EV Battery Technology, Market Trends, the Global Supply Chain, and Investment Implications

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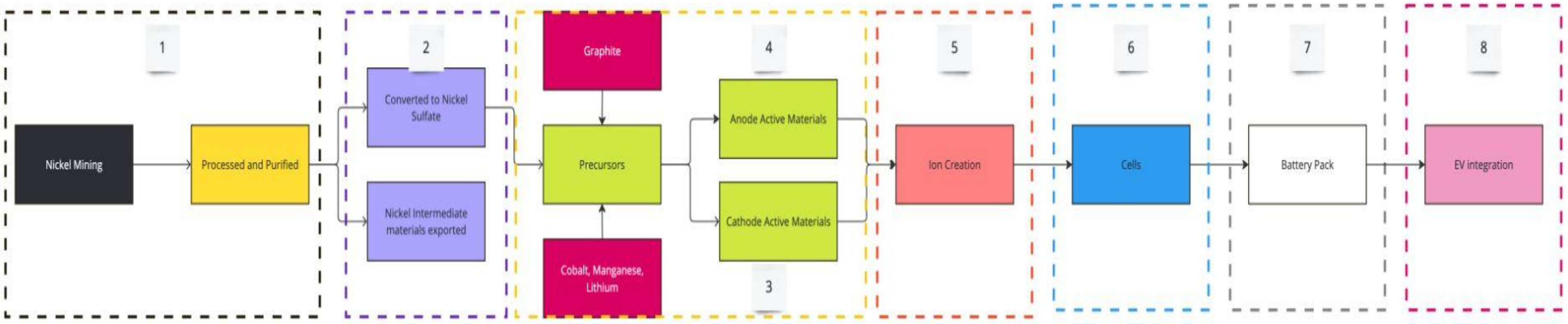


Stages of Production for Nickel-Based Batteries:

Upstream:

1) Mining & Processing

Midstream

2) Production of Nickel Sulfate
3) Cathode Material Manufacturing
4) Anode Material Manufacturing
5) Ion Creation Process

Downstream

6) Battery Cell Manufacturing
7) Battery Pack Assembly
8) Integration into EVs

Types of Nickel Ores	Mining Techniques	Extraction
Sulfide Ores	Underground Mining: Involves creating tunnels to reach the ore deposits	For both types of mining, the ore is accessed by drilling holes then filling them up with explosives to break up the rock. After blasting, the broken rock (muck) is transported to the surface or processing plant. This can be done using haul trucks, conveyors, or lifts.
Laterite Ores	Open-Pit Mining: Involves removing large amounts of overburden to access the ores beneath. Utilises large-scale earth moving operations	

Ore Processing

Processed: Once removed from the Earth, they are processed mechanically: Crushed, sorted, ground, screened, decanted, filtered, and dried

Extraction: After drying, it is treated chemically or through high temperature smelting to extract the nickel

Purification: Further purified with a solution, then converted into nickel sulfate, which is crucial for producing cathode materials for EV batteries

Nickel Sulfate Production

Nickel oxide is then dissolved into sulfuric acid, giving a concentrated solution of nickel sulfate heptahydrate

↓

On further heating and increasing the pressure in the reactor, blue crystalline Nickel Sulfate is formed

↓

By treating the crystals with a diluted solution of Barium carbonate, elimination of impurities takes place.

Cathode Material Manufacturing: Nickel

Raw Material Preparation: Gather the necessary materials. For example, for an NMC battery, the materials needed include processed nickel, manganese, and cobalt. For an NCA battery, this would be nickel, cobalt, and aluminum

Wet Chemical Reaction/Co-Precipitation: The different metal salts are dissolved in water to form a solution. This solution is then reacted with a precipitating agent (usually a base like sodium hydroxide) to form metal hydroxides

Liquid/Solid Phase Separation: Isolating metal hydroxides from the liquid phase

Drying: Removing moisture from the hydroxides

Lithiation and Treatment: Mix the dried hydroxides with a lithium source (such as lithium carbonate or lithium hydroxide). Put the mixture through high-temperature calcination to form lithium metal oxides.

Anode Material Manufacturing: Nickel

Raw Material Preparation: Gather the necessary materials. For example, for an NMC battery, the materials needed include processed nickel, manganese, cobalt, and lithium. For an NCA battery, this would be nickel, cobalt, aluminum, and lithium

Mixing and Formulation: The prepared materials are mixed together with conductive additive (typically graphite) and binders (polymeric materials like PVDF - polyvinylidene fluoride) in a solvent to form a slurry

Coating: Slurry is coated onto a metallic foil substrate (most often aluminum or copper foil) to ensure even distribution of active materials and additives

Drying & Solvent Removal: Undergoes drying to remove solvent, leaving a layer of active material and additives

Ion Creation Process: Nickel

Solvent/Salt Selection: Mixture of solvents chosen based on their ability to dissolve lithium salts. Common ones include ethylene carbonate and dimethyl carbonate. Generally, the lithium salts chosen are $LiClO_4$(lithium perchlorate) and $LiPF_6$

Formulation and Mixing: Selected solvent/solvent mixture is combined with the lithium salt. Additives such as stabilizers and flame retardants may be incorporated to enhance the performance of the electrolyte

Purification and Degassing: Electrolyte mixture undergoes purification process to remove any impurities. Degassing processes, such as vacuum treatment, are used to remove dissolved gases from the electrolyte

Quality Control/Packaging & Storage: First goes through rigorous quality control to ensure its stability under varying temperature conditions, and then packed in sealed containers

Battery Cell Manufacturing: Nickel

Slitting then drying: Electrode materials are coated onto current collectors, then coated foils are slit into narrow strips. These strips are thoroughly dried to remove and remaining moisture and solvents

Cutting then winding/stacking: Dried strips are cut into individual pieces which are either wound into cylindrical shapes or stacked into layers with separators in between. This allows ion flow and prevents short circuits

Terminal Welding then canning/enclosing: Electrodes are connected to current collectors and terminal through welding. The assembles cell components are then enclosed in metal or plastic casing, which is sealed to prevent moisture and air

Electrolyte Integration: Injects mixture of solvents and lithium salts into the layered assembly of cathode and anode materials.

Formation and Testing for Quality Control: Tests done to ensure safety and consistency. Cell undergoes initial charging and discharging cycle to stabilize performance

Battery Cell Assembly: Nickel

Cell Selection: Cells are selected based on capacity, voltage, and internal resistance. This is a crucial step, and can affect battery performance greatly

Module Assembly & Connection: Individual cells are grouped into modules, then arranged into certain configurations. Individual cells are connected using spot/ultrasonic welding to ensure electric current flow between cells

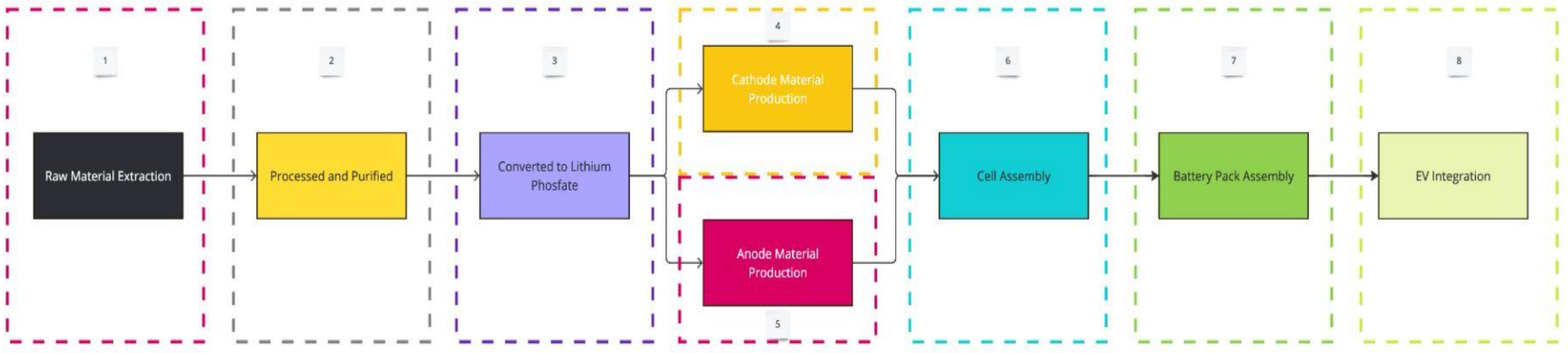
Battery Management System (BMS) Integration: BMS integrated to monitor state of charge (SoC), health (SoH), temperature, and safety parameters, helping prevent overcharging, discharging, and overheating

Housing, Cooling, and Testing: Assembled modules and BMS are placed in protective housing, then cooled. Final testing takes place to ensure it meets performance and safety standards

Nickel-Based Battery Integration into EVs

Key Takeaways:

- Ensure Battery Management System (BMS) is set up correctly to vehicle specifications
- After creating a proper enclosure for the battery pack, mount it within the actual EV chassis. Generally, it is placed in the floor of the vehicle, between the front and rear axles.
- Integrate both high and low-voltage connections between the battery pack and the important parts of the vehicle (motor, BMS, etc)
- Testing: Perform safety tests to ensure that it meets all standards and regulations
- Generally about 3.5-3.7 volts are required for NMC/NCA batteries per cell



Stages of Production for Lithium Iron Phosphate (LFP) Batteries:

Upstream:

1) Mining

Midstream:

2) Processing
3) Cathode Material Manufacturing
4) Anode Material Manufacturing

Downstream

5) Battery Cell Manufacturing & Assembly
6) Integration into EVs

Lithium Extraction Methods:	Future Possibilities:
Hard Rock Mining: - Spodumene ore is extracted using open-pit or underground mining techniques. - The ore is crushed and roasted. After cooling, it is roasted again with sulfuric acid (acid leaching), producing lithium sulfate. - Hydrogen in sulfuric acid is replaced with lithium ions, resulting in lithium sulfate and an insoluble residue.	Opportunities are present with lithium extraction using lithium-bearing clays
Alternate Minerals that are used for commercial extraction, although are not as rich in lithium as spodumene: Lepidolite, petalite, amblygonite, eucryptite.	Another major opportunity is with the use of both hydrochloric acid and sulfuric acid in the acid leaching process
Brine Extraction: Brine (water with a high-concentration solution of salt, typically sodium chloride or calcium chloride) is pumped from underground reservoirs into evaporation ponds. - Solar evaporation concentrates the lithium, a process taking several months. **Note:** While brine extraction might take less labor and is easier to do, it takes a lot longer to extract the lithium than tradition hard rock mining	

Iron Extraction Methods	**Phosphate Extraction Methods**	**Future Opportunities**
Open-Pit or Underground Mining: Iron ores are extracted using conventional mining methods **Blasting and Hauling:** Large-scale blasting and hauling equipment are used to remove the ore from the mine	**Surface Mining:** Phosphate is simply extracted using traditional surface mining	Opportunities being explored for making the process more efficient. For example, the use of automated machinery and robotics in mining can possibly increase precision as well as reduce labor costs among other things.
Iron is extracted from its ore through a process called **smelting**, which involves heating the ore in a blast furnace until the metal becomes spongy and the chemical compounds break down	After extracting the rock, it is crushed and ground. It then takes on a process called **beneficiation**. Essentially, this entails separating and concentrating phosphate minerals from the surrounding material to obtain a high-purity phosphate concentrate. Afterwards, it is processed through acid treatment. Finally, it is purified through a chemical synthesis process, creating lithium iron phosphate	Improvements for the beneficiation process are also being explored to improve the efficiency as well as the recovery rates of the desired concentrates.

Cathode Material Manufacturing: Lithium Iron Phosphate

Batching and Mixing: Weigh and mix iron phosphate, lithium carbonate, glucose, and deionized water in set proportions

Sand Grinding: Transfer mixed slurry to sand mill for coarse grinding to about one micron, then fine grinding to about 300 nanometers

Spray Drying: Put slurry into spray drying equipment where water evaporates quickly, drying the raw material mixture into semi-finished powder

High-Temperature Sintering: Use an automatic loading system to roast spray-dried powder in a high-temperature furnace filled with nitrogen, forming lithium iron phosphate

Jet Pulverization: Use a fluidized bed type airflow pulverizer to crush the roasted material to fine powder, which is then collected

Anode Material Manufacturing: Lithium Iron Phosphate

Material Preparation: Primary active material used is graphite. Conductive carbon black is generally added to enhance conductivity. PVDF is then used to hold the active and conductive additive together

Mixing and Coating: The active material, conductive additives, and binder are mixed in the solvent to form a slurry. Slurry is then coated onto copper foil, which serves as current collector. Then passed through drying oven to leave behind layer of anode

Calendering and Slitting: Dried electrode sheet passed through calendering machine, compressing material. Calendered electrode sheet is slit into narrow strips

Cutting and Final Drying: Slit electrode strips are cut into pieces of a certain size for the battery cells. Cut electrode pieces undergo final drying step to remove moisture

Battery Cell Manufacturing & Assembly: Lithium Iron Phosphate

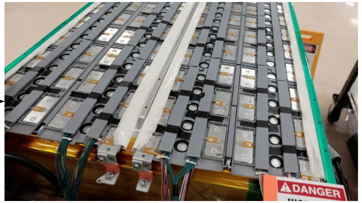
Electrode Preparation: First the LFP material is mixed with a conductive agent and binder to form a slurry, which is coated onto an aluminum foil and dried. Similar process using graphite (anode material) coated onto copper foil and dried

Electrode Cutting: Dried electrode sheets are cut into specific sizes, then pressed to achieve required thickness

Cell Assembly: Depending on choice of cell type, electrodes are stacked/wound, with separators between cathode and anode. Electric tabs are welded onto electrodes to ensure strong electric connections

Electrolyte Filling and Sealing: Assembled cells are placed into casings, electrolyte (typically lithium salt) is filled into the cell. Finally, cells are sealed to prevent moisture

Testing and Aging: Batteries are charged to establish a solid electrolyte interphase (SEI) layer on the anode to permit faster lithium transport, then aged to assess long-term stability



Integration into EVs: LFP Batteries

Key Takeaways:

- Integrate thermal management systems to maintain proper and optimal temperatures
- Implement a Battery Management System to monitor and control cell
- Create a proper enclosure for the battery pack, mount it within the actual EV chassis. Generally, it is placed in the floor of the vehicle, between the front and rear axles in the center of gravity.
- Integrate both high and low-voltage connections between the battery pack and the important parts of the vehicle (motor, BMS, etc)
- Testing: Perform safety tests to ensure that it meets all standards and regulations
- Generally about 3.2-3.3 volts are required for LFP batteries per cell

Most Prominent Competing Battery Technologies

These batteries are the top competitors for the EV market:

- Lithium-Ion Batteries (Nickel Based)
- Lithium Iron Phosphate Batteries
- Lithium Sulfur Batteries
- Hydrogen Fuel Cells
- Sodium Ion Batteries
- Solid-State Batteries

Lithium-Ion Technology

Overview	Advantages	Disadvantages
Battery electric vehicles (BEVs) use lithium-ion batteries (such as NMC, NCA, or LFP) to store electrical energy and power the electric motors Main Component: - Nickel - Manganese	- **Energy Efficient:** BEVs are extremely efficient in converting stored electrical energy to motion, with efficiencies generally around 80-90% - **Infrastructure:** Electric charging infrastructure is currently more widespread and is developing at a rapid pace worldwide - **Environmental Impact:** Zero tailpipe emissions	- **Range and Charging Time:** Despite improvements and new innovations, these BEVs face challenges with range and charging times compared to traditional internal combustion engine vehicles and other technologies - **Recycling Processes:** Recycling a lithium-ion battery consumes more energy and resources than producing a new battery - **Extraction Processes:** Cobalt, a big component, is mined in the Democratic Republic of Congo, where the mines are plagued with human rights issues

Lithium Iron Phosphate Batteries

Overview	Advantages	Disadvantages
Lithium Iron Phosphate (LFP) batteries are another type of lithium-ion battery that use lithium iron phosphate as the cathode material. Many major EV suppliers such as Tesla and BYD utilize LFP battery types in the majority of their vehicles	- **Safety:** Generally, LFP batteries are more stable and also less prone to thermal runaway as compared to other lithium-ion batteries - **Longer Cycle Life:** These batteries have a longer lifespan, often exceeding 3000 charge-discharge cycles. For comparison, NMC batteries typically achieve 1000-2000 cycles - **Cost-Effective:** As LFP batteries use materials that are more abundant, the cost of production is lower	- **Lower Energy Density:** The most relevant downside is that LFP batteries have lower energy densities compared to NMC and NCA batteries, resulting in a larger and heavier battery for the same capacity - **Lower Voltage:** Lower nominal voltage of LFP cells could lead to overall lower energy output

Lithium Sulfur Batteries

Overview	Advantages	Disadvantages
Lithium Sulfur batteries are an emerging form of battery technology that use sulfur as the cathode material and lithium as the anode. There is currently a lot of ongoing research into the viability and usage of this battery type, due to some concerns with the battery chemistry	- **Higher Energy Density:** Li-S batteries have a higher energy density, which can potentially provide longer ranges and higher power outputs for EVs while still remaining compact. Theoretically, the use of sulfur in an EV could double its range compared to Li-ion - **Availability/Cost-Effective:** Sulfur is cheap and plentiful, while also remaining inexpensive, especially as compared to lithium ion batteries that use cobalt and nickel. Li-S batteries have the potential to make electrification something that is abundant	- **Stability Issues:** Research is still being done to formulate a chemistry which ensures the stability of both the lithium and sulfur, both of which are often difficult to control - **Shorter Life Cycle:** Generally lasts around 1000 charge-discharge cycles, as compared to 2000 from li-ion. The source of this problem is the chains of lithium polysulfides that form during each charge, which simply clog such batteries. Many methods have been tried to increase the lifespan of such cells, but each had its drawbacks.

Hydrogen Fuel Cells

Overview	Advantages	Disadvantages
Hydrogen fuel cells are another type of cell that instead converts hydrogen gas into electricity through a chemical reaction with oxygen. Fuel cell electric vehicles (FCEVs) use hydrogen stored in high-pressure tanks to produce electricity, which then powers an electric motor	- **Higher Energy Efficiency:** Fuel cells avoid thermal bottlenecks because it directly converts chemical potential energy to electricity. Higher efficiencies compared to regular internal combustion, but worse than BEVs - **Decarbonized Power:** Produces zero tailpipe emissions, and if hydrogen is fueled from renewable energy (such as solar), then process is entirely decarbonized - **Long Range/Quick Refueling:** On a single tank, can often exceed 300 miles. Refuels in just a few minutes similar to gas	- **Charging Infrastructure:** Large lack of widespread hydrogen refueling stations, causing a significant barrier to the adoption of FCEVs - **Hydrogen Production:** Currently, most hydrogen produced from natural gas through steam methane reforming, emitting CO2. Green hydrogen is more sustainable but currently more expensive - **Cost:** Hydrogen fuel cells are expensive to produce, making FCEVs generally more expensive than BEVs

Sodium Ion Batteries

Overview	Advantages	Disadvantages
Sodium Ion (Na-ion) batteries are another form of emerging technology that use sodium ions as the charge carriers, similar to how lithium ions are used in lithium-ion batteries. It is generally seen as the most viable alternative to lithium ion batteries, and these batteries are already being used by energy companies around the world to store renewable energy.	- **Reduced Costs:** The sodium to lithium ratio in the earth's crust is 23,600 parts per million (ppm) to 20 ppm, essentially meaning that there is a much larger abundance of sodium to be extracted, at a lower cost. Additionally, it can also use lower cost materials, such as replacing copper foils with aluminum foils. - **Scalability:** The factories that produce lithium ion batteries all have the necessary resources to produce sodium ion batteries as well - **Safety:** Lower flammability risk levels due to ability to discharge	- **Lower Energy Density:** Causes vehicle's range to be lower with the same battery size. Lithium batteries have densities between 150-220 Wh/kg (watt-hour per kilogram), while sodium batteries are around 140-160 Wh/kg - **Charging Cycles:** Currently, Na-ion life cycles are shorter than li-ion, although there is still a lot of research going into this issue as it is still in developmental stage

Solid-State Batteries

Overview	Advantages	Disadvantages
Solid-state batteries are a more advanced type of battery that uses solid electrolytes instead of the liquid/gel electrolytes. This battery technology seems to have the most potential for revolutionizing the EV industry, although it still has some distance to cover before it reaches production. They are already widely used in smaller devices such as smartwatches and pacemakers, but have yet to be fully developed in the EV space	- **Energy Density:** Due to the use of solid electrolytes compared to liquid electrolytes, these batteries can hold anywhere between 2 to 10 times the capacity of a lithium-ion battery - **Safety:** Use of solid electrolytes completely eliminates the risk of leakage and flammability associated with liquid electrolytes, reducing the risk of fires and thermal runaway - **Faster Charging:** These batteries can support significantly faster charging times, and they have the potential for long lifecycles too	- **Cost:** Currently, the manufacturing process and the materials needed are expensive, especially compared to li-ion batteries. - **Development Stage:** Solid-state batteries are still largely in the R&D phase, with several technical challenges as well as manufacturing challenges to scale production

Ecosystem of Recycling: Comparison between Battery Types

Key Takeaways:

- Recycling batteries at the end of their life cycles is crucial to minimize the negative environmental impact, recover valuable materials, and ensure the overall sustainability of the production process
- Viable recycling processes only exist for these battery technologies today:
  - Lithium-Ion Batteries (Both nickel-based and LFP)
  - Hydrogen Fuel Cells

Lithium Ion Batteries

Recycling Processes	Economic Viability	Challenges
- **Hydrometallurgical:** Begin by shredding batteries into a powder called black mass. The black mass is then leached with acid. Metals like cobalt, lithium, and nickel are taken out from the resulting liquid and converted into raw materials for batteries. - **Pyrometallurgical:** Burn batteries in a furnace to produce a slag containing lithium, which isn't usually recovered, and an alloy of other metals, like cobalt, copper, and nickel. Those metals are then separated and converted into chemicals for battery production.	Instead of recycling and reusing the same battery, they simply extract the valuable metals/resources from the batteries. There is a large and established market for these recycled materials such as nickel, cobalt, and lithium, providing strong financial incentives for recycling	- **Complex Disassembly**: Disassembly is extremely labor and energy-intensive for this process, on top of being costly - **Environmental Impact** Certain recycling practices, especially pyrometallurgical, can be energy-intensive and harmful to the environment - **Safety:** Handling used batteries involves certain risks as a result of hazardous materials

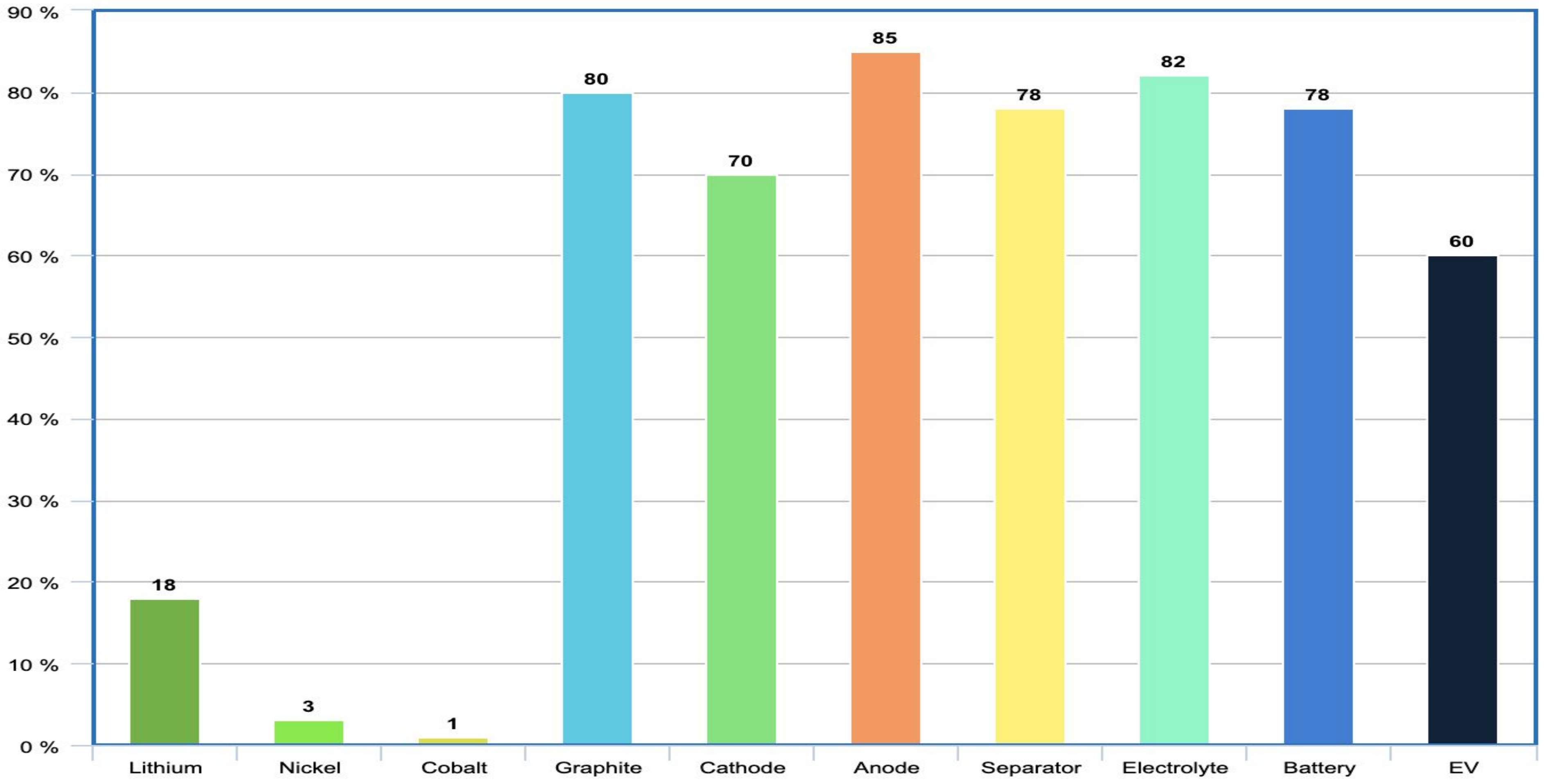
Hydrogen Fuel Cells

Recycling Processes	Economic Viability	Challenges
- **Mechanical Processing**: Initial disassembly of fuel cell components to separate materials. The components, such as bipolar plates, membrane electrode assemblies, and catalysts, are separated for further processing. - **Hydrometallurgical Processing**: Precious metals like platinum, used in the catalysts, are leached from the components using chemical solutions. These metals are then recovered and refined to be reused in new fuel cells.	- **High Economic Value**: The recovery of precious metals, particularly platinum, provides significant economic value. Platinum is expensive and highly sought after, making the recycling of hydrogen fuel cells economically attractive. - **Established Market**: There is a well-established market for recycled platinum and other metals, which provides strong financial incentives for recycling hydrogen fuel cells.	- **Complex Disassembly**: The intricate design of fuel cells makes disassembly labor and energy-intensive, which increases overall costs. - **Environmental Impact**: Certain recycling practices, especially hydrometallurgical methods, can be energy-intensive and may involve the use of hazardous chemicals. - **Technical Barriers**: The technology for efficient recycling of all components of hydrogen fuel cells is still developing, presenting challenges in achieving complete material recovery.

Battery Technology Leaders: China

- Largest producer and consumer of EV batteries.
- Dominant position in the global battery supply chain
- Extensive production capacity and control over key raw materials such as lithium and cobalt.

China's Share in different segments of Global Electric Vehicle Supply Chain %

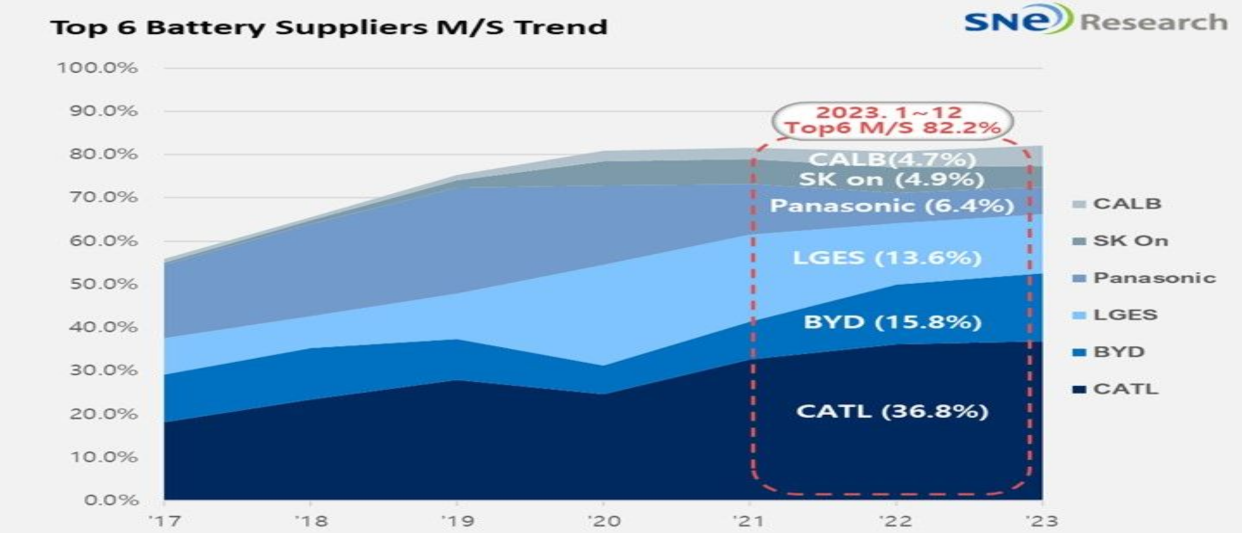


Production Leaders in China: CATL & BYD

- In 2023, **CATL**'s share of the global EV battery market stood at approximately 34%, making them the largest EV battery producer in the world
- They are at the forefront of innovation, especially with LFP and NMC batteries. They partner and supply batteries to many large brands worldwide, include Tesla, BMW, Volkswagen among others
- **BYD** also stood respectably at approximately 15%, making them the second largest EV battery producer globally
- BYD not only produces their own batteries, but they also manufacture their own electric vehicles, giving themselves significant control over the entire production process
- They are one of the leading LFP battery developers, and their competitive edge lies with their low costs and high safety standards. They have also formed many strategic partnerships worldwide with names such as Tesla, Toyota, and more
- **Both** companies are actively working to develop new battery technologies, with a large focus on Sodium Ion batteries especially

Battery Technology Leaders: South Korea

- 3 companies leading the market create the global presence for South Korea
- Second largest market share in global EV battery market
- Renowned for their innovation in multiple battery chemistries, particularly NMC and NCA
- Large Scale Manufacturing



* Annual Cumulative Global Battery Usage for xEV (Unit: GWh)

Rank	Battery Supplier	2022. 1~12	2023. 1~12	Growth Rate	2022 M/S	2023 M/S
1	CATL	184.4	259.7	40.8%	36.2%	36.8%
2	BYD	70.5	111.4	57.9%	13.9%	15.8%
3	LG Energy Solution	71.6	95.8	33.8%	14.1%	13.6%
4	Panasonic	35.6	44.9	26.0%	7.0%	6.4%
5	SK On	30.1	34.4	14.4%	5.9%	4.9%
6	CALB	18.5	33.4	80.9%	3.6%	4.7%
7	Samsung SDI	23.9	32.6	36.1%	4.7%	4.6%
8	Guoxuan	13.9	17.1	23.1%	2.7%	2.4%
9	EVE	7.0	16.2	129.8%	1.4%	2.3%
10	Sunwoda	9.1	10.5	15.4%	1.8%	1.5%
Others		44.4	49.4	11.3%	8.7%	7.0%
Total		509.2	705.5	38.6%	100.0%	100.0%

Production Leaders in South Korea: LG Energy Solution, SK On, & Samsung SDI

- In 2023, **LG Energy Solution** stood as the 3rd largest EV battery producer globally, behind CATL and BYD
- They are renowned worldwide for their expertise in lithium ion batteries, including NCMA cathode
- In 2023, **SK On** and **Samsung SDI** stood at a market share of approximately 5% and 4.6%, respectively, placing them at the number 5 and 7 spots globally, respectively
- **SK On** is known and highly respected for their high performance NMC batteries, also seen through their various partnerships with companies such as Ferrari and Nissan
- **Samsung SDI** is perhaps the most promising of the Korean companies in their strive for solid state and alternative advanced battery technologies. They currently are partnered and supply batteries to companies such as Volvo and Hyundai
- All 3 countries are at the forefront of the push for solid-state batteries, a new technology that promises innovations such as better safety, energy density, and more

Government Policies & Incentives

- Purchase Incentives
  - Direct Subsidies/Grants
    - Examples:
      - In the US, the Inflation Reduction Act (IRA) provides a tax credit of up to $7,500 for new EVs and FCEVs
      - China provides a subsidy of US$2,700 to consumers who switch from conventional fuel-based cars to EVs
  - Tax Rebates
    - Examples:
      - In Austria, the government offers large VAT rebates for EVs under $80,000
      - German government offers buyers up to €9,000 in grants for EVs and plug-in hybrids

Government Policies and Incentives

- **Charging Infrastructure Development**
  - **Government Investment in Charging Networks**: Funding for building extensive public EV charging infrastructure
    - Examples:
      - European Union: As a union, they outlined minimum requirements for the creation of the necessary infrastructure to support EV usage and the EU's climate objectives
      - China: China has the largest public EV charging infrastructure in the world, including the most fast chargers and slow chargers. This development is to support their ambition of supporting the world's largest EV fleet

Government Policies and Incentives

- **Battery Recycling and Research Funding**
  - **Government Investment in Battery Technology:**
    - Examples:
      - Japan: As part of their circular economy vision, Japan has developed plans to subsidize and assist with battery recycling projects
      - European Union: The Horizon Europe program is a major programme in the EU to promote research and development; it is also a key provider for funding towards battery technologies

Geopolitical Factor

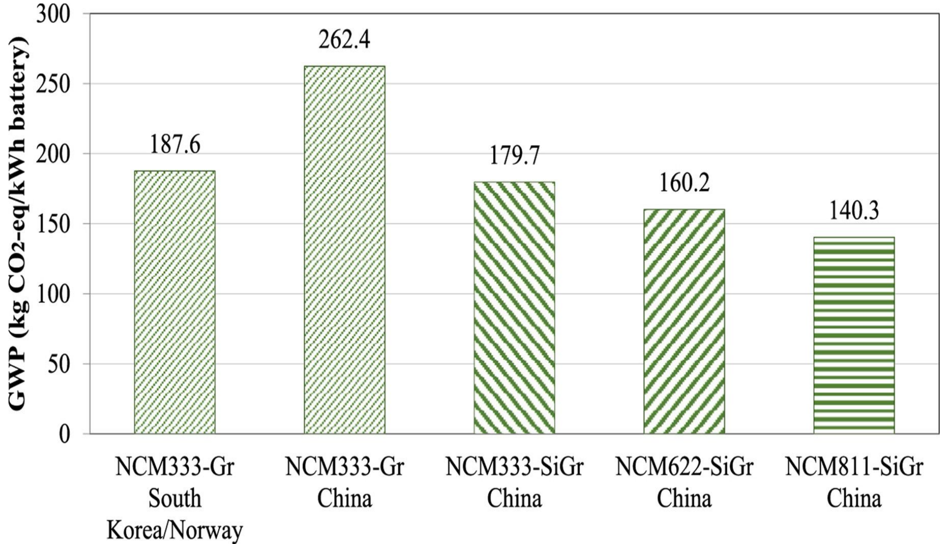
Global Supply Chains for Battery Materials:

- Critical Minerals and Human Rights Violations
  - Examples:
    - The Democratic Republic of Congo:
      - The DRC supplies over 70% of the world's cobalt, a mineral necessary for lithium-ion batteries
      - Cobalt mining in the DRC is heavily associated with several severe human rights violations, including child labor, poor working conditions, and environmental degradation.
    - South America:
      - Lithium is heavily mined in areas like and around Chile, Argentina, and Bolivia (the Lithium Triangle)
      - Indigenous communities in the lithium triangle have protested against lithium mining, which they say threatens their way of life.

Geopolitical Factor

Ethical Sourcing:

- China's Dominance in Battery Production
- China has been heavily critisized for their mining and refining processes' heavy impact on the environment
- China has major role in DRC's mining operations, linked to human rights abuses



Geopolitical Factor

Ethical Sourcing Response:

US/EU Response:

- The EU & the US are actively trying to reduce reliance on Chinese-based production, and have also setup regulations to control the impact
- Section 1502 of Dodd-Frank addresses human rights by targeting conflict minerals, reducing funding for armed groups in mining regions such as the DRC
- The European Battery Alliance promotes responsible sourcing and recycling initiatives to reduce reliance on ethically problematic suppliers.

Geopolitical Factor

Alliances: Free Trade Agreements

- **Supply Chain:** FTAs can streamline trade and reduce tariffs on essential materials and components for EV battery production, fostering a more efficient supply chain and encouraging investment in local manufacturing.
- **Market Access and Expansion**: FTAs provide manufacturers with easier access to larger markets by reducing trade barriers, helping scale their operations, increase production capacity, and potentially lower costs through economies of scale

Example: USMCA (U.S.-Mexico-Canada Agreement):

- Mandates significant percentage of EV parts from North America, incentivizing local production while reducing reliance on imports such as China
- Encourages sustainable production practices in the region, specifically for the EV sector

Conclusion

Key Takeaways:

- EV battery technology is central to the future of sustainable transportation, with rapid advancements and diverse competing technologies.
- Strategic geopolitical factors and international trade agreements play a critical role in shaping the global battery supply chain.
- Recycling and sustainability efforts are essential to the long-term viability of battery production, impacting both economics and environmental concerns.

Investment Implications:

- Investing in battery technologies offers significant growth potential as EV adoption accelerates globally.
- Strategic partnerships and international cooperation will continue to influence the supply chain, market dynamics, and profitability.

Looking Ahead:

- The evolution of battery technologies, coupled with supportive policies and incentives, will shape future opportunities in the EV market.
- For investors, understanding the technological landscape, sustainability practices, and geopolitical factors will be key to identifying valuable opportunities.