ACHIEVING RESILIENCE AND SUSTAINABILITY FOR THE EV BATTERY SUPPLY CHAIN

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Batteries are a key enabler of the clean energy transition in mobility, which makes their supply chains vital at a time when the electric vehicle (EV) market is growing dramatically and billion-dollar investments have been announced in new EV battery gigafactories around the globe.

However, battery supply chains remain complex, global, and fragile, with many still evolving from scratch. Their resilience is impacted by a growing number of factors, from rising raw material costs to geopolitical disruption. Average battery pack prices have risen in 2022, the first increase since 2013. Environmental, social, and governance (ESG) concerns, greater regulation, and governments' desire to localize battery production add to pressure on already-stretched global supply chains. All of these factors lead to potential bottlenecks that affect production.

Given the importance of batteries to decarbonizing transport and achieving Net Zero targets, resilience in EV battery supply chains is a business, political, and societal imperative.

As this article explains, success requires new, more circular approaches across the wider battery value chain, built on greater transparency and an end-to-end view that will bring security of supply going forward.

THE CHALLENGES TO BATTERY SUPPLY CHAIN RESILIENCE

Batteries are central to current and future generations of EVs. Yet, the precious metals required for today's lithium ion (Li-on) batteries are scarce, and in many cases, current supplies will not meet predicted demand.

As can be seen in Figure 1, the battery supply chain is complex and typically distributed across multiple industrial sectors, geographies, and players.

SUPPLY CHAIN	RAW MATERIAL MINING	MATERIAL PROCESSING	CELL PRODUCTION	BATTERY ASSEMBLY	BATTERY INSTALLATION	LIFECYCLE MANAGEMENT
KEY ACTIVITIES	• REQUIRED RAW MATERIALS AND QUANTITIES DEPEND ON CELL CHEMISTRY • FIVE MINERALS ARE CONSIDERED CRITICAL FOR LI-ION BATTERIES: NICKEL, COBALT, GRAPHITE, MANGANESE AND LITHIUM • MINING METHODS DEPEND ON MATERIALS, LOCATION, ETC.	• DETAILS OF MATERIAL REFINING PROCESS VARY BASED ON TYPE OF MATERIAL • REFINING TYPICALLY INCLUDES PROCESS STEPS OF LEACHING, SOLUTION PURIFICATION AND BATTERY METAL OR BATTERY CHEMICAL PRODUCTION	• CELL PRODUCTION CONSISTS OF THREE MAIN PROCESS STEPS: ELECTRODE MANUFACTURING, CELL ASSEMBLY AND CELL FINISHING • ELECTRODE MANUFACTURING AND CELL FINISHING ARE INDEPENDENT OF CELL TYPE; CELL ASSEMBLY PROCESS DEPENDS ON CELL GEOMETRIES	• CONFIGURATION OF ASSEMBLED BATTERY CELLS INTO LARGER MODULES ALREADY COMBINED WITH SOME ELECTRONIC MANAGEMENT • BATTERY MODULES ARE INTEGRATED IN BATTERY PACK WITH SYSTEMS THAT MANAGE, E.G., POWER, CHARGING AND TEMPERATURE	• BATTERY PACKS ARE INSTALLED IN THEIR SPECIFIC APPLICATION (BATTERY ELECTRIC AND PLUG-IN HYBRID VEHICLES, ETC.) • INSTALLED BATTERIES ARE THEN READY FOR THEIR 1ST LIFECYCLE USAGE	• AFTER SEVERAL YEARS OF USAGE, A BATTERY'S 1ST LIFECYCLE ENDS • BATTERIES ARE EITHER REPURPOSED (2ND LIFECYCLE AS STATIONARY ENERGY STORAGE SYSTEMS) OR RECYCLED • RECYCLED MATERIALS ARE FED BACK INTO CELL PRODUCTION
MAIN OUTCOME	RAW MATERIAL	BATTERY METAL/ CHEMICAL	BATTERY CELL	BATTERY PACK	INSTALLED BATTERY PACK	REUSED/RECYCLED BATTERY

FIGURE 1: THE END-TO-END BATTERY SUPPLY CHAIN

It is also extremely volatile, impacted by a range of factors that challenge resilience, sustainability, and productivity:

1. INCREASING BUT UNPREDICTABLE BATTERY GROWTH

The vast majority (approximately 89 percent) of batteries will be destined for EVs, with a further 8 percent for the energy storage sector. Driven by a combination of rising consumer demand and government action, the EV market is growing dramatically and rapidly. As the world swaps fossil fuels for electric power, countries and players are scrambling to adjust.

To meet this need, global battery production is expected to increase 14-fold between 2018 and 2030, with a CAGR of 25 percent. An impressive number of new, multi-billion-dollar gigafactories have been announced across the globe, funded by a combination of new players, governments and traditional automotive companies. In Europe alone, battery production capacity is expected to reach more than 1,100 GWh by 2030 if all plans are fully realized.

However, the complexity of supply chains and scarcity of raw materials mean there are questions over whether consumer-driven demand for EV batteries can be met on the production side. As was demonstrated by the shortage of semiconductors disrupting production post-pandemic, the automotive supply chain has limited resilience around key components.

To further complicate supply chain planning, there is a wide range of views on how much demand will increase and whether it can be met. Forecasts for global EV battery demand in 2030 vary from 1.5 to 4 terawatt hours (TWh) of annual new installed capacity[1].

Scale will be vital to success, but moving from today's lower production volumes to achieve planned targets is not straightforward. As well as securing raw materials, scaling will require companies to quickly build expertise and invest in the right production tools if they are to operate efficiently and effectively. There are already indications that a lack of available production equipment may become a further bottleneck as multiple new gigafactories are built simultaneously.

2. RAW MATERIAL SCARCITY

Batteries rely on a global supply chain, bringing together a range of materials such as metals from Africa, lithium from Latin America/Australia, nickel from Russia, and refined materials from China. In many cases, first-movers such as Chinese battery manufacturers have already secured vital supplies, leaving new players searching for sources. Raw material prices have risen dramatically – the average copper price has increased significantly from approximately $6.0k/mt in 2019 to approximately $9.3k/mt in 2021, while the average nickel price grew from roughly $13.9k/mt to about $18.5k/mt over the same time period. Prices have spiked even further in 2022 due to geopolitical uncertainty and sanctions.

> ***RAW MATERIAL PRICES HAVE RISEN DRAMATICALLY – THE AVERAGE COPPER PRICE HAS INCREASED SIGNIFICANTLY FROM APPROXIMATELY $6.0K/MT IN 2019 TO APPROXIMATELY $9.3K/MT IN 2021.***

Predicted demand outstrips current supply, particularly in regions such as the EU, which lack major local sources. For example, graphite, lithium, and cobalt are already on the European Commission's list of critical raw materials, flagged as potentially having high importance and supply risks. There is a danger that current fossil fuel dependencies in areas such as the EU could simply be replaced by new dependencies on imported minerals required for EV battery manufacture.

1. https://www.iea.org/data-and-statistics/charts/annual-ev-battery-demand-projections-by-region-and-scenario-2020-2030

3. VOLATILE MARKET DYNAMICS

Not only do battery manufacturers have to secure the right materials, but they must also ensure these are delivered on time and in sufficient volumes. Supply chain disruptions caused by the pandemic, the closure of the Suez Canal, and sanctions on Russia all highlight a lack of resilience that impacts production. Increasing tensions between China and the West are also leading European and US players to reduce their exposure to and reliance on the country. Growing protectionism around the world is likely to increase risks as governments potentially channel local resources to their own national champions.

THE SHIFT TO EVS CHANGES THE DYNAMICS OF THE AUTOMOTIVE MARKET, WITH BATTERIES MAKING UP A MUCH HIGHER PERCENTAGE OF A VEHICLE'S VALUE (40 PERCENT IN 2020, PREDICTED TO DROP TO APPROXIMATELY 27 PERCENT IN 2030).

The shift to EVs changes the dynamics of the automotive market, with batteries making up a much higher percentage of a vehicle's value (40 percent in 2020, predicted to drop to approximately 27 percent in 2030). This impacts the relationships between players, and how much value (and margin) they can derive from EVs.

On the technology side, future battery composition is not fixed. A raft of new chemistries are being introduced to meet demands for greater power and capacity and reduce cost by lowering reliance on scarcer materials, and at the same time increase sustainability. Players, whether manufacturers, OEMs, or recyclers, all need to be able to build plans that cope with this uncertainty.

4. GROWING REGULATORY OBLIGATIONS

Players in the value chain need to meet a growing number of existing local and international regulations for safely and responsibly extracting raw materials, and then producing, transporting, and disposing of batteries when they reach end of life.

Regulations are increasing as the market for li-ion batteries grows. For example, the proposed EU Regulatory Battery Framework will increase the percentages of recycled content required within new batteries and set stricter targets for recycling efficiencies. The aim is not only to drive a more circular battery economy, but also to reduce reliance on importing or mining scarce raw materials, which will further drive down the carbon footprint of EVs. Battery recycling also brings new, growing opportunities for players.

5. THE REQUIREMENT FOR SUSTAINABILITY

Many argue that while EVs themselves do not rely on fossil fuels, the supply chain that creates their batteries has major environmental and social impacts due to mining, refining and transport. Regulations such as the EU Battery Framework and the increased focus on measuring and reporting on ESG impacts are making the supply chain more transparent, as is the push to create a circular battery economy.

Achieving sustainability is a key requirement across the supply chain, as companies need to meet ESG criteria and invest in areas such as recycling to increase resilience. Certification must be in place to show that any new raw materials have been mined responsibly. Demonstrating sustainability is also vital to increase business resilience, as it impacts the ability to attract talent and investment and make sales.

EU LEGISLATION AND POLICIES RELATED TO BATTERY RECYCLING ARE EXPECTED TO IMPACT AND STRENGTHEN THE ENTIRE CHAIN

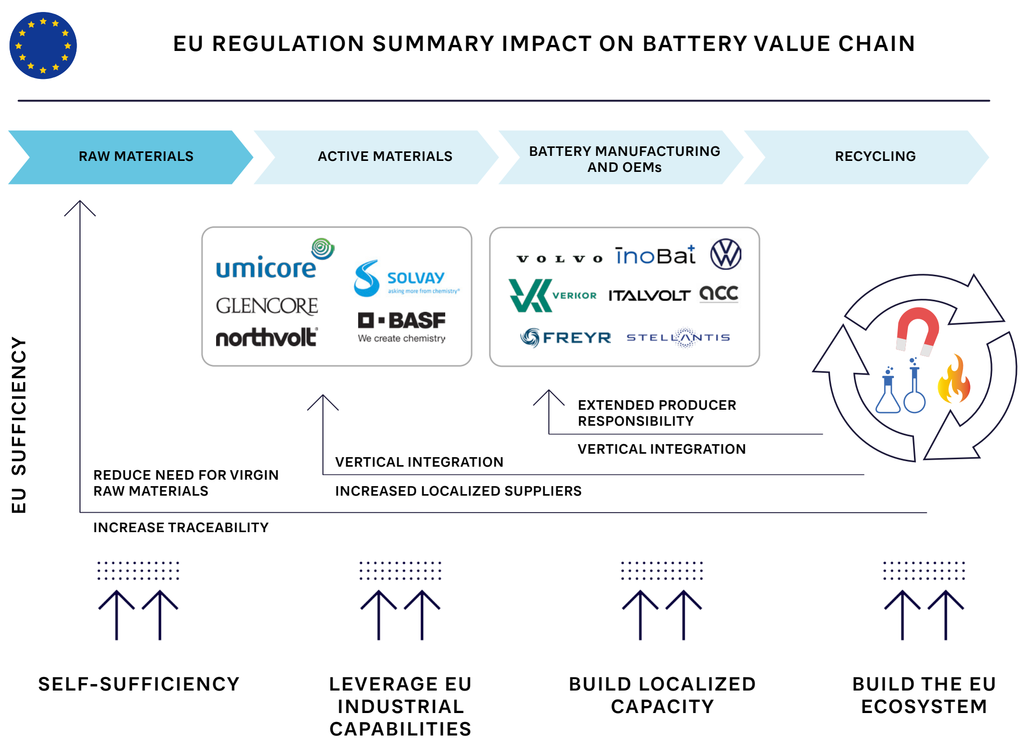

FIGURE 2: IMPACT OF EU LEGISLATION AND POLICIES ON BATTERY VALUE CHAIN

A TOOLKIT FOR BUILDING A RESILIENT BATTERY VALUE CHAIN

The lithium-ion battery value chain differs from other industrial value chains due to its specific challenges. Successfully building resilience into the value chain requires players to take an end-to-end perspective, from raw material sourcing to recycling – wherever they are within the supply chain. They need to understand the key upstream and downstream challenges and how they will impact their business to make plans that increase control. Unlike in many other sectors, the supply chain extends to critical materials, unstable global regions, and various industries, and faces unprecedented surges in demand. This requires a transparent, holistic understanding of supply chain risks, strong forecasting capabilities, and a nimble and innovative approach both upstream and downstream:

ENSURING TRANSPARENCY AND UNDERSTANDING

In such a complex and dynamic supply chain, taking a silo-based approach is simply not enough. For example, if you are a battery cell manufacturer, you need to understand and safeguard both material supply and the end-of-life needs of OEM customers, and research the requirements, constraints, opportunities, and technologies along the whole chain. You then need to use this to identify current and potential risks. More and more battery producers are engaging in upstream and downstream activities – for example, both BYD and Tesla are looking at acquiring lithium sources. Risks can change quickly in a volatile ecosystem, so this needs to be a constant exercise.

DEVELOPING THE RIGHT FORECASTING CAPABILITIES

While it is growing rapidly, the battery market is still immature. There are a range of competing predictions around future demand. Everything from potential battery technology changes to regulation can impact demand for particular raw materials and finished products. Developing strong forecasting across a range of scenarios is therefore vital to deciding where opportunities are strongest and how the right level of supplies can be safeguarded, such as through the right investments. Forecasting should focus not just on raw materials, but also other inputs. For example, the large number of planned gigafactories is leading to high demand for both skilled staff and the equipment used within them. Battery producers are already facing shortages in both areas. This needs to be planned for, along with wider automotive supply chain issues, such as the global shortage of semiconductors.

Once battery players have built this end-to-end perspective, they can understand better how they can control factors to mitigate risks. Typical actions to achieve control cover a spectrum of models, from full vertical integration (as practiced by Tesla) to a looser, partnership-based approach (as done by many other OEMs). Electric vehicle manufacturer BMW, for example, set up a fully fledged battery-cell competence center not to bring production in-house, but to better understand technology and production processes.

STRONG VERTICAL INTEGRATION

One strategic answer to building resilience is vertical integration, a strategy adopted early by Tesla, when it was contrary to then-current industry practice. Pulling key parts of the battery and components value chain in-house gives a high degree of control and mitigates risk. In the case of Tesla, vertical integration includes:

- In-house battery production (and development)
- Significant internal software and semiconductor skills, including designing own chips. This allows greater flexibility and agility – for example, it makes it more straightforward to switch between different types of chip, mitigating availability risks
- Acquisition of suppliers – from those that provide production tooling down to raw material suppliers, and even mining licenses. For example, Tesla has purchased Grohmann Engineering (a specialist in manufacturing automation), ATS Automation Tooling Systems, and Hibar Systems

REGIONALIZATION/VERTICAL INTEGRATION

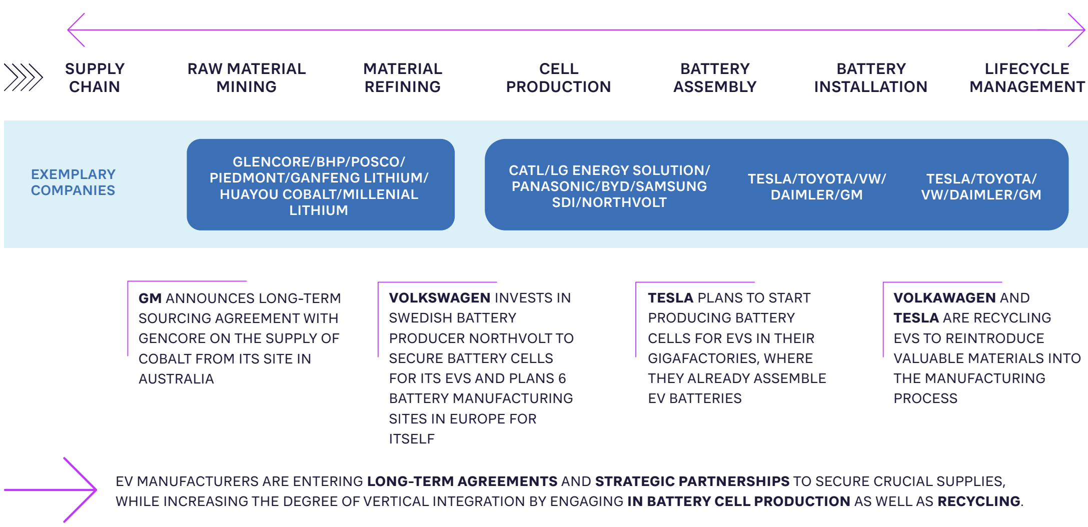

FIGURE 3: PARTNERSHIPS AND VERTICAL INTEGRATION ACROSS THE BATTERY SUPPLY CHAIN

However, full vertical integration is not possible for all players, and does have downsides. In a growing market, acquiring key suppliers or partners requires deep pockets, particularly as there is a shortage of available targets that have not already partnered or taken investment from other, competing players. Given the fast-changing nature of the EV ecosystem, there is also a significant risk that acquisitions will not deliver long-term value or will tie a player to a technology, process, or material that will be potentially superseded.

STRATEGIC PARTNERSHIPS AND ECOSYSTEMS

To avoid risks from straight vertical integration, many EV OEM and battery players enter strategic partnerships. Those provide new approaches to value creation, going beyond traditional buyer/seller relationships. They deliver resilience by minimizing key battery supply chain risks, but also provide access to IP, experience, and innovation. They include:

- Joint ventures and investments. For example, Volkswagen has invested in battery technology company QuantumScape and battery producer Northvolt to secure upstream and downstream battery knowledge
- Partnerships to guarantee supply of materials or capabilities. BMW has an agreement with Ganfeng to source sustainable lithium for batteries from Australia
- Experience exchange and cooperation in industry alliances between manufacturers and other players along the battery value chain, such as Eurobat and NAATBatt, to access knowledge and capabilities from complementary players
- Joint selling/production – working together to develop battery technologies at lower cost and higher performance. Example partnerships include Mercedes-Benz and ACC, General Motors and Posco, and Stellantis and LG. There are also joint ventures between upstream battery players such as BASF and Shanshan
- Cooperation – resource sharing without investment or creation of a separate legal entity. Examples of this include long-term strategic contracts (such as between Umicore and ACC) and the intent to establish a battery recycling cluster in Finland driven by BASF, Fortum and Nornickel

NEXT-LEVEL INTEGRATED BUSINESS PLANNING

Truly integrated business and supply chain planning is a key prerequisite of building resilience across the battery supply chain. Volatility and uncertainty require continuous synchronization of strategic, tactical and operational plans between all partners in the extended supply chain and the company’s internal organizational units.

Adopting an integrated business and supply chain planning process allows battery companies along the value chain to fundamentally reduce the time it takes all players to react to changes in demand, adapting their supply and manufacturing capacities and priorities more quickly. Companies should look to increase capacity across the supply chain (such as for raw materials, refining and recycling). Unaligned decisions and priorities within functional silos and the supply ecosystem are avoided. For example:

- The CFO of a battery supply manufacturer clearly understands when to invest in new manufacturing capacity to avoid future delivery constraints, including a clear understanding of ramp-up processes and potential technology-induced capacity constraints.

- The production and materials manager is able to ensure that they have all labor and material requirements in place to meet demand, including machinery for specific processes.

- The maintenance team knows exactly what activities it needs to do and the optimal time to overhaul equipment.

It is key to align planning across all aspects of the organization (R&D, commercial, demand, production/supply and financial) and use this to create a joint strategic and operational plan. In the case of battery production, this must be extended beyond the borders of the individual organization. This provides a clear, real-time, end-to-end, aligned view that acts as a single source of truth for fast, agile, fact-based decision-making. Applying AI and automation on top of this process can then augment human capabilities, helping to mitigate risk in a complex, dynamic supply chain.

IT IS KEY TO ALIGN PLANNING ACROSS ALL ASPECTS OF THE ORGANIZATION (R&D, COMMERCIAL, DEMAND, PRODUCTION/SUPPLY AND FINANCIAL) AND USE THIS TO CREATE A JOINT STRATEGIC AND OPERATIONAL PLAN.

Against a background of fast-paced production ramp-ups and the resulting fight for all kinds of required resources, better planning will be even more decisive. It also enables battery companies to dynamically remodel their supply chains, such as by substituting suppliers or adding new, local sources of critical raw materials such as recycled batteries.

INSIGHTS FOR THE EXECUTIVE

The battery value chain is both extensive and complex, ranging from raw material producers all the way to recyclers, and impacting the thinking and planning of a wide range of companies. To ensure resilience, executives therefore need to:

- Build a strong understanding of current and future battery value chain characteristics, focused on the key risks
- Use this to evaluate potential concerns and identify opportunities for vertical integration
- Enable holistic, end-to-end SCM by creating and implementing specific tools and processes to improve transparency and steering across organizational borders
- Extend partnerships across the battery ecosystem to fill gaps, build capacity, and mitigate risk – and think beyond traditional structures of suppliers, OEMs, competitors, etc.
- Focus on securing a sustainable supply of the battery materials they need. This should be sustainable in two ways – meeting ESG criteria and being reliable, long-term, and able to scale with the business needs, such as by embracing circular supply chains
- Increase technical and process flexibility by optimizing R&D, procurement, and manufacturing. For example, build in agility to cope with emerging battery chemistries and the introduction of new materials, while creating redundant sourcing of key components
- Where possible, simplify and rebuild supply chains, substituting distant with local suppliers (such as close-by battery recyclers) to mitigate volatility and introduce diversification of sources

Achieving resilience will require continuous innovation across the full range of supply chain tactics, not only diversifying suppliers and vertical integration, but also adopting a holistic approach that takes the entire value chain into account.

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