LME Focus Day: Battery Materials Session

Barry Corbett, Head of Buy-Side Sales, LME

London, 27 October 2022

LME
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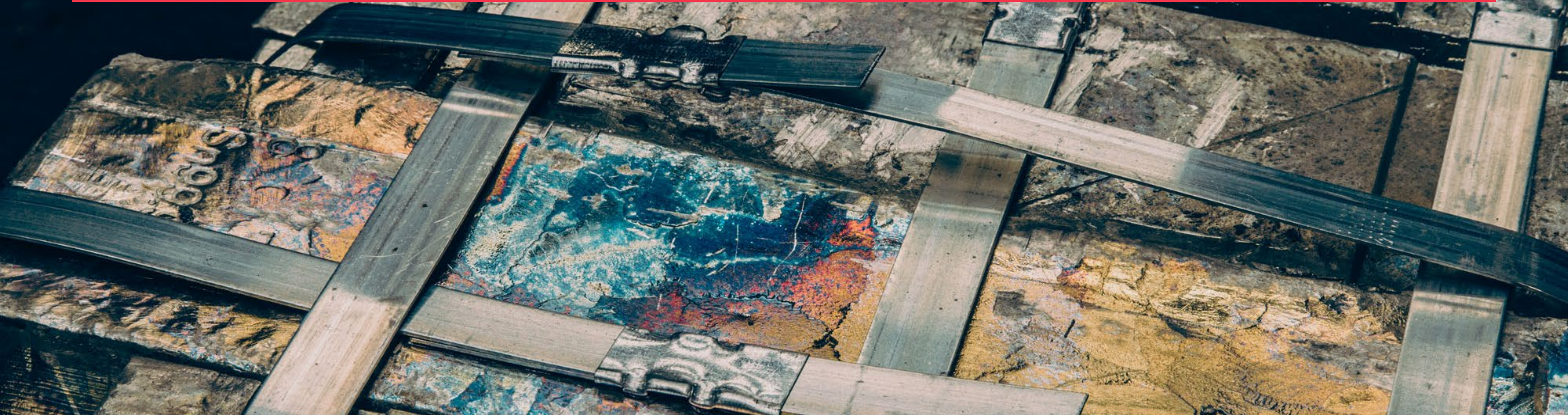
SETTING THE GLOBAL STANDARD



Battery metals

Moderator:

Barry Corbett, Head of Buy-Side Sales, *LME*

Panellists:

- Ken Hoffman, Expert for McKinsey's Basic Material Institute, *McKinsey*
- Simon Price, CEO, *Exawatt*

Winning the EV battery raw material race

Yes, we have enough raw materials to secure an electric future

Ken Hoffman, CFA

The Battery Show

September 2022

What do consumers want in an EV?

Range, range, range…

Recharge times

Price

THERE IS NO SUCH THING AS LONG-TERM MATERIAL DEFICITS!

Supply and Demand meet at price, its that simple

Executive summary

Short answer, yes, we will have enough metals for EV's

Despite the seemingly constant drumbeat of doubters, the EV industry has a host of options when it comes to battery chemistries either already developed or will soon be commercialized.

It will take many years for the EV industry to completely dominate markets, but the path to full electrification is unstoppable with batteries that will exceed performance of ICE competitors.

Choice and changes to density and materials

Battery densities, cycle lives, and performance in a variety of settings will ensure continued increase in customer satisfaction.

Densities will increase with the adoption of new anode materials, such as silicon and lithium metal, and cathode materials including addition manganese.

OEM's need to follow the "waves"

OEM's need to ride the waves of innovation to provide products that meet the needs of consumers, at the right value point.

Changes in technology mean that OEM's have the risk of locking into an "old technology" only to be surpassed by newer technology. The risk of material shortages does exist, but a careful OEM alignment of technology and procurement should limit risks.

What if we went 100% EV today?

AUTOS

Stellantis CEO warns of electric vehicle battery shortage, followed by lack of raw materials

PUBLISHED TUE, MAY 24 2022·4:52 PM EDT | UPDATED TUE, MAY 24 2022·5:58 PM EDT

TIME 2030

← BACK TO HOME

Lithium Is Key to the Electric Vehicle Transition. It's Also in Short Supply

A looming graphite shortage could snarl the EV battery supply chain

Lithium constraints have dominated headlines, but experts say a lack of graphite could soon create supply headaches for automakers.

Published July 28, 2022

Business | Cell-side analysis

Could the EV boom run out of juice before it really gets going?

Quite possibly, for want of batteries

AUTOS

EV battery costs could spike 22% by 2026 as raw material shortages drag on

PUBLISHED WED, MAY 18 2022·9:18 AM EDT | UPDATED WED, MAY 18 2022·10:18 AM EDT

Electric vehicles and the nickel supply conundrum: Opportunities and challenges ahead

It is near impossible to impose today's battery chemistry on tomorrow's needs

Chemistries will change in density and composition-- a 50% increase in density could reduce nickel usage by as much as 45 kg in a 100 kWh pack.

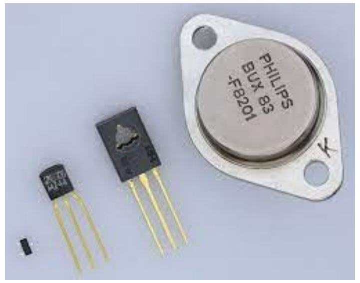
The timeline to 100% adoption is uncertain– It may take 15-20 years for full EV adoption, if ever.

New metal production technologies could vastly alter supplies– New material extraction techniques promise to vastly reduce costs, processing time, ESG footprint, and time to market

Recycling will become ever more reliable and a larger part of the metals stream post 2030

Waves of change have highlighted the move from vacuum tubes to semi conductors

Being ready for change is essential



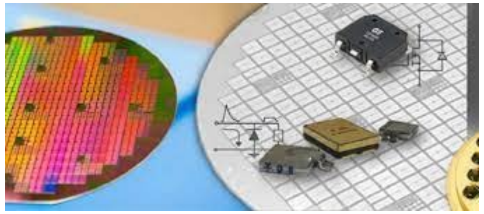
1950's-1970's

1970's-present

Silicon Valley is born

Japanese companies take the lead

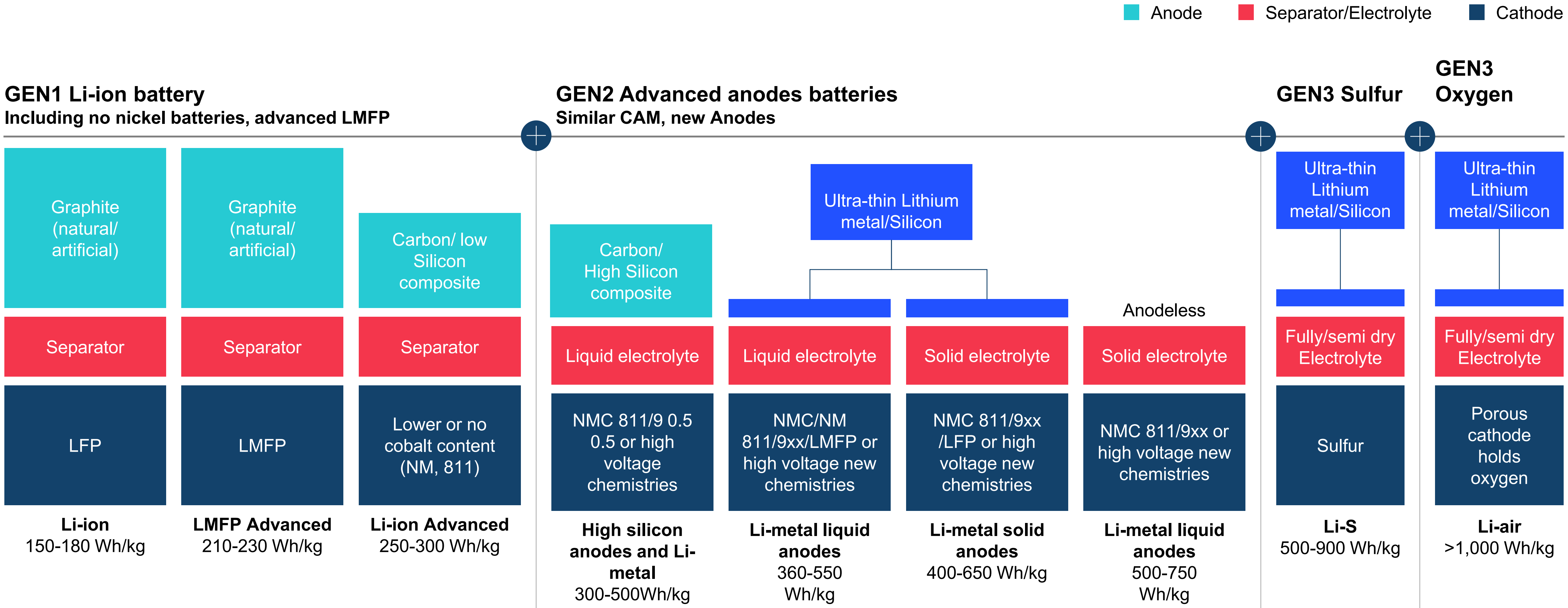
1914-1950's



Western Electric leads US names

We see battery chemistry evolving continuously and not in a straight line

- Understand cathode AND anode material qualities and implications



Note that some of these chemistries may be surpassed by innovations, ie semi-solid state

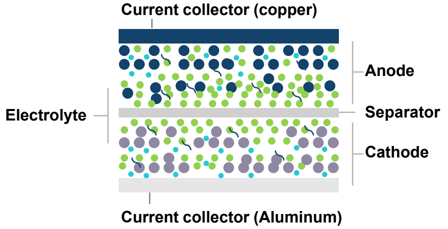
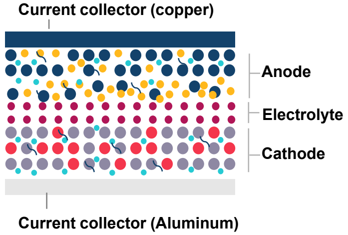
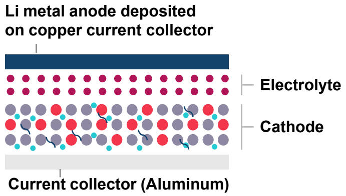
1. Very early stage reflexion
2. Based on 7-year contracts in average, last known supply order signed with Volkswagen in March 2021

Source: Team analysis, Bernstein

Innovations in battery chemistry fall into three categories

- Competitors fall into three innovation categories with varying energy density potential

Composite (e.g., graphite / silicon) · Catholyte · Conductive carbon · Anolyte
Solid electrolyte · Liquid electrolyte · Active material (CAM) - NMC · Binder

Innovation category	Diagram	Core innovations	Practical energy density limit	Examples
Improvements to Li-ion		Incremental energy density improvements to cathode & anode, cell design, heat dissipation techniques etc.	300-400Wh/kg	24m, microvast, Tesla, Panasonic, FREYR Clean battery solutions
Novel ways of incorporating high silicon in anode		High (>10%) silicon loading in the anode, enabled through novel solutions to current swelling & conductivity challenges	350-450Wh/kg	SILA, ENOVIX, nexeon, amprius, Group14 Engineering, ADVANO, NANOGRAF Technologies, ENEVATE
Shift to lithium metal anode		Use of Lithium metal as anode material to significantly increase potential energy density; includes solid state and semi-solid state cells	500-600Wh/kg	SolidPower, QuantumScape, CATL, ionic materials, A123 Systems, SES, Toyota, ProLogium, Samsung

Shift to solid state eliminates fire risk and enables li-metal to unlock higher energy density

Source: Experts interviews, press search, research literature review

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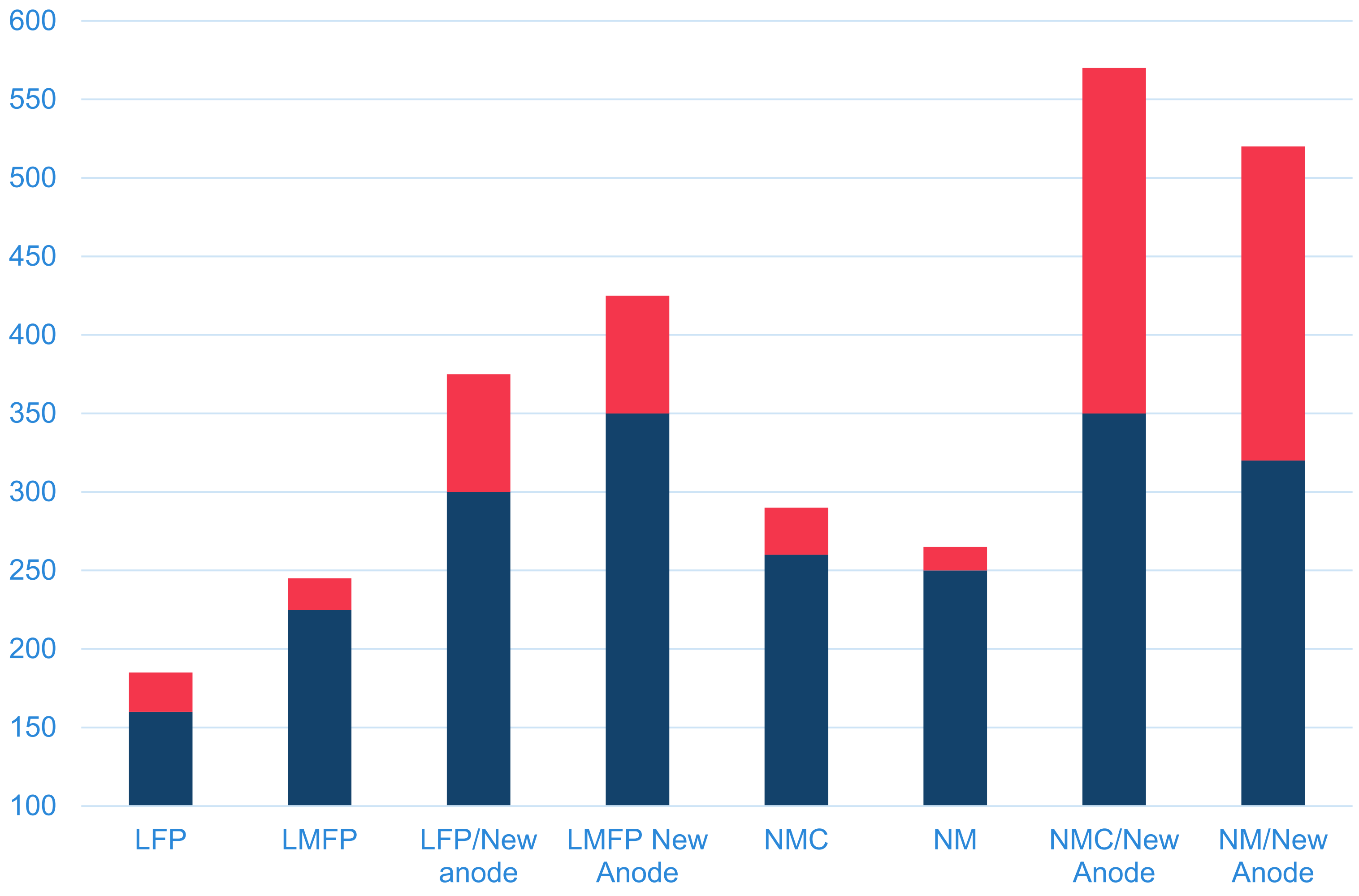
The pairing of anode technology with cathode metals to give optionality to EV growth



The evolution of chemistries will increase density and reduce materials

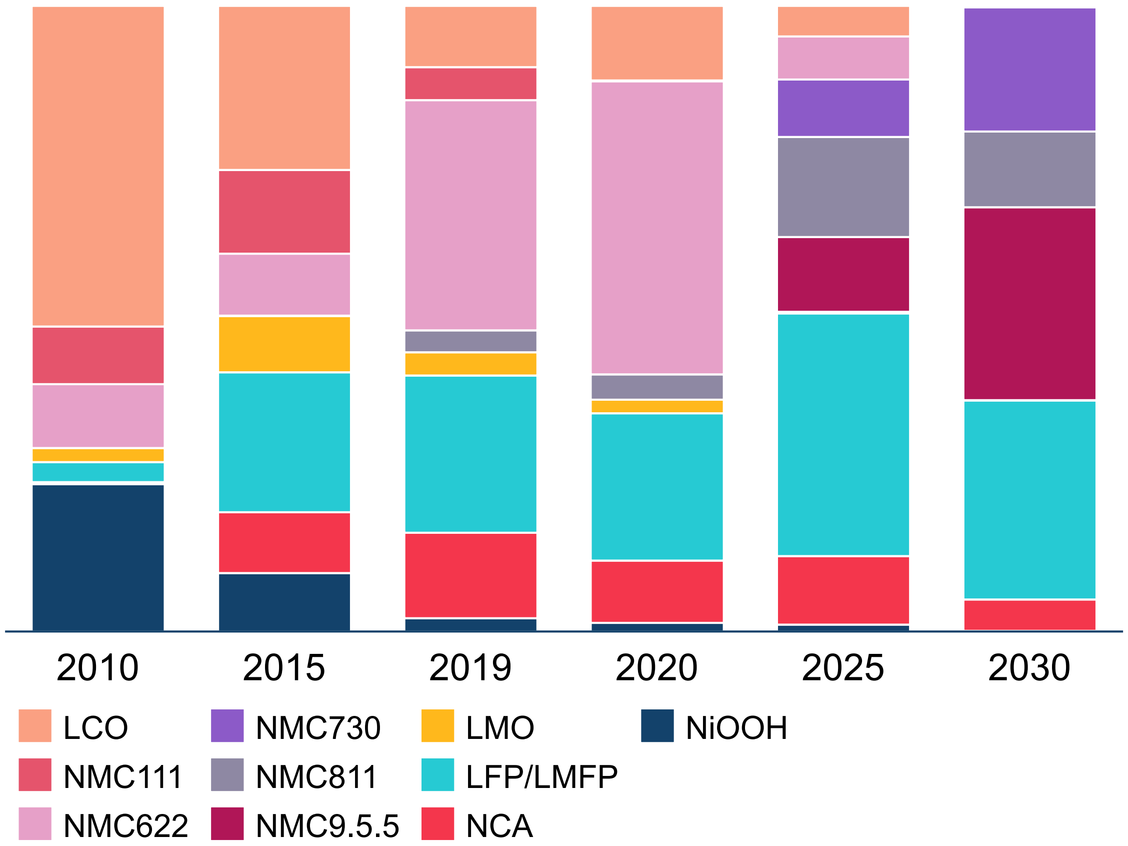
There are many advancements occurring in the development of battery chemistries.

The increased use of manganese would reduce the need of nickel.

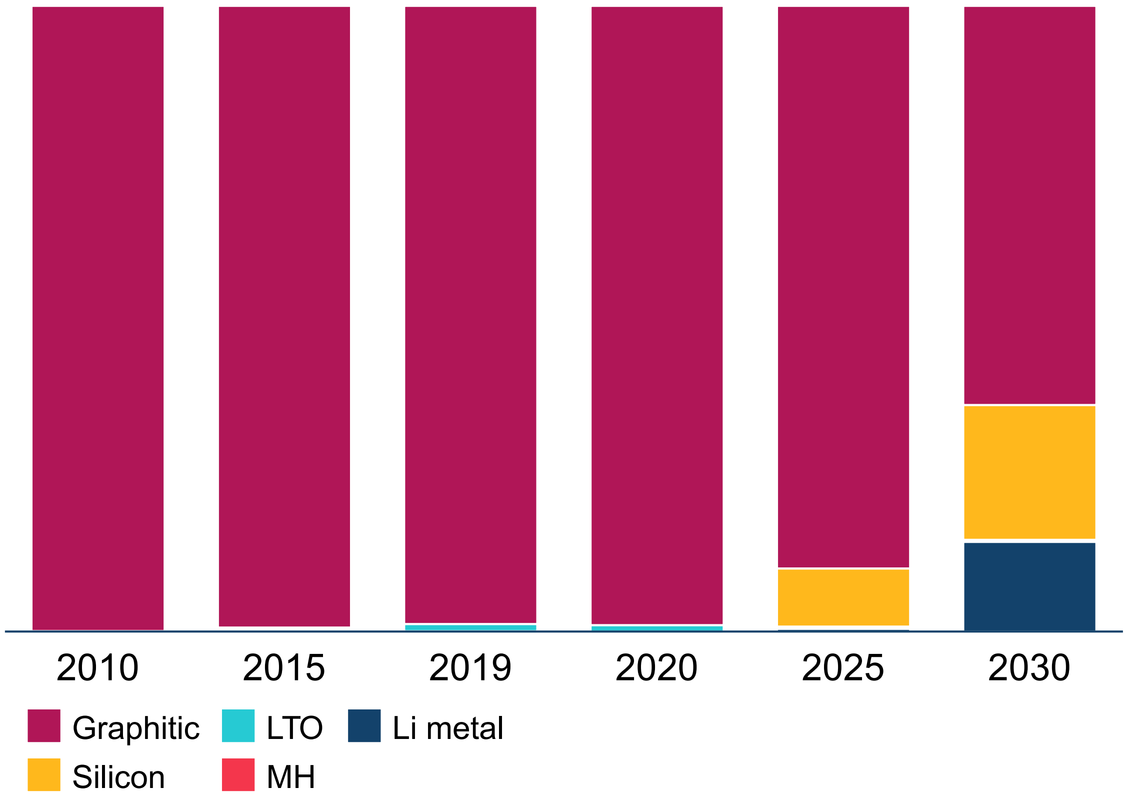
The introduction of silicon and lithium metal anodes will greatly increase the density of any cathode material.

Backup: Cathode and anode technology evolution to drive the market towards lithium hydroxide and lithium metal adoption

Cathode Split, GWh



Anode Split, GWh



Source: McKinsey Battery Demand Model

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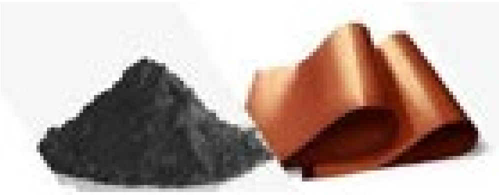
New battery technology could see a similar trend, only faster

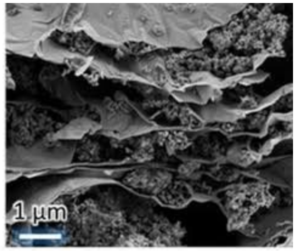
Anode technology could dramatically shift density and costs



2010's

Graphite anodes

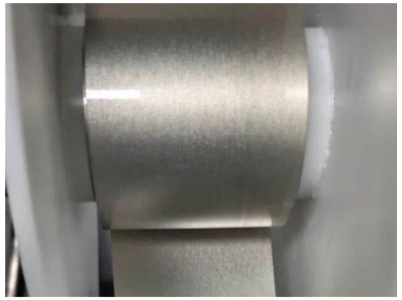
2025



Silicon anodes add density, reduce costs and material needs

2028+

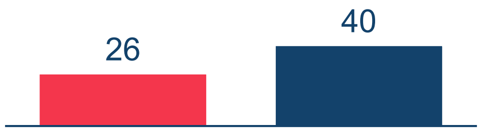
lithium metal anodes further increase density and reduce costs and materials



How we look at material demand depends on many factors, including time and technology

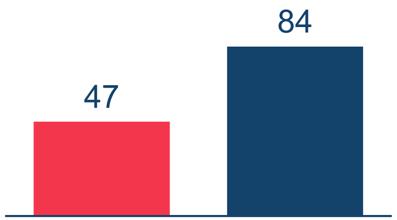
- % of Class 1 nickel to 100% EV adoption

North America– steady state



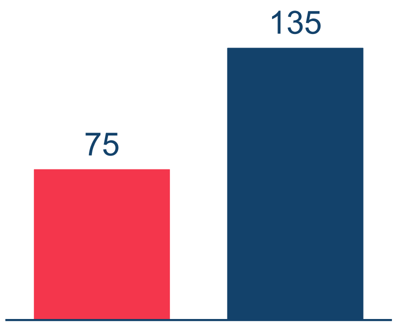
Current chemistry and production makes the world look very short nickel, but this will change

Global– Steady State



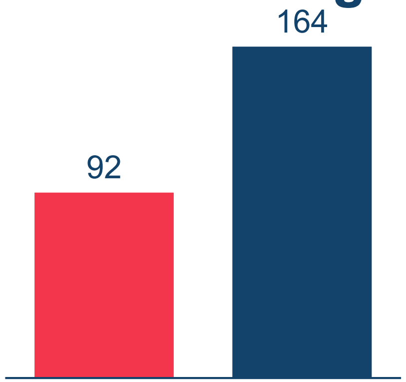
On a global basis, nickel supplies come closer to meeting 100% EV situation– Assume 1/3 LFP

Global– Density improvement



Moving from NMC with average 250 Wh/kg to 400 Wh/kg over the next decade using improvements in anode technology

Global Density and CAM change



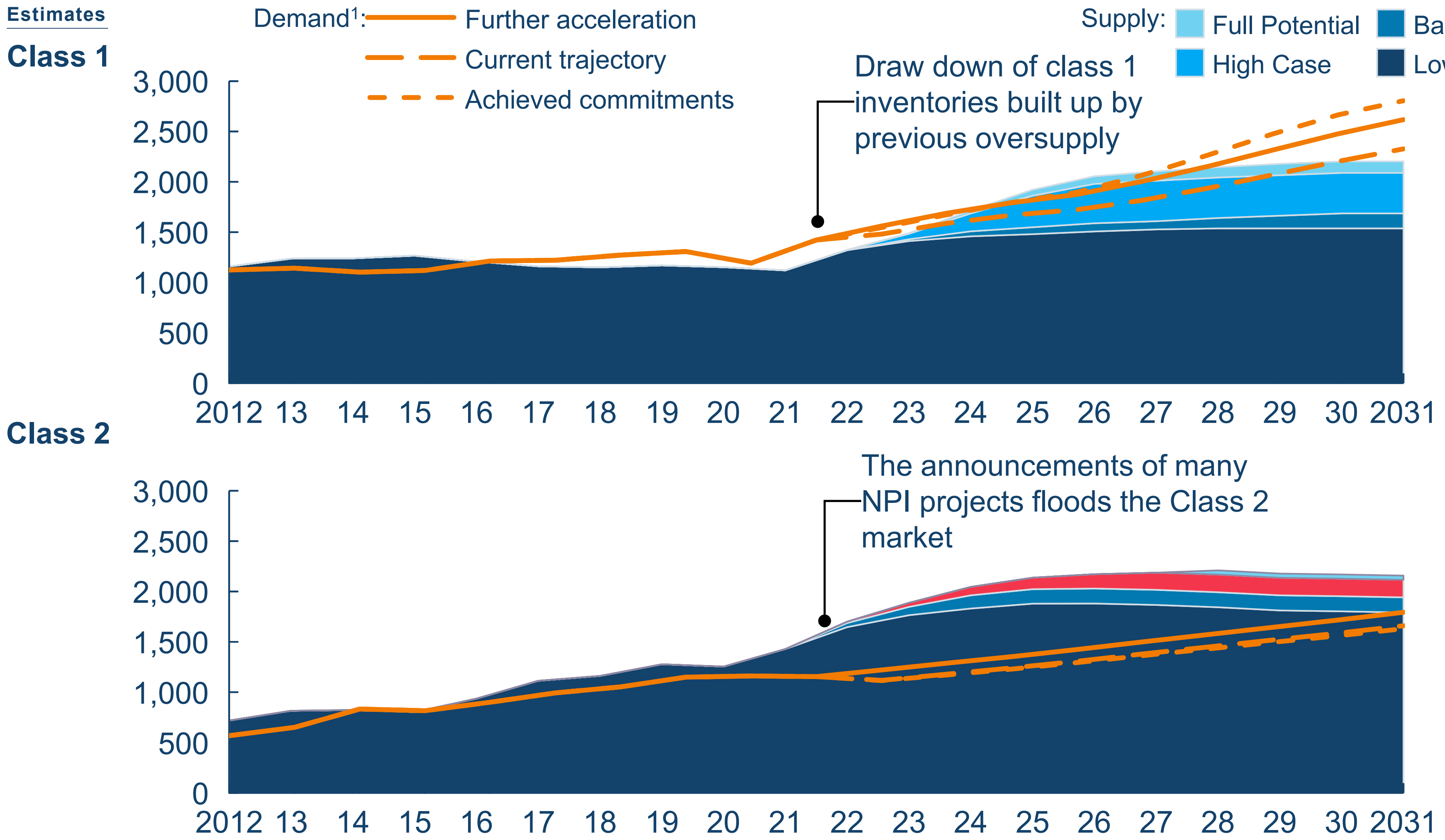
Moving to a higher manganese CAM as well as net density improvements due to anode technology

2022 2032

* Assumes 100% adoption at average total vehicle sales over the past decade with a NA battery of 100 kWh and 100% NMC 811 while a Global 60 kWh battery with 1/3 LFP and 2/3 NMC 811

We expect a short-term Class 1 thightness, compensated by either significant supply pipeline growth via NPI conversion or substitution of nickel usage

Refined nickel supply capacity and demand by class of nickel, in kt Ni



Key assumptions

Batteries demand requires 100% Class 1 nickel

Primary nickel stainless steel production in China uses ~5% of Class 1, and production in the RoW Class 1 usage for stainless steel decreases from 85% in 2018 to ~75% in 2030

Alloys use class 1 nickel, 50-60% of remaining applications need class 1 nickel

Implications

Without continued changing consumption patterns, Class 1 shortage after 2023

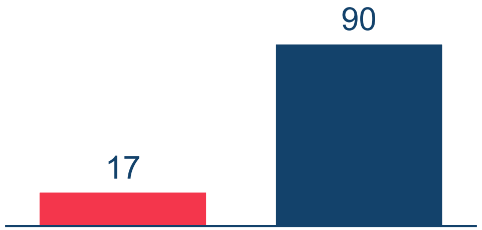
1. Class demand based on the current demand profile. Shifts in demand are likely to happen with evolving technology and price dynamics

Source: MineSpans, McKinsey Nickel demand model

Lithium seems more like a problem, however, the earth is not short lithium…

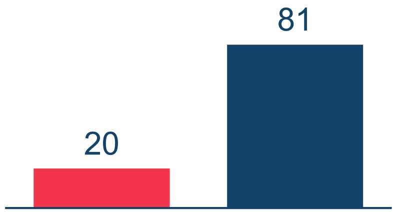
- % of lithium to 100% EV adoption

North America– steady state



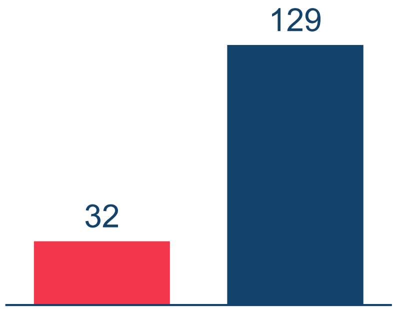
Current chemistry and production makes the world look very short lithium, but this will change

Global– Steady State



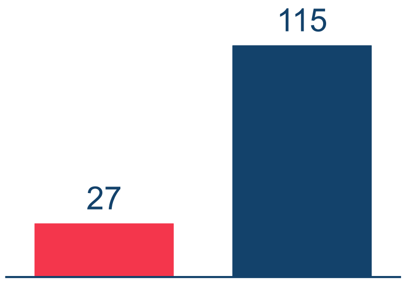
Lithium mines take far shorter to market than base metal mines, and supplies should expand

Global– Density improvement



Moving from NMC with average 250 Wh/kg to 350 Wh/kg over the next decade using improvements in anode technology-Lithium metals does not have a big impact on demand

Global Density and CAM change



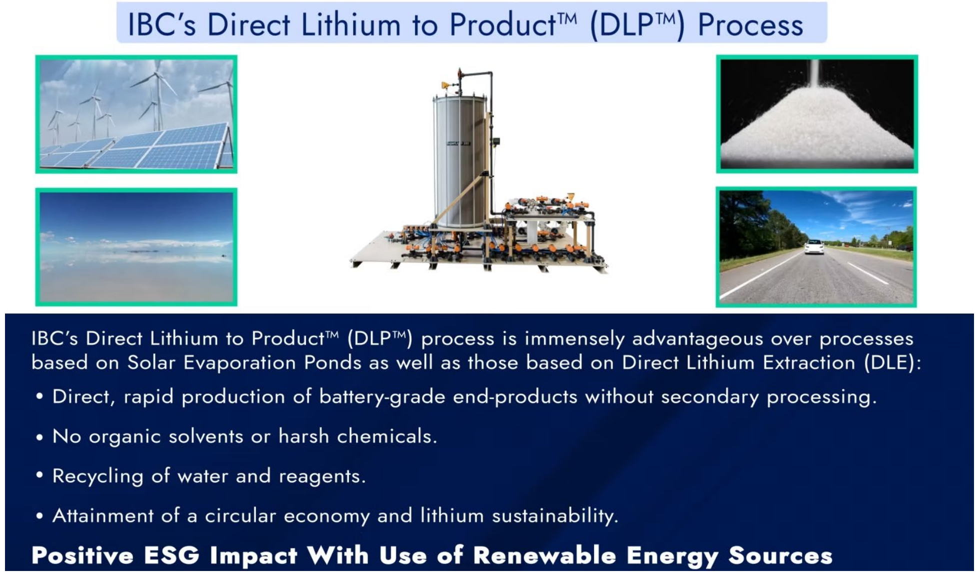
Moving to a higher manganese CAM would lower overall density thus increase lithium needs

2022 2032

Direct Lithium Extraction and DLP is being developed as an alternative to conventional lithium brine production

Companies advancing the technology could unlock new resources

DLP technology could rapidly raise LiOH production



Companies advancing the DLE/DLP technology

LAKE RESOURCES

Partnering with Lilac Solutions to use DLE technology in the Kachi brine deposit in Argentina

Currently under pilot trial and DFS fully funded

Capacity of 25.5 ktpy LCE, targeted by 2024

STANDARD lithium – POWERING THE FUTURE

Partnering with Lanxess to produce lithium carbonate from oilfield brines in Arkansas, using spent brine from bromine production

Currently under pilot trial, with tests for hydroxide conversion

Capacity of ~21 ktpy LCE

VULCAN ENERGY RESOURCES – Zero Carbon Lithium®

Piloting a DLE process for geothermal brines in Germany, using brine from electricity generation plants

DFS expected by mid-2022

Capacity of 35 ktpy LCE by 2024 being targeted

ENERGYSOURCE MINERALS

Partnering with Compass Minerals to use ILiAD processing system to produce 11,000 mt of LCE product at Compass' Salt Lake facilities.

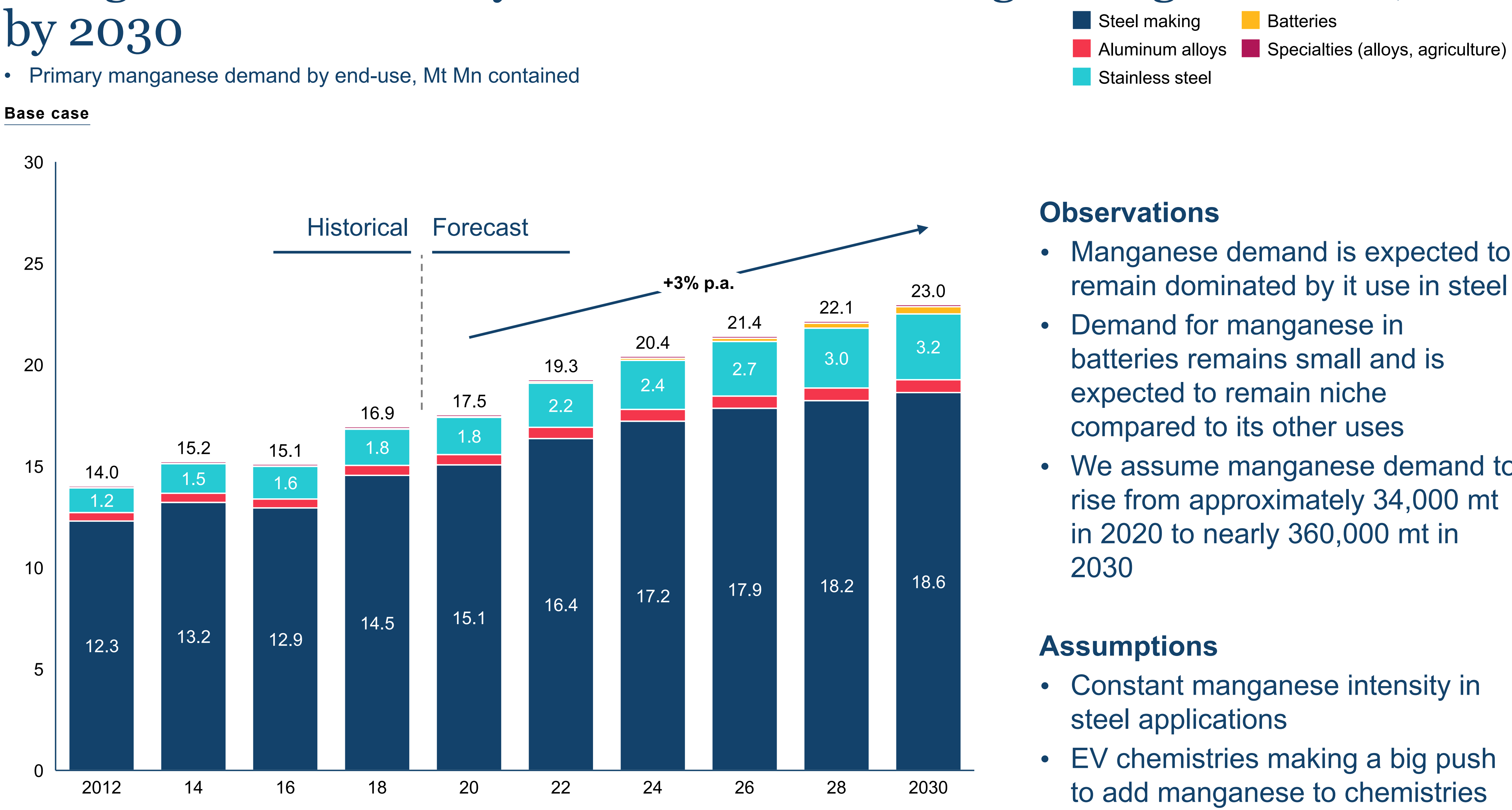
Expected start-up by 2025

Source: IBC Advanced Technologies website; Company websites and presentations

Manganese is driven by steel- even if EV manganese growth of 1,000% by 2030

- Primary manganese demand by end-use, Mt Mn contained

Base case



Observations

- Manganese demand is expected to remain dominated by it use in steel
- Demand for manganese in batteries remains small and is expected to remain niche compared to its other uses
- We assume manganese demand to rise from approximately 34,000 mt in 2020 to nearly 360,000 mt in 2030

Assumptions

- Constant manganese intensity in steel applications
- EV chemistries making a big push to add manganese to chemistries

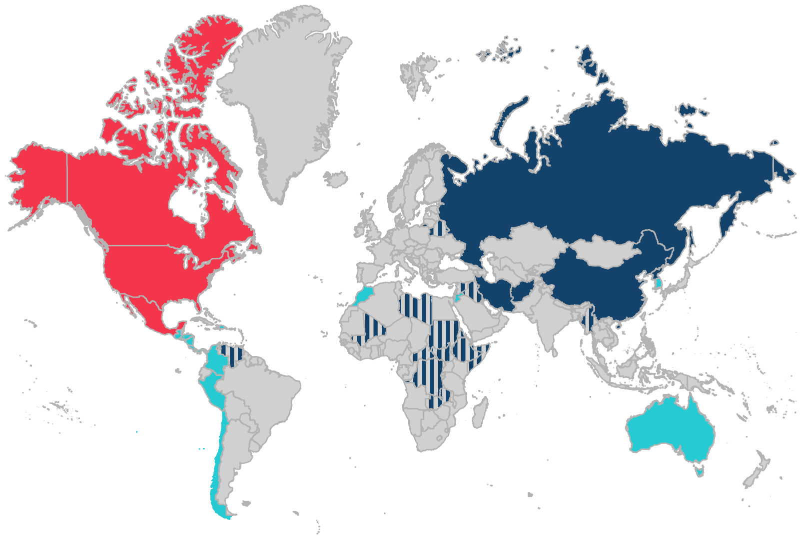
Source: McKinsey manganese demand model

To qualify for tax credits, EVs will need to source batteries from free trade countries

- Sec. 13401 Clean Vehicle Credit

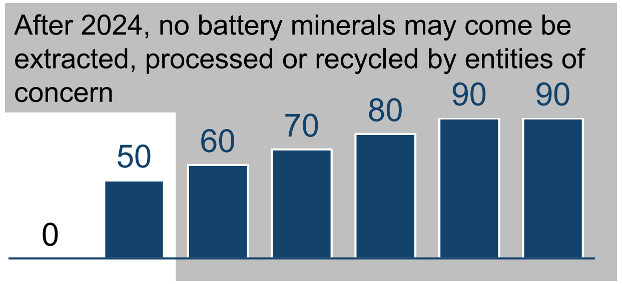
Map of free trade agreements

- Covered nation[1]
- Countries with OFAC sanctions[2]
- USMCA
- Countries with active US free trade agreements

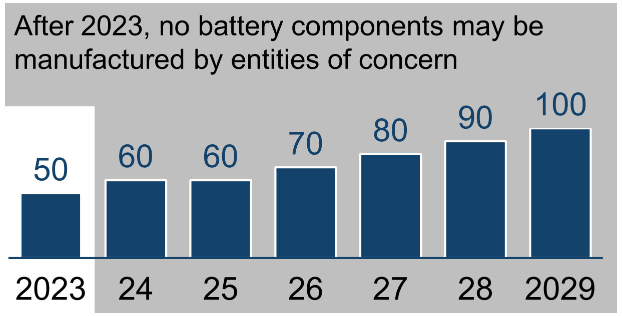


Battery sourcing requirements

Share of battery materials extracted/processed in US or country with free trade agreement percent



Share of battery manufactured in North America percent



1. As defined in section 2533c(d) of title 10
2. Includes a mix of OFAC-sanctioned countries and countries with significant numbers of sanctioned industries and companies

Source: US Inflation Reduction Act (2022), 10 USC § 4872(d)(2), Infrastructure Investment and Jobs Act (2021)

Battery sourcing requirements

To qualify for EV tax credits, an increasing share of battery materials must be extracted and processed in countries with free trade agreements; batteries recycled in North America count

By 2029, all EV batteries must be produced in North America, beyond material source requirements

Vehicles with **battery materials sourced from "foreign entities of concern"** do not qualify for subsidies; this excludes minerals from China, Russia, and OFAC sanctioned countries/companies

To qualify for tax credits, after 2024, critical battery materials may not be sourced from foreign entities of concern. No battery components may be manufactured by foreign entities of concern after 2023

Some countries have OFAC sanctions that affect state-owned businesses, individual companies, or sectors

Canada, Chile and Australia are likely to benefit from free trade requirement rules

Reducing the Lithium Supply Deficit

Smaller battery packs: Inevitable? Achievable?

Prepared for LME Focus Day

London, October 27, 2022

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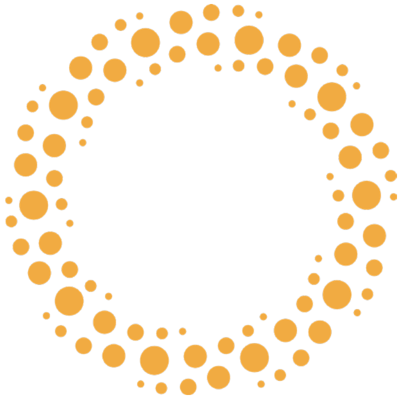
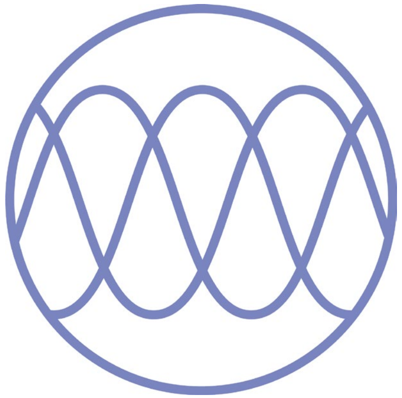
The electrification of everything

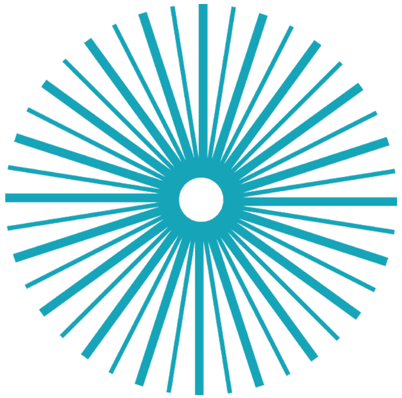


Generation



Conversion

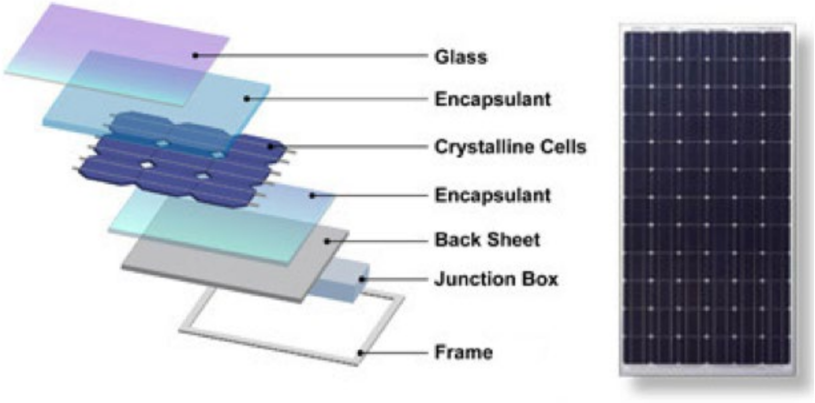
Storage

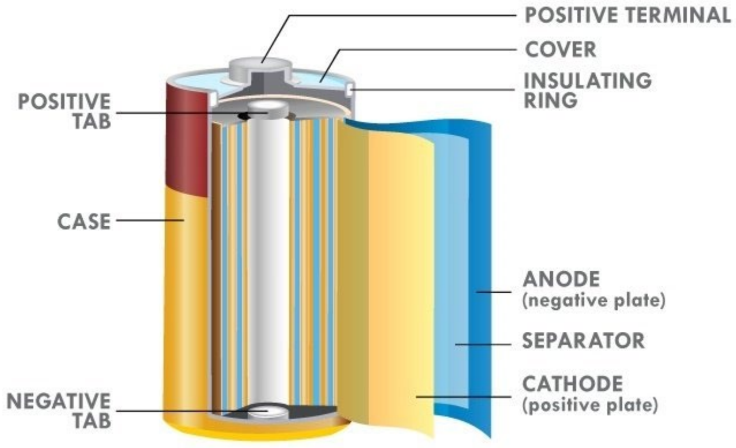


Consumption

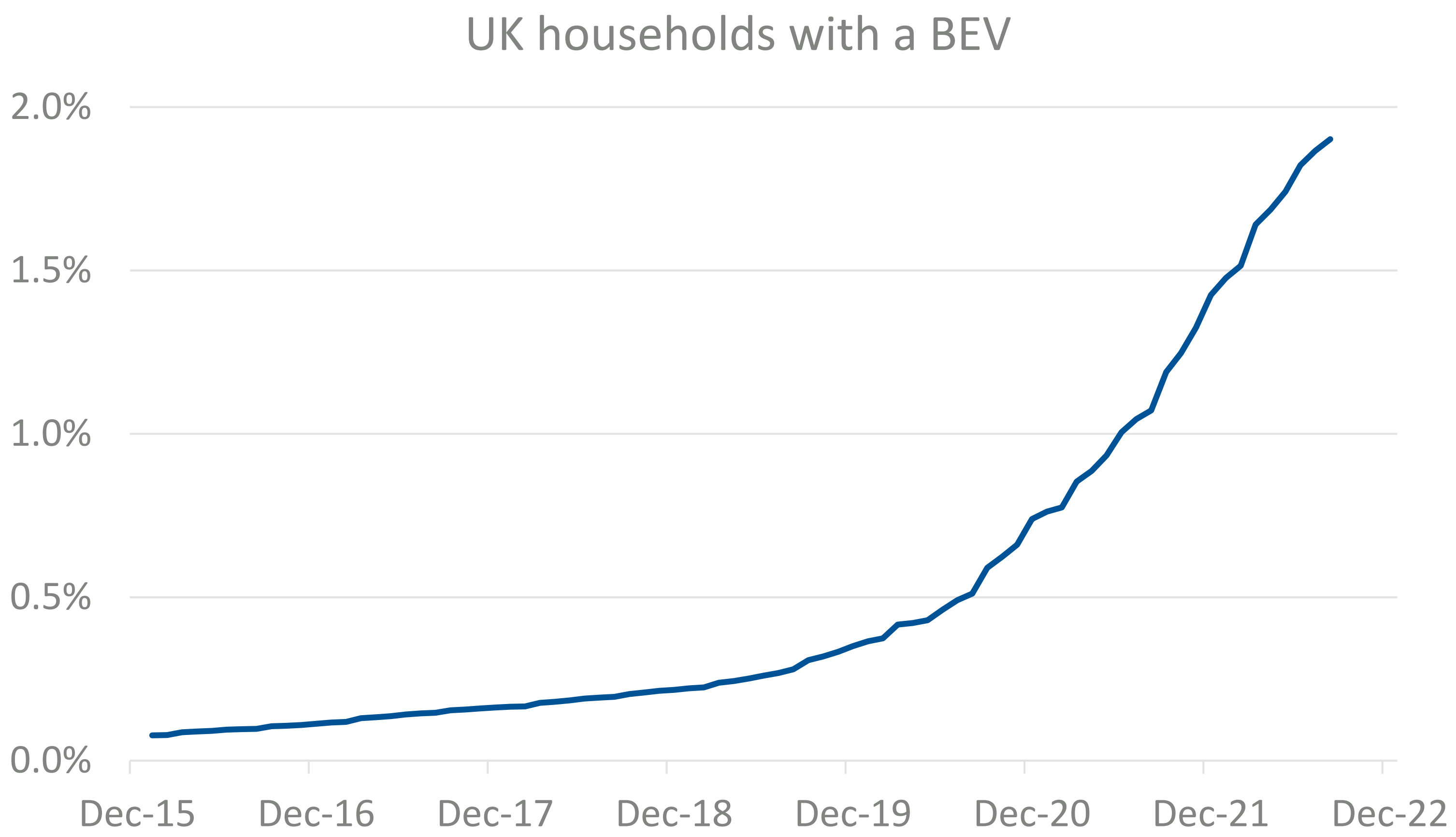
About Exawatt

Strategic consulting and market analysis in industries that support **decarbonisation through electrification**



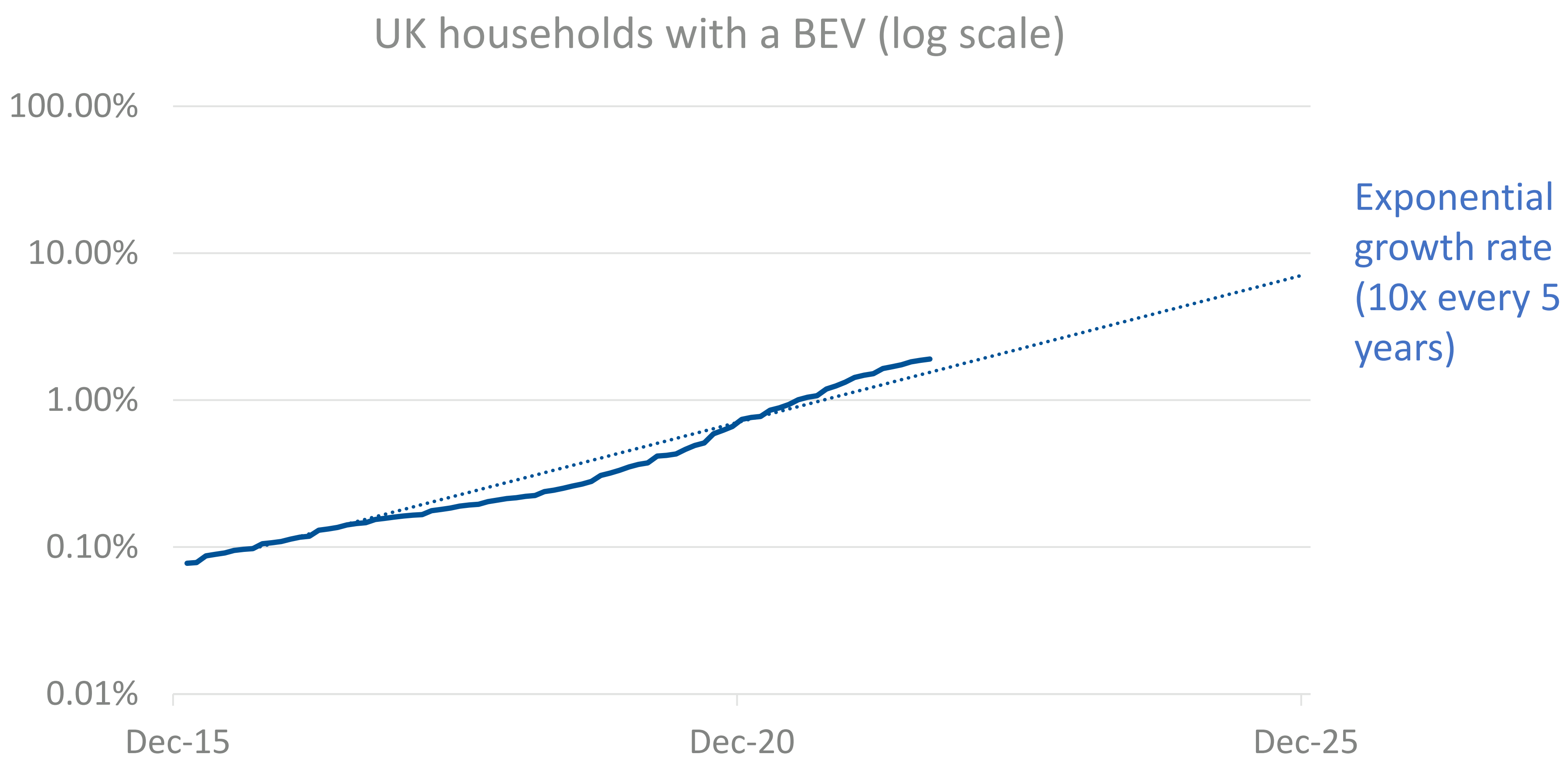


BEV sales are booming



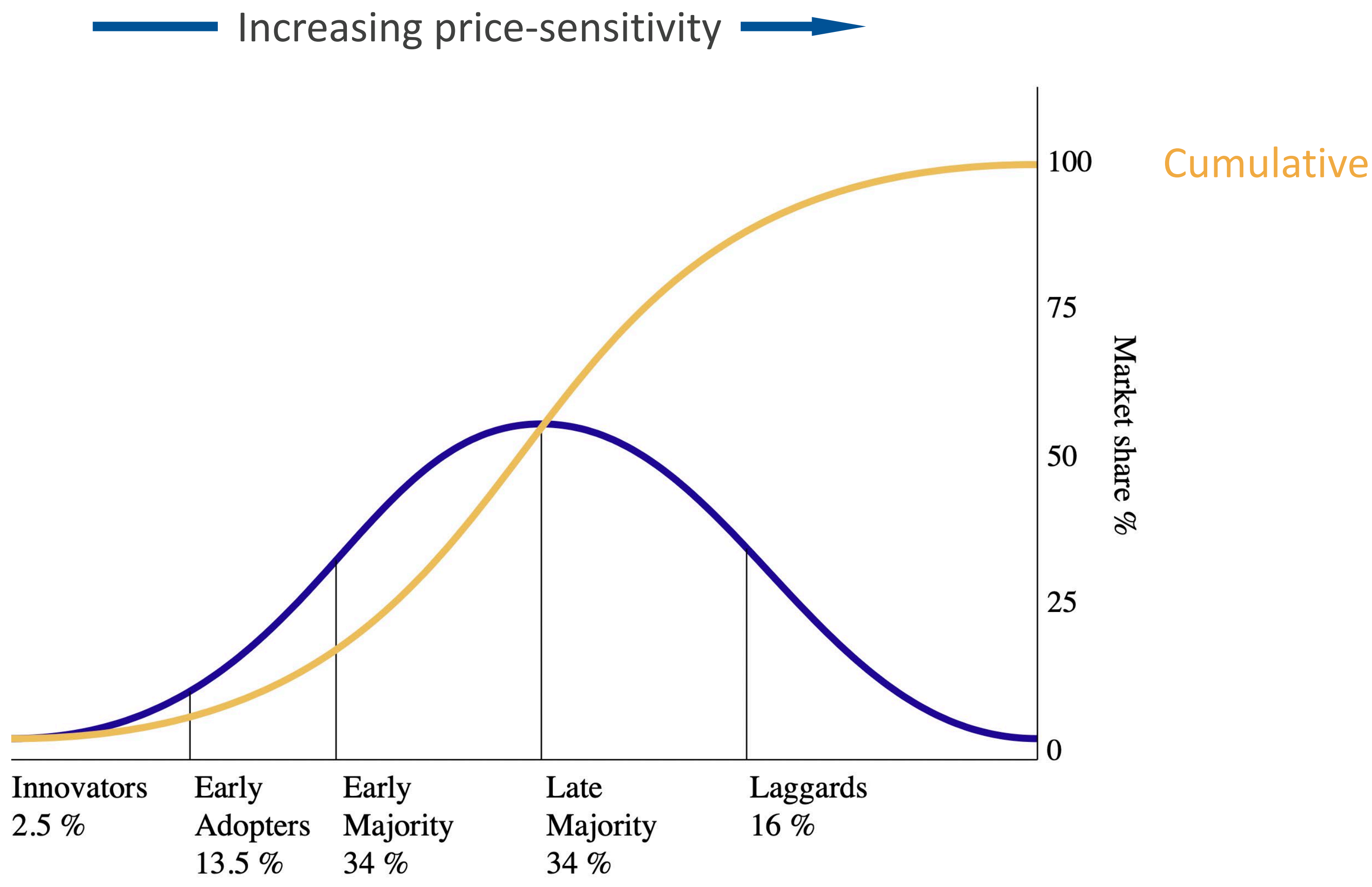
Source: Exawatt analysis of SMMT and UK Office for National Statistics data

BEV sales growth rate has accelerated



Source: Exawatt analysis of SMMT and UK Office for National Statistics data

We’re in the early adopter phase



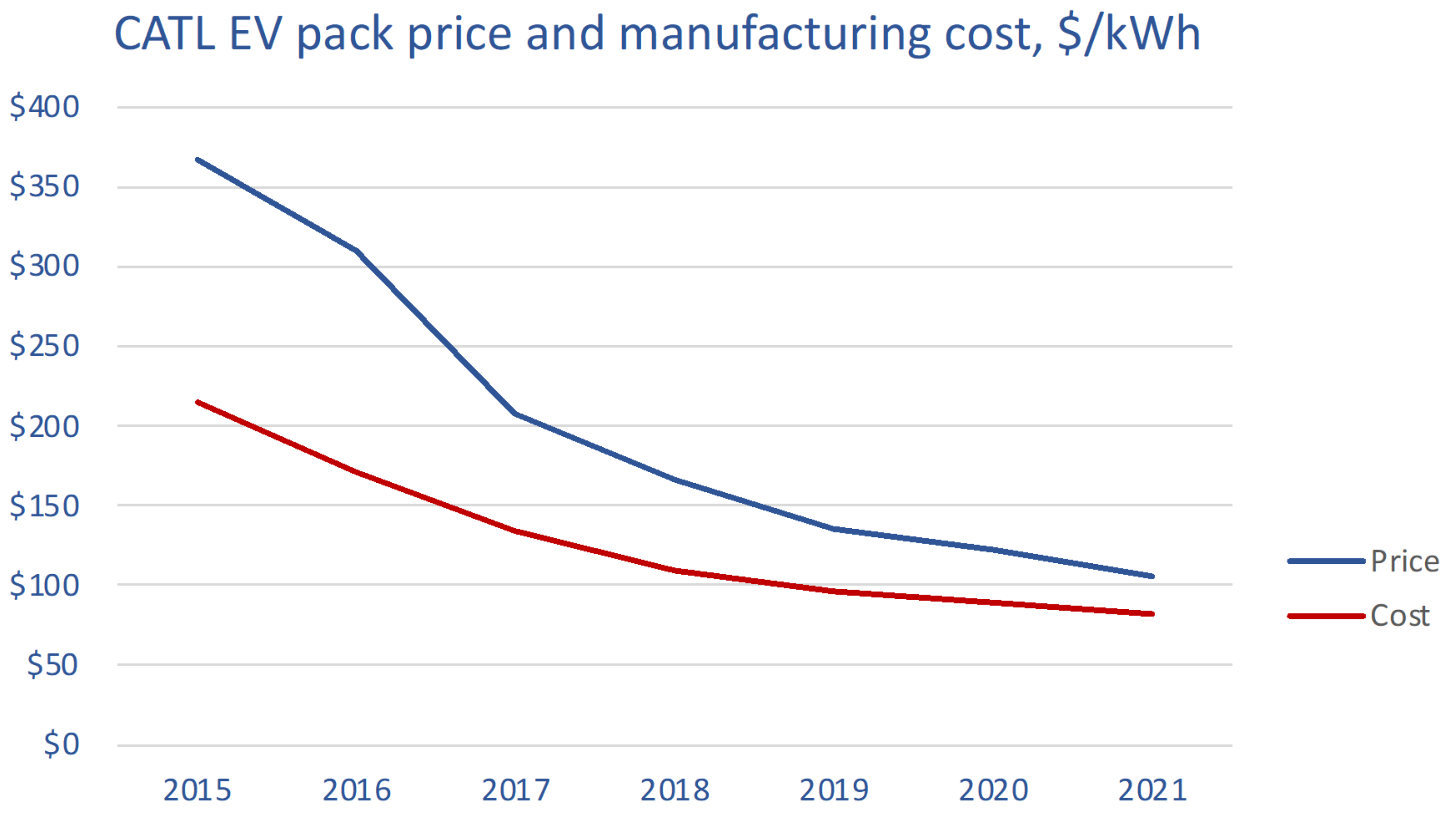
Source: Rogers Everett - Based on Rogers, E. (1962) Diffusion of innovations. Free Press, London, NY, USA., Public Domain.

Manufacturing cost and price: batteries

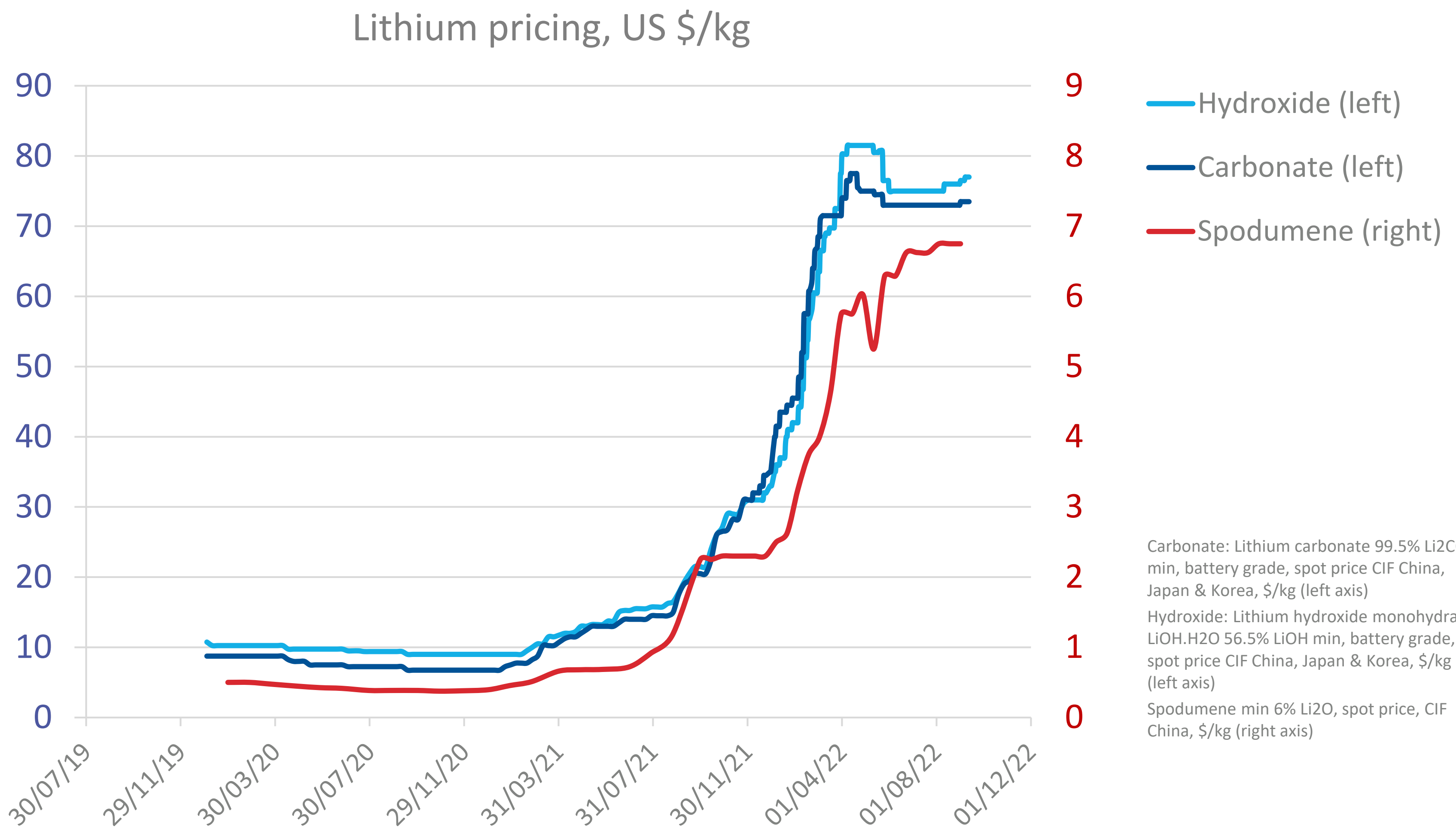
$$\frac{\$}{kWh}$$

Decrease (← numerator $)

Increase (→ denominator kWh)



Source: Exawatt analysis of CATL financial disclosures

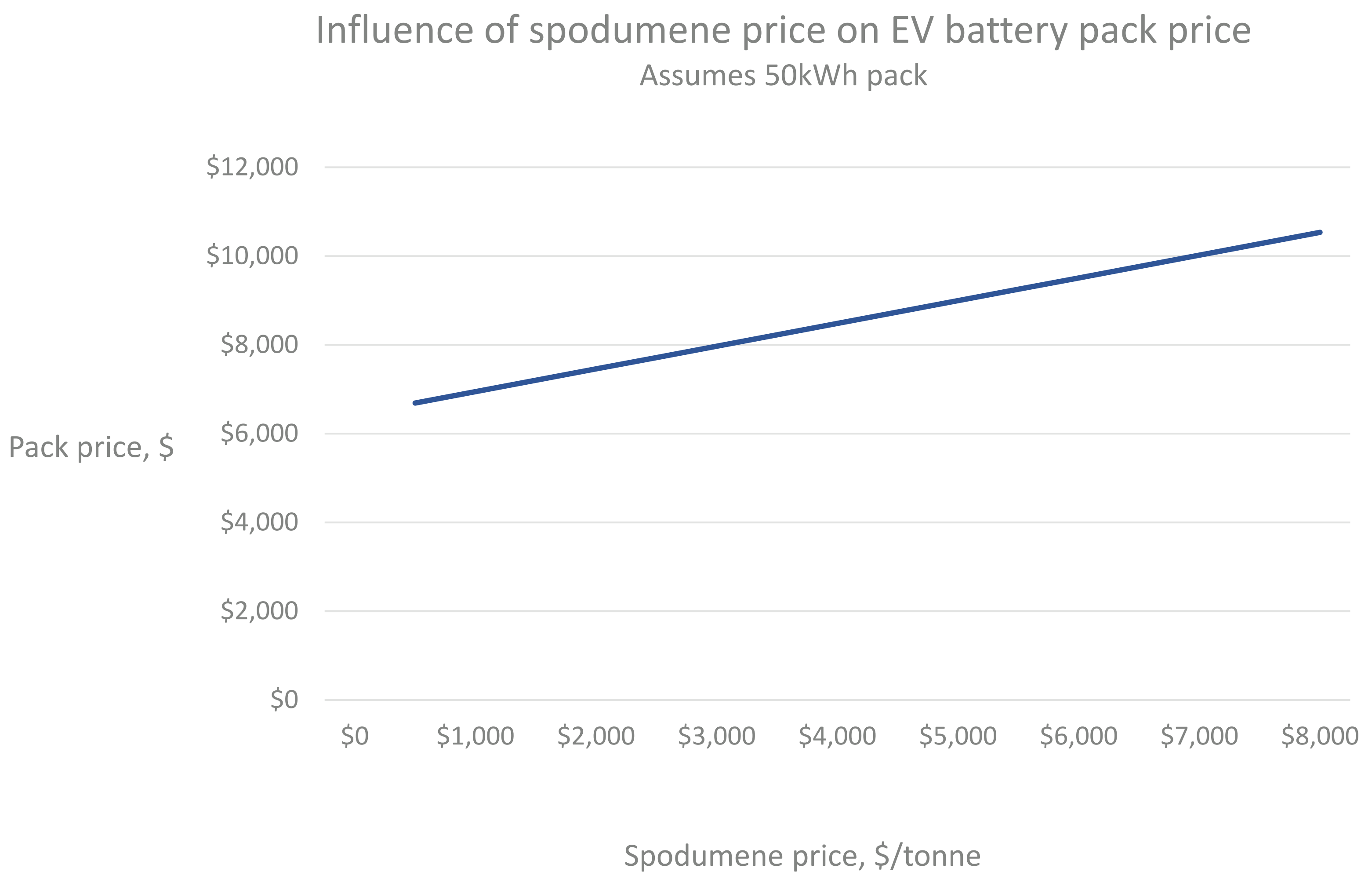


Carbonate: Lithium carbonate 99.5% Li_2CO_3 min, battery grade, spot price CIF China, Japan & Korea, $/kg (left axis)

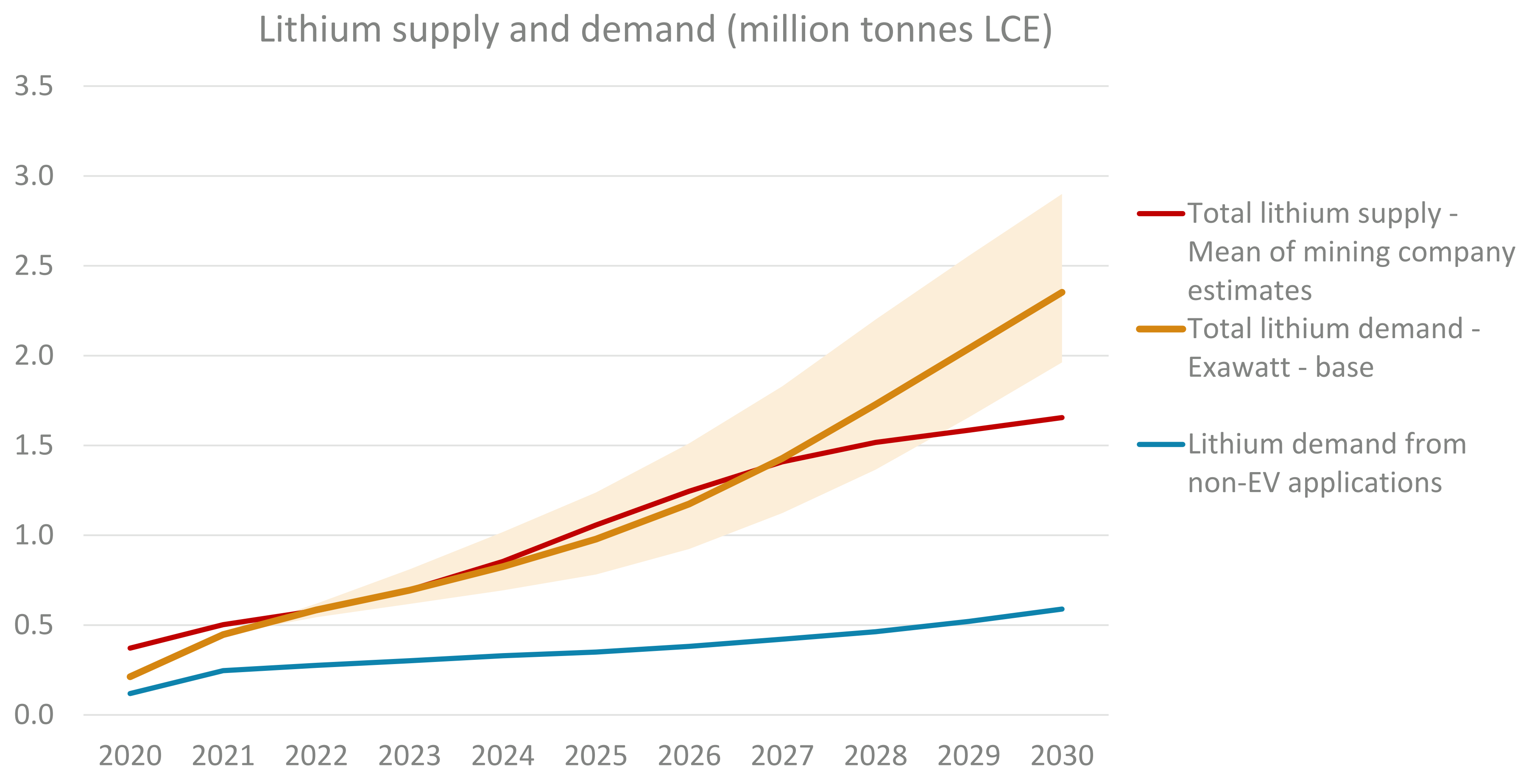
Hydroxide: Lithium hydroxide monohydrate $LiOH.H_2O$ 56.5% LiOH min, battery grade, spot price CIF China, Japan & Korea, $/kg (left axis)

Spodumene min 6% Li_2O, spot price, CIF China, $/kg (right axis)

Source: Fastmarkets

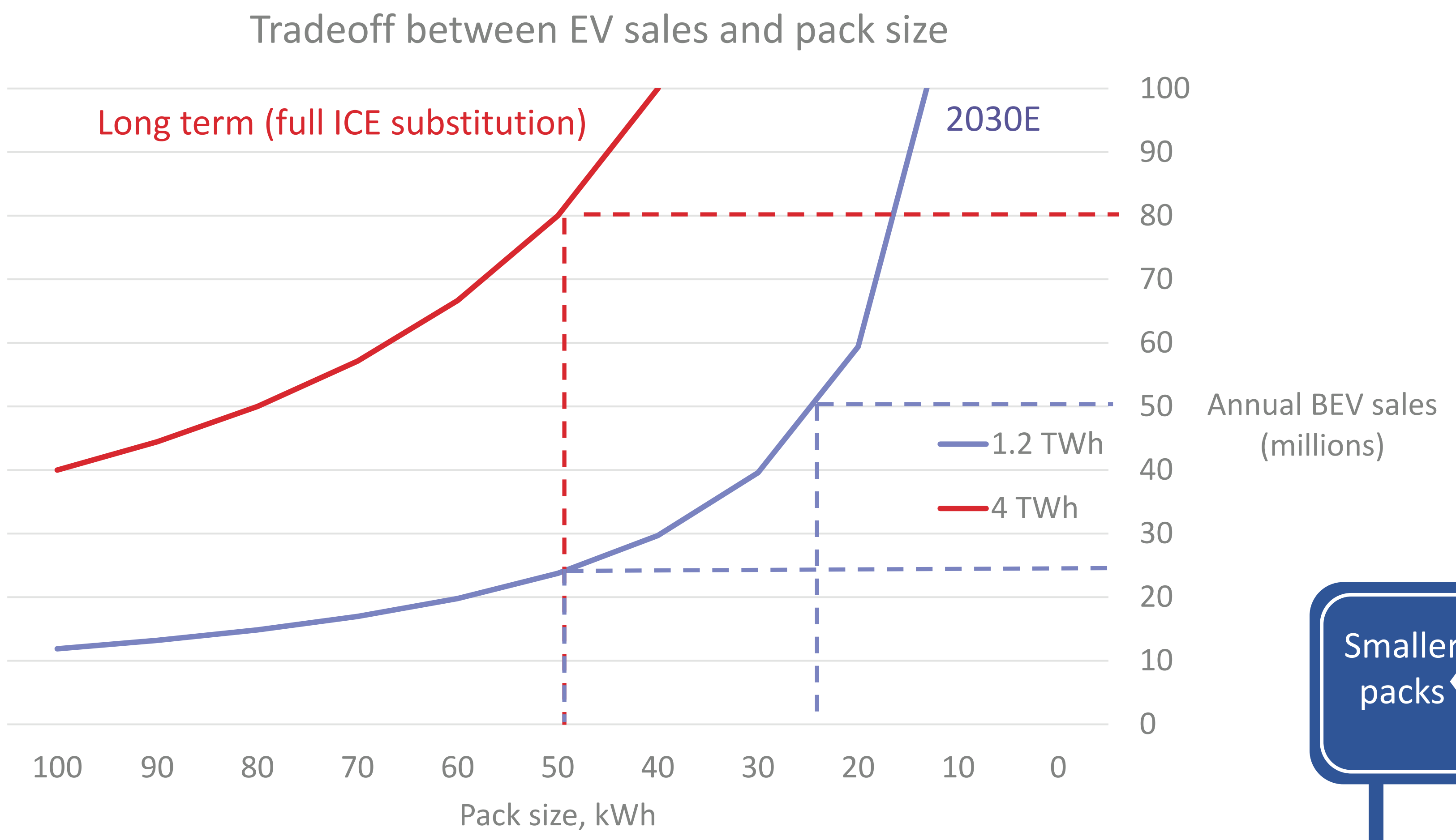


Source: Exawatt

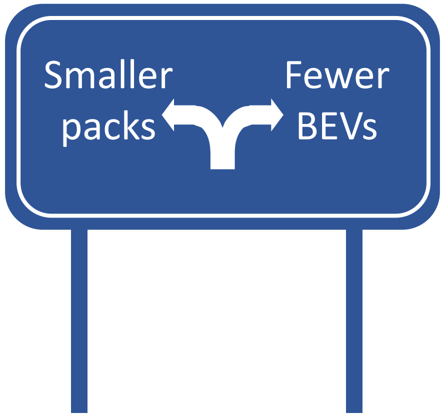


Source: Exawatt (LCE demand), mean of lithium extraction company forecasts (LCE supply)

How do we reduce the lithium supply deficit?

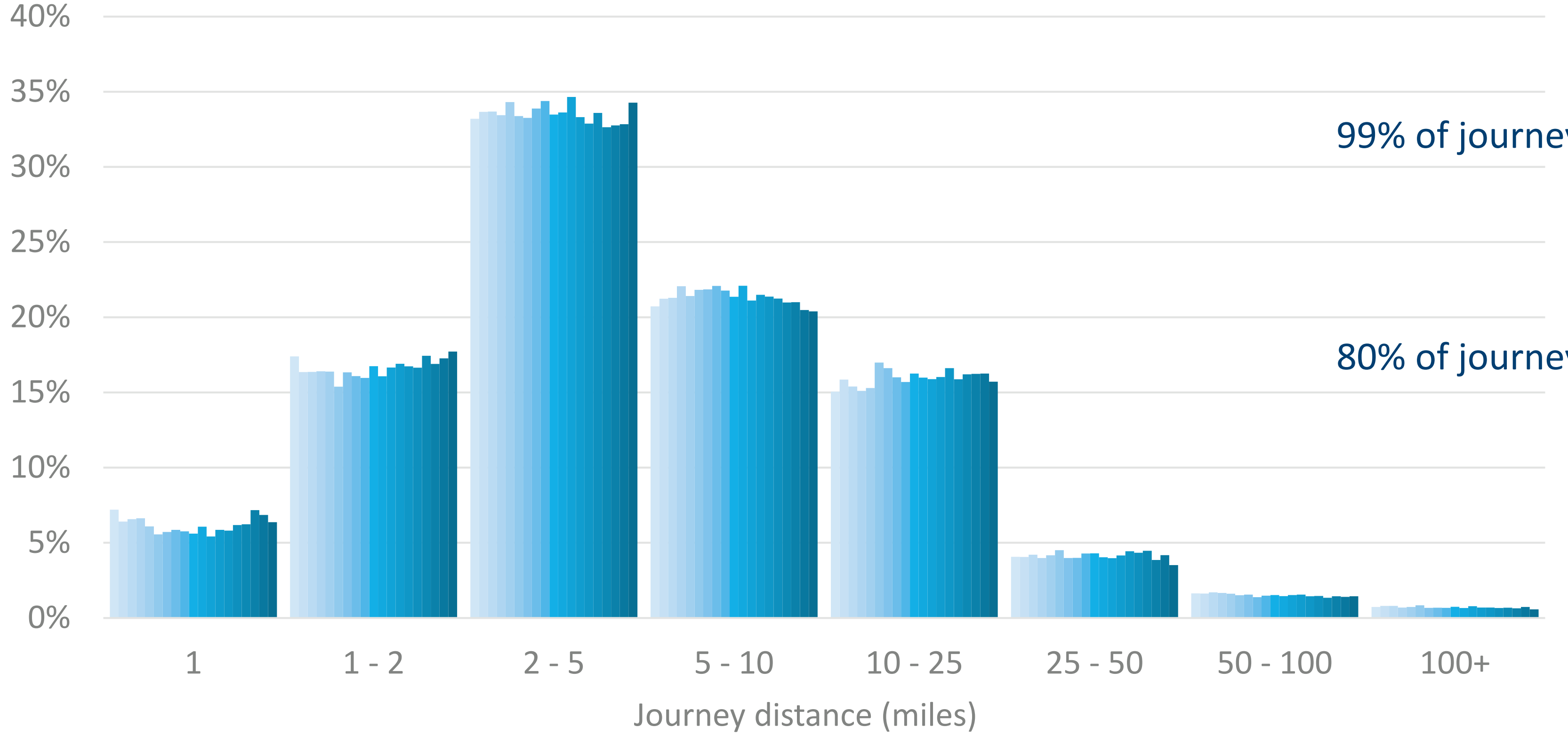


Source: Exawatt



Are smaller packs possible?

Annual UK car/van driver journeys by distance
2002 to 2020



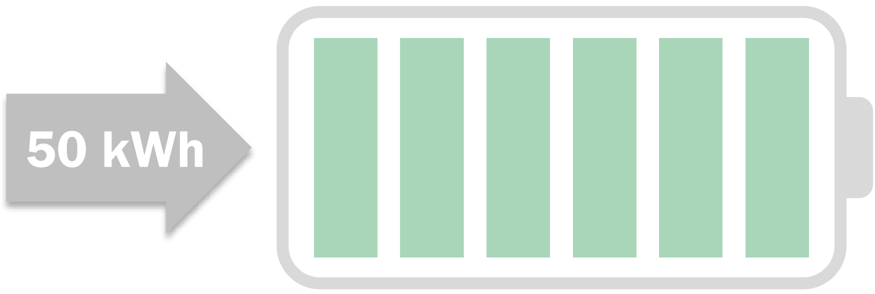
99% of journeys are <100 miles

80% of journeys are <10 miles

Source: UK National Travel Survey, Department for Transport

How can we enable a move to smaller batteries?

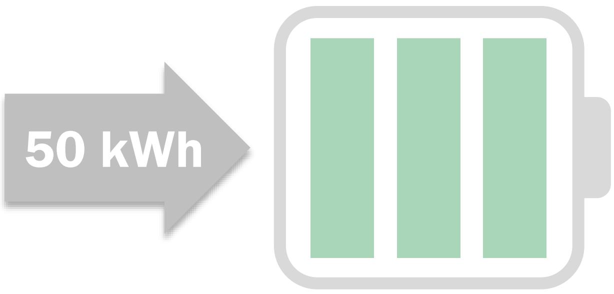
No lithium supply constraints



50 kWh

1h
(i.e. 1C)

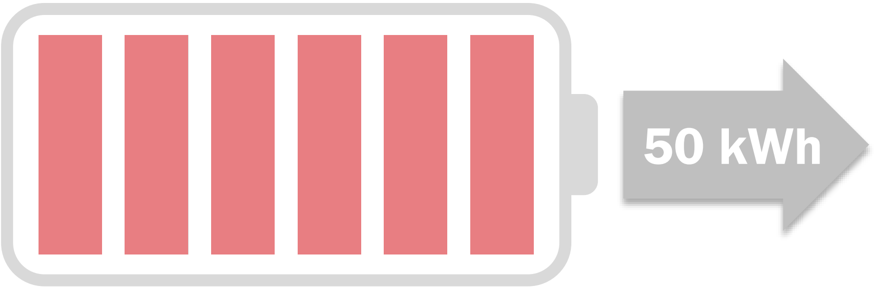
Lithium supply constrained



25 kWh

0.5h
(i.e. 2C)
more degradation

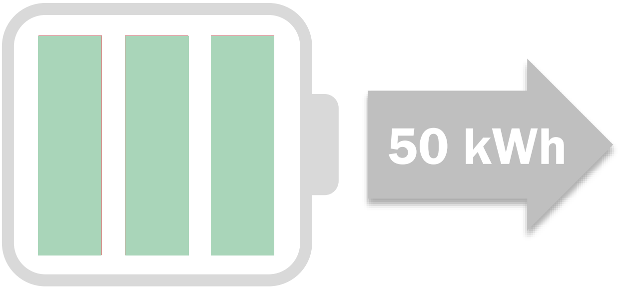
No lithium supply constraints



50 kWh

1 cycle

Lithium supply constrained

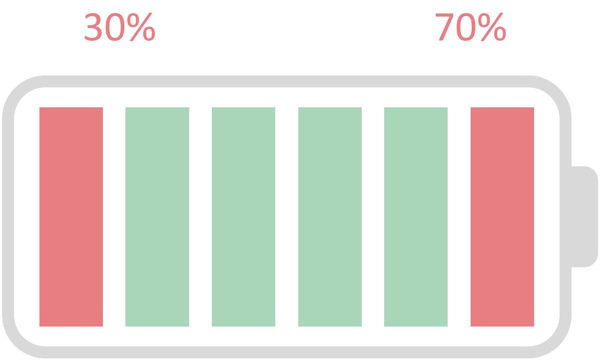


25 kWh

2 cycles

More degradation

No lithium supply constraints



50 kWh

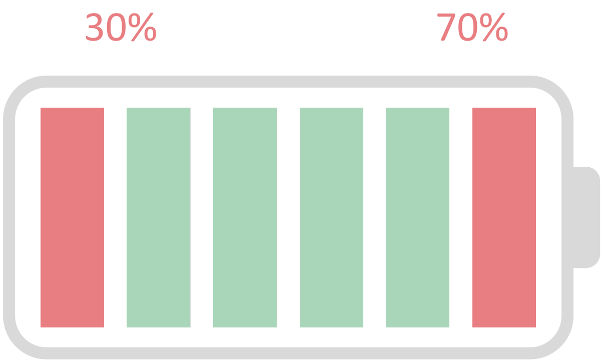
NMC
Limited DoD

Lithium supply constrained

25 kWh

NMC
Limited DoD

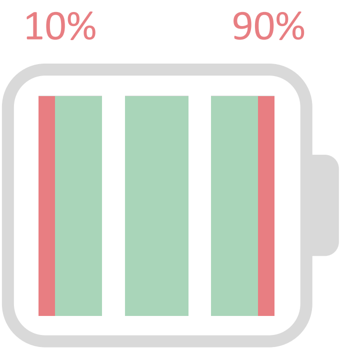
No lithium supply constraints



50 kWh

NMC
limited DoD

Lithium supply constrained



25 kWh

LFP
high DoD

Safer, cheaper cells with high cycle life, high DoD and high C-rate

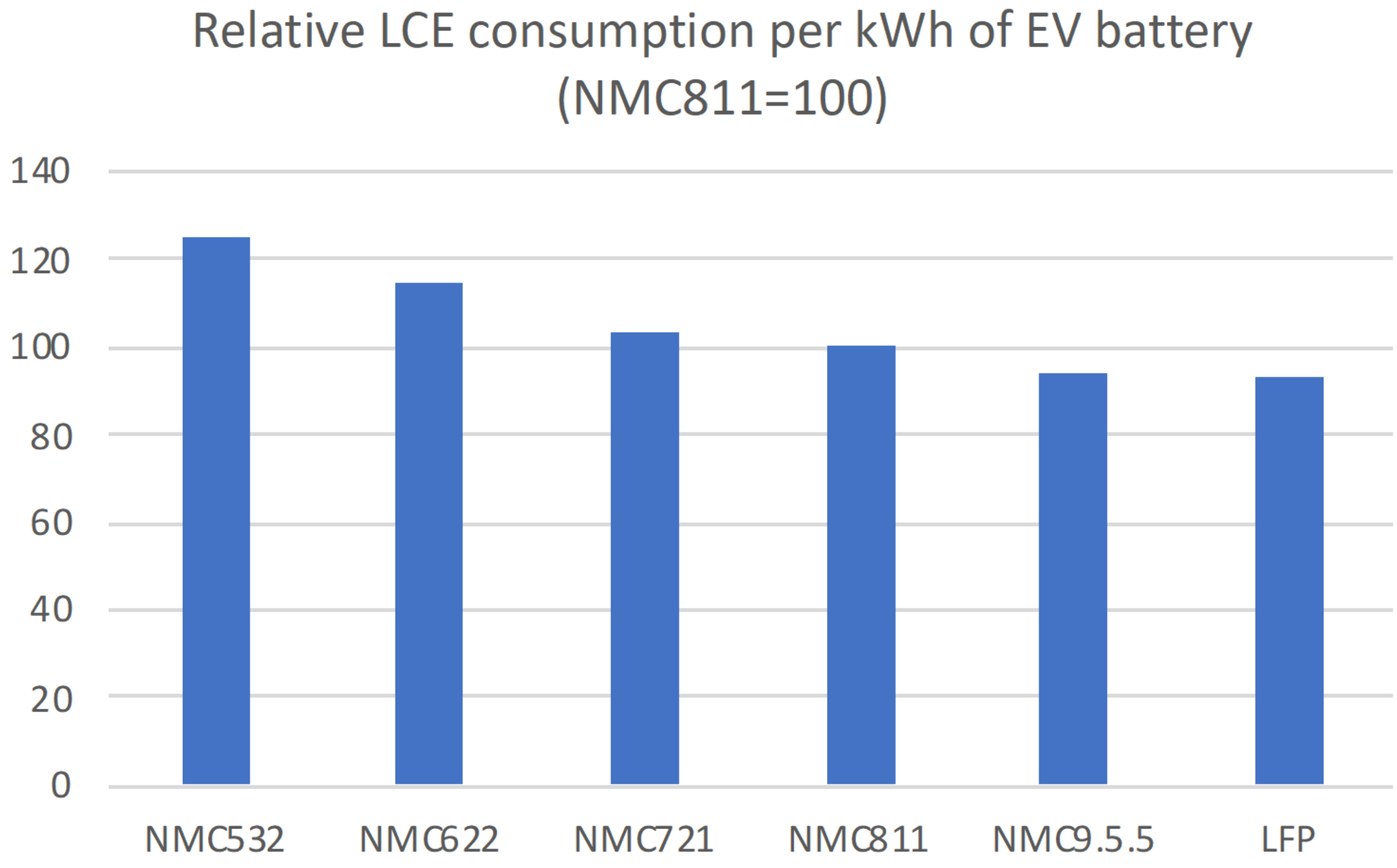
Widespread ultra-rapid charging on major roads

Improved “fuel economy” (powertrain efficiency)

Alternative vehicle configurations (range extenders?)

New vehicle ownership models…

$$\frac{kg}{kWh}$$

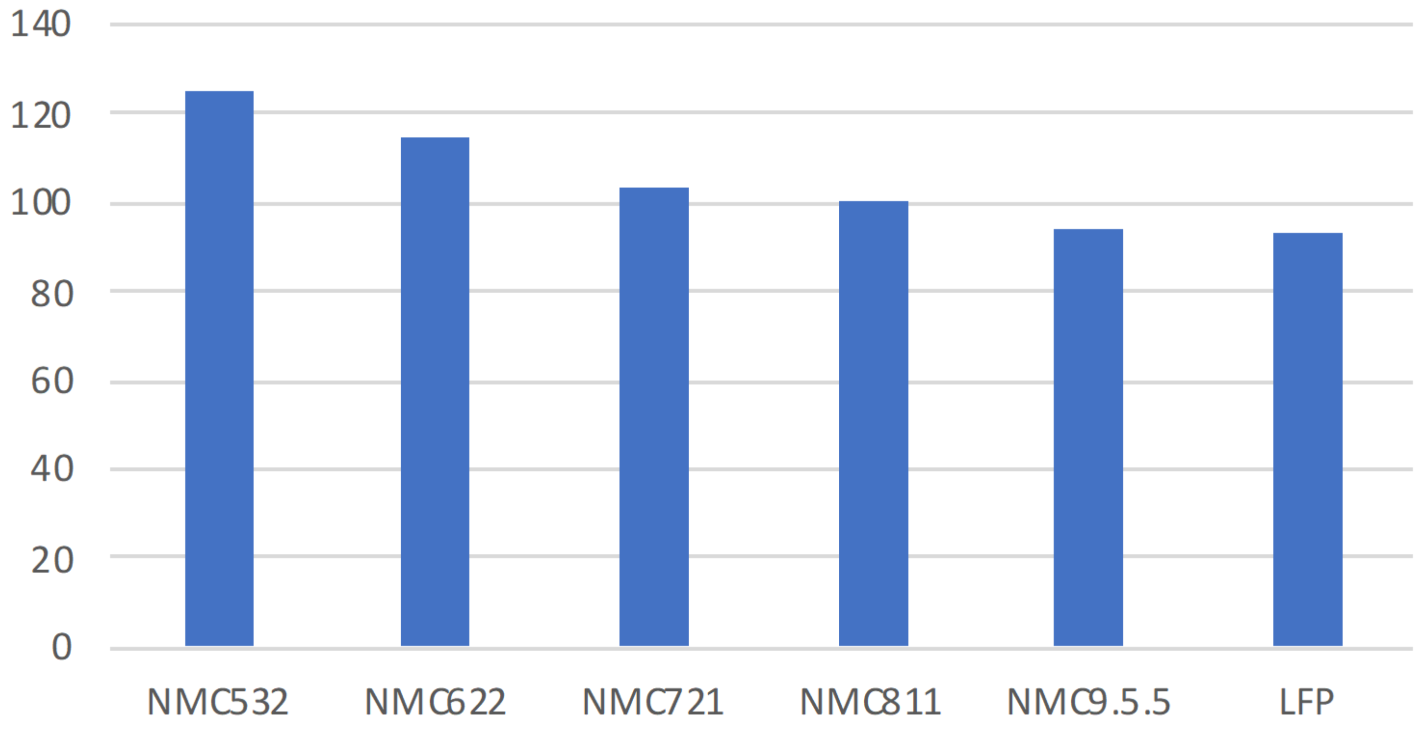


Source: Exawatt

A widespread transition to LFP would reduce pressure on the lithium supply…

…as would increased adoption of sodium-ion batteries

Relative LCE consumption per kWh of EV battery (NMC811=100)



Source: Exawatt

A widespread transition to LFP would reduce pressure on lithium supply

...as would increased adoption of sodium-ion batteries

We’ll need:

Smaller battery packs (and the chemistries and cell designs that enable them)

Improved charging infrastructure on major roads

Improved “fuel economy” (powertrain efficiency)

Alternative vehicle configurations (range extenders?)

New vehicle ownership models…

…and **reduced lithium intensity – the critical challenge of this decade**

Thank you!

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LME Focus Day 2022

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