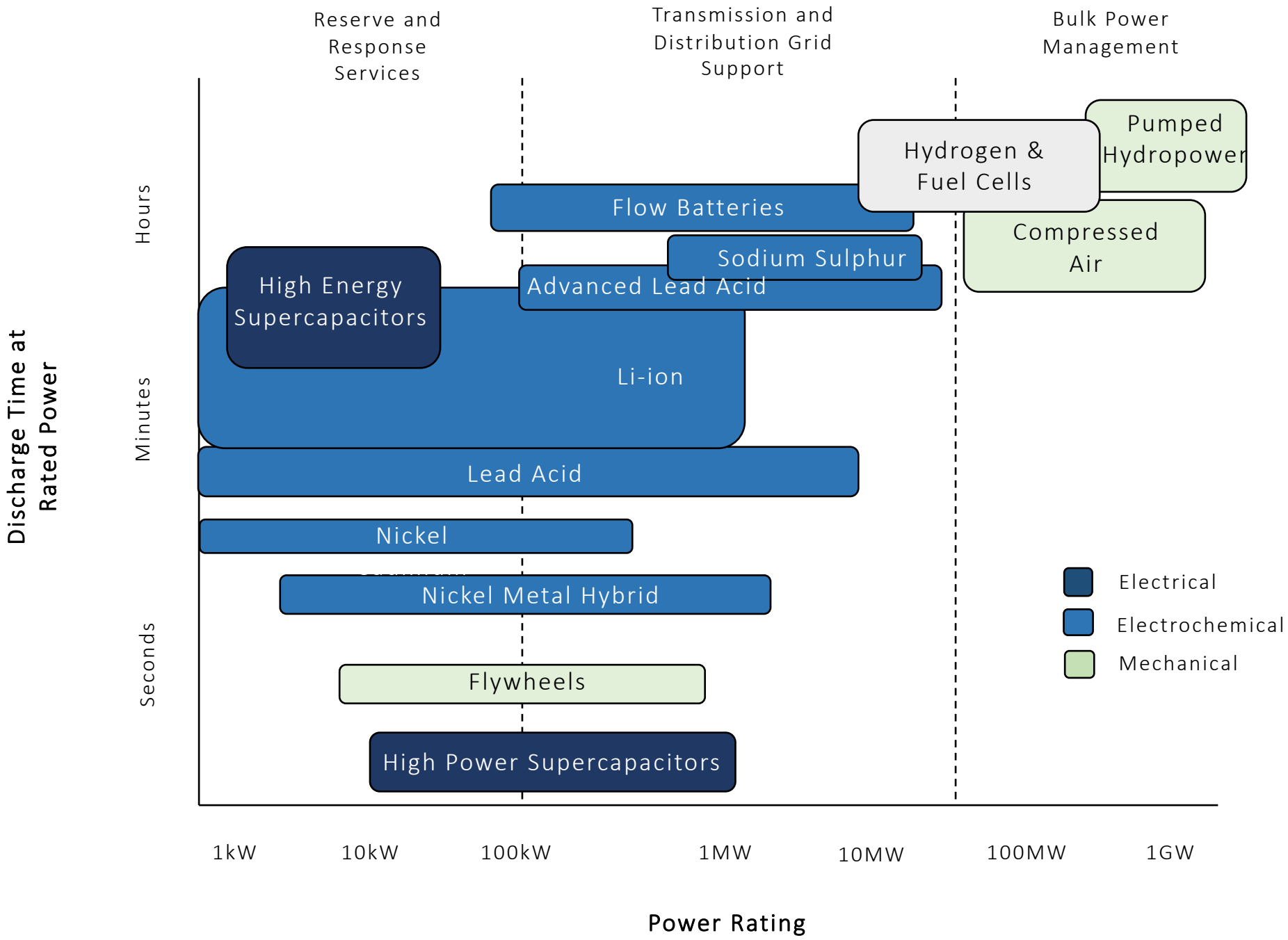


Source: "Energy Transitions, Uncertainty, and the Implications of Change in Risk Preferences of Fossil Fuel Investors" Oxford Institute for Energy Studies (OIES), 2019. Massif Capital.

Uncertainty

Increasing hurdle rates

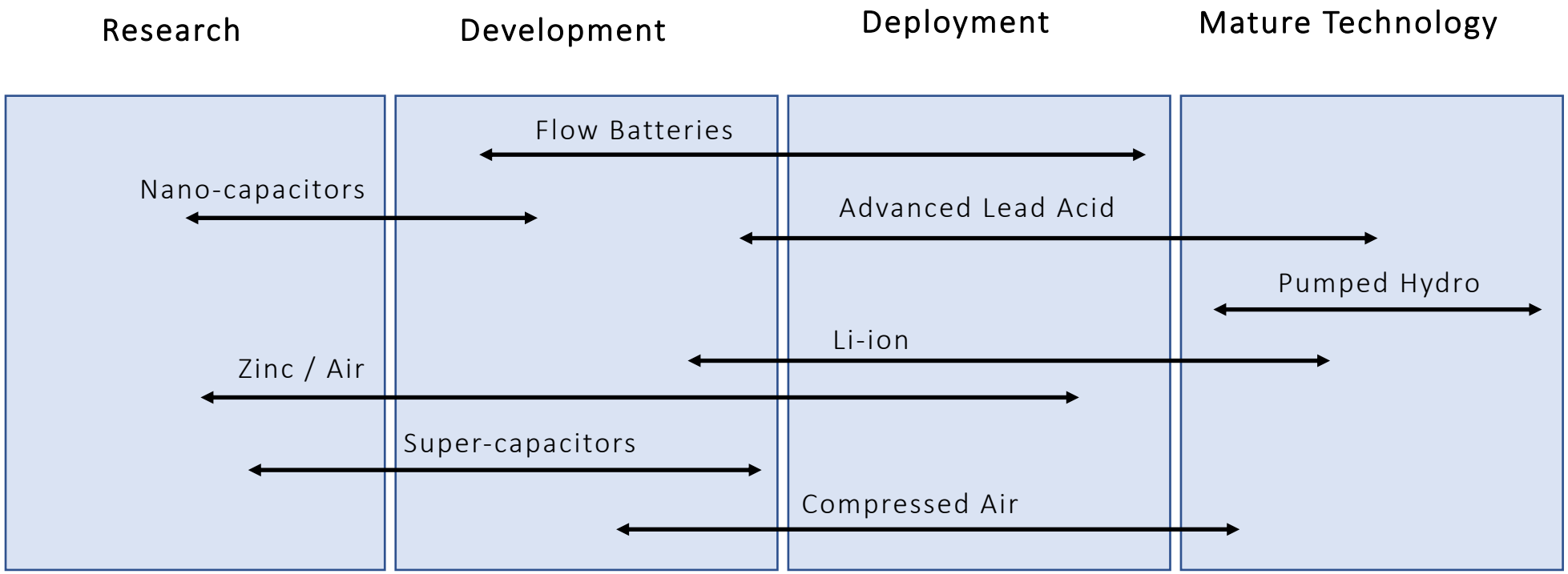
Declining investment



Source: Massif Capital, Sprake, David & Vagapov, Yuriy & Lupin, Sergey & Anuchin, Alecksey. (2017). Housing Estate Energy Storage Feasibility for a 2050 Scenario. 10.1109/ITECHA.2017.8101925.

TECHNOLOGY PIPELINE

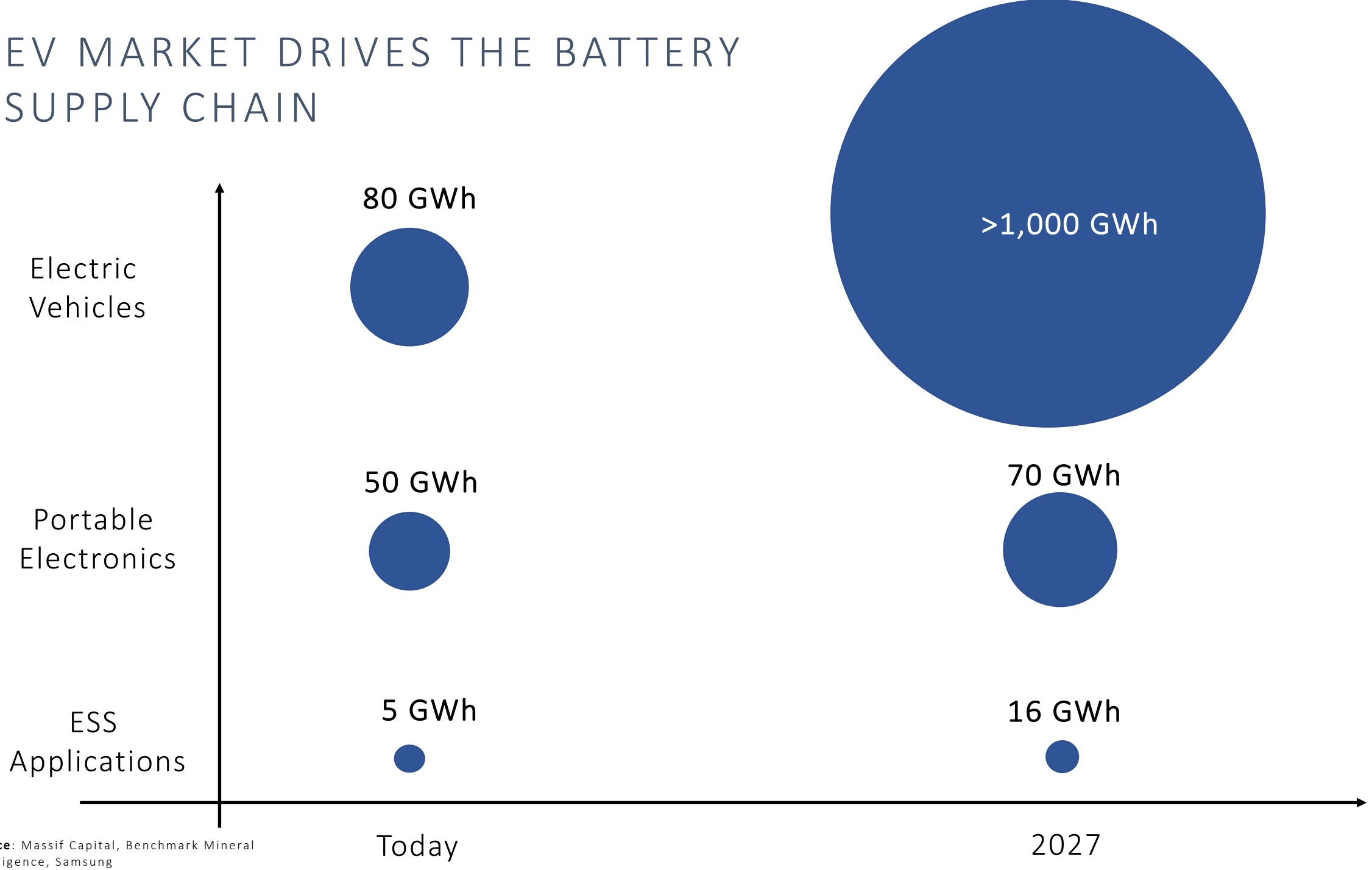
Technologies span the development pipeline with non-lithium batteries delivering important capability.



Source: Massif Capital, EPRI

In electricity markets, the biggest hurdle to get storage on the grid is **market development**

EV MARKET DRIVES THE BATTERY SUPPLY CHAIN



Source: Massif Capital, Benchmark Mineral Intelligence, Samsung

VARIANCE IN CATHODE ARCHITECTURE

Today, the cathode drives both the economic and performance characteristics of the lithium-ion battery.

Lithium cobalt oxide (LCO)	Prominent technology in the consumer electronic market. Optimizes energy density (important in small form factors) but is less competitive on total cycle life and degradation. It's high cobalt usage places greater risk on supply.
Lithium nickel manganese cobalt (NMC)	Most prominently used in the EV market today. NMC has several chemical variants, most notably NMC 532 and NMC 622. The numbers denote the ratios of nickel, manganese and cobalt. There is significant R&D work right now on transition to a 8:1:1 ratio which would require much more nickel and less cobalt. The EV battery world is on a 5-year design cycle. Through 2025, we expect 5:3:2 mix or 6:2:2 mix to remain dominate with 8:1:1 not seeing commercialization until 2026. The principal hurdle at this point is cycle life.
Lithium nickel cobalt aluminum (NCA)	First commercial chemistry to try and substitute cobalt for nickel.
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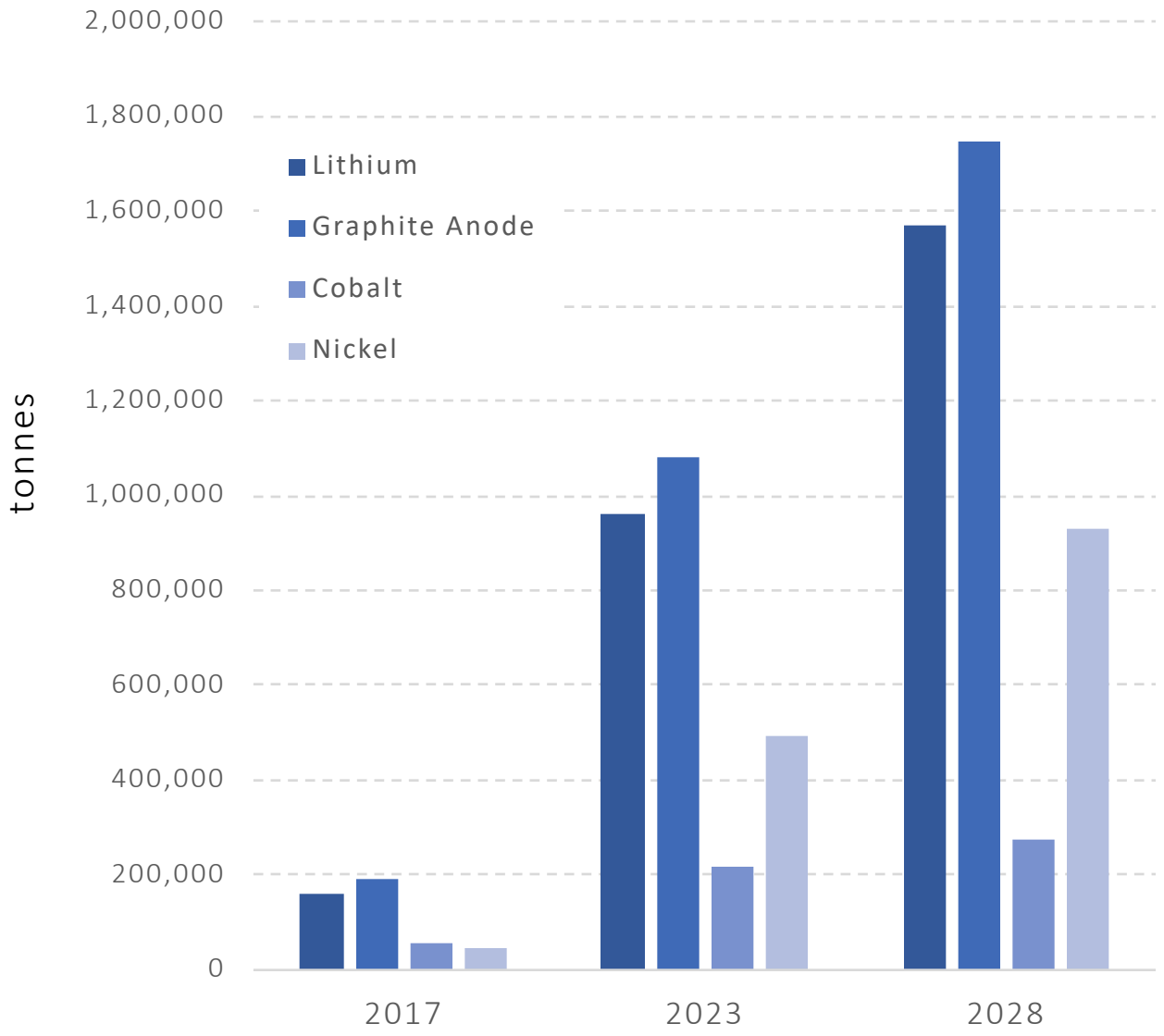
Sources: Massif Capital, LLC; Boston Consulting Group, Various OEM and Technology and Spec. Sheets, 2019

Demand growth is **underappreciated**

UNPRECEDENTED GROWTH IN SELECT METALS ON THE HORIZON



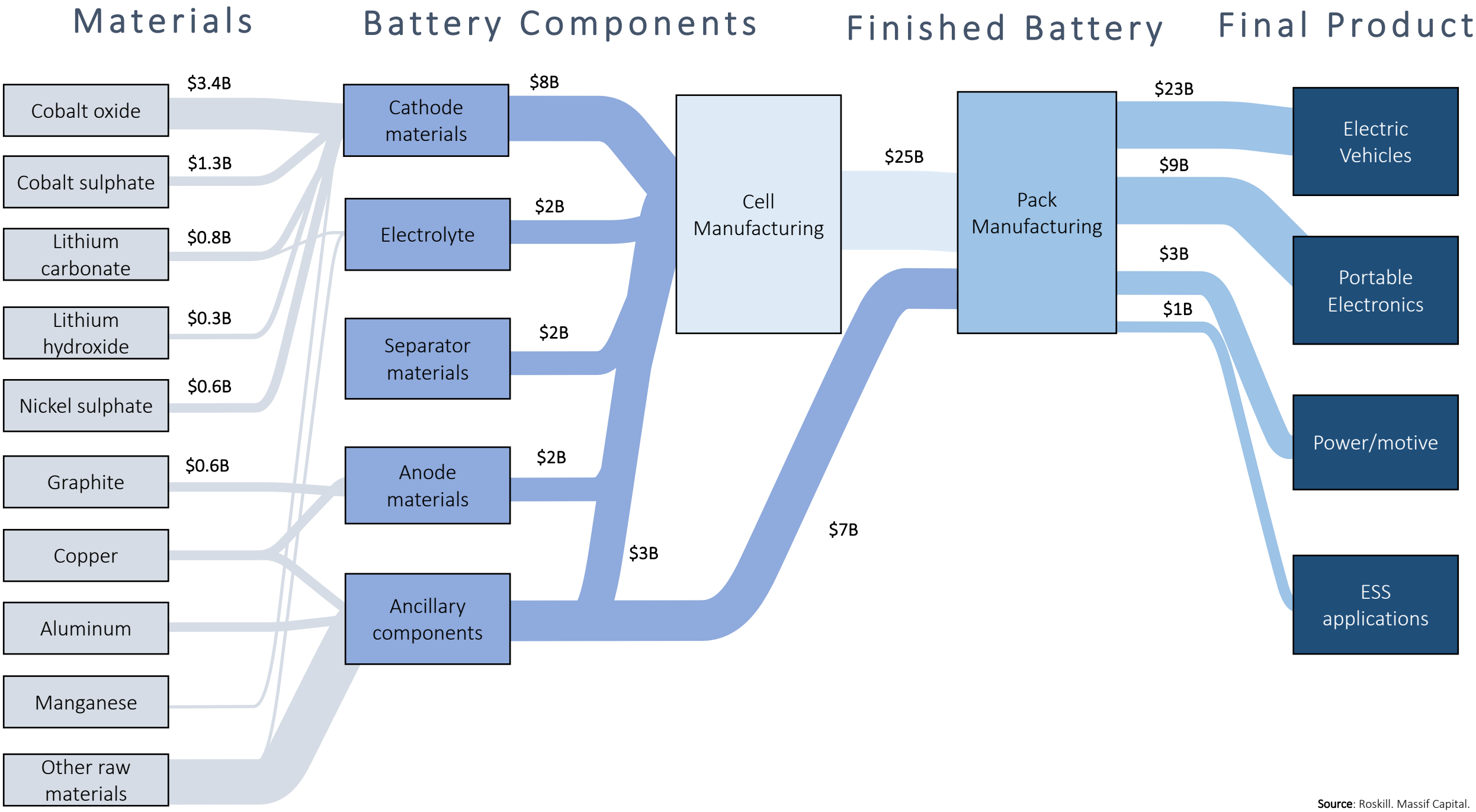
8x lithium

7x graphite

19x nickel

4x cobalt

Source: Benchmark Mineral Intelligence. Massif Capital.

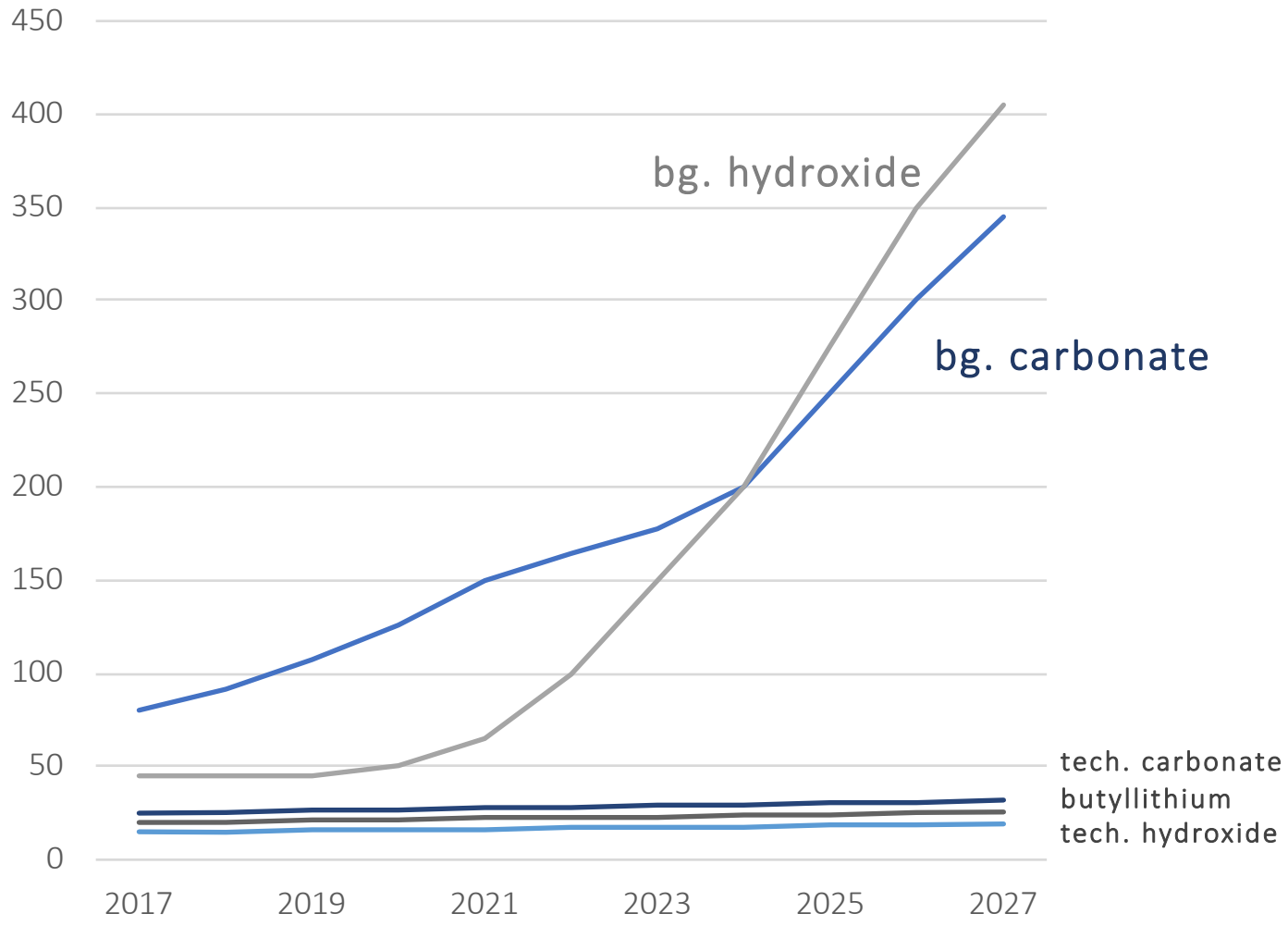


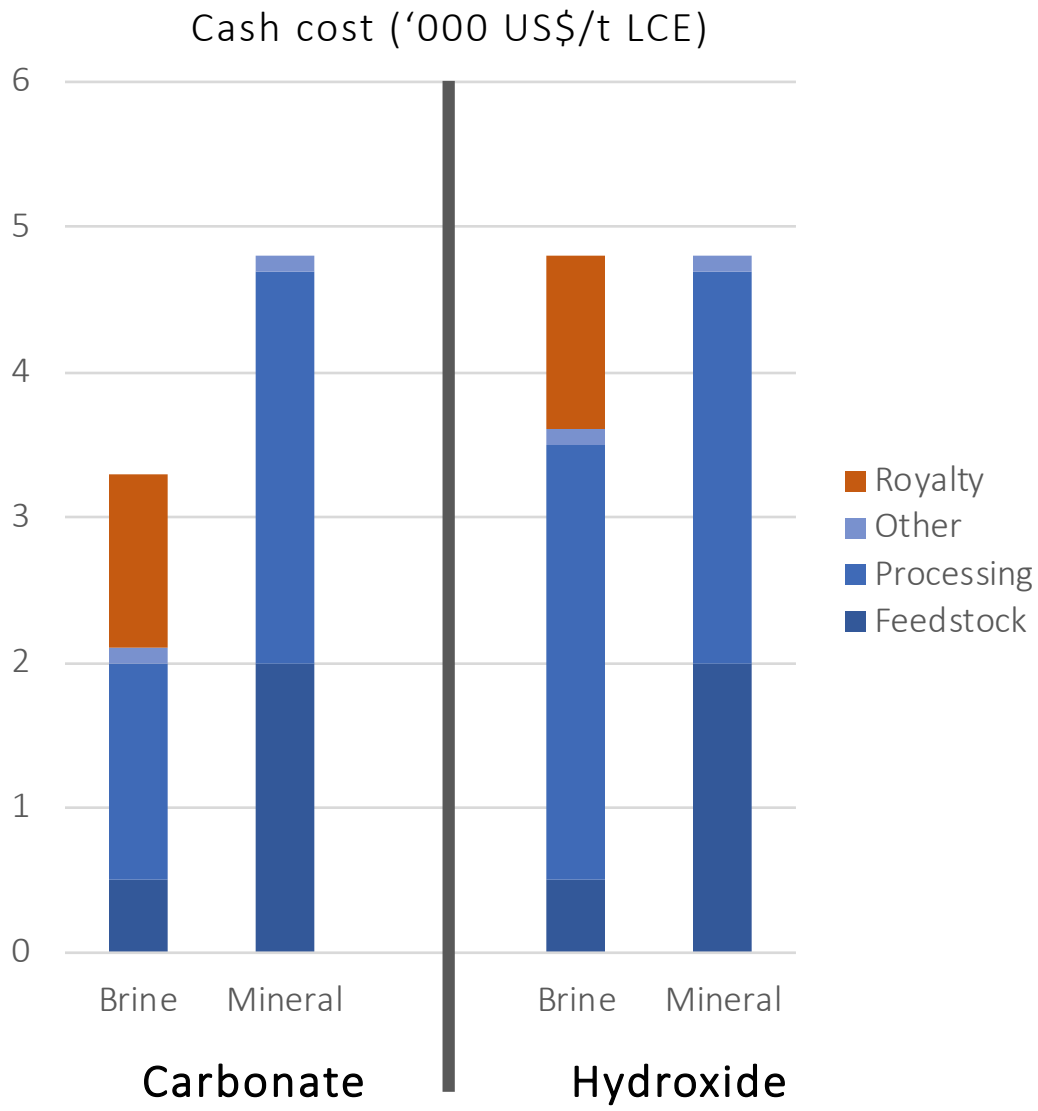
Source: Roskill. Massif Capital.

Lithium is not a mining business

HYDROXIDE VS. CARBONATE

Hydroxide demand will surpass carbonate demand by the mid 2020's, led by higher nickel loading.



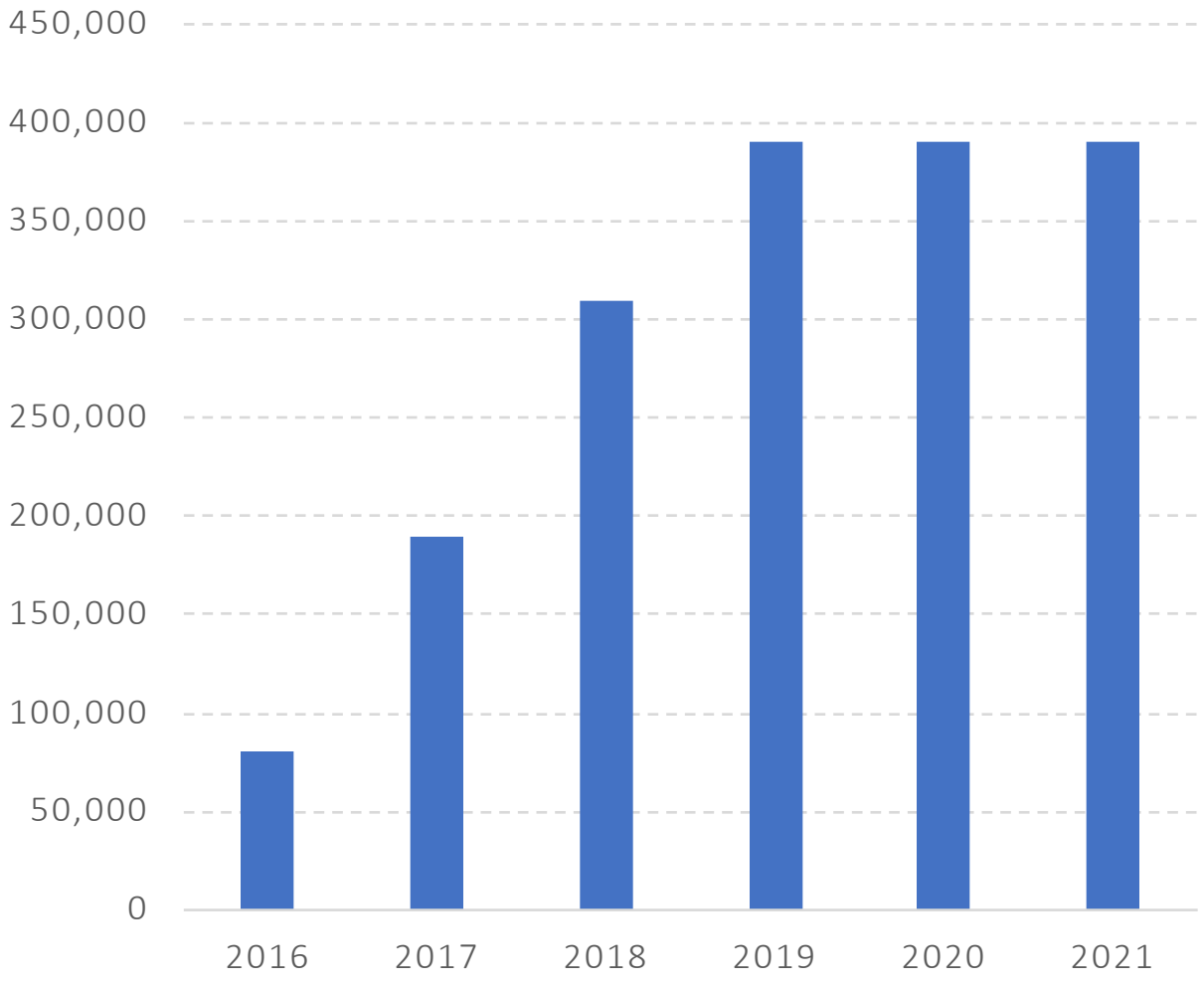


Source: Roskill. Massif Capital.

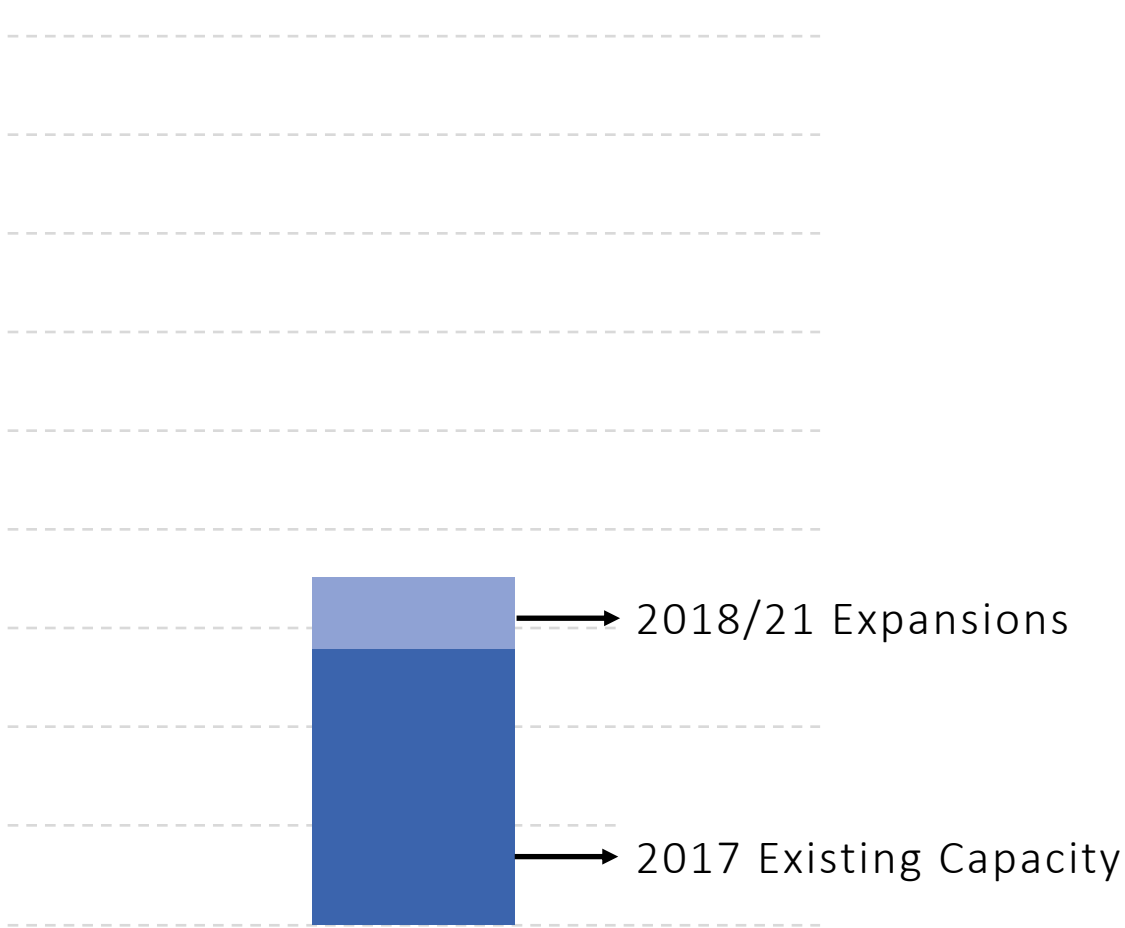
AUSTRALIAN SPODUMEME GROWTH

Conversion capacity, and vertically integrated producers, are significantly lagging spodumene production.

Tonnes of Spodumene *(Australia | Brazil)*



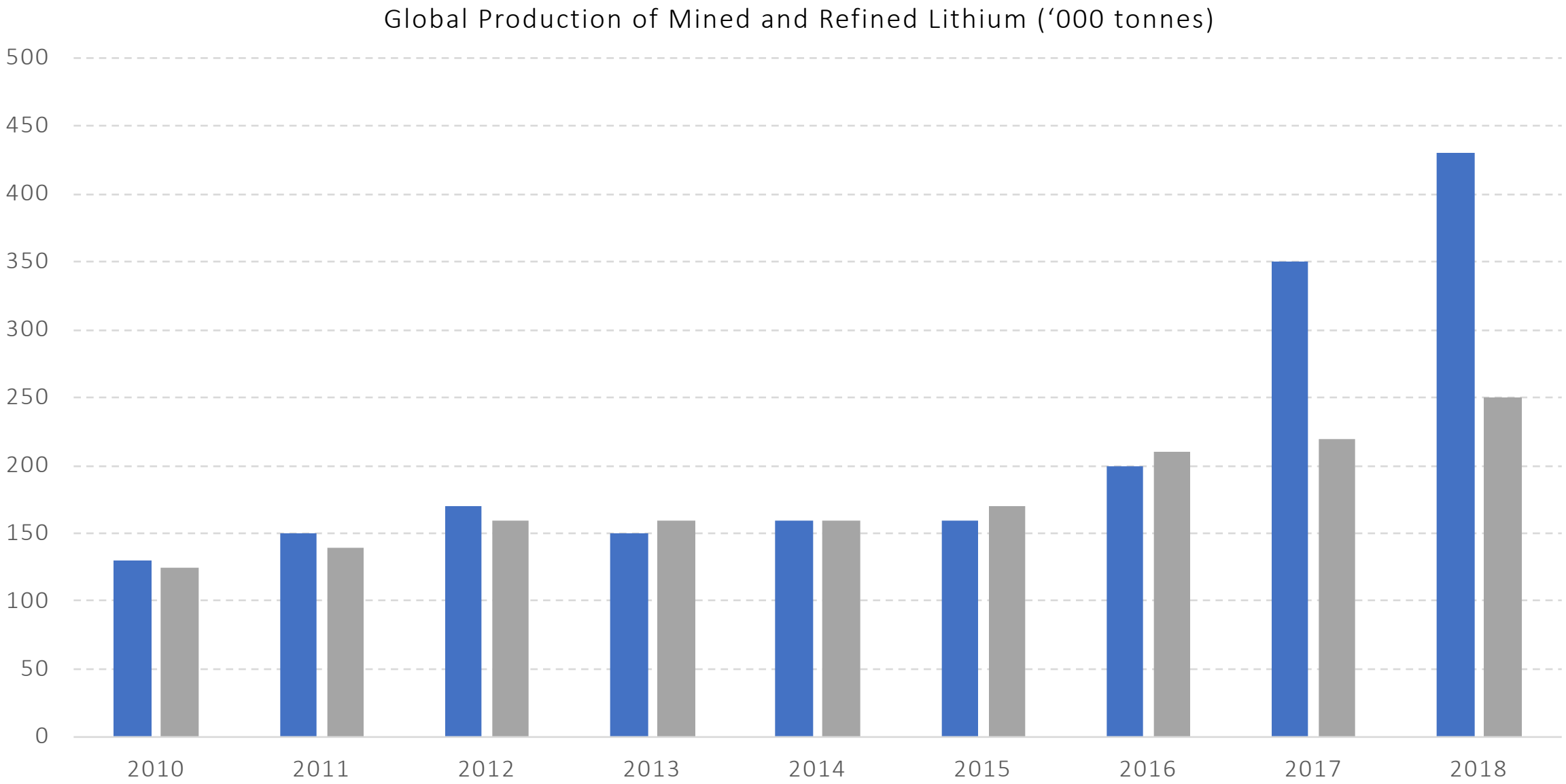
Conversion Capacity



Source: Roskill. Massif Capital.

HISTORICAL PRODUCTION

2017 saw an **outbreak** of an expanding problem: refining capacity is not keeping pace with mined production.



Source: Roskill. Massif Capital.

COMPOUNDING RISK

The EV supply chain is reliant on complex, mutually exclusive, markets.

Lithium

Scaling production takes time

Evident bottlenecks

Battery grade lithium is a new product

Cobalt

Reliant on two separate markets

Political & social risk

Class 1 Nickel

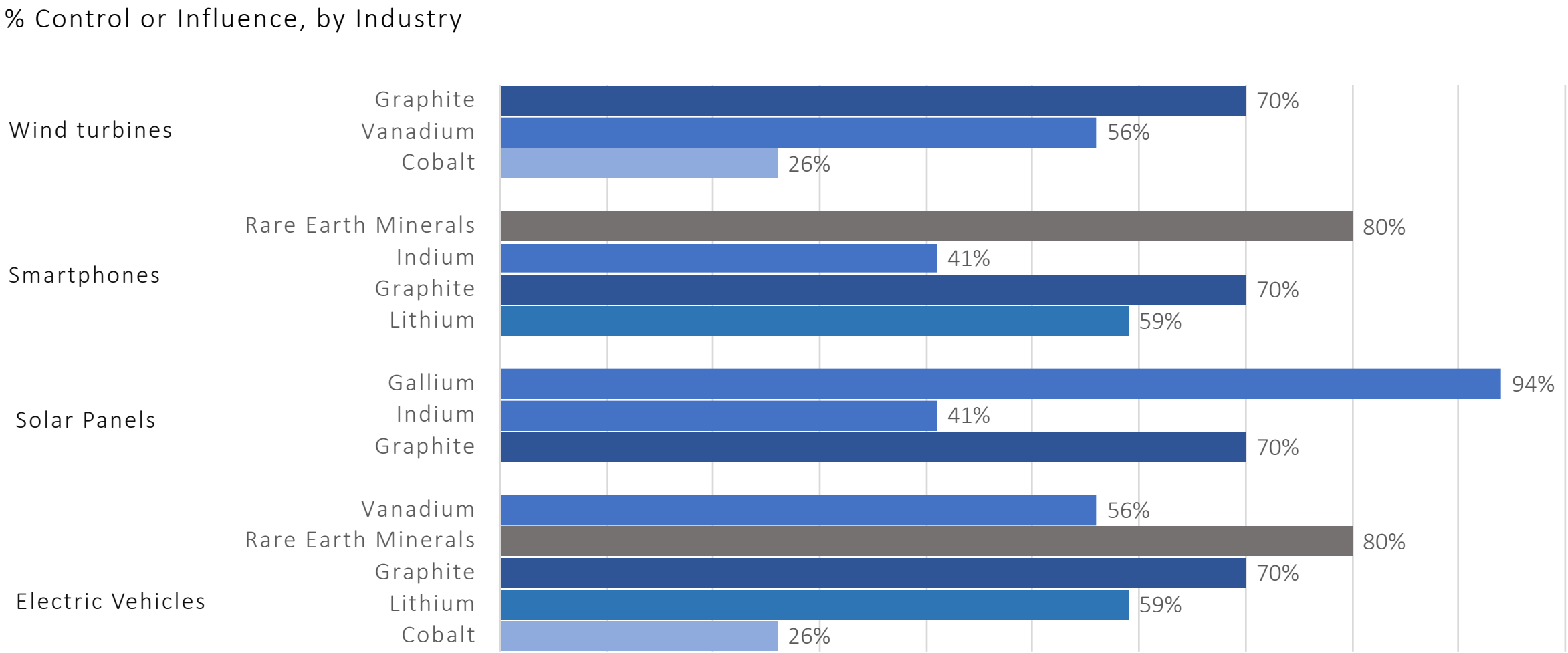
Sulfite deposits are rare

Bifurcated market?

Sources: Massif Capital, LLC; Framework inspired by RSC Global. "The Battery Revolution: Balancing Progress with Supply Chain Risks"

CHINA IS IN CONTROL

The Chinese have a dominant share of critical metals.

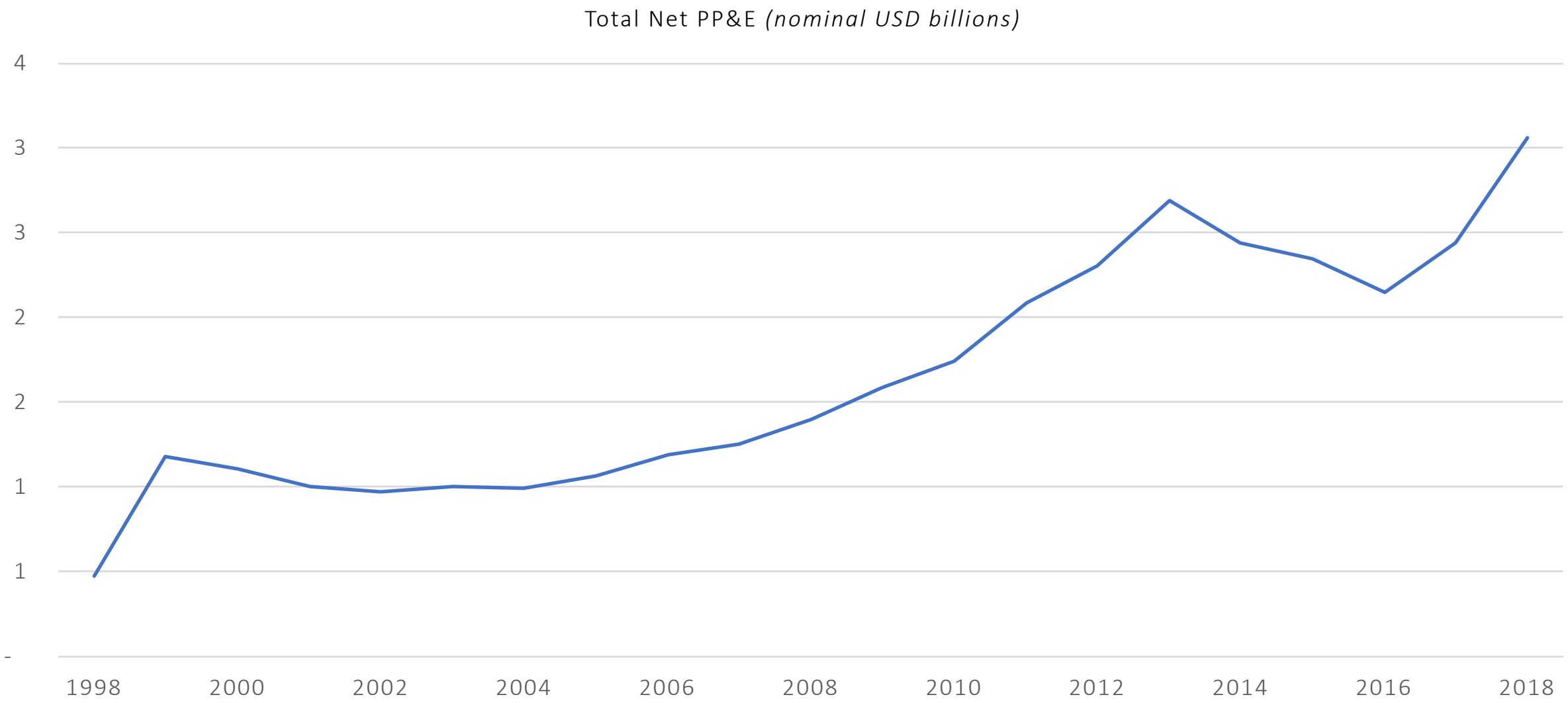


Source: Massif Capital, LLC, "Mining the Future" Foreign Policy, May 2019

OPPORTUNITY

COMPANIES ARE RESPONDING

If the top 5 lithium producers look to hold market share, their asset base is set for exponential growth.



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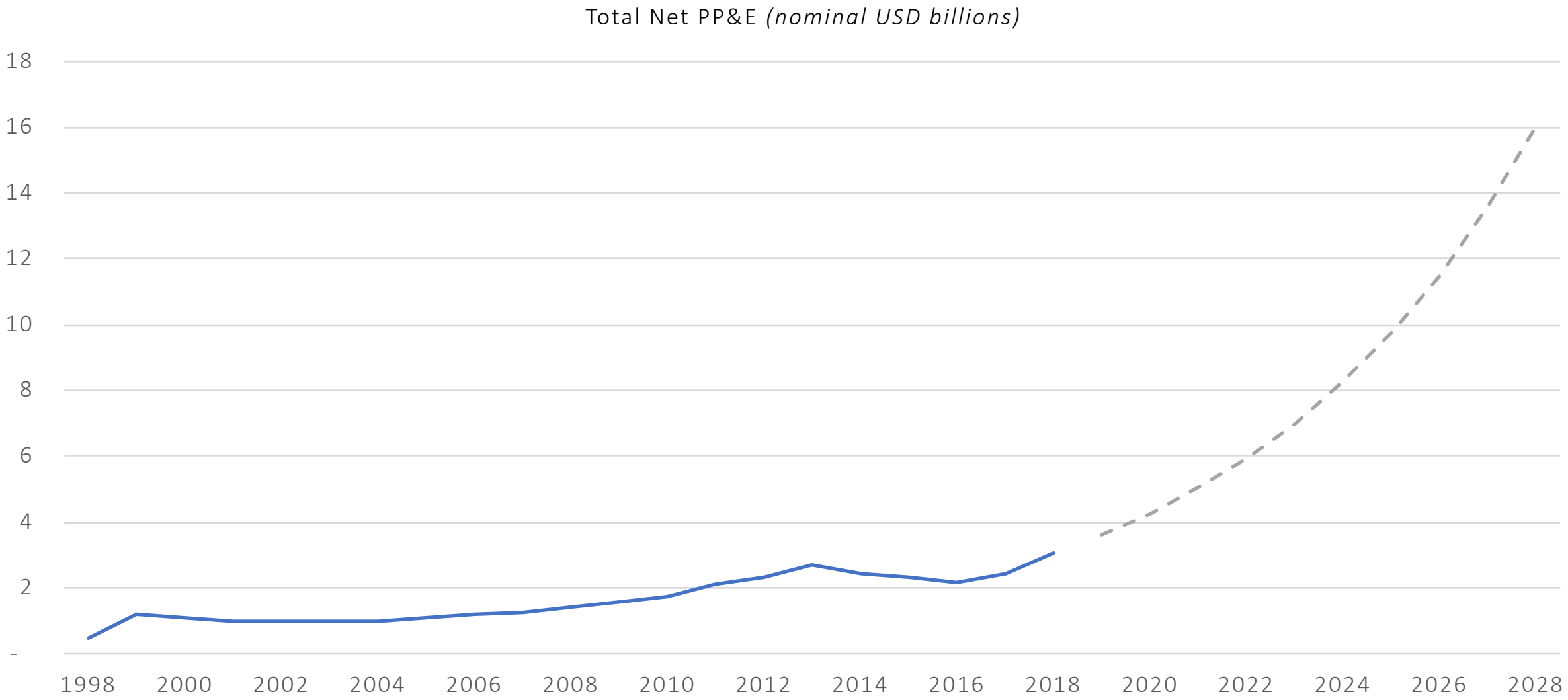
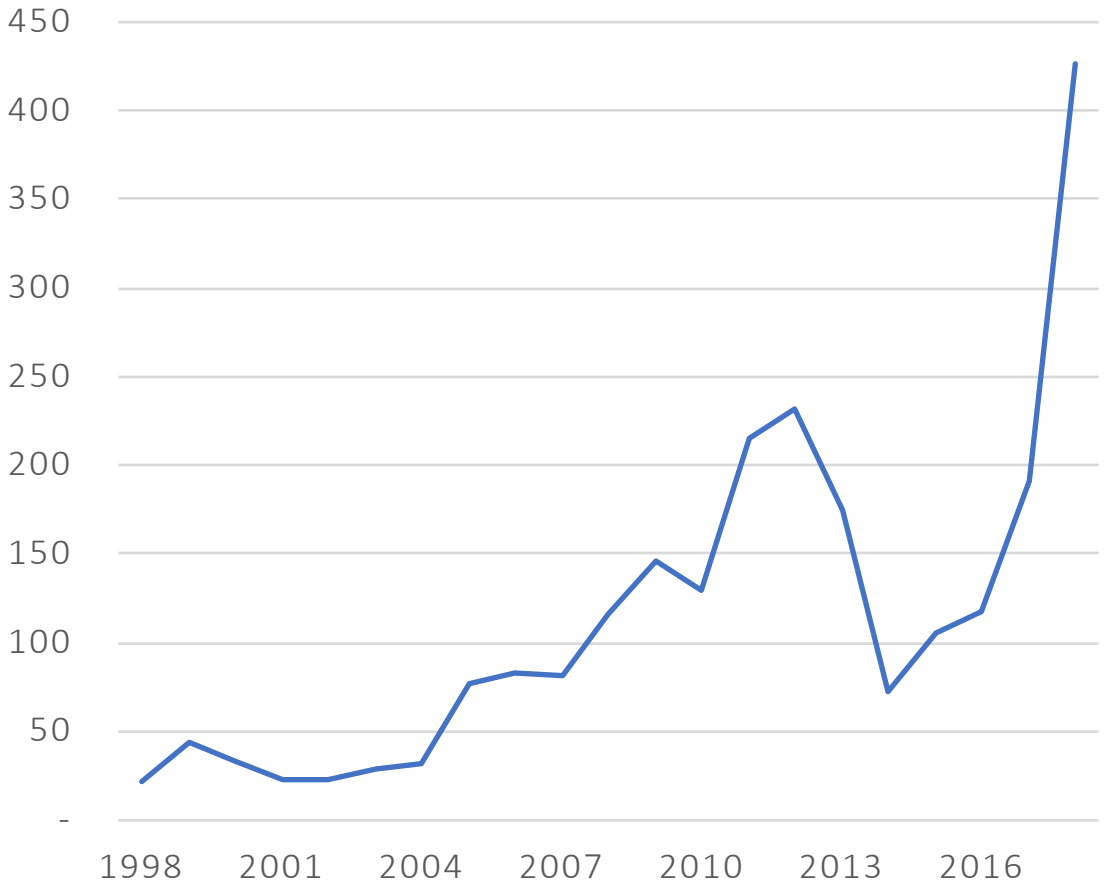


Source: Massif Capital.

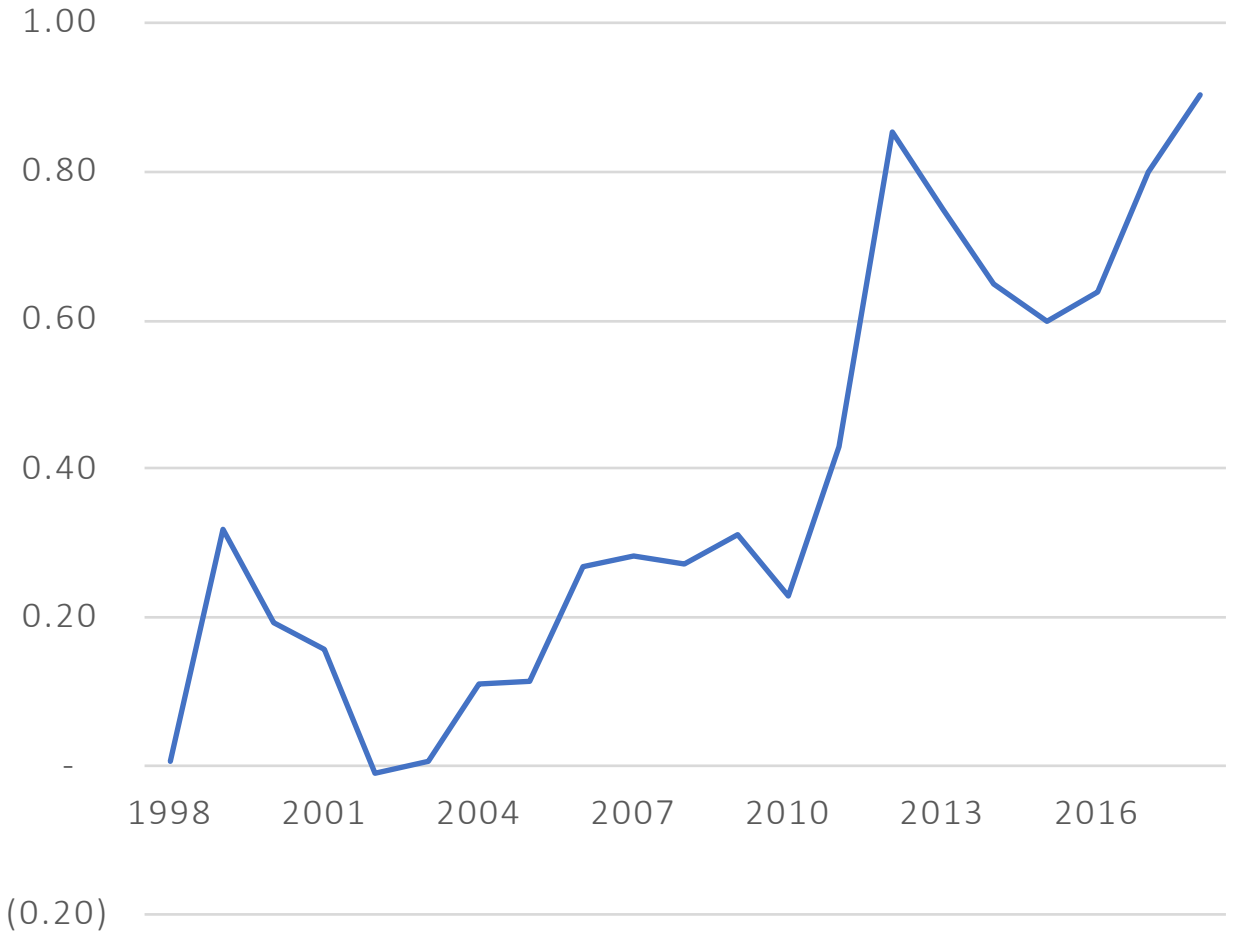
COMPANIES ARE RESPONDING

Paired with an evident rise in CAPEX, many producers are at a compelling investment point in their capital cycle.

CAPEX Weighted Average, by Market Cap
(nominal USD millions)



CAPEX Adjusted for D&A
Weighted Average, by Market Cap
(nominal USD millions)

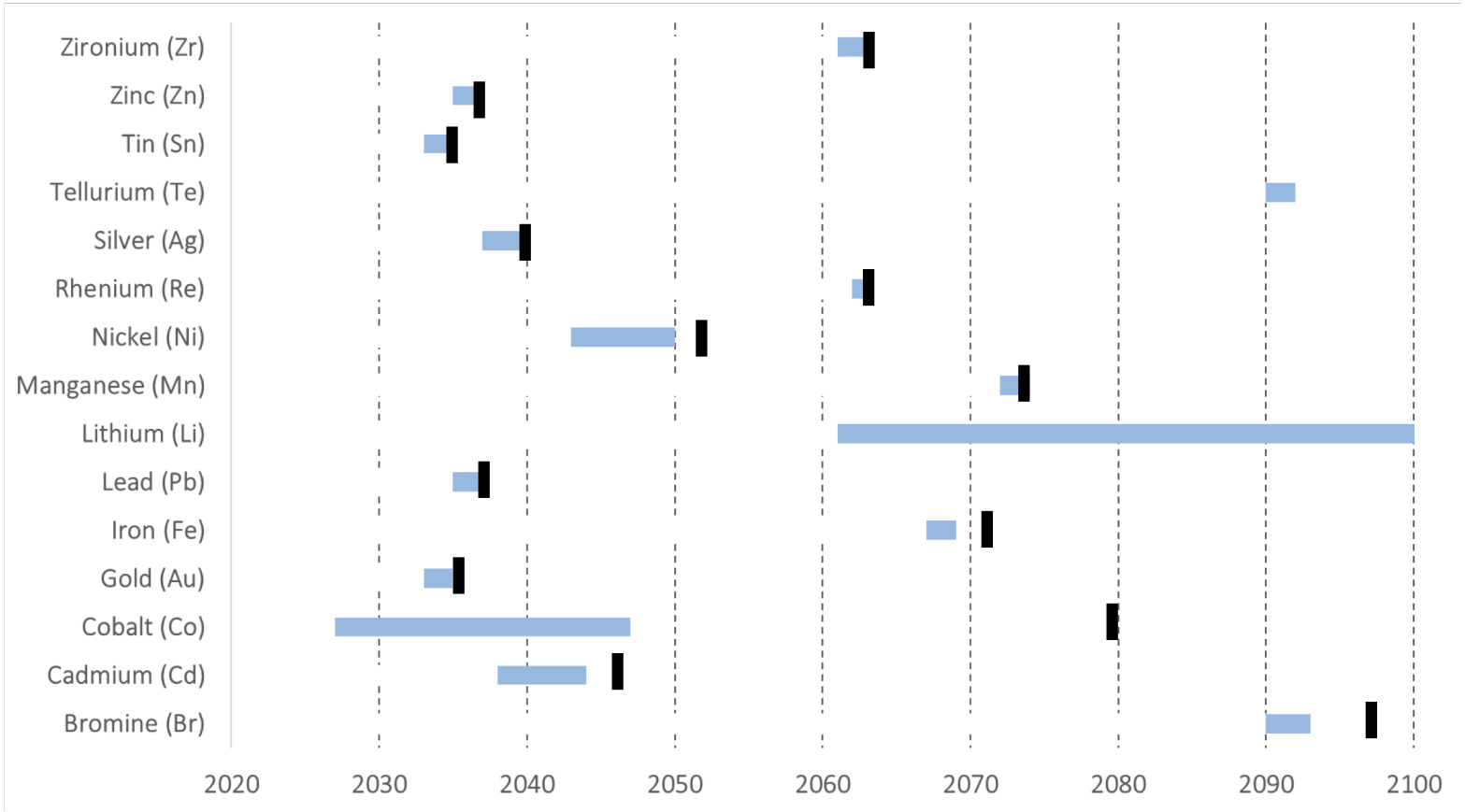


Source: Massif Capital.

Appendix

Depletion Horizons Based on Reserves

Demand from the energy sector ranging across energy scenarios (blue) and demand without the energy sector (**black**)



Sources: Massif Capital, LLC; "Enough Metals? Resource Constraints to Supply a Fully Renewable Energy System" Resources Journal, January 2019

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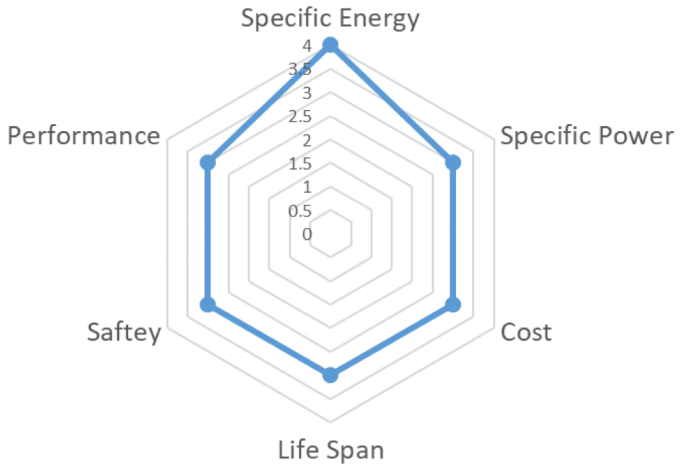
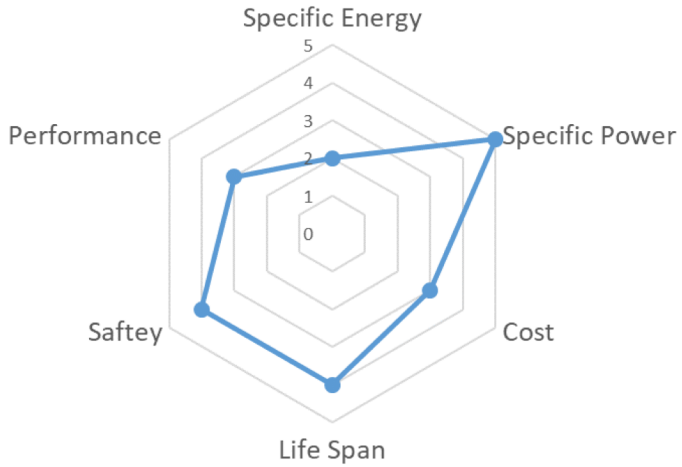
NMC	LFP
(Excels at specific energy)	*(Excellent safety but moderate specific energy)*





Sources: Massif Capital, LLC; Boston Consulting Group, Various OEM and Technology and Spec Sheets, 2019

2018 NMC 622 Cathode

Cobalt Price (USD/lb)

LCE price (USD/t)	15	25	40
5,000	-6% / 196	-2% / 205	2% / 213
10,000	-3% / 201	- / 208	5% / 216
14,600	-1% / 206	2% / 213	7% / 223

2018 NMC 811 Cathode

Cobalt Price (USD/lb)

LCE price (USD/t)	15	25	40
5,000	-4% / 121	-2% / 123	0% / 126
10,000	-2% / 124	- / 126	5% / 129
14,600	1% / 127	2% / 129	7% / 132

% change to base

USD to base

Sources: Massif Capital, LLC; "Lithium and cobalt – a tale of two commodities", Metals and Mining, McKinsey & Company, June 2018

The picture above is a matrix of the change in battery pack cost (USD/kWh), relative to a change in either the Cobalt Price (x axis) or the LCE price (y axis). In the NMC 622 cathode structure, the middle cell in the matrix suggests that at a $25 per lb cobalt price and a $10,000 per ton LCE price, a battery pack is roughly $208 per kWh of energy capacity. Each cell returns two values, a % change from the base (top left) and the total USD/kWh (bottom right). You will notice that a NMC 811 cathode structure, at the same price of the raw material, costs almost half of the NMC 622 at just $126 per kWh.

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