# Automotive Battery Supply Chain 2022:

## Risks, Regulation & Resiliency Rise Up The Agenda

## Table of Contents

# 1. Introduction: The Relentless Rise of the Battery Supply Chain

## 1.1 Transformational Period

The next 20 years are set to be the most transformative in the history of the automotive industry. Climate-change mitigation policies and emissions regulations will lead ultimately to the phasing out of the internal combustion engine (ICE) in most countries by 2030-2040, with a widespread shift to electric vehicles primarily powered by lithium-ion batteries. We forecast that global EV production will increase from 6.2m units in 2022 to 63.5m units in 2035 (see **Figure 2.1**). While regulations are the main driver of this shift, most notably the **EU's proposed de-facto ICE vehicle ban by 2035**, which is edging inexorably closer to becoming law, Germany is currently vetoing the legislation with some disquiet also from five other EU member states who want to delay the implementation date to 2040..Nonetheless, the legislation is likely to become law in one form or another, albeit with some minor concessions.  Furthermore, post-Covid national government stimulus programmes, subsidies and incentives, as well as changing consumer patterns, including in response to increasingly high fuel prices, are also contributing to a rapid acceleration in electrification.

The resulting automotive industry wide pivot to electrification is the driving force behind the biggest capital reallocation in 100 years, with multi-billion investments for new EV assembly plants, gigafactories and investments further upstream being announced on an almost daily basis.

However, while the end-point of electrification is relatively clear, the exact roadmap towards that destination is still being drawn. That is why the battery supply chain will become pivotal to current and future automotive strategy for all stakeholders.

***"The battery supply chain will become pivotal to current and future automotive industry strategy for all stakeholders."***

## 1.2 A Completely New Battery Supply Chain

The rise in EV sales and production will clearly require commensurate capacity in the battery supply chain. Fundamentally, this means the automotive industry must continue to reorient from being largely a mechanical engineering industry geared around ICE production and venture further into new areas of the chemical industry. Adapting to evolving chemistries, new cell/pack technology and software will require production and logistics that can adapt flexibly to an increasingly rapid rate of change – creating many opportunities as well as challenges.

Based on current investment plans, global lithium-ion battery production capacity will grow from 183 plants with a combined annual capacity of 959 gigawatt hours (GWh) in 2022 to 320 plants with 4,072 GWh annual capacity by 2030. As a reference, one gigawatt hour can supply batteries for around 15,000 EVs. While there is currently considered to be enough overall gigafactory capacity through 2024-2025, that does not preclude specific shortages between individual cell suppliers and OEMs. However, the real challenge is that the battery supply chain must not only expand at the gigafactory level, but throughout the entire supply chain, including midstream components and upstream raw materials, plus the recycling of raw materials to create a true 'closed loop'.

***"The real challenge is that the battery supply chain must not only expand at the gigafactory level, but also with midstream components and upstream raw materials, plus recycling of the raw materials to create a true 'closed loop'."***

The battery supply chain is not only about meeting rising EV demand – it is also fast turning into a critical economic race for OEMs as well as the wider strategic economic interest of individual countries. An EV battery can be 30-40% of a vehicle's value; it is therefore clear why the battery value chain is of such vital economic as well strategic importance. The battery supply chain is long and complex with battery cell production and most of the upstream currently dominated by Asia, with Europe and North America needing to catch up. Western OEMs and governments want to take more control of the battery value chain, rather than let supply, profits and jobs shift away to Asia.

*"The battery supply chain is not only about meeting rising EV demand, it is fast turning into a critical economic race for OEMs as well as the wider strategic economic interests of individual countries."*

However, in that technological and economic race, it's easy to overlook another significant constraint: potential skills shortages. The huge pivot to electrification will require a massive re-skilling of the existing automotive workforce, bringing into play new industrial skillsets from the world of chemicals, electronics and software. With that objective in mind, the US government has announced $800 million in job training funding for the 'Talent Pipeline Challenge' to train more workers for high-quality skilled jobs in the EV manufacturing, broadband and construction sectors.

## 1.3 Supply Chain Risks & Resiliency

*"OEMs are gradually increasing 'semi-vertical integration' across all parts of the battery value chain to improve supply chain security."*

Another motivation for OEMs to gradually increase vertical integration across all parts of the battery value chain is to improve the security and resiliency of supply – a hard lesson learned from the Covid crisis and subsequent semiconductor shortages. OEMs are achieving this through a range of strategic investments including a combination of supply agreements, joint ventures and other partnerships throughout the battery supply chain and are increasing their own development and production competencies.

However, despite the relative certainty of electrification, OEMs, suppliers and governments face many risks in this transition, including the increasingly urgent imperative to develop a carbon-neutral manufacturing process and battery supply chain.

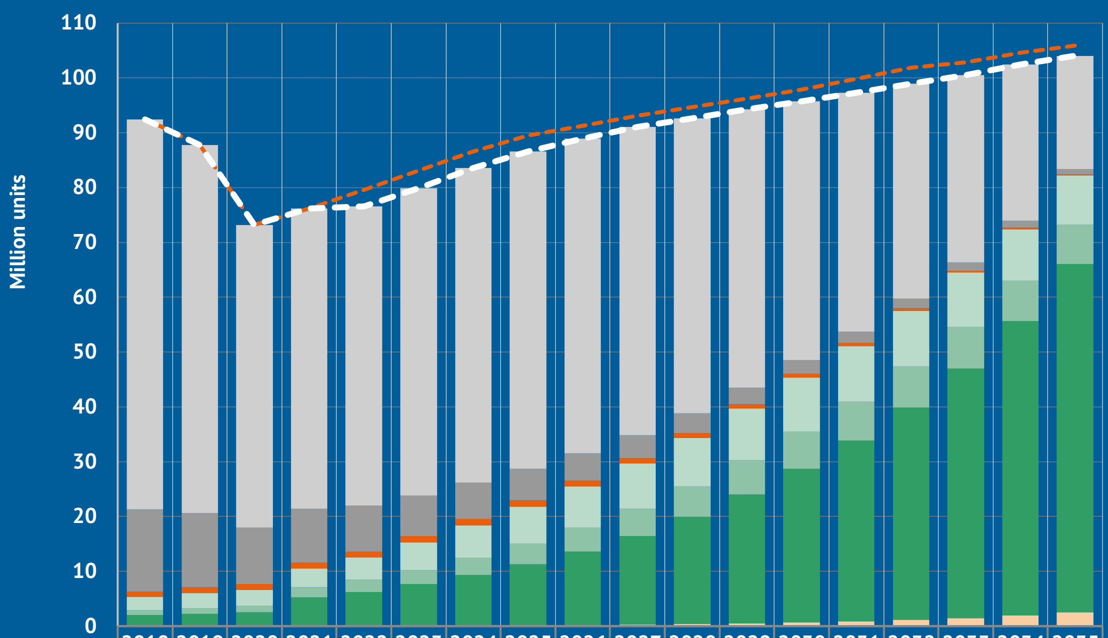
The automotive industry is anticipating potential upstream battery raw material shortages from the middle to the end of the decade that could even overshadow current semiconductor shortages. Furthermore, recent price spikes for lithium, cobalt and nickel have been triggered by the Russia-Ukraine crisis and by a growing imbalance due to disrupted and constrained supply and surging EV demand. This imbalance illustrates why OEMs are forming supply agreements in the upstream battery supply chain. However, raw material shortages and price spikes pose a substantial risk to the unprecedented battery supply chain investments being made, upending EV business models and potentially jeopardising wider electrification targets and climate objectives.

*"Raw material shortages and price spikes pose a substantial risk to the unprecedented battery supply chain investments being made, upending EV business models and potentially jeopardising wider electrification targets and climate objectives."*

Nonetheless, the battery supply chain is set to be a major development in the automotive sector over the next decade. It will require new production, sourcing, logistics and supply processes. Now is the time to understand the dynamics and key players in the emerging battery supply chain.

## 2. Global Light Vehicle Production Forecast by Powertrain 2018-2035

**Figure 2.1 Global Light Vehicle Production Forecast by Powertrain 2018-2035**

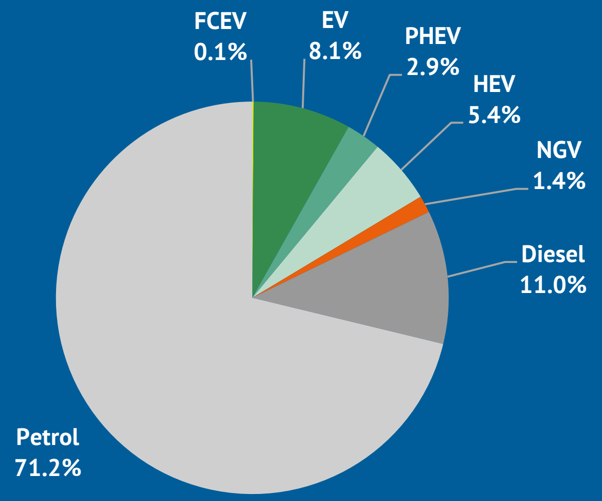



| | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Petrol | 71.1 | 67.2 | 55.2 | 54.8 | 54.5 | 56.0 | 57.4 | 57.8 | 57.4 | 56.2 | 53.8 | 50.8 | 47.2 | 43.5 | 39.3 | 34.2 | 28.4 | 20.6 |
| Diesel | 15.1 | 13.6 | 10.4 | 9.8 | 8.4 | 7.4 | 6.6 | 5.8 | 5.0 | 4.2 | 3.6 | 3.0 | 2.5 | 2.1 | 1.8 | 1.5 | 1.3 | 1.1 |
| NGV | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 | 0.4 | 0.4 | 0.3 | 0.2 |
| HEV | 2.4 | 2.8 | 2.9 | 3.4 | 4.1 | 5.0 | 6.0 | 6.7 | 7.5 | 8.2 | 8.9 | 9.5 | 9.9 | 10.1 | 10.1 | 9.9 | 9.3 | 8.9 |
| PHEV | 0.9 | 1.1 | 1.2 | 1.8 | 2.2 | 2.6 | 3.1 | 3.8 | 4.3 | 5.0 | 5.6 | 6.1 | 6.8 | 7.2 | 7.5 | 7.6 | 7.5 | 7.2 |
| EV | 2.0 | 2.2 | 2.5 | 5.2 | 6.2 | 7.5 | 9.2 | 11.1 | 13.4 | 16.2 | 19.5 | 23.6 | 28.0 | 33.0 | 38.7 | 45.5 | 53.7 | 63.5 |
| FCEV | 0.03 | 0.04 | 0.04 | 0.06 | 0.08 | 0.10 | 0.14 | 0.18 | 0.23 | 0.30 | 0.40 | 0.52 | 0.69 | 0.89 | 1.16 | 1.51 | 1.97 | 2.57 |
| Pre-war | 92.5 | 87.8 | 73.2 | 76.2 | 79.6 | 83.1 | 86.6 | 89.5 | 91.3 | 93.1 | 94.7 | 96.2 | 97.9 | 99.8 | 101.9 | 102.8 | 104.6 | 105.9 |
| Global | 92.4 | 87.8 | 73.2 | 76.2 | 76.6 | 79.9 | 83.6 | 86.6 | 88.9 | 91.0 | 92.6 | 94.3 | 95.8 | 97.3 | 99.0 | 100.5 | 102.4 | 104.1 |

**Source:** Historical data: Various Automoitve Associations, Forecast: Automotive from Ultima Media

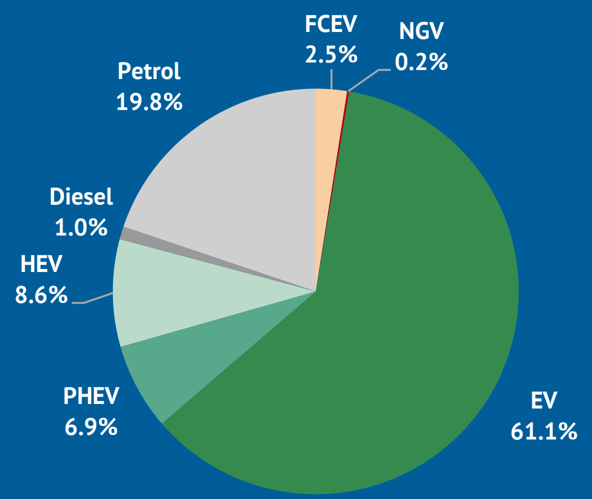
**Key:** NGV (Natural Gas Vehicle) HEV (Hybrid Electric Vehicle) PHEV (Plug-in Hybrid Electric Vehicle) EV (Electric Vehicle) FCEV (Fuel Cell Electric Vehicle)
'Pre-war' refers to the forecast outlook before the current Ukraine-Russia conflict

Figure 2.2 Global Light Vehicle Production by Powertrain 2022 %




**Source:** Automotive from Ultima Media

Figure 2.3 Global Light Vehicle Production by Powertrain 2035 %




**Source:** Automotive from Ultima Media

As EV production and sales are expected to increase by 20% per year from 2022 to 2035, the battery supply chain will need to keep pace. However, there will be a regional divergence in the pace of electrification, with Europe electrifying fastest, followed by Asia Pacific and then North America. With 73% of battery cell manufacturers currently based in Asia, North American and European battery supply chains require huge investment. Nonetheless, Europe's battery supply chain is still set to lag Asia in production capacity by 2030. See **Table 7.1** and **Figure 7.1.**

## 3. Global Lithium-Ion Battery Production Capacity and Demand Forecast

With EV sales growing by 20% a year, battery production capacity will not only need to keep well above demand– and it will actually also need to grow even faster than EV demand (see **Figure 3.1**).

The reason is partly because the kilowatt hour (KWh) battery capacity required per electric vehicle is set to increase by 4% per year over the next decade as battery prices fall, with OEMs fitting larger capacity batteries to better meet consumer expectations by improving driving range and reducing 'range anxiety'. Battery production will therefore actually need to increase slightly faster than EV production volumes, i.e. by around 24% a year.

***"Because of increasing EV battery sizes, overall battery production capacity will actually need to increase slightly faster than EV volumes, i.e. by around 24% a year."***

***"Battery production capacity therefore needs to be kept well above actual battery demand to mitigate against supply chain and production issues."***

Battery production plants usually have a realistic 'capacity utilisation rate' of ~70% of the theoretical maximum stated capacity. For example, there may be a slowdown because of a shortage of cobalt or cathodes, or due to quality control issues. Battery production capacity therefore needs to be kept well above actual battery demand to mitigate against supply chain and production issues.

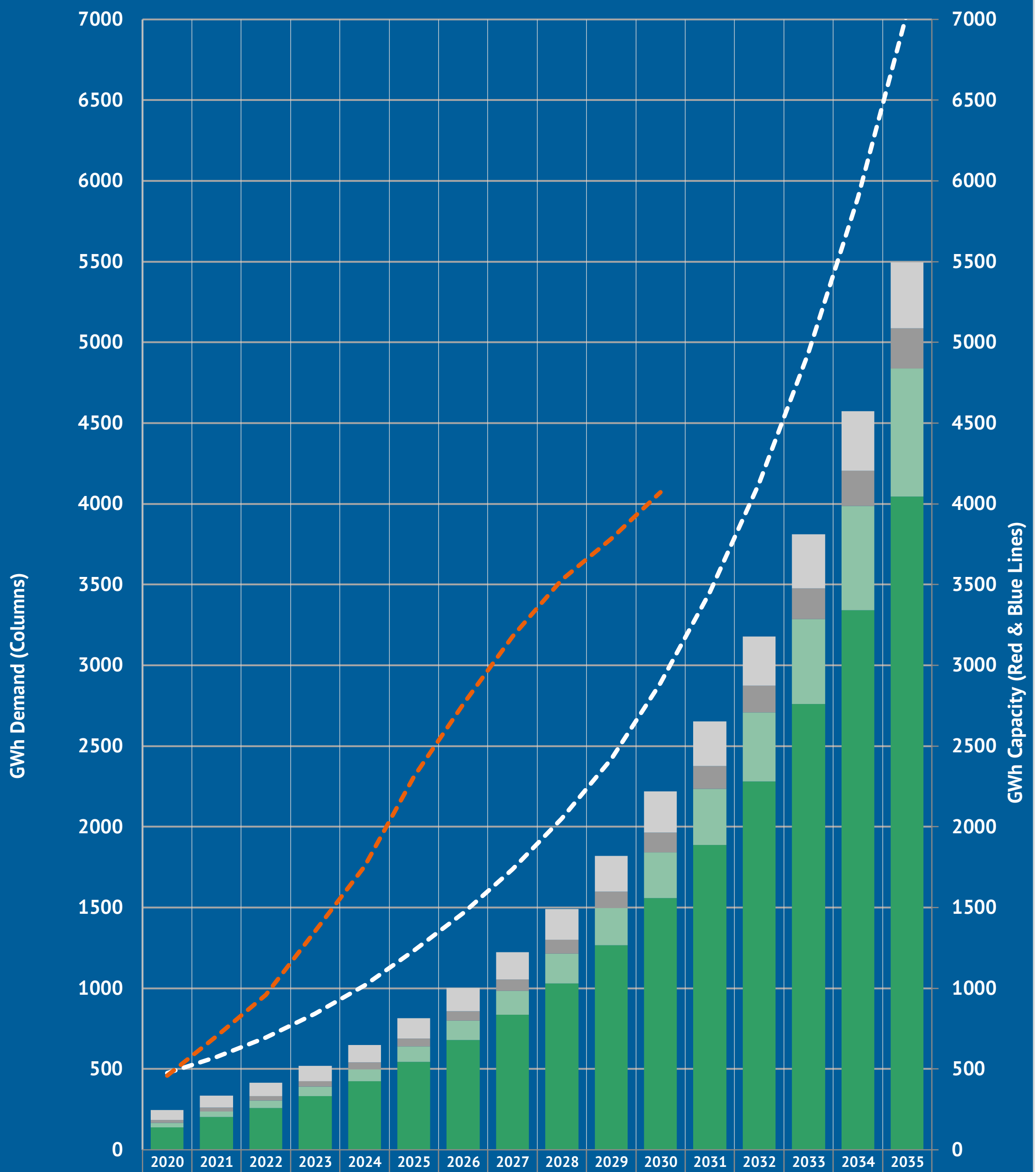
OEM battery supply agreements often lock in OEMs to that cell supplier for not only contractual but also technical reasons. Cell suppliers have different cell formats and different chemistries, therefore, when an OEM experiences a capacity shortage from a supplier, it is not simply a case of switching to another cell producer. This is another reason that battery production capacity must be kept well above EV battery demand.

***"Based on current investment plans, global lithium-ion battery production capacity will grow from 183 plants with 959 GWh capacity in 2022 to 320 plants with 4,072 GWh capacity by 2030."***

As previously stated, based on current investment plans, global lithium-ion battery production capacity will grow from 183 plants with 959 GWh capacity in 2022 to 320 plants with 4,072 GWh capacity by 2030.

However, while gigafactory investment is gathering pace, the real challenge is that the battery supply chain must not only expand at the gigafactory level, but also throughout each stage of the value chain and also in the recycling of raw materials to create a true 'closed-loop'.

Figure 3.1 Lithium Battery Demand & Production Forecast 2020-2035




| | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumer | 60 | 72 | 83 | 95 | 110 | 126 | 145 | 167 | 192 | 220 | 253 | 279 | 306 | 337 | 371 | 408 |
| Storage | 20 | 24 | 29 | 35 | 41 | 50 | 60 | 72 | 86 | 103 | 124 | 142 | 164 | 188 | 217 | 249 |
| Electric CV | 25 | 35 | 45 | 57 | 73 | 94 | 117 | 147 | 184 | 229 | 282 | 347 | 427 | 525 | 646 | 794 |
| Electric PV | 140 | 203 | 260 | 333 | 426 | 545 | 681 | 838 | 1031 | 1268 | 1559 | 1886 | 2283 | 2762 | 3342 | 4044 |
| Required capacity | 475 | 575 | 695 | 841 | 1018 | 1232 | 1466 | 1737 | 2050 | 2419 | 2891 | 3455 | 4128 | 4933 | 5895 | 7045 |
| Stated plans | 459 | 704 | 959 | 1353 | 1756 | 2310 | 2761 | 3179 | 3529 | 3783 | 4072 | | | | | |

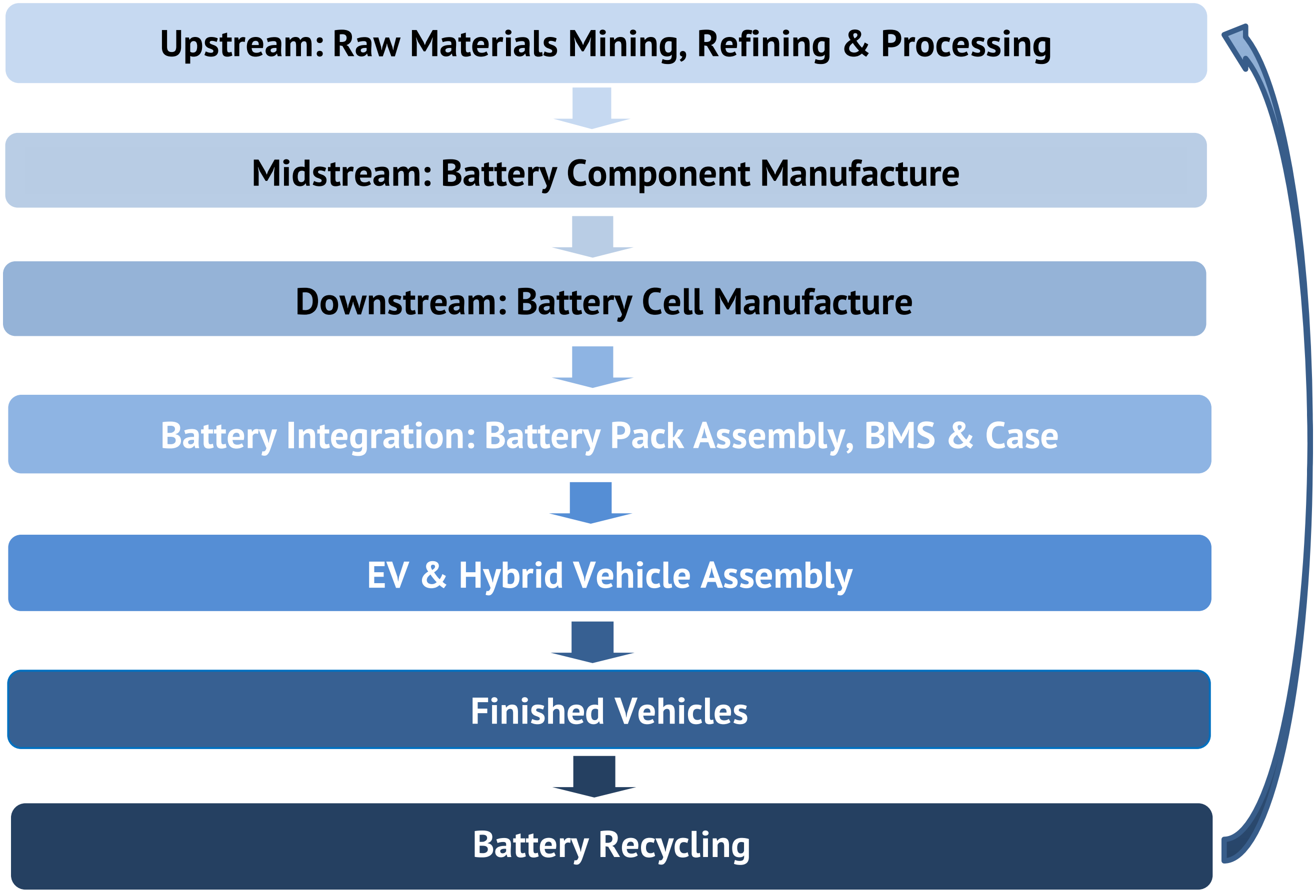
**Source:** Automotive from Ultima Media

## 4. Mapping the Automotive Battery Supply Chain

The battery supply chain is long and complex, in part because the industry is currently highly 'horizontally integrated' with companies specialising in each stage of the process, such as mining and cathode or cell manufacturing. However, there are moves towards partial or semi-vertical integration among OEMs; Stellantis, GM, Ford, Tesla and VW have become involved in cell manufacture through joint ventures, while many are also forming supply agreements with raw materials suppliers further upstream.

Most significantly, the automotive battery supply chain is giving notable rise to a set of companies almost entirely unrelated to legacy automotive suppliers. This emergence is risky for OEMs and tier 1 suppliers, many of whom could see a large share of value creation shift to other players, as for EVs the battery can represent 30% - 40% of the vehicle production value. Furthermore, the current battery value chain is heavily focused in Asia, especially among cell suppliers and further upstream, which is an existential risk to manufacturers and suppliers in Europe and North America.

Figure 4.1 Automotive Battery Supply Chain Schematic Diagram




**Source:** Automotive from Ultima Media

Furthermore, the holistic battery supply chain extends beyond the complete battery pack and finished vehicle. An often-overlooked aspect has been the increasingly important 'closed loop' potential for materials in this supply chain. The recycling stage will become increasingly important as volumes are ramped up and shortages of raw materials emerge.

# 5. Upstream: Raw Material Mining, Refining and Processing

## 5.1 Raw Material Mining

The main four elements used in lithium-Ion batteries are lithium, manganese, cobalt and nickel, primarily sourced from Australia, Chile, Argentina, Russia, Brazil, Canada, Indonesia, South Africa and the Democratic Republic of Congo (DRC), specifically for cobalt. Small amounts of copper, graphite and iron are also used but these metals are considered to be relatively abundant and therefore of less concern. However, the 'upstream' battery supply chain is under increasing pressure for a multitude of reasons:

- Russia's invasion of Ukraine has contributed to spikes in most commodity prices, particularly lithium, cobalt and nickel (see price data in **Figures 5.2, 5.4, 5.6** and **5.8)**. However, a growing imbalance due to disrupted supply and surging EV demand has also led to price rises. OEMs are so concerned by a looming capacity crunch in upstream raw materials that they are forming multi-year, multi-source supply agreements with upstream mining companies. See **Table 5.1.**

- Raw material shortages put supply chains under strain and the resulting price spikes pose a substantial risk to industry-wide battery supply chain investments, undermining EV business models and potentially jeopardising the broader shift to electrification and associated climate objectives.

- Current mining capacity only exists in very specific regions of the world, so there will be a growing need to regionalise raw material production, particularly in the EU and US. Concerns over a lack of upstream raw material supply and investment led to the **European Raw Materials Alliance** being formed in 2020 with current funding of €2 billion. However, the true investment required is estimated to be in excess of €100 billion.

- Furthermore, **EU Battery Regulation** around sustainability and rules of origin is currently being proposed. This is not law yet, but the European Commission expects the final regulatory framework to be adopted in 2022 and be applicable by 2023 at the latest. This new legislation will increasingly phase in the requirement for an increasing percentage of locally sourced materials within batteries rising gradually to 2027.

- However, the mining sector has struggled to respond to growing EV demand. The challenge here is the limited timeline given the lack of such mining facilities currently in Europe and that it can take 5-7 years to develop new mining capacity, compared to the 2-3 years to develop a new gigafactory. The above legislation also stipulates supply chain due diligence requirements – for example, by January 1, 2026, industrial batteries must have an electronic record. This so-called 'battery passport' will help OEMs comply with regulations and make traceable the origins and carbon footprint of every battery made, helping manufacturers to compete with imported Asian batteries and also help better inform consumers.

- A further challenge is that automotive-grade batteries require an unusually high purity of raw materials – particularly manganese – and only a small percentage of refineries can currently produce this grade of material.

- The expected capacity crunch will also need to be mitigated by developing recycling capacity to 'close the loop' and reduce the need for virgin raw material mining and extraction.

**Table 5.1 Major OEM Supply Agreements and Partnerships with Mining Companies**

| OEM | Supplier | Mineral | Source Location |
|---|---|---|---|
| Audi | Umicore | Nickel & Cobalt | |
| BMW | Livent | Lithium | Australia, Argentina |
| BMW | Ganfeng Lithium Co. | Lithium | Argentina, Australia |
| BMW | Mangrove Lithium | Lithium | |
| BMW | Managem Group | Cobalt & Lithium | |
| BYD | Huayou Cobalt | Cobalt | DRC |
| Daimler | Albermarle | Lithium | |
| Ford | Glencore | Cobalt | Australia |
| Ford | Redwood Materials | Cobalt, Lithium & Nickel | |
| Ford | Lake Resources | Lithium | Argentina |
| GM | Glencore | Cobalt | Australia |
| GM | Controlled Thermal Resources | Lithium | US |
| Mercedes | Albermarle | Lithium | |
| Renault | Vulcan Energy Resources | Lithium | Germany |
| Renault | Managem Group | Cobalt | Morocco |
| Stellantis | Vulcan Energy Resources | Lithium | Germany |
| Stellantis | Salton Sea | Lithium | US |
| Tesla | Glencore | Cobalt | DRC |
| Tesla | Ganfeng Lithium Co. | Lithium | Argentina, Australia |
| Tesla | BHP Group | Nickel | Australia, Columbia |
| Tesla | Vale | Nickel | New Caledonia |
| Tesla | Talon Metals | Nickel concentrate | US |
| Tesla | Sichuan Yahua Industrial Group | Lithium Hydroxide | |
| Toyota JV | BHP Group | Nickel Sulphate | |
| VW Group | Vulcan Energy Resources | Lithium Hydroxide | Germany |
| VW Group | Umicore | Cathode materials | |
| VW Group | Huayou Cobalt | Cobalt/Nickel Sulphates | DRC |
| VW Group | Tsingshan Group | Cobalt & Nickel | Indonesia |

**Source:** Automotive from Ultima Media

## 5.2 Lithium

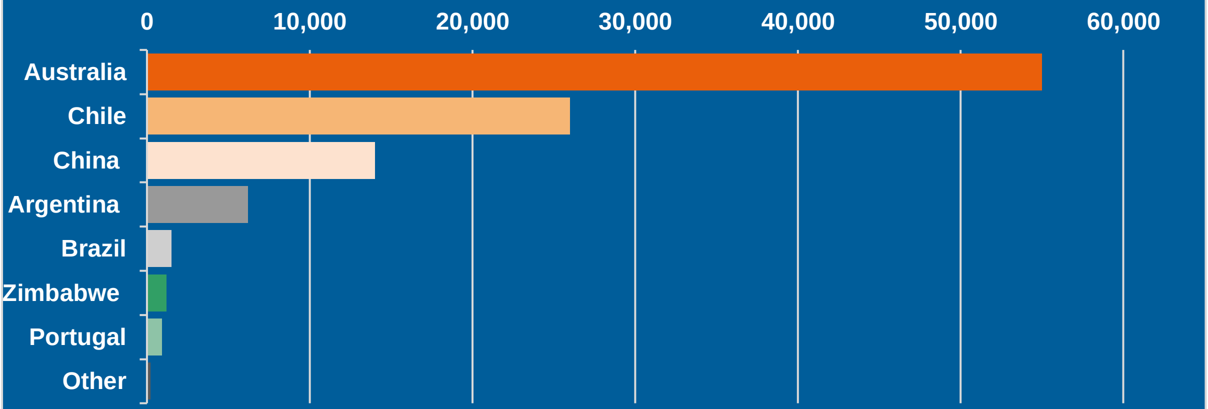
Lithium remains predominantly sourced from Australia, Chile and China. Rising EV demand, limited regions of supply and recent disruptions in the supply chains, including from Covid lockdowns in China, have all contributed to a dramatic five-fold spike in prices compared to the long-run average (see **Figure 5.2**).

Table 5.2 Leading Lithium Suppliers

| Company | Locations | OEMs supplied |
|---|---|---|
| Ganfeng Lithium | Australia, Argentina | BMW, Audi, VW, Tesla |
| Tianqi Lithium Industries Inc. | Australia, China | |
| Albermarle | Australia, Chile | |
| Sociedad Química y Minera (SQM) | Australia, Chile | |
| Livent Corp. | Argentina | BMW |
| Other Companies: Allkem, Lithium Americas, MGX Minerals, Nemaska Lithium, Sichuan Yahua Industrial Group, Controlled Thermal Resources (CTR), Redwood materials, Vulcan Energy Resources, Galaxy Resources Limited, Mineral Resources, Pilbara Minerals, Kidman Resources, Talison Lithium, Altura Mining, Mali Lithium, Orocobre, Piedmont Lithium, Prospect Resources | | |

**Source:** Automotive from Ultima Media

Figure 5.1 Lithium Production by Region 2021 (Tons)




**Source:** US Geological Survey

Figure 5.2 Lithium Carbonate Price 2018-2022 (Chinese Yuan per Ton)


**Source:** Trading Economics

## 5.3 Cobalt

Cobalt is almost entirely sourced from the DRC and remains ethically contentious because of poor working practices, including exploitative child labour. Supply constraints and surging EV demand have also led to cobalt prices more than doubling in the past few years (see **Figure 5.4**). Many battery manufacturers are therefore seeking to phase out cobalt to circumvent both supply and ethical issues.

**Table 5.3 Leading Cobalt Suppliers**

| Company | Locations | OEMs supplied |
|---|---|---|
| Glencore | DRC | BMW, Tesla, Ford, GM |
| Eurasian Resources Group | DRC | |
| China Molybdenum | DRC | |
| Gecamines | DRC | |
| Zhejiang Huayou Cobalt | DRC | BYD, VW |
| Other Companies: Tsingshan Group, Redwood Materials, Managem Group, Vale, Sumitomo Metal Mining, Cobalt Blue, Jinchuan Group International Resources, Katanga Mining, BASF, Korea Resources Corporation, Pengxin International Mining Co., Umicore | | |

**Source:** Automotive from Ultima Media

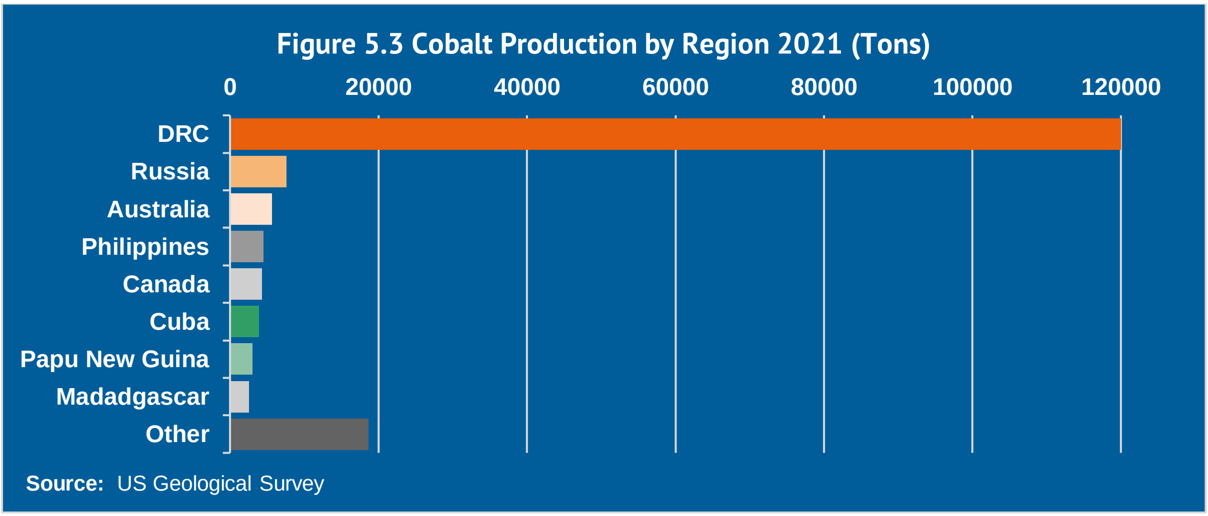



**Figure 5.4 Cobalt Price 2018-2022 ($ per Ton)**


**Source:** Trading Economics

## 5.4 Nickel

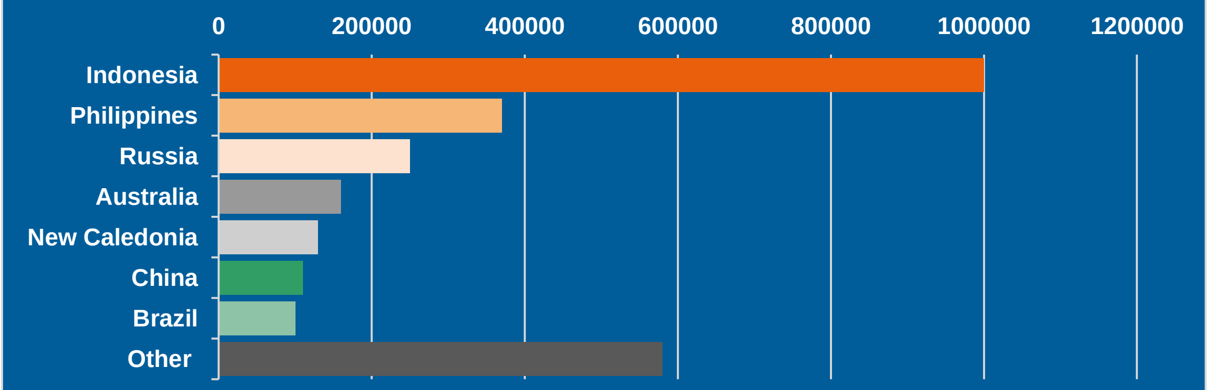
Nickel is primarily sourced from Indonesia, the Philippines and Russia. Sanctions and supply chain constraints following Russia's invasion of Ukraine led to a large price spike in early 2022. The price has since stabilised somewhat albeit at levels that are twice the long-run average (see **Figure 5.6**).

**Table 5.4 Leading Nickel Suppliers**

| Company | Locations | OEMs supplied |
|---|---|---|
| Vale | Indonesia, Canada, New Caledonia, Brazil | Tesla |
| Norilsk Nickel | Russia, Australia, South Africa | |
| Jinchuan Group Ltd. | Indonesia, DRC, Zambia | |
| Glencore | Australia, New Caledonia, Canada | |
| BHP Billiton Ltd. | Australia, Columbia | Tesla, Toyota / Panasonic JV |
| Other Companies: Umicore, Redwood Materials, Talon Materials, Sumitomo Metal Mining Co, Sherritt International, Eramet, Anglo American, Minara Resources, Chemco, SNNC, First Quantum Minerals, Panoramic Resources, Independence Group, Western Areas, Mincor Resources, Terrafame Oy, IGO Ltd., Lundin Mining corp., Western Areas ltd. Nickel Asia Corp., South 32, MCC-JJJ Mining, Benguet, Platinum Group Metals, Berong Nickel, Eramen Nickel | | |

**Source:** Automotive from Ultima Media

**Figure 5.5 Nickel Production by Region 2021 (Tons)**




**Source:** US Geological Survey

**Figure 5.6 Nickel Price 2012-2022 ($ per Ton)**


**Source:** Trading Economics

## 5.5 Manganese

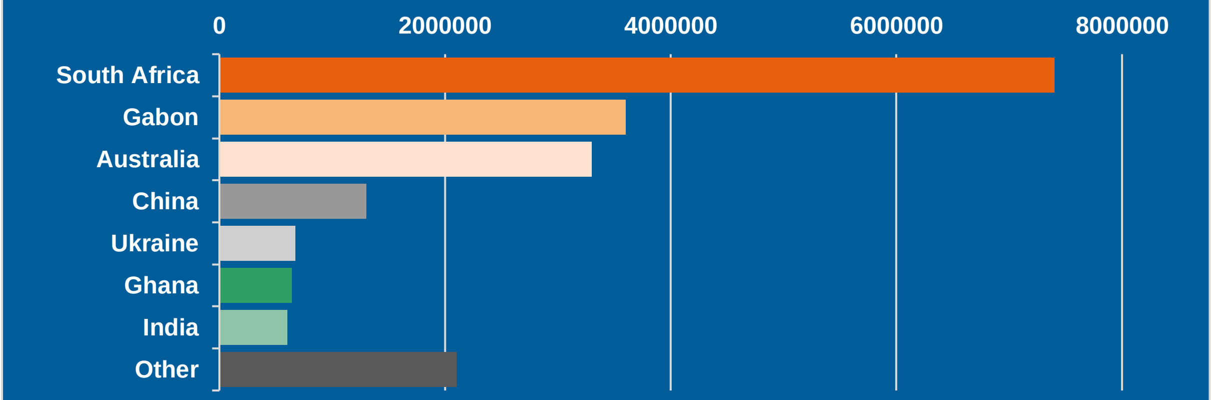
Manganese is mainly sourced from South Africa, Gabon and Australia. Whilst there has not been a price spike (see **Figure 5.8**), a challenge is that automotive grade batteries require a high purity of refined manganese and only a small number of refineries can produce this grade of material, meaning that the industry is highly reliant on a small number of suppliers.

**Table 5.5 Leading Manganese Suppliers**

| Company | Locations |
|---|---|
| South32 | South Africa, Australia |
| Anglo American | South Africa, Australia, Brazil, Finland |
| BHP Group | South Africa, Australia |
| Eramet | Africa, Gabon |
| Vale | Brazil |
| Other Companies: Assmang Xiangtan Electrochemical Scientific, South Africa Manganese, Autlan, Jupiter Mines, Consolidated Minerals (Consmin) | |

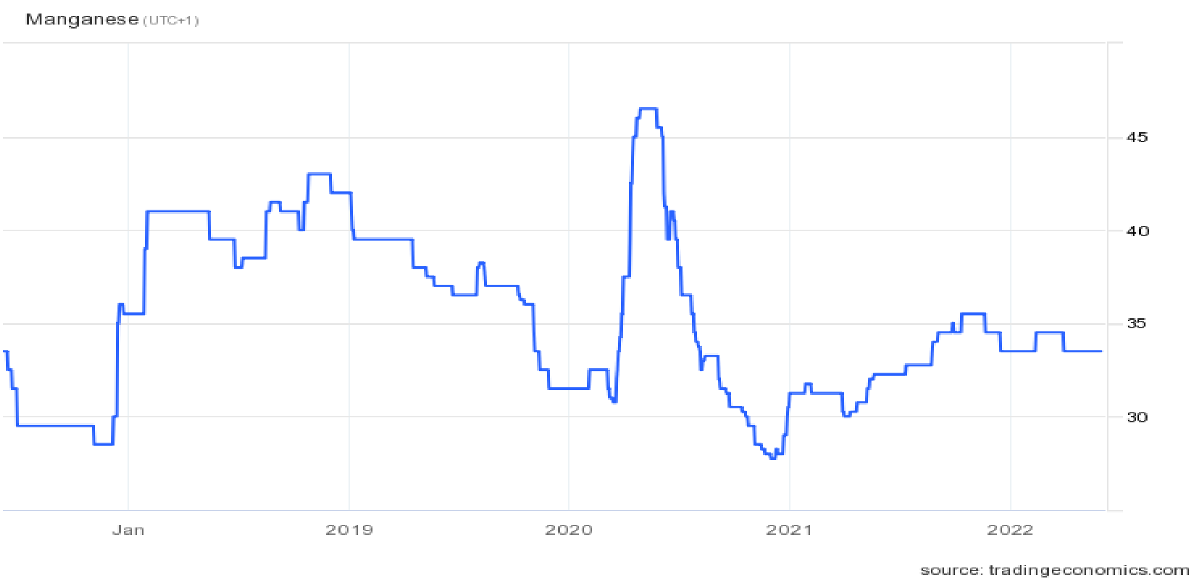
**Source:** Automotive from Ultima Media

**Figure 5.7 Manganese Production by Region 2021 (Tons)**




**Source:** US Geological Survey

**Figure 5.8 Manganese Price 2012-2022 (Chinese Yuan per Ton)**




**Source:** Trading Economics

## 5.6 Chemical Refining and Processing

> *"Chemical refining & processing of raw minerals to produce lithium, cobalt, nickel & manganese remains highly concentrated in the Asia Pacific."*

The chemical refining and processing of raw minerals to produce lithium, cobalt, nickel and manganese remains highly concentrated in the Asia Pacific. In that context, the challenge for Europe and North America is in regionalising this part of the upstream supply chain.

**Table 5.6 Lithium Processing Plants**

| Company | Location | Material |
|---|---|---|
| Albermarle | China, Australia, Chile, US | Lithium Hydroxide, Brine, Carbonate |
| Ganfeng | China, Australia, Argentina, Mexico | Lithium products |
| Livent | China, US, Argentina | Lithium Carbonate, Hydroxide |
| SQM | Chile, Australia | Lithium Carbonate / Hydroxide |
| Tianqi Lithium | China, Australia | Lithium Hydroxide |
| Other Companies: Allkem, Galaxy Resources, Mineral Resources, Orocobre, Pilbara Minerals, Piedmont Lithium, Savannah Resources, Yahua Industrial Group; Vulcan Energy Resources, Youngy | | |

**Source:** Automotive from Ultima Media

**Table 5.7 Nickel Processing Plants**

| Company | Location | Material |
|---|---|---|
| Vale | Indonesia, China, S. Korea, Canada, Japan, UK, Taiwan | Nickel products |
| BHP Group | Australia | Nickel Sulphate |
| Glencore | Australia, New Caledonia, Norway, Canada | Nickel products |
| Norilisk Nickel (Nornickel) | Russia, Finland | Nickel products |
| Pacific Rim Cobalt Corp. | Indonesia | Nickel products |
| Other Companies: Ceria, Eramet, Huayou Cobalt, Jinchuan Group, Ningbo Lygend | | |

**Source:** Automotive from Ultima Media

**Table 5.8 Cobalt Processing Plants**

| Company | Location | Material |
|---|---|---|
| Huayou Cobalt | China | Refined cobalt |
| Jinchuan Group | China | Refined cobalt |
| Green Eco manufacture Hi-tech | China | Refined cobalt |
| Ganzhou Yi Hao / Umicore | China | Refined cobalt |
| Ganzhou Tengyuan Cobalt Industrial, | China | Refined cobalt |
| Other Companies: Jiayuan Cobalt Holding, Zhuhai Kelixin Metal Materials, Hanrui Cobalt, Jianlong Heavy Industry Group, Vale, Sherritt / General Nickel | | |

**Source:** Automotive from Ultima Media

**Table 5.9 Manganese Processing Plants**

| Company | Location | Material |
|---|---|---|
| South 32 | Australia, South Africa | Refined manganese |
| Consolidate Minerals | Australia, Ghana | Refined manganese |
| Eramet | Gabon | Refined manganese |
| Vale | Brazil, Canada | Refined manganese |
| TEMCO | Australia | Refined manganese |
| Other Companies: Assmang Proprietary Limited, Anglo American, African Rainbow Minerals, Compania Minera Autlan, ERACHEM Comilo, Metals X | | |

**Source:** Automotive from Ultima Media

## 6. Midstream: Battery Component Manufacture

> *"The midstream manufacture of cathodes, anodes, electrolytes and separators remains very highly concentrated in Japan and China."*

Cathodes, anodes, electrolytes and separators are highly niche products dominated by a few specialist companies in Japan and China. This means that even as battery cell gigafactories are created in other regions, the midstream supply chain will still be reliant on Asian suppliers of cell components until midstream capacity is developed in other regions. This raises serious questions about capturing the entire lucrative battery supply chain, the security of that supply chain and the environmental sustainability of continuously shipping large quantities of battery components from Asia to western markets.

Furthermore, as EV and battery volumes grow and the need to bring down their costs continues, the role of logistics in the manufacturing process becomes ever more critical. Inbound will require new varieties of packaging for the multiple incoming liquids and solid materials. Battery component production requires drying rooms and cleanrooms with very high levels of hygiene, so in-plant logistics will necessitate AGVs and increased automation, which will also play a key role in reducing costs and improving plant efficiency, quality and production speed.

**Table 6.1 Leading Cathode Manufacturers**

| Company | Locations |
|---|---|
| Umicore | South Korea, China, Poland |
| Nichia | Japan |
| Toda Kogyo | Japan |
| Beijing Easpring | China |
| Ningdo Jinhe | China |
| Other companies: GEM, Shanshan Energy, Xiamen Tungsten, Kingray New Materials Science & Tech, BASF, Gotion High Tech, Johnson Matthey | |

**Source:** Automotive from Ultima Media

**Table 6.2 Leading Aluminium Foil Manufacturers**

| Company | Location | Clients |
|---|---|---|
| Sumitomo Light Metal Industries | Japan | Panasonic |
| Nippon Foil Mfg | Japan | |
| Targray | Various | |
| UACJ Foil Corporation | Japan | |
| CHAL | China | |
| Other Companies: Avocet Steel, Shanghai Metal, Nanoshel, OKChem, Haomei, TOB New Energy | | |

Source: Automotive from Ultima Media

**Table 6.3 Leading Anode Materials Manufacturers**

| Company | Location | Clients |
|---|---|---|
| Hitachi Chemicals | Japan | Samsung SDI, LG Chem, Panasonic, Hitachi |
| BTR Energy | China | Samsung SDI, LG Chem, Panasonic, Sony, BYD |
| Nippon Carbon | Japan | |
| Ningbo Shanshan | China | LG Chem, Sony, Lishen, BAK and BYD |
| Hunan Shinzoom Technology | China | BYD, CATL and Far East First |
| Jiangxi Zeto New Energy Tech | China | BAK Battery |
| Other Companies: Mitsubishi Chemical, LS Mtron Carbonics, ShanshanTech, Tokai Carbon | | |

**Source:** Automotive from Ultima Media

**Table 6.4 Leading Copper Foil Manufacturers**

| Company | Location | Clients |
| --- | --- | --- |
| Furukawa Electric | Japan | |
| Nippon Foil Mfg | Japan | |
| Nippon Denkai | Japan | AESC Envision |
| Doosan Corporation | Hungary, Luxembourg | |
| Targray | Various | |

**Source:** Automotive from Ultima Media

**Table 6.5 Leading Electrolyte Manufacturers**

| Company | Location | Clients |
| --- | --- | --- |
| CapChem Technology | China | Samsung SDI, Panasonic, Sony, BYD, Lishen, BAK, Coslight |
| Tinci Materials Tech | China | Sony, BYD, CATL, Guoxuan, Wanxiang, Coslight |
| Guotai-Huarong GTHR | China, Poland | Samsung SDI, LG Chemicals, ATL, Lishen, Panasonic |
| Panax-Etec | China | Samsung SDI, LG Chemicals |
| Ningbo Shanshan | China | LG Chem, Sony, Lishen, BAK and BYD |
| Other Companies: Mitsui Chemicals, Ube, Mitsubishi Chemicals, Targray, LG Chem, DuPont, Daikin | | |

**Source:** Automotive from Ultima Media

**Table 6.6 Leading Separator Manufacturers**

| Company | Location | Clients |
| --- | --- | --- |
| Asahi Kasei | Japan | Samsung SDI, LG Chem, Panasonic, Sony, Hitachi, AESC |
| Toray Tonen | Japan | Samsung SDI, LG Chemicals, Sony |
| SKI | Japan | Samsung SDI, Sony |
| Celgard | US | LG Chem, Panasonic, AESC Envision |
| Senior Technology Material | China | LG Chem, BYD, Guoxuan, Lishen, CALB |
| Other Companies: Entek, Victory Precision Manufacture / Suzhou Greenpower New Energy Materials, Ube, Jinhui Hi-tech, BNE, Cangzhou Mingzhu, Shanghai Energy New Materials, Zhongke Science and Tech, Donghang, Newmi Tech, Sinoma, SK IE Technology Company, Evonik, Litarion | | |

**Source:** Automotive from Ultima Media

# 7. Downstream: Battery Cell Manufacture

## 7.1 Gigafactory Analysis

*"Based upon current stated investment plans, Europe is expected to achieve an astonishing 36% share of global GWh capacity by 2030 and become nearly comparable in capacity to China's 43% in 2030."*

Lithium battery gigafactories, are currently heavily focused in Asia, which has nearly 73% of capacity in 2022, with China representing the largest share. However, gigafactory investment is accelerating in other regions as there is a compelling need to regionalise the battery supply chain to reduce transport costs, mitigate supply chain disruptions and reduce carbon footprint. Europe is where OEMs have announced the most new capacity, with 46 gigafactories currently in the pipeline and more likely to follow. Based upon current stated investment plans, Europe is expected to achieve an astonishing 36% share of global GWh capacity by 2030 and become nearly comparable in capacity to China's 43% in 2030.

The battery companies entering the automotive industry through the new battery supply chain demonstrate the need and opportunity for new partnerships. In the US, Tesla set the framework at its Nevada gigafactory with its JV with Panasonic and is set to expand production capacity even further at the plant. To mitigate risks and share investment costs, many OEMs and cell suppliers are following suit, forming joint ventures to establish new gigafactories. These partnerships include Stellantis and GM with LG Energy Solution; Ford with SK On; Renault and Nissan with AESC Envision; and Volvo Cars with Northvolt, among many others. Meanwhile, in other cases OEMs are also investing in new cell suppliers to support investment, such as Stellantis and Mercedes-Benz, and energy giant Total for battery start-up Automotive Cells Company (ACC). Volkswagen Group, meanwhile, has invested in Chinese battery producer Gotion, and is also planning to build its own battery cells.

Even as they invest in joint ventures and in-house production, OEMs are also agreeing long-term supply arrangements with major cell suppliers, such as BMW and Tesla with China's CATL (see **section 7.3**).

Many of the new cohort, especially the cell manufacturers such as CATL, LG Energy Solution, Panasonic and SK On, may come to rival major Tier-1 suppliers in size and potentially displace legacy auto's ICE powertrain players.

Another factor in gigafactory location is that energy can account for 40% to 50% of battery production costs. Therefore, it's not only important in terms of sustainability targets to be located near low-cost renewable power, but also from the perspective of bringing battery prices down, as renewable energy will likely be cheaper in the medium to longer term.

*"A key factor in the investment in battery cell production is that lithium-ion batteries are not commodified and are unlikely to become so."*

A key factor in the investment in battery cell production is that lithium-ion batteries are not commodified and are unlikely to become so. There remain significant differences in chemistry, cell format, energy density, price per KWh, safety, charging and discharge performance, and the complex interplay of all of those factors varies according to the vehicle application. For example, supercar batteries are higher quality with high-energy density and discharge performance, compared to the lower cost, lower energy density batteries utilised in an entry-level EV, where the balance of requirements are very different.

Furthermore, the technology is constantly evolving; incremental improvements are being made in battery chemistry and new variants are emerging, including lithium sodium chemistries and the much heralded 'solid state' batteries. These changes, while not fundamentally affecting the design of a gigafactory, will almost certainly require flexibility in manufacturing processes as well as changes in the sourcing, supply chain and logistics involved.

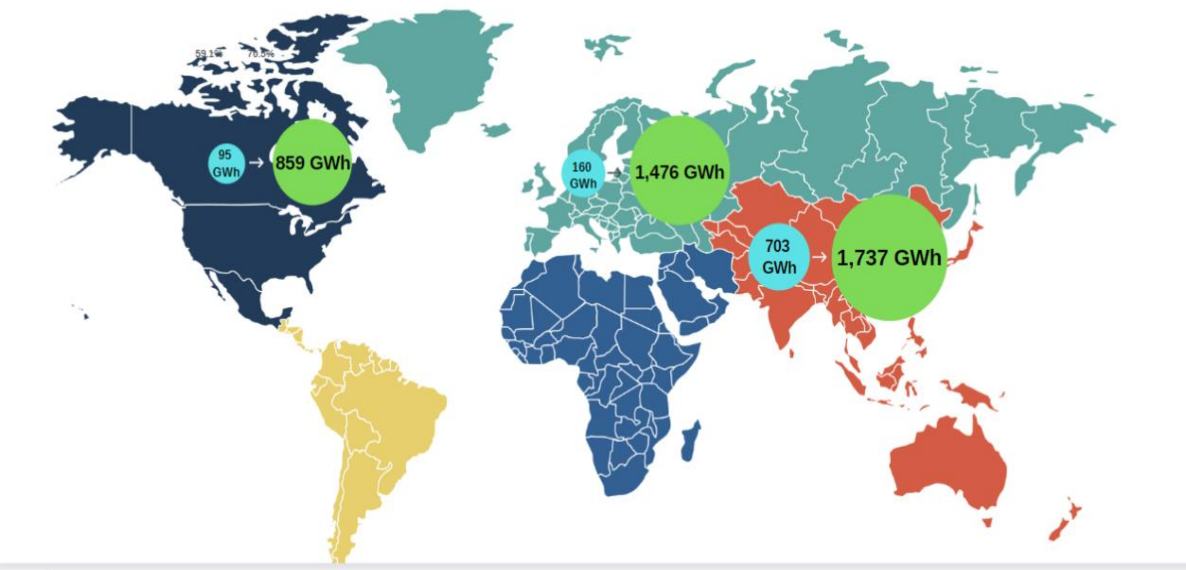
Ultimately the significance of lithium batteries not being commodified is that there is competitive advantage to be had among cell suppliers with cell technology being an industry of constant incremental advances.

**Table 7.1 Lithium Battery Gigafactories and Production Capacity Forecast by Region 2022 vs. 2030 (GWh)**

| Region | Current plants | Future plants* | Total current + future plants* | 2022 capacity (GWh, % share) | 2030 capacity (GWh, % share) |
|---|---|---|---|---|---|
| Asia Pacific | 141 | 61 | 202 | 703 GWh (73%) | 1,737 GWh (43%) |
| Europe | 27 | 46 | 73 | 160 GWh (17%) | 1,476 GWh (36%) |
| N. America | 15 | 30 | 45 | 95 GWh (10%) | 859 GWh (21%) |
| Total | 183 | 137 | 320 | 959 GWh | 4,072 GWh |

Source: Automotive from Ultima Media *Announced plants. We expect more to fulfil future demand

**Figure 7.1 Lithium Battery Production Capacity Forecast by Region 2022 vs. 2030 (GWh)**




**Source:** Automotive from Ultima Media

The full battery gigafactory database can be found here – [https://www.automotivemanufacturingsolutions.com/ev-battery-production/lithium-ion-battery-gigafactory-database/41937.article](https://www.automotivemanufacturingsolutions.com/ev-battery-production/lithium-ion-battery-gigafactory-database/41937.article)

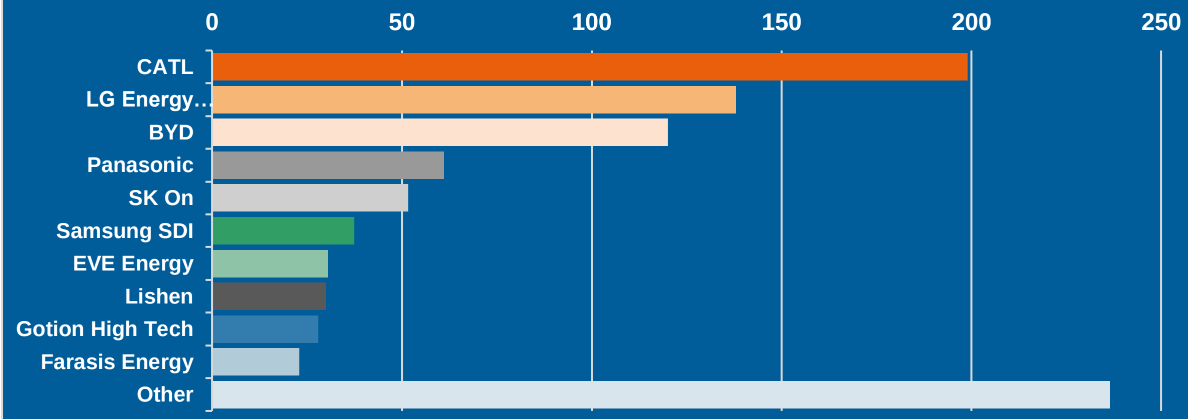
## 7.2 Top 10 Battery Cell Manufacturers

**Table 7.2 Top 10 Battery Cell Manufacturers 2022***

| Rank | Company | HQ | Capacity In 2022* | Plants 2022* | OEMs supplied |
|---|---|---|---|---|---|
| 1 | Contemporary Amperex Technology Ltd. (CATL) | China | 199 GWh | 10 | BAIC, BMW, Dongfeng, Foton, GAC, Geely, Honda, Hyundai-Kia, Mercedes, Nanjing Golden Dragon, Renault-Nissan-Mitsubishi, SAIC, Stellantis, Tesla, Toyota, Volvo Cars, VW Group, Xiamen King Long, Yutong, Zhongtong |
| 2 | LG Energy Solution | South Korea | 138 GWh | 6 | Ford, Geely, General Motors, Hyundai, Jaguar, RNM, Stellantis, Tesla, VW, Volvo Cars |
| 3 | BYD | China | 120 GWh | 6 | BYD, Changan auto, Toyota, Great Wall Motor, Dongfeng Motor, Chery Auto, NIO, Xpeng Motors., Tesla |
| 4 | Panasonic | Japan | 61 GWh | 9 | BMW, Ford, Honda, Tesla, Toyota |
| 5 | SK On | South Korea | 51.7 GWh | 6 | Mercedes Benz, BAIC, Hyundai, Jaguar Land Rover, Ferrari, Kia, VW Group |
| 6 | Samsung SDI | South Korea | 37.5 GWh | 13 | Akasol, BMW, Hyundai-Kia, JAC, Stellantis, Volvo Cars, VW Group |
| 7 | EVE Energy | China | 30.5 GWh | 3 | Geely, Kia Motors |
| 8 | Lishen | China | 30 GWh | 3 | Dongfeng, JAC, Geely, Jinlong, Kandi Tech, Zhongtong, Qingyuan, FAW |
| 9 | Gotion High Tech | China | 28 GWh | 8 | Ankai Bus, BAIC Motor, Dongfeng Motor, JAC, Jianghuai Automobile, Jinlong, Sunwin, Shenwo, Zhongtong, Zoomlion, VW Group |
| 10 | Farasis Energy | China | 23 GWh | 2 | BAIC, Changan, Great Wall, Jiangling, Mercedes-Benz |
| Other Companies | | | 236.5 GWh | 123 | |
| | Global | | 955 GWh | | |

**Source:** Automotive from Ultima Media *Capacity expected by the end of 2022

**Figure 7.2 Top 10 Battery Cell Manufacturers by Production Capacity (GWh) 2022***




**Source:** Automotive from Ultima Media * Capacity expected at the end of 2022

## 7.3 OEMs and Battery Cell Supplier Agreements

> *"To mitigate against supply shortages, OEMs are diversifying their battery cell suppliers, moving from a single sourcing model to a multi-sourcing model"*

As securing the supply of lithium-ion battery cells is critical to mitigate against shortages and production losses, OEMs are increasingly moving away from exclusive single-sourcing supply agreements with cell suppliers to multi-sourcing supply agreements with multiple suppliers (see **Table 7.3)**. This approach also protects the OEM against technological advances that could competitively disadvantage them if they are locked into a cell supply agreement. It's notable also that there is a long qualification period for new battery suppliers as battery cells cannot easily be swapped to another supplier. So by multi-sourcing in advance of that scenario, OEMs are mitigating against future supply chain shortages and disruption.

What's noteworthy about the supplier relationships is that OEMs who have joined the EV race later – such as Honda and Toyota – have relatively low diversification, with just one or two battery suppliers. In contrast, OEMs that are more advanced and market leaders in EVs, such as VW and Tesla, now have a highly diversified range of battery suppliers, illustrating the clear direction of travel. For example, five years ago VW used to rely on single suppliers, such as Samsung SDI, while today it has significantly diversified its supplier base, which now includes LG Energy Solution, SK On, CATL and Northvolt, as well as having plans to build its own batteries. As well as investing in building its own batteries, Tesla has also expanded its partnerships, previously working only with Panasonic but now partnering with a wide array of suppliers including LG Energy Solution, and in China with CATL, BYD and EVE Energy.

### Table 7.3 Summary of Major OEM Groups and Battery Cell Suppliers Agreements

| OEM Group | Cell Supplier | Cell Supplier | Cell Supplier | Cell Supplier | Cell Supplier | Cell Supplier |
|---|---|---|---|---|---|---|
| BMW | CATL | Northvolt | | | | |
| BYD | BYD | | | | | |
| Mercedes-Benz | LG Energy Solution | SK On | ACC | | | |
| Ford | LG Energy Solution | Panasonic | SK On (US) | BYD (China) | CATL (China) | |
| General Motors | Ultium (LG Energy Solution / GM JV) | | | | | |
| Honda | Panasonic | CATL | | | | |
| Hyundai-Kia | SK On | LG Energy Solution | CATL | | | |
| Renault-Nissan-Mitsubishi | AESC Envision | LG Energy Solution | CATL (China) | Toshiba | Lithium Energy Japan Corp. | |
| Stellantis | LG Energy Solution | CATL | ACC | | | |
| Tesla | Panasonic | LG Energy Solution | CATL | EVE Energy | BYD | |
| Toyota | Panasonic | | | | | |
| VW Group | LG Energy Solution | Samsung SDI | SK On | CATL (China) | Gotion (China) | Northvolt (Scania) |

**Source:** Automotive from Ultima Media

# 8. Battery Integration

**8.1 Battery Management Systems (BMS), Thermal Management Systems (TMS) & Battery Pack Cases**

A single raw battery cell on its own is of little use in a vehicle as it is a very powerful but unregulated power source. An EV needs usable battery packs with a battery management system (BMS) and a thermal management system (TMS) to ensure safe charging, monitor individual cells, regulate temperature and control demand discharge under a wide range of driving scenarios and atmospheric conditions. The overall battery pack case is also important in thermal management, and to protect and ensure the reliability of individual cells. Battery integration is vital and results in a very sophisticated piece of hardware, chemistry and software, all of which plays a critical role in battery and EV performance.

*"Battery integration is vital and results in a very sophisticated piece of hardware, chemistry, as well as software, all of which plays a critical role in battery and EV performance."*

Some casings are also being developed to become structural battery packs, for example to become a structural component of the vehicle, saving weight and improving the overall EV efficiency. Examples include Tesla's Model Y incorporating a structural battery pack and GM's Ultium batteries also strengthening the car. Battery cell companies BYD and CATL are also involved with structural battery packs.

**Table 8.1 Leading Battery Management Systems (BMS) Companies**

| |
|---|
| BYD, CATL, Eberspächer, Ficosa, G-Pulse, Hella, Idneo Engineering Services Company, Leclanche, LG Energy Solution, Lithium Balance, Nuvation Energy, NXP Semiconductors, Panasonic Corporation, Renesas Electronics, Robert Bosch, Roboteq, SVOLT, Tesla<br><br>Other Companies: Analog Devices, AVL LIST, Battery Systems, Calsonic Kansei Corporation, Continental, Denso Corporation, Elithion, Hitachi, Horiba Mira, Infineon Technologies, Intel Corporation, Ion Energy, Johnson Matthey, Marelli, Maxim Integrated Products, Midtronics, Mitsubishi Electric, Navitas System, Orient Technology, Preh, Ricardo, Samsung SDI, Silicon Labs, ST Microelectronics, Texas Instruments, Toshiba Corporation, Vitesco Technologies |

**Source:** Automotive from Ultima Media

**Table 8.2 Thermal Management Systems (TMS) Companies**

| |
|---|
| Borgwarner, Calsonic Kansei, CapTherm Systems, Continental, Dana, Gentherm, Hanon System, LG Energy Solution, MAHLE, Robert Bosch, Samsung SDI, Valeo, VOSS Automotive |

**Source:** Automotive from Ultima Media

**Table 8.3 Battery Pack Casing Companies**

| |
|---|
| ArcelorMittal, CF Linamar, Constellium, Continental Structural Plastics (CSP), EDAG Group, Gestamp, Hanwha Advanced Materials, Hitachi Metals, Minth Group, Nemak, Norsk Hydro, Novelis, POSCO, SGL Carbon, Thyssenkrupp, TRB Lightweight, UACI Corporation, Voestalpine |

**Source:** Automotive from Ultima Media

## 8.2 Battery Module and Pack Assembly Plants

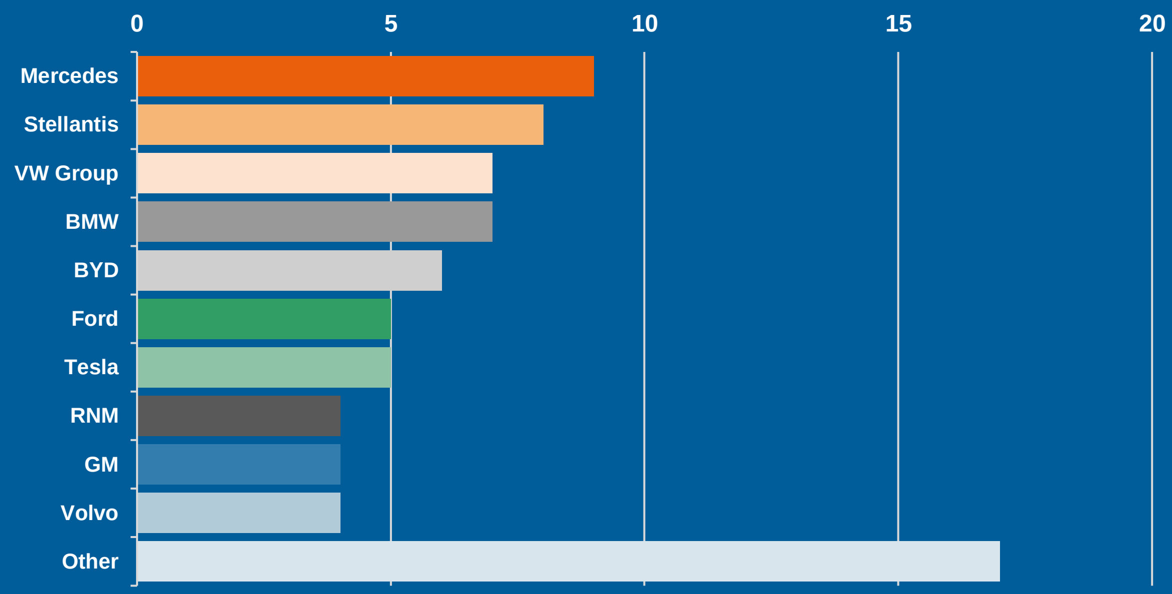
Battery pack assembly plants are where the battery 'integration' occurs – the battery cells are arranged into modules and these are then combined into battery packs, incorporating the BMS, TMS, casing and enclosure. However, some cell suppliers such as CATL are developing 'cell-to-pack' technology that circumvents the need for modules, thereby streamlining the integration process.

Rising fuel and logistics costs in transporting increasingly heavy batteries, the challenges of moving 'dangerous goods', concerns around supply chain security and new regulation on the carbon footprint of batteries are all driving increasing regionalisation, localisation and even hyper-localisation of the integration of modules, packs and casings in close proximity to vehicle assembly plants or even next to the actual vehicle assembly lines.

> ***"Battery pack assembly is increasingly localised or 'hyper-localised' to the specific OEM assembly plant."***

While EV start-ups can outsource pack assembly or give this task to cell manufacturers, larger volume OEMs will often arrange for the battery pack assembly to be located close to the vehicle production site to minimise logistics costs and improve supply chain efficiency – but also, crucially, to keep control of the critical pack assembly process in-house and retain it as a key competitive advantage.

**Figure 8.1 Major OEM Battery Pack Assembly Plants**

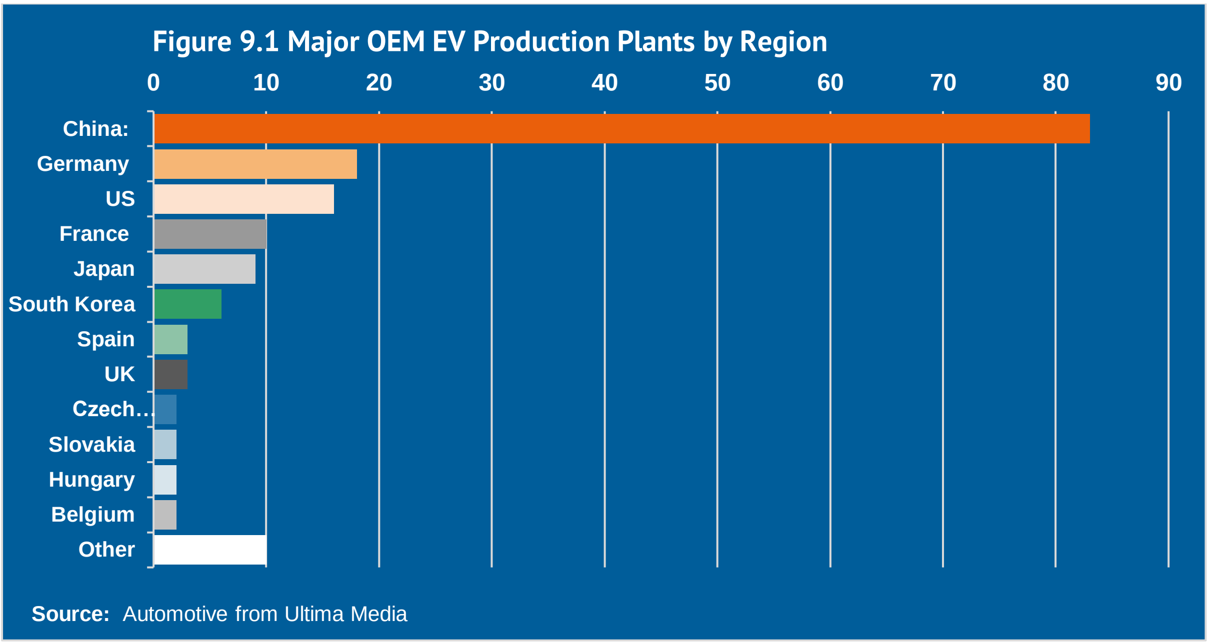


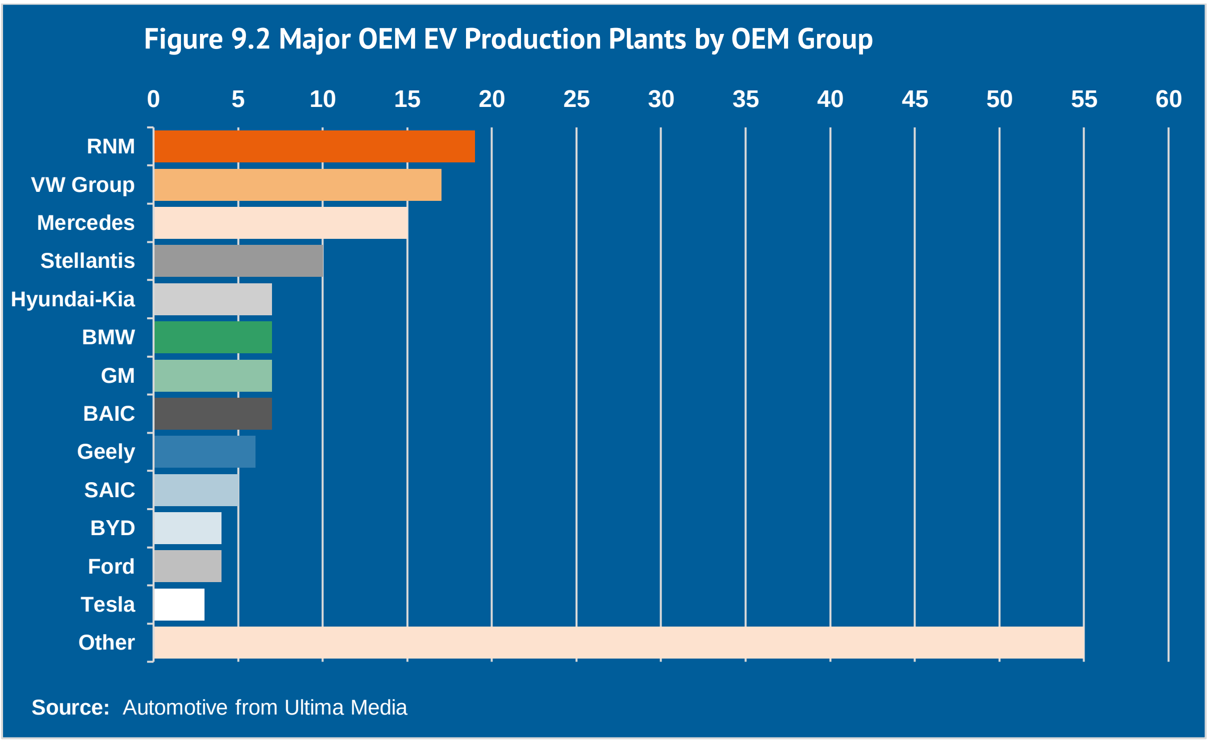

**Source:** Automotive from Ultima Media

## 9. OEM EV Vehicle Assembly Plants

The location of EV assembly plants is increasingly important. Battery weight, regulation, the security of the supply chain and localisation are all critical factors intertwined with plant location. Additionally, the battery sourcing model varies within those parameters, with some OEMs importing batteries, whereas others, such as Audi and Tesla, assemble batteries in the vehicle assembly plant. EV production strategy varies by OEM with many opting to add EVs alongside existing ICE models, including GM, BMW and Volvo Cars. However, more OEMs – including GM and Ford – are following the VW approach and converting plants into pure EV production sites.

> *"The location of EV assembly plants is increasingly important. Battery weight, regulation, security of the supply chain and localisation are all critical factors intertwined with plant location."*



## 10. Recycling Automotive Batteries

> *"The ramping up of recycling capacity will feed back into the production of new battery components and be vital in plugging the predicted gap in upstream raw materials."*

In an ideal battery supply chain, first-generation EV batteries will move through their useful lifecycles and then into a 'closed loop'. The ramping up of recycling capacity will feed back into the production of new battery components and be vital in plugging the predicted gap in upstream raw materials, also helping towards the goal of carbon-neutral battery production. However, recycling lithium-ion batteries is a relatively new industry and primarily based in Asia, which means that most batteries used in other markets will need to be returned to Asia for processing. China currently accounts for more than two thirds of all recycling facilities handling the approximate 100,000 tonnes of batteries currently being recycled. South Korea is second with around one sixth of global recycling capacity. Beyond those two countries, the industry is otherwise highly fragmented with a 'long tail' of many other smaller players attempting to enter this burgeoning market. Interestingly, many OEMs are bringing recycling in-house as part of the vertical integration trend, primarily to help secure the supply of raw materials. This is evident at carmakers such as VW, Renault, Kia, Honda and Tesla but also cell suppliers such CATL, SK On and Northvolt.

**Table 10.1 Leading Lithium Battery Recycling Companies**

| Company | Location |
|---|---|
| Green Eco Manufacturing Resource (GEM) | Shenzen, China |
| Hunan Brunp Recycling Technology | Hunan Province, China |
| Quzhou Huayou Cobalt New Material | Quzhou, China |
| Ganzhou Highpower Technology | Shenzen, China |
| Guangdong Guanghua Sci-Tech | Guangdong, China |

**Source:** Automotive from Ultima Media

**Table 10.2 Other Lithium-Ion Battery Recycling Companies Outside of China**

| Companies | Plants |
|---|---|
| Tesla, AERC Recycling Solutions, Li-Cycle Corporation, Battery Recycling Made Easy, Honda/ Battery Resources JV, Redwood Materials, Umicore, Green Technology Solutions, Retriev Technologies Inc. | US |
| VW, ACCUREC Recycling, BASF, Duesenfeld | Germany |
| AkkuSer Oy, Fortnum | Finland |
| American Manganese, Glencore, Neometals, Li-Cycle Corporation, Retriev Technologies Inc. | Canada |
| Umicore | Belgium |
| Eramet-Valdi, SNAM | France |
| Glencore International | Norway |
| BASF, Eramet & SUEZ J-V for battery recycling | Multiple locations |
| Batrec Industrie | Wimmis, Switzerland |
| Ganfeng Lithium | Mexico |
| Johnson Matthey | MoU with Stena Recycling |
| Nippon Recycle Center Corporation | Osaka, Japan, Aichi, Japan, Miyagi, Japan |
| Northvolt / Hydro | Sweden, Norway |
| Recupyl | Grenoble, France, Singapore |
| Stena Recycling | 173 locations in 7 EU countries |

**Source:** Automotive from Ultima Media

# 11. Conclusion: Battery Supply Chain Highly Rewarding but Risky

## 11.1 Investment in The Battery Supply Chain Continues Apace but Risks are Real

We forecast that the necessary rate of capacity growth in the battery supply chain needs to be at least 24% a year for the next decade and beyond. This presents enormous new business opportunities for OEMs and automotive suppliers. Spurred on in part by government incentives, EV sales surged throughout the Covid pandemic, and the business case for battery supply chains now looks much safer than even a year or two ago, with a stream of new investments for battery gigafactories and throughout the upstream supply chain expected to continue.

While the regulatory roadmap to net zero is clear, the precise path to electrification is likely to be paved with challenges and risks. Obstacles that must be navigated include, an industry backlash against ICE ban target dates, achieving the necessary economies of scale to bring battery prices down, consumer resistance to EVs, a lack of charging infrastructure and real concerns around the upstream supply. Many experts regard $100 per KWh as the threshold at which EVs will achieve price parity with ICE vehicles and become mainstream through consumer demand alone without subsidies. However, after a continuous fall over the past decade, recently battery prices have actually increased. Supply chain disruption triggered by the pandemic, combined with surging EV demand, has created an imbalance in supply and demand. Furthermore, Russia's invasion of Ukraine has compounded those supply chain constraints, exacerbated the shortages and driven up the price of battery raw materials. Consequently, those elevated and volatile raw material prices pose a real risk to the unprecedented level of battery supply chain investments, undermining EV business models and potentially jeopardising wider electrification targets and climate objectives.

> ***"Elevated and volatile raw material prices pose a real risk to the unprecedented battery supply chain investments being made, undermining OEM's EV business models and potentially jeopardising wider electrification targets and climate objectives."***

Governments cannot subsidise EVs continuously. In fact, in May 2022 the UK government scrapped passenger car EV purchases subsidies and other countries, such as Germany are signalling that they may follow suit soon. And furthermore, once EVs become mainstream the resulting hole in government finances from dwindling ICE fuel duties may need to be plugged by introducing road charging. This could in turn lead to stalling EV sales and missed electrification targets.

Nevertheless, the wholesale push to electrification is resulting in the biggest capital reallocation in the automotive industry in more than 100 years. In that context, capturing the battery supply chain becomes an increasingly important element and explains why OEMs are strategically investing in it.

Furthermore, as the battery supply chain matures as a sector, we expect to see growing industry consolidation through mergers and acquisitions to reduce investment risk and help achieve the economies of scale essential to bring battery and EV prices down. After a decade of continually falling battery prices, current price spikes in raw materials are leading to battery price rises, and that may well put more pressure on cost cutting elsewhere in the manufacturing processes and the supply chain.

Ultimately the need for economies of scale means that cell companies are likely to achieve organic growth as well as merge and acquire other smaller players. And the profusion of new battery start-ups, some with some very promising R&D into solid-state batteries, will likely cause a flurry of acquisitions by major cell suppliers and even OEMs eager to acquire new technology and hard-to-find talent. These manufacturers will look to gain crucial competitive advantages with any potential leap forward in battery technology – demonstrating how lithium batteries will remain uncommodified.

## 11.2 Building Supply Chain Resilience

Continuing supply chain disruptions are motivating OEMs to deploy various strategies, including being more vertically integrated. However, this would be more accurately described as a 'semi'-vertically integrated supply chain, as full vertical integration would require partial or full acquisition of the battery supply chain companies in question, or else complete in-house development.

But legacy OEMs also risk losing an enormous part of the value chain in the transition to EVs, of which the battery is at the heart. For example, VW has announced it plans to create six gigafactories in Europe by 2030 with a total capacity of 240 GWh. Furthermore, beyond cell manufacture, OEMs such as VW are openly talking about more vertical integration.

VW CEO Herbet Diess, when discussing plans for a Spanish gigafactory, commented that the plan was to create "a full ecosystem of suppliers from lithium extraction to the assembly of batteries".

> **The plan is to create *"a full ecosystem of suppliers from lithium extraction to the assembly of batteries."*** VW CEO Herbet

> ***"End to end vertical integration is the ultimate solution."*** Ashwani Gupta, COO of Nissan

And Ashwani Gupta, COO of Nissan, has also been quoted in the context of the shift to electrification as saying "end to end vertical integration is the ultimate solution".

While there is currently considered to be enough overall gigafactory capacity through 2024-2025, that does not preclude there being specific shortages between individual cell suppliers and OEMs. Furthermore, rapid growth in EV demand is likely to change that equation over the next few years. There is widespread concern that upstream materials and mining capacity are failing to keep pace with demand, and particularly so in Europe and North America. Therefore, the automotive industry is anticipating potential upstream battery raw material shortages from the middle to the end of the end of the decade, which could even overshadow current semiconductor shortages. Some commentators have suggested that OEMs need to become mining companies. However, it is more realistic that OEMs will increasingly form supply agreements and partnerships with upstream mining companies to semi-vertically integrate and 'lock-in' security of supply.

> ***"The automotive industry is anticipating potential upstream battery raw material shortages from the middle to end of the end of the decade which could even overshadow current semiconductor shortages."***

In cell manufacture, to mitigate risks and share investment costs, many OEMs and cell suppliers are forming joint ventures, partnerships and alliances to establish new gigafactories. OEMs are also increasingly moving away from exclusive single-sourcing supply agreements with cell suppliers in favour of multi-sourcing supply agreements with a range of suppliers. This approach helps mitigate against supply disruption and also protects the OEM against technological advances made by one company that could competitively disadvantage a carmaker if they are locked into a cell supply agreement with only one supplier.

A further strategy to build stronger, more resilient battery supply chains is to regionalise and localise battery manufacture. Rising fuel and logistics costs in transporting increasingly heavy batteries, real concerns around supply chain security and new regulation on the carbon footprint of batteries are all contributing to increasing regionalisation of cell manufacturers and localisation - even 'hyper-localisation' - of battery integration of modules, packs and casings in close proximity to vehicle assembly plants.

Another challenge is the regulation around moving batteries, which are classed as 'dangerous goods". Logistics companies are investing in the skills, knowledge, permits and equipment required to achieve this. For example, the multitude of different battery types often require different sets of handling requirements, such as based on thermal and humidity standards. There are also space and packaging considerations that impact the design of the battery warehousing facilities. Clearly this also affects staff training in order to maintain those battery handling requirements.

More innovations are emerging to deal with these challenges. For example, at the South Korean port of Busan, which exports around 90% of that country's EV batteries, the port authority is working with Vesta, South Korea's largest container manufacturer, to develop battery-safe shipping containers specifically to transport lithium-ion batteries. This is likely to include monitoring temperature and moisture content, as extreme heat and water are potentially hazardous for a battery.

### 11.3 Government's Role in the Battery Supply Chain

Governments are very concerned that the lucrative battery supply chain could slip away to Asia, and with it a considerable part of the automotive value chain that is considered to be a major 'pillar industry', ultimately impacting GDP, jobs and wider economic prosperity. Governments therefore have a crucial strategic role in developing the battery supply chain and are doing so through a mixture of regulation and public funding to further support private investment.

> *"Governments therefore have a crucial strategic role in developing the battery supply chain and are doing so through a mixture of regulation and public funding."*

The EU previously funded the development of the battery value chain through the European Investment Bank and through its Horizon 2020 research programme. From January 2021, the EU allocated an additional €2.9 billion in state aid for the **European Battery Innovation** programme to fund R&D and invest in battery plants with the expectation that it will result in private companies investing up to €9 billion.

The **EU Battery Regulation** phasing in from 2023 around sustainability and rules of origin will also require an increasing percentage of locally sourced materials within batteries, increasing gradually to 2027. The legislation also requires supply chain due diligence requirements; by January 1, 2026, industrial batteries will have to have an electronic record. This 'battery passport' will help OEMs comply with the regulation and trace the origins and carbon footprint of every battery model, helping them compete with Asian imported versions. This European Commission position suggests it is at least partly clothing its economic aims for the battery value chain in terms of sustainability pursuits. Nonetheless, the regulations would in effect help to coerce the development of a much-needed European battery supply chain.

However, the sustainability objectives are real, with the ultimate end goal of achieving the 'carbon neutral battery' so that EVs are genuinely reducing overall emissions, not merely from the tailpipe. To that end, many battery cell suppliers are adapting plants and production processes to become carbon neutral. For example, in March 2022 CATL announced what it claims is the world's first carbon-neutral battery plant in Yibin in China's Sichuan Province, and which was officially granted a zero-carbon PAS 2060 certification. This is an important signal of the direction of travel for the wider industry, as CATL aims to achieve this status across all of its plants.

> *"To that end, many battery cell suppliers are adapting their plants and production processes to become carbon neutral."*

Further downstream, Webasto has begun operating a pack assembly plant in Schierling, Bavaria, Germany that is entirely solar powered. While pack assembly only contributes a relatively small amount to a battery's overall carbon footprint, it demonstrates how carbon-neutral production needs to extend to every part of the value chain, not just at the gigafactory level.

## 11.4 The Battery Supply Chain is a Competitive Advantage

Recent supply chain disruptions, shortages and the inability to fulfil customer demand is becoming a major issue, with EV waiting times reported to be around 9-12 months in some cases. Some of these long waiting times are linked with battery supply shortages primarily driven by upstream shortages, and supply disruptions compounded by surging EV demand. However, in most cases, EVs are suffering production delays, as are ICE vehicles, due to wider supply chain woes, more specifically around semiconductor shortages that still plague the entire industry. But EVs are particularly affected by these semiconductor shortages as EVs typically contain a larger number of semiconductors per vehicle compared to ICE vehicles. In that context, OEMs that can supply customers and not have long waiting lists will clearly be at a considerable competitive advantage, generating more revenue and being more able to capture market share.

Therefore, managing and controlling the supply chain is emerging as a clear competitive advantage and will likely become even more so as EV production and demand ramp up. That will put even more impetus on supply chain visibility, semi-vertical integration – including partnerships, alliances and JVs – supply and production planning, as well as logistics and inventory management. The Covid crisis, semiconductor shortages and now the Ukraine-Russia conflict have all demonstrated how vital resilient supply chains are when trying to keep production flowing despite the seemingly relentless disruptions that the world inflicts upon the automotive industry. Those who succeed in the emerging battery sector and EV race will depend on commanding a well-managed, agile, flexible, multi-sourced and resilient supply chain.

> ***"Those who succeed in the emerging battery sector and EV race will depend on commanding a well-managed, agile, flexible, multi-sourced and resilient supply chain."***

## 12. Glossary

| | |
|---|---|
| **ACC** | Automotive Cells Company |
| **AGV** | Automated Guided Vehicle |
| **BMS** | Battery Management System |
| **BYD** | Chinese OEM and cell manufacturer 'Beyond Your Dreams' |
| **CATL** | Contemporary Amperex Technology Limited |
| **CEO** | Chief Executive Officer |
| **COO** | Chief Operating Office |
| **DRC** | Democratic Republic of the Congo |
| **EU** | European Union |
| **EV** | Electric Vehicle |
| **FCEV** | Fuel Cell Electric Vehicle |
| **GDP** | Gross Domestic Product |
| **Gigafactory** | A large battery cell manufacturing plant (nominally above 1 GWh) |
| **GM** | General Motors |
| **GWh** | Gigawatt hour (1,000,000,000 Watts for 1 hour) |
| **HEV** | Hybrid Electric Vehicle |
| **ICE** | Internal Combustion Engine |
| **JV** | Joint Venture |
| **KWh** | Kilowatt Hour (1,000 Watts for 1 hour) |
| **LV** | Light Vehicle |
| **M&A** | Mergers & Acquisitions |
| **MWh** | Megawatt Hour (1,000,000 Watts for 1 hour) |
| **NGV** | Natural Gas Vehicle |
| **OEM** | Original Equipment Manufacture |
| **PAS 2060** | Carbon neutrality standard and certification |
| **PHEV** | Plug-in Hybrid Electric Vehicle |
| **R&D** | Research & Development |
| **RNM** | Renault-Nissan-Mitsubishi alliance |
| **TMS** | Thermal Management System |
| **US** | United States |
| **Vertical Integration** | When the value chain from materials to end product is owned by 1 company |
| **VW** | Volkswagen |

## 13. Companies Mentioned

**OEMs & Brands:**

Abarth, Acura, Akasol, Alfa Romeo, Alpine, AMG, Ankai Bus, Audi, BAIC Motor, BAW, BMW, Bugatti, Buick, BYD, Cadillac, Changan auto, Chery Auto, Chevrolet, Chrysler. Citroen, Dacia, Daihatsu, Daimler, Datsun, Dodge, Dongfeng Motor, DS, Ducatti, FAW, FCA, Ferrari, Fiat, Ford, Foton, GAC, Geely, General Motors (GM), Genesis, GMC, Great Wall Motor, Haval, Hino, Honda, Hyundai-Kia, Infiniti, JAC, Jaguar, Jaguar Land Rover (JLR), Jeep, Jianghuai Automobile, Jiangling, Jinlong, Kandi Tech, Kia Motors, Lada, Lamborghini, Lancia, Land Rover, Lexus, Lincoln, Lynk & Co, Mahindra & Mahindra, MAN, Maruti Suzuki, Maserati, Maxus, Mazda, Mercedes-Benz, MG, Mini, Mitsubishi, Nanjing Golden Dragon, NIO, Nissan, Opel, Ora, Peugeot, Polestar, Porsche, Qingyuan, Ram, Renault, Renault-Nissan-Mitsubishi (RNM), Roewe, Rolls-Royce, SAIC, Samsung Motors, Scania, SEAT, Shanghai Sunwin, Shenwo, Skoda, Smart, Stellantis, Subaru, Suzuki, Tata Motors, Tesla, Toyota, Vauxhall, Venucia, Volkswagen Group, Volvo Cars, VW Group, Wey, Wuling, Xiamen King Long, Xpeng Motors, Yuejin, Yutong, Zhongtong, Zoomlion

**Upstream: Mining, Refining and Processing Companies:**

Albermarle, Altura Mining, Anglo American, Assmang Xiangtan Electrochemical Scientific, Autlan, BASF, BHP Billiton Ltd., BHP Group, Chemco, China, Molybdenum, Cobalt Blue, Consolidated Minerals (Consmin), Controlled Thermal Resources (CTR), Eramet, Eurasian Resources Group, First Quantum Minerals, Galaxy Resources Limited, Ganfeng Lithium Co., Gecamines, Glencore, Huayou Cobalt, Independence Group, Jinchuan Group International Resources, Jupiter Mines, Katanga Mining, Kidman Resources, Korea Resources Corporation, Lake Resources, Lithium Americas, Livent Corp., Mali Lithium, Managem Group, MGX Minerals, Minara Resources, Mincor Resources, Mineral Resources, Nemaska Lithium, Norilsk Nickel, Orocobre, Panoramic Resources, Pengxin International Mining Co., Piedmont Lithium, Pilbara Minerals, Prospect Resources, Redwood Materials, Sherritt International, Sichuan Yahua Industrial Group, SNNC, Sociedad Química y Minera (SQM), South Africa Manganese, South32, Sumitomo Metal Mining Co., Talison Lithium, Talon Materials, Talon Metals, Tianqi Lithium Industries Inc., Tsingshan Group, Umicore, Vale, Vulcan Energy Resources, Western Areas, Zhejiang Huayou Cobalt

**Midstream: Battery Component Manufacturers**

Asahi Kasei ,BASF, Beijing Easpring, BNE, BTR Energy, Cangzhou Mingzhu, CapChem Technology, Celgard, Daikin, Do-Fluoride Chemicals, Donghang, DuPont, Entek, Evonik, GEM, GS E&C, Guotai-Huarong (GTHR), Guoxuan High Tech, Hitachi Chemicals, Hunan, Shinzoom Technology, Jiangxi Zeto New Energy Tech, Jinhui Hi-tech, Johnsson Matthey, Kingray New Materials Science & Tech, LG Chem, Litarion, LS Mtron Carbonics, Mitsubishi Chemical, Mitsui Chemicals, Newmi Tech, Nichia, Ningbo Shanshan, Ningdo Jinhe, Nippon Carbon, Panax-Etec, Senior Technology Material, Shanghai Energy New Materials, Shanshan Energy, ShanshanTech, Sinoma, SK IE Technology Company (SKIET), SKI, Suzhou Greenpower New Energy Materials, Targray, Tinci Materials Tech, Toda Kogyo, Tokai Carbon, Toray Tonen, Ube, Umicore, Victory Precision Manufacture, Xiamen Tungsten, Zhongke Science and Tech

**Downstream: Battery Cell Manufacturers**

A123 Systems, ACC, Adani, Akasol, Amara Raja, Amperex Tech (TDK), AMTE Power, Asia Pacific total, Ather Energy, Automotive Cell Company (ACC), AVIC Lithium Battery Co., BAK Battery, BAK Battery, Barden cells Ltd , Basquevolt, Beyonder, BHEL-Libcoin consortium, Blackstone Resources, Blue Energy Co. , BlueOvalSK, BMZ / Terra & others, Bollore, BritishVolt, BYD, CATL, CBAK Energy, Cenat New Energy / Evergrande, China Aviation Lithium Battery (CALB), CITIC Guoan Group/CITIC, Monguli Power Technology Co., Coslight, Customcells, Desai Battery Technology Co., DFD, DLG, Dongguan Large Electronics, Durapower, Dynavolt, Electrovaya, ElevenEs, Energy Absolute, Energy Renaissance, Envision AESC, E-One Molie Quantum Energy Corp., Eurocell, EVE Energy, Exide, Farasis Energy, FREYR, Funeng Technology, Gangfeng

Lithium China, Go Charge Go Asia (GCG Asia), Gotion High Tech, GPSC, GrePow, GS Yuasa, GSR Capital, Guangzhou Fullriver Battery New Technology, HBL Power, Hero / Electrovaya, High Energy Batteries, High Star, Honda, Hyperbat, HZM Electronics, Iberdola, Imperium3, InfraNomics, Innolith, Inobat Auto, Inverted Energy, Italvolt, Jiangsu Fengchuen New Energy Power Technology Co., Jiangsu Tafel New Energy Technology Co., Ltd., JSW Energy, KORE Power, Leclanche, LG Energy Solution, Li Energy, Liacon, Lion Electric, Lishen, Listrom, Lithium Energy Japan, Lithium Werks, Lithops / FAAM, MARII, McNair, Microvast, Monbat (EAS Batteries), Morrow Batteries, National Power, Neuvo Pplus Companyr, Northvolt, Panasonic, Penghui Power / Guangzhou Great Power Energy & Tech, Perfect Amperex Technology, PEVE/ Sinogy Toyota, Phi4tech, Phylion Battery, Prime Planet Energy and Solution, Primearth EV (PEVE), ProLogium, QuantumScape, Reliance, Rosatom, SAFT, SAIC Motor, Samsung SDI, SES, Shandong Goldencell Electronics Technology, Shandong Weineng Environmental Protection Power Technology Co., Shandong Winabattery, Shenzhen Eastar Battery, Shenzhen HLC Battery Technology, Shenzhen Kayo Battery , Shenzhen Waterma Battery, Sichuan Energy Investment Huading Guolian Power Battery Industrial Base, Sila Nanotechnologies, SK Innovation, SK On, Solid Energy Systems, Solid Power, Statevolt, Stromvolt, Sunlight, Sunwoda, Suzuki, SVOLT, Tata AutoComp Systems Ltd., Tata Group, Tenpower, Tesla, Tesvolt, Tianneng, Tohoku Murata Manufacturing,Toshiba, Ultium cell, Vaillant, Varta, Verkor, Vinfast, Vingroup, Vision, VW Group / Société Européenne, Wanxiang A123, XALT Energy, Xiangyang Ahead Cell Technology, Yinlong New Energy Co, Youlion, Zhuoneng New Energy Corporation, Zorlu

**Battery Integration: BMS**

BYD, CATL, Eberspächer, Ficosa, G-Pulse, Hella, Idneo Engineering Services Company, Leclanche, LG Energy Solution, Lithium Balance, Nuvation Energy, NXP Semiconductors, Panasonic Corporation, Renesas Electronics, Robert Bosch, Roboteq, SVOLT, Tesla, Analog Devices, AVL LIST, Battery Systems, Calsonic Kansei Corporation, Continental, Denso Corporation, Elithion, Hitachi, Horiba Mira, Infineon Technologies, Intel Corporation, Ion Energy, Johnson Matthey, Marelli, Maxim Integrated Products, Midtronics, Mitsubishi Electric, Navitas System, Orient Technology, Preh, Ricardo, Samsung SDI, Silicon Labs, ST Microelectronics, Texas Instruments, Toshiba Corporation, Vitesco Technologies

**Battery Integration: Casings**

ArcelorMittal, CF Linamar, Constellium, Continental Structural Plastics (CSP), EDAG Group, Gestamp, Hanwha Advanced Materials, Hitachi Metals, Minth Group, Nemak, Norsk Hydro, Novelis, POSCO, SGL Carbon, Thyssenkrupp, TRB Lightweight, UACI Corporation, Voestalpine

**Battery Integration: Pack Assembly**

Arrival, ATW Automation, Audi, BMW, BMZ GmbH, Bolloré, BorgWarner/Romeo, BYD, Daimler, ElringKlinger AG, Ford, Geely, GM, GS Yuasa, Hyperbat, Jaguar Land Rover, Kreisel Electric, Microvast, Northvolt, RNM, Scania, Stellantis, Tesla, Valmet Automotive, Volvo, VW, Webasto

**Battery Recycling**

ACCUREC Recycling, AERC Recycling Solutions, AkkuSer Oy, American Manganese, BASF, Batrec Industrie, Battery Recycling Made Easy, Battery Resourcers, Duesenfeld, Eramet, Fortnum, Ganfeng Lithium, Ganzhou Highpower Technology, Glencore International, Green Eco Manufacturing Resource (GEM), Green Technology Solutions, Guangdong Guanghua Sci-Tech, Hunan Brunp Recycling Technology, Johnson Matthey, Li-Cycle Corporation, Neometals, Nippon Recycle Center Corporation, Northvolt, Quzhou Huayou Cobalt New Material, Recupyl, Retriev Technologies Inc. , SNAM, Stena Recycling, SUEZ, Tesla, Umicore, VW

## 14. Appendix



Ultima Media Ltd *part of* Süddeutscher Verlag
401 King Street
Hammersmith
London, W6 9NJ
**www.ultimamedia.com**
+44 (0)20 8987 0900

**Disclaimer**
All facts and figures are believed to be accurate at the time of publication; Ultima Media accepts no responsibility for inaccuracies due to future developments in the market or incorrect information provided by Ultima Media's sources. Ultima Media is unable to accept any legal liability for any consequential loss or damage, however caused, arising as a result of any actions taken on the basis of the information provided in this report.

---

**Christopher Ludwig**
Editor-in-Chief, Ultima Media
christopher.ludwig@ultimamedia.com
+44 (0)208 987 0968

---

**Daniel Harrison**
Automotive Analyst, Ultima Media
daniel.harrison@ultimamedia.com
+44 (0)208 987 0946

---