Battery Supply Chain in Europe

Overview of Raw Materials, Bottlenecks & Solutions

Mirza Qutab Baig
Sr. Analyst
qutab.baig@powertechresearch.com

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Table of Contents

CO_2 Emissions by Transport Sector

Global CO_2 Emissions

Transport Sector is Contributing Significantly to CO_2 emissions

Approximately one-quarter of global CO_2 emissions are accounted by transportation sector.

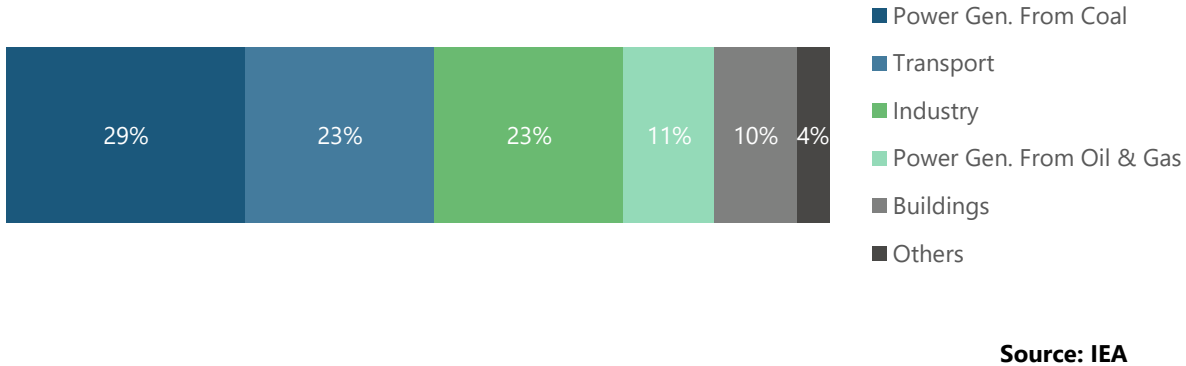
With a share of 23%, the transport industry was the second-largest source of CO_2 emissions.

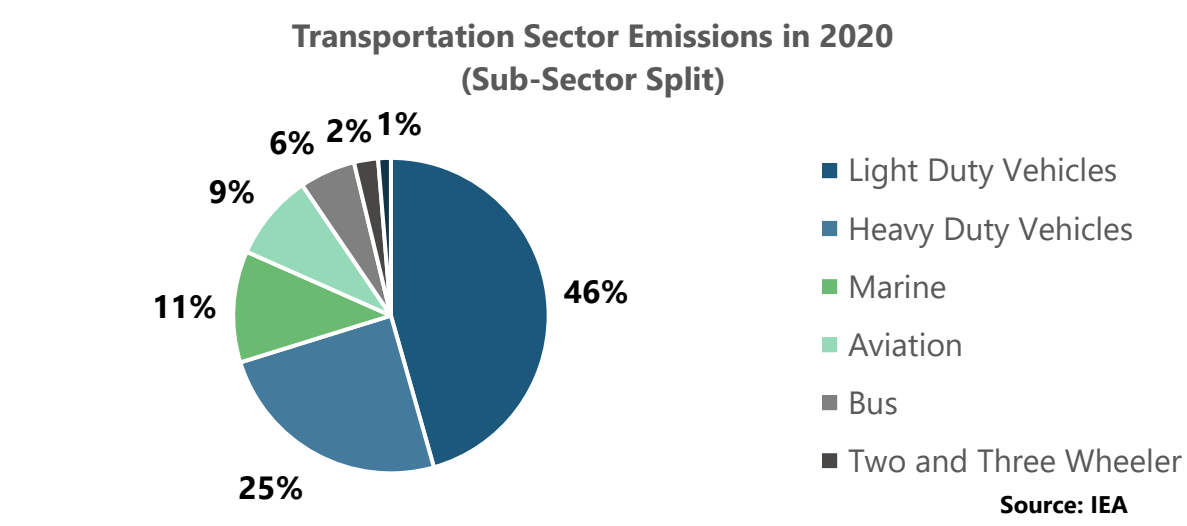
U.S., China, EU, and India account for 46% of the global CO_2 emissions from transportation.

Post Covid-19, the demand for transport sector has rebounded and is expected to rise continuously.

However, the Net-Zero Emissions target requires global transport sector to reduce its emissions by 20%.

The electrification of the transportation sector is necessary for the sector's transition to achieve low-emission targets.

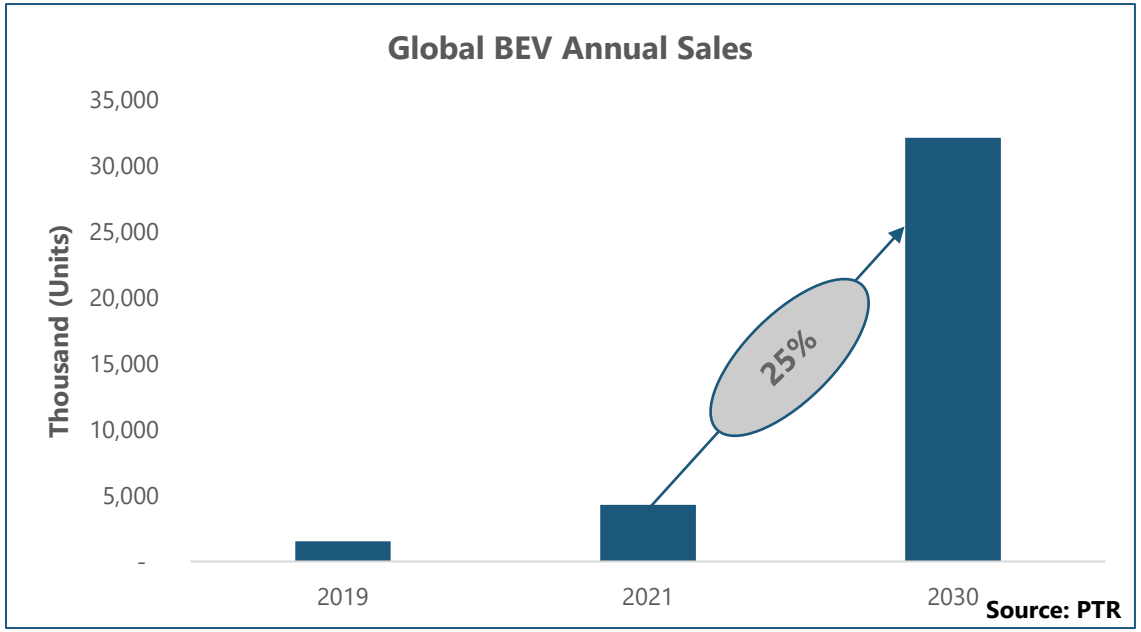


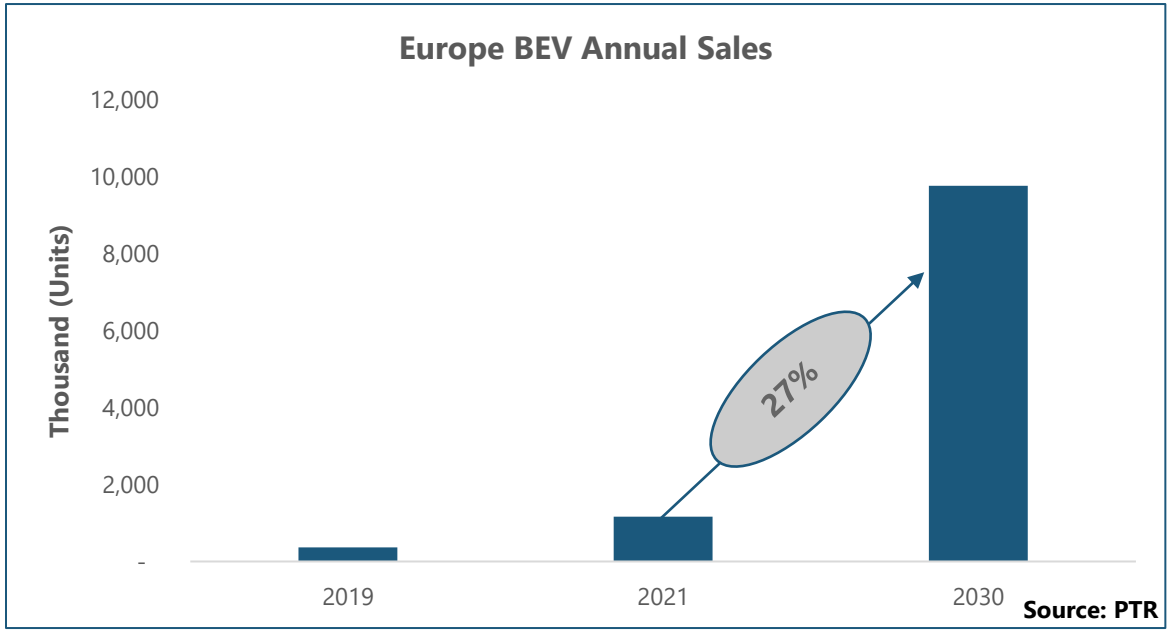


Landscape of Global and European EV Market

Global EV Market for Passenger Vehicles

Unprecedent Growth of Battery Electric Vehicles (BEVs) Market Globally and in Europe





- The global electric car stock gained significant traction in 2021, as a result of efforts and incentives of a decade. China was the leading country in EV market.
- The EV market has been stimulated by govts plans of phasing out Internal Combustion Engine (ICE) vehicles and by vehicle OEMs announcements of introducing electric models.
- Incentives and grants for the EV industry has played a key role in driving the adoption of the green technology.
- Global BEV sales continues to show massive growth, with sales of BEV doubled in 2021 as compared to 2020.

Battery Chemistries and Trends in Europe

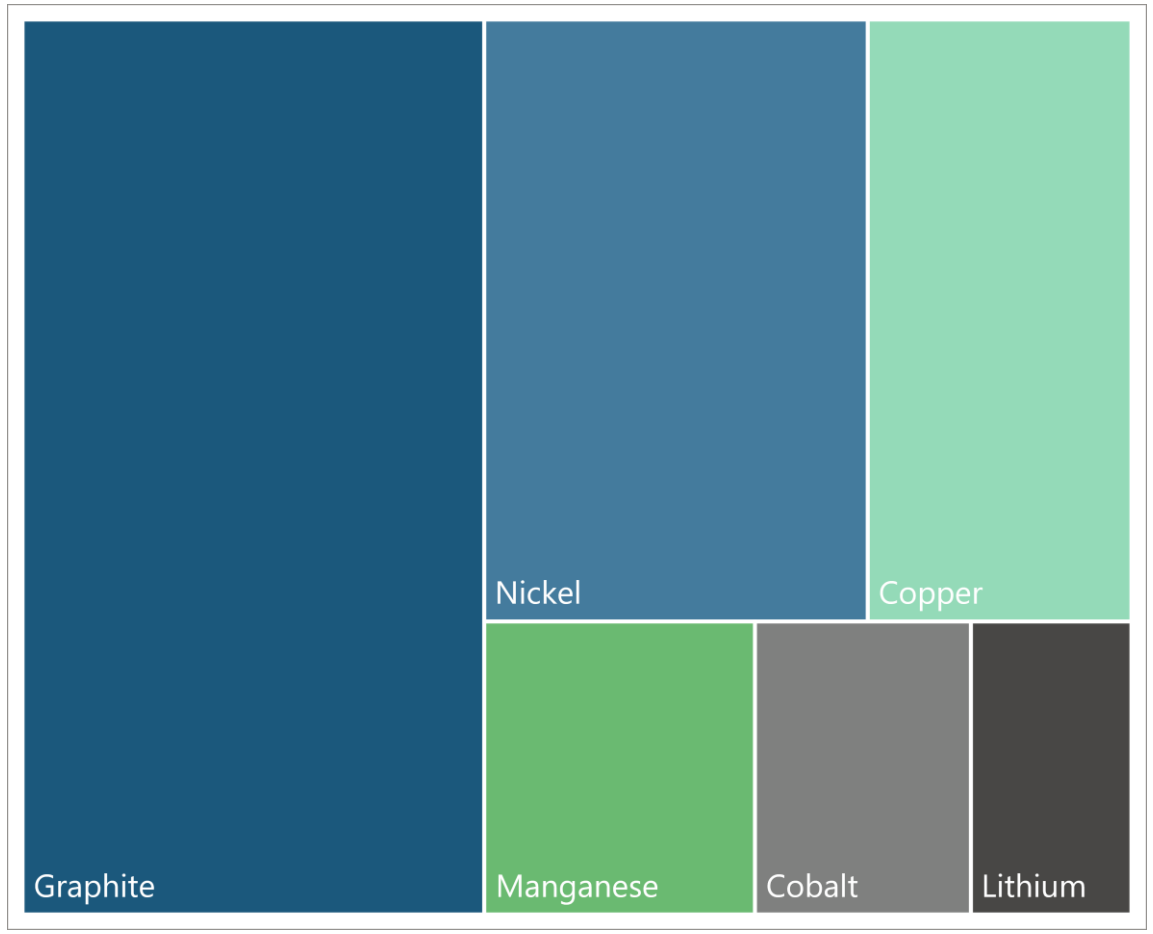
Electric Vehicle Batteries

Overview of Battery Chemistry & Material Breakdown

EV Battery Chemistry Breakdown

LFP	• Anode is made up of graphite and cathode is made up of lithium iron phosphate • One major drawback is its low specific energy
NMC	• Lithium Nickel-Manganese-Cobalt Oxide (NMC) battery possess high energy density • Types of NMC in EVs: NMCS23, NMC622, NMC721
NCA	• Lithium Nickel-Cobalt-Aluminum Oxide (NCA) possess high energy density and power • Requires more safety monitoring.
LCO	• Lithium Cobalt Oxide (LCO) possesses high specific energy and high cost due to content of cobalt • Smart Fortwo EV uses this technology
LMO	• A lithium-ion manganese oxide battery (LMO) uses manganese dioxide, MnO2, as the cathode material. It has around 30% lower energy density than LCO

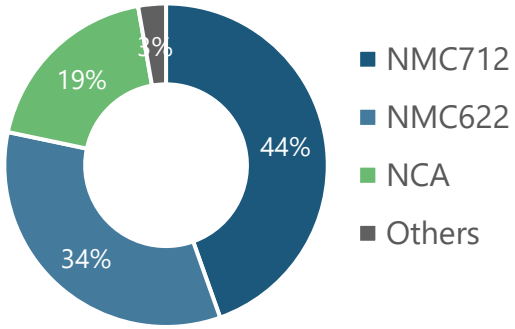
EV Battery Material Breakdown
Based on the weight (kg)



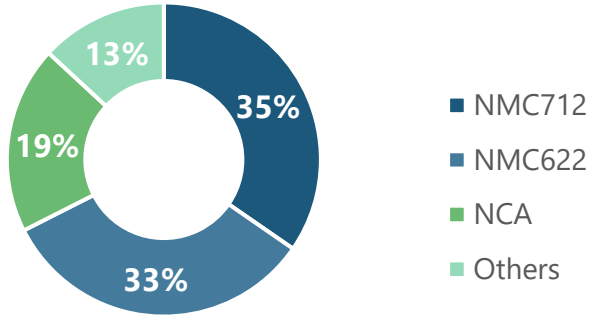
Europe BEV Chemistry Mix - 2020

Overview of Battery Chemistries in Europe

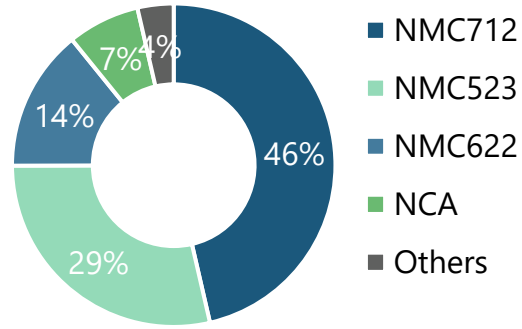
Germany BEV Chemistry Mix (2020 Sales)



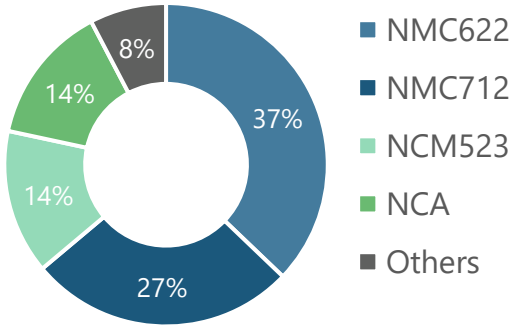
Europe BEV Chemistry Mix (2020 Sales)



France BEV Chemistry Mix (2020 Sales)

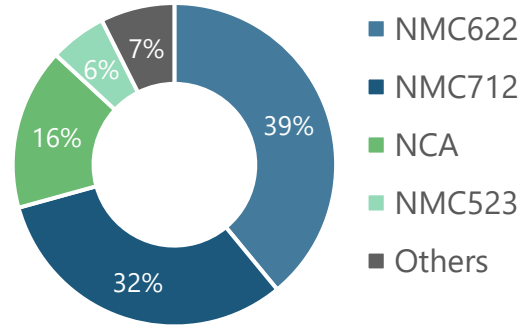


Norway BEV Chemistry Mix (2020 Sales)



- In 2020, 730,538 BEVs were newly registered in Europe and the most prevalent battery used was NMC. There are different variations of NMC depending on the percentages of Nickel (Ni).
- As can be seen in figure, 35% of the BEVs in Europe had the NMC712 variation 33% had NMC622 and 11% had NMC523
- NMC622 (with 60% nickel, manganese 20%, and cobalt 20%) is considered a safe choice

Netherlands BEV Chemistry Mix (2020 Sales)



Others: NMC811, LFP

Source: Cleanfi Oy

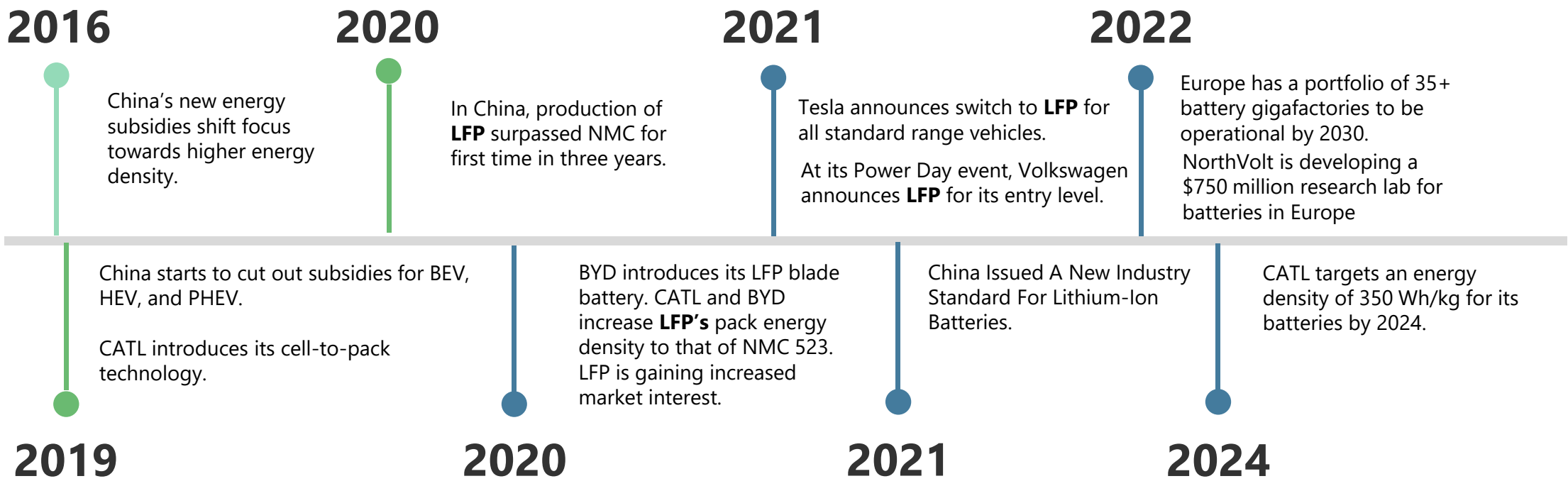
Electric Vehicle Battery Trends

Overall Change in Battery Chemistry Trends

	EV Players	Battery Manufacturers
LFP: Lithium-iron-phosphate technology being used for batteries is gaining traction as it does not require cobalt and nickel content, which makes this battery cheaper.	TESLA, Ford, RIVIAN, Volkswagen	CATL, BYD
Nickel percentage is continuously being increased in NMC/NCA cells to reduce cobalt content. Battery manufacturer in North America are targeting batteries with greater than 90% nickel content in it by 2024.	BMW, RIVIAN, GM	SK innovation, posco
Solid State Batteries will be the newest technology to be used in EVs by next decade. As these kind of batteries have a solid electrolyte, hence they possess more stability and are said to have a lower battery degrading capacity.	Ford, BMW, Mercedes-Benz, TOYOTA	QuantumScape, ProLogium, Solid Power, Panasonic

Electric Vehicle Battery Trends

Advancements in Battery Technology & Production Trends by Battery Manufacturers



Electric Vehicle Battery Trends

Advancements in Battery Technology & Production Trends by Automotive Manufacturers

- Tesla has plans to develop its own battery production capability to reduce reliance on third-party suppliers.
- Tesla Increased its recycling capacity by 50 tons of recycled material per week in 2021.

- SAIC Motor, in collaboration with CATL has plans to develop an EV battery with a range up to 1,000 km before 2025. The battery would have a 30-40% higher energy density as compared to the existing batteries

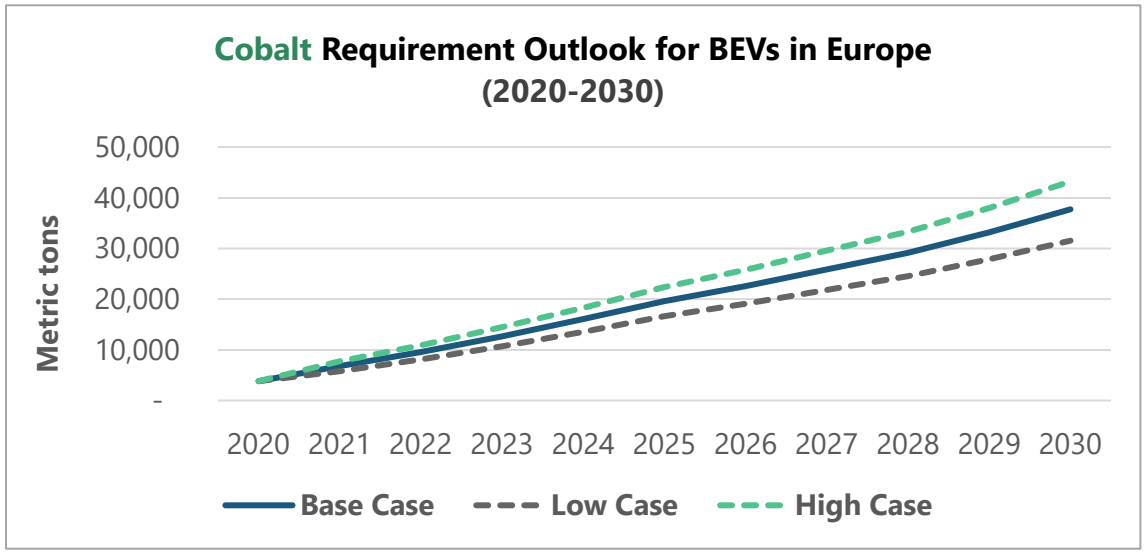
- General Motors is targeting a 60% reduction in battery costs compared to its current Chevrolet Bolt battery by 2025. Moreover, it is also working on increasing the volumetric energy density by 3 times, targeting 1,200 Wh/L.

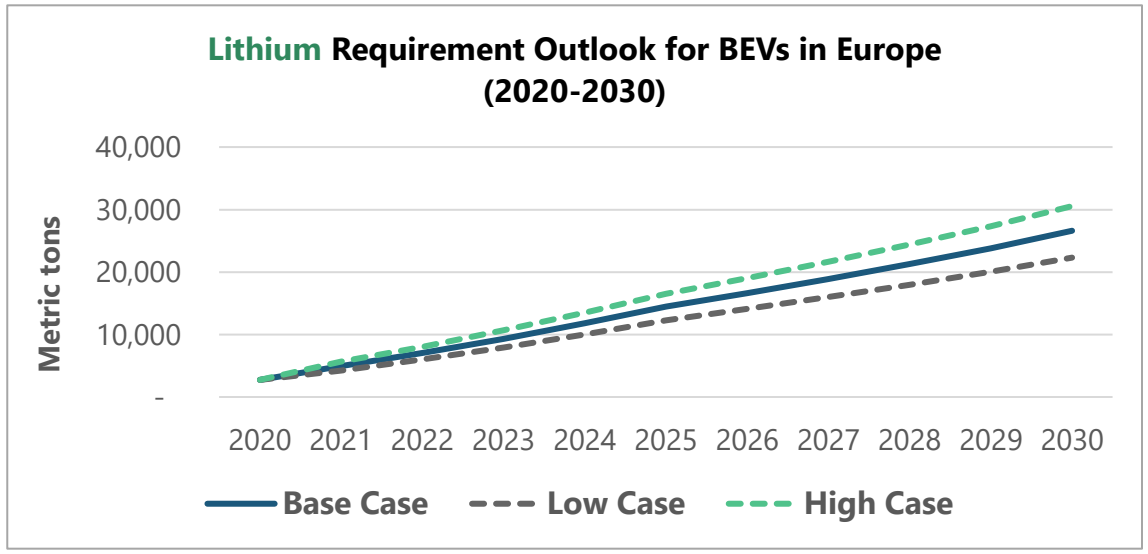
- Hyundai is focused on second life recycling. It has selected Wartsila as a technology and commercial partner, for the utilization of second-life electric vehicle (EV) batteries

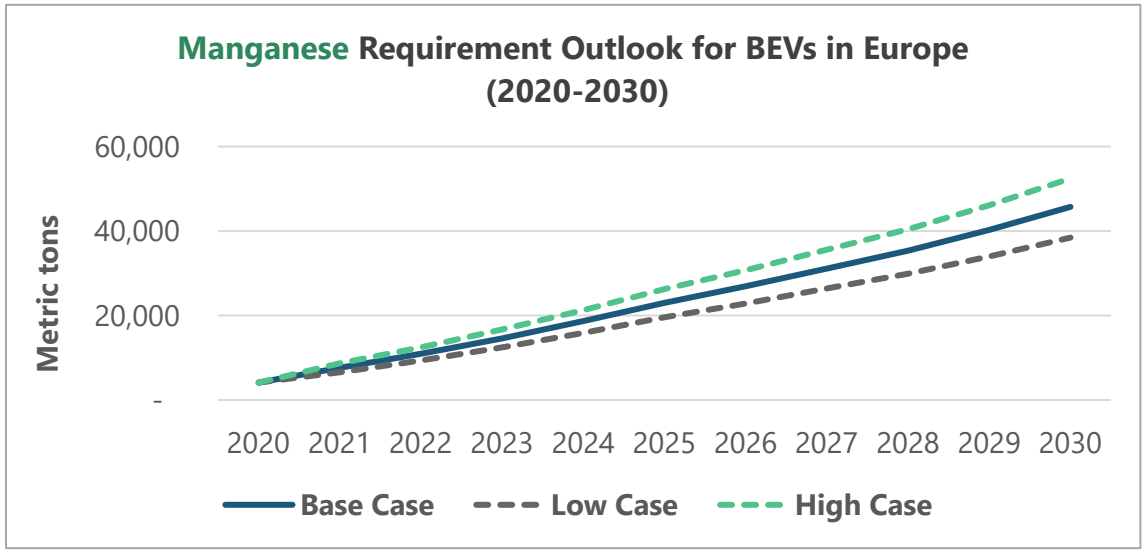
Battery Raw Materials Demand in Europe

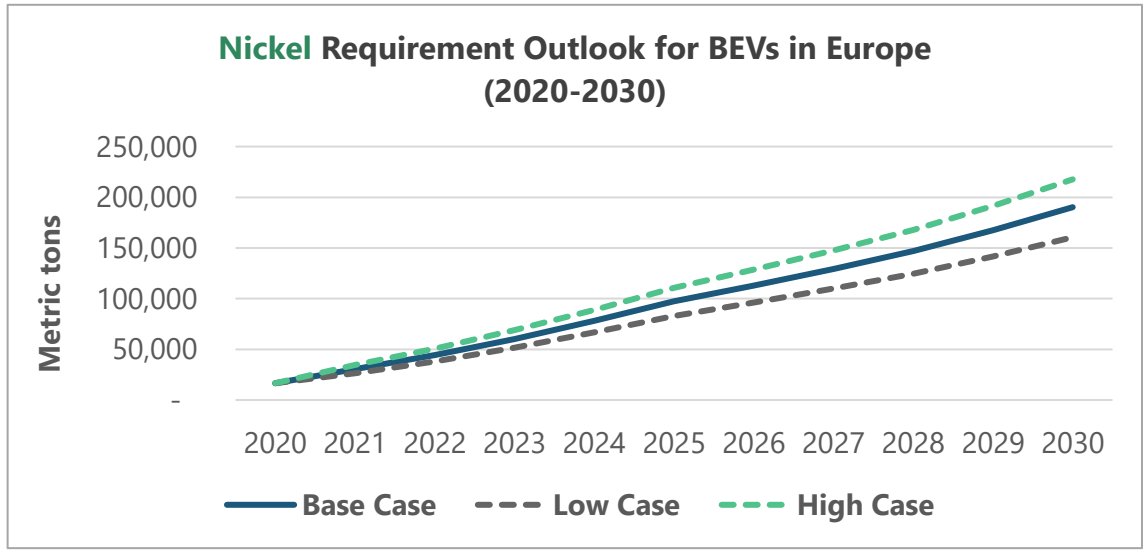
Raw Materials Outlook for Europe

Increase in Demand of Raw Materials used for the EV Battery





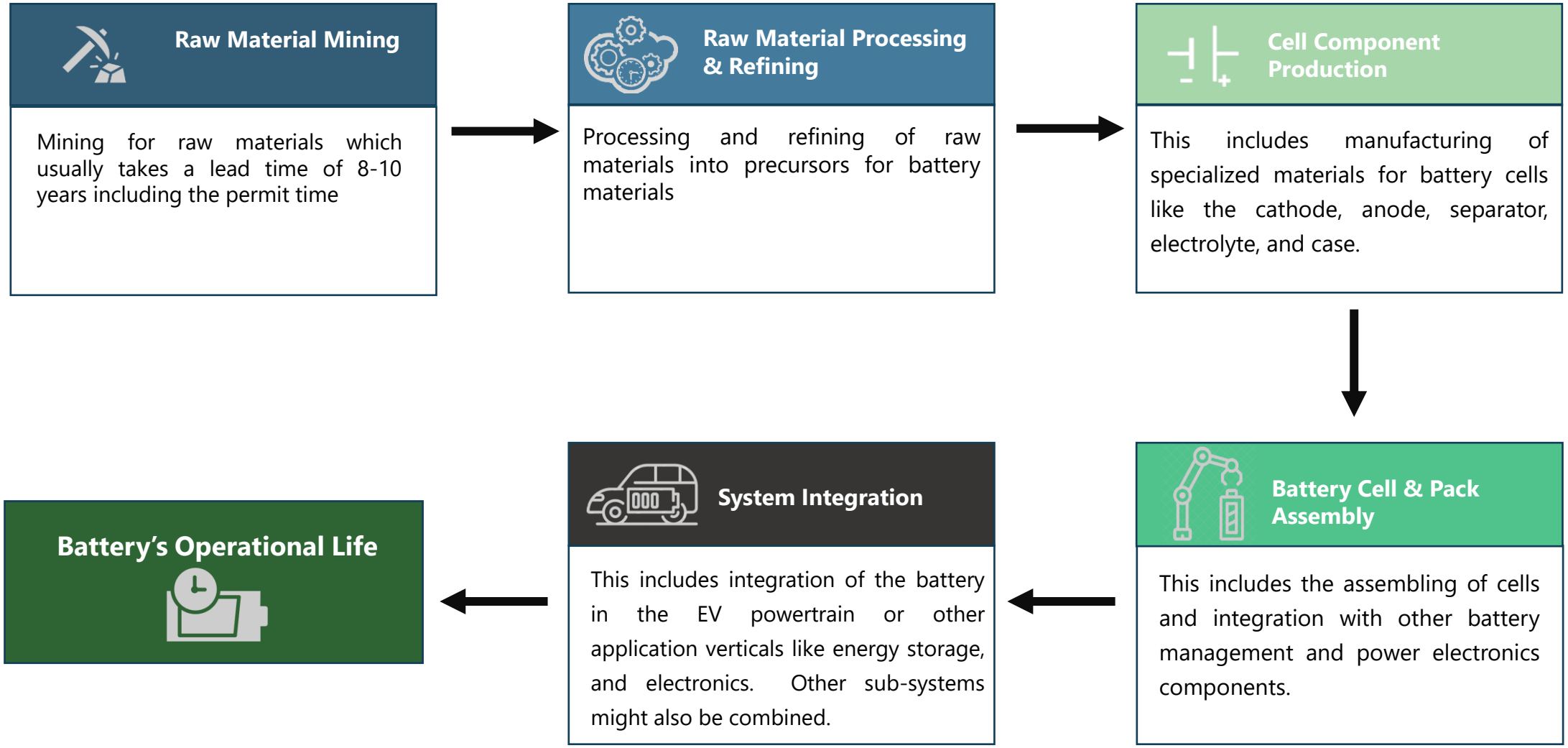




Supply Chain Disruptions in Europe

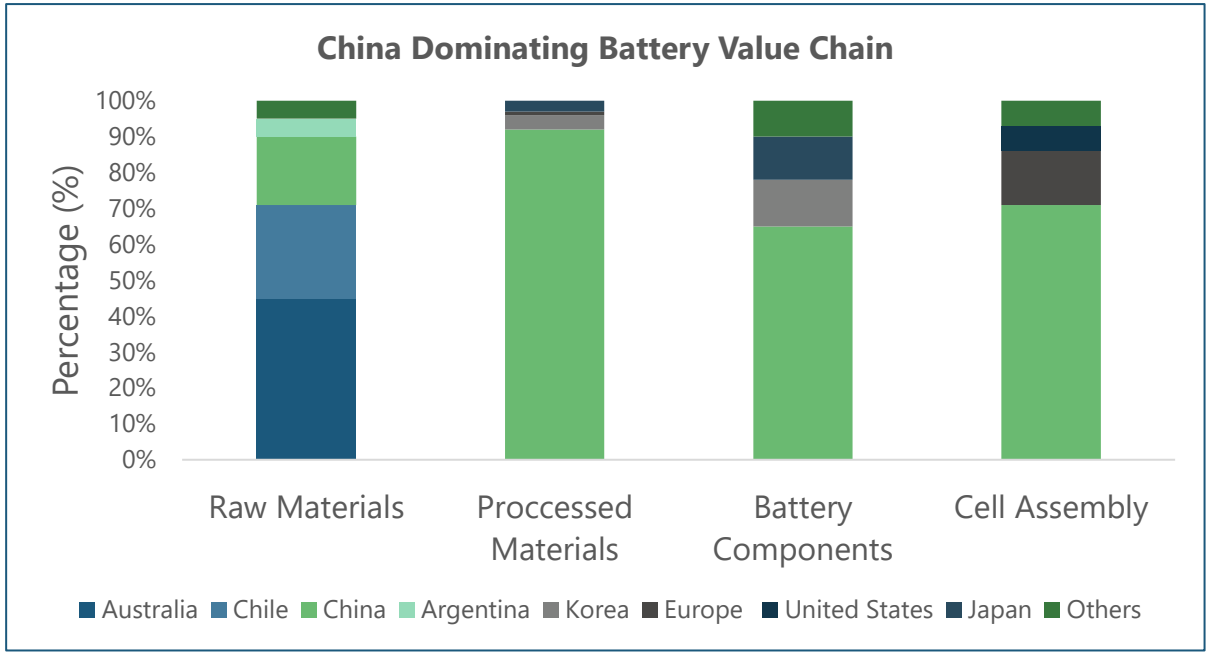
Battery Supply Chain Overview

Stages in Battery Life from mining to commercial utility



Raw Material Supply Chain Disruptions

Challenges in Raw Material Supply Chain Hindering the Outlook for Smooth Energy Transition



Causes of Supply Chain Disruptions

- Rate of EV production vs rate of mining of raw materials.
- Biggest Market of EV i.e., Europe dependent on other regions for raw material sourcing/Raw material sourcing by European EV manufacturers
- Ukraine-Russia crisis
- Covid-19 Pandemic Effect

Raw Material Supply Chain Disruptions

Challenges in Raw Material Supply Chain Hindering the Outlook for Smooth Energy Transition

Challenges for Europe

Planned Gigafactories
in Europe need to secure raw materials for their production

350kt
lithium demand by 2030 from 23kt in 2020 due to massive growth in planned giga factories, e-mobility sector, and stationery storage

Self Sufficiency
of critical raw materials and developing domestic supply chain.

Impact of Supply Chain Disruptions

144%
price increase per vehicle between March 2020 and May 2022.

15%
increase in prices of battery packs if raw material prices continue to increase.

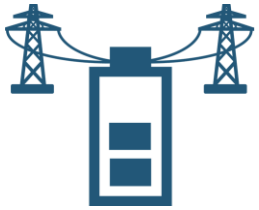
ICEs
sales to be banned by 2035, could also be delayed because of the supply chain disruptions.

Efforts to Secure Raw Material Supply Chain

Secondary Supply Chain Methods

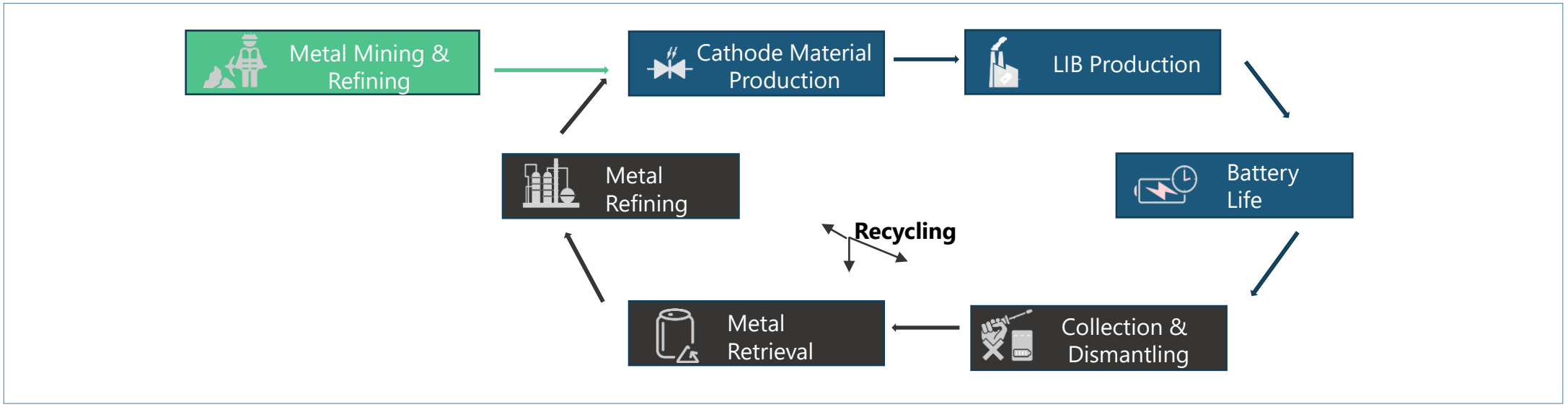
Use of Second Life Batteries & Recycling will enable a circular economy for Europe

- **Reuse/Second Life Batteries**



- Providing second-life to EV batteries
- EV battery experiences only a 20% drop of cell capacity from rated value
- Hyundai has estimated that 29 GWh of second-life batteries will be there by 2025.
- These batteries can be used to meet the demand of energy storage technology.

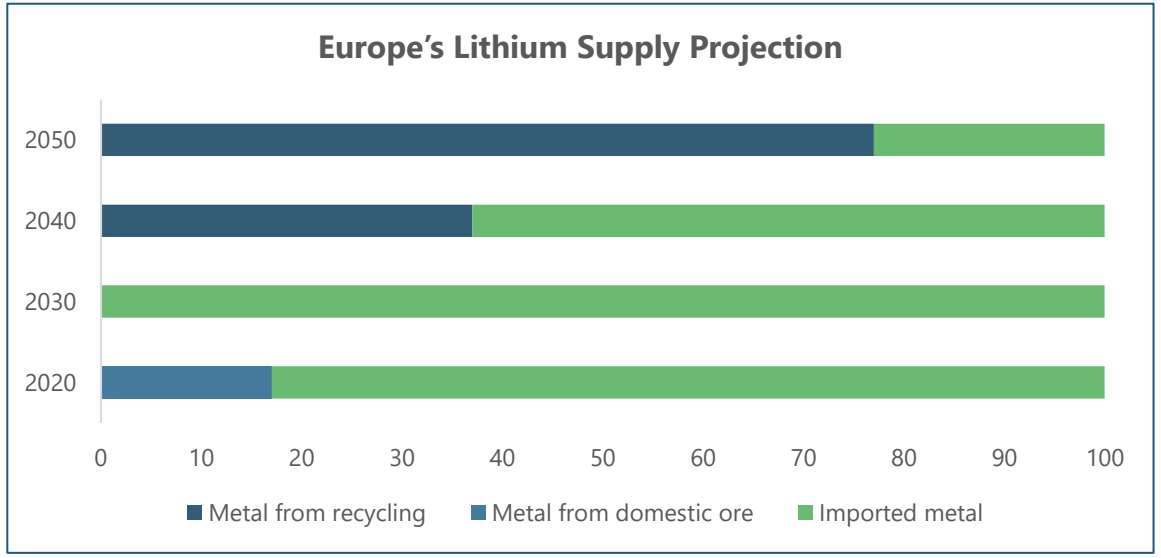
- **Battery Design with Recycling in Mind**



Recycling Potential in Europe

Europe can increase its self-sufficiency by recycling critical raw materials

- Approximately 1.9 million tons of waste batteries are produced annually in Europe.
- In Europe, lead acid batteries lead the pack in recyclability with close to a 99% recycling rate.
- At present, the collection and the recycling rates for lithium-ion batteries are very low, however it has potential to reach 150kt LCE by 2040.
- The EU's proposed Batteries Regulation sets mandatory recycling targets for lithium from batteries, and a recycling efficiency requirement of 70%.



Raw Material Recycling Facilities

Investment in battery recycling initiatives can help Europe develop domestic supply chain

Presence of Recycling Facilities in Europe

	Li-ion	Ni-Cd	Ni-Mh	Pyro metal	Hydro metal	Thermal	Mechanical	Coll/Sort/ Shred/Prep
ACCUREC-Recycling GmbH	✓	✓	✓	✓	✓			
Duesenfeld GmbH	✓				✓		✓	
EDI - Euro Dieuze Industries	✓	✓		✓			✓	
Fortum Corporation (aka Crisolteq)	✓				✓			
Neometals Ltd	✓	✓			✓		✓	
NorthVolt Ett	✓				✓			
Societe Nouvelle d'Affinage	✓	✓	✓	✓	✓	✓		
Veolia Environment	✓	✓			✓			

Material Recycling Methods

Way Forward

Alternatives to navigate through raw material bottlenecks in Europe

Short -Term

Alliances & Partnerships

European battery manufacturer could initiate acquisitions and alliances to diversify their supply chain of raw materials for their planned gigafactories.

Fundings & Incentives

EU could announce tax incentives and fundings for refining and recycling facilities.

Possible Solutions for Securing Supply chain

Innovation in R&D

Investing in research for alternative technologies which could be used for batteries for energy storage and EVs depending on less critical minerals

Raw Material Supply Chain

To build a supply chain comprising of a balance between imports and domestic production

Long-Term

Questions