Q2 2022

rho motion magazine

Setbacks and sustainability:

The short- and long-term issues facing the EV market

In this issue:

Battery recycling comes to the fore

Will supply issues disrupt demand in the EV market?

Two-wheeler electrification matters too

Introduction to the magazine

Adam Panayi
Managing Director, Rho Motion

Hello and welcome to the Q2 2022 edition of the Rho Motion Magazine.

As ever the analyst team at Rho Motion are free to write up an article on whatever they feel are the key issues that they have come across in their research. We're also very grateful for the contributions of Alfred H Knight, Mitra Chem and E-Magy to this quarter's magazine.

The lead article in this edition comes from my colleague Mina Ha, who has decided to focus on the outlook for battery recycling, which is becoming a key pre-occupation for OEMs and cell manufacturers, among others. Battery recycling presents a logistical, economic, and environmental challenge, and is already shaping decision making around chemistry selection and investment ahead of the real volumes coming later in the decade. On a similar note, our Battery Research Lead, Ulderico Ulissi has written about strained value chains and the role of energy storage, taking a typically practical view of how cost and performance interact when making technology choices.

My colleague Charles Lester looks at the current state of play in the EV market, and discusses the headwinds facing the industry at present, similarly Yu Du and Jie Xu take a deeper dive into the Chinese market and how recent lock downs impacted production and supply chains there.

Research Manager Iola Hughes provides an update on the ESS market and how battery storage increases in importance for renewable and other energy supply, while my colleague Will Roberts provides insight on the much overlooked two and three wheeler market. Finally, we provide a summary of the latest financial news in the sector with some highlights from our Energy Transition Capital Tracker.

I hope you enjoy the magazine,
Adam

Photo: Adobe Stock

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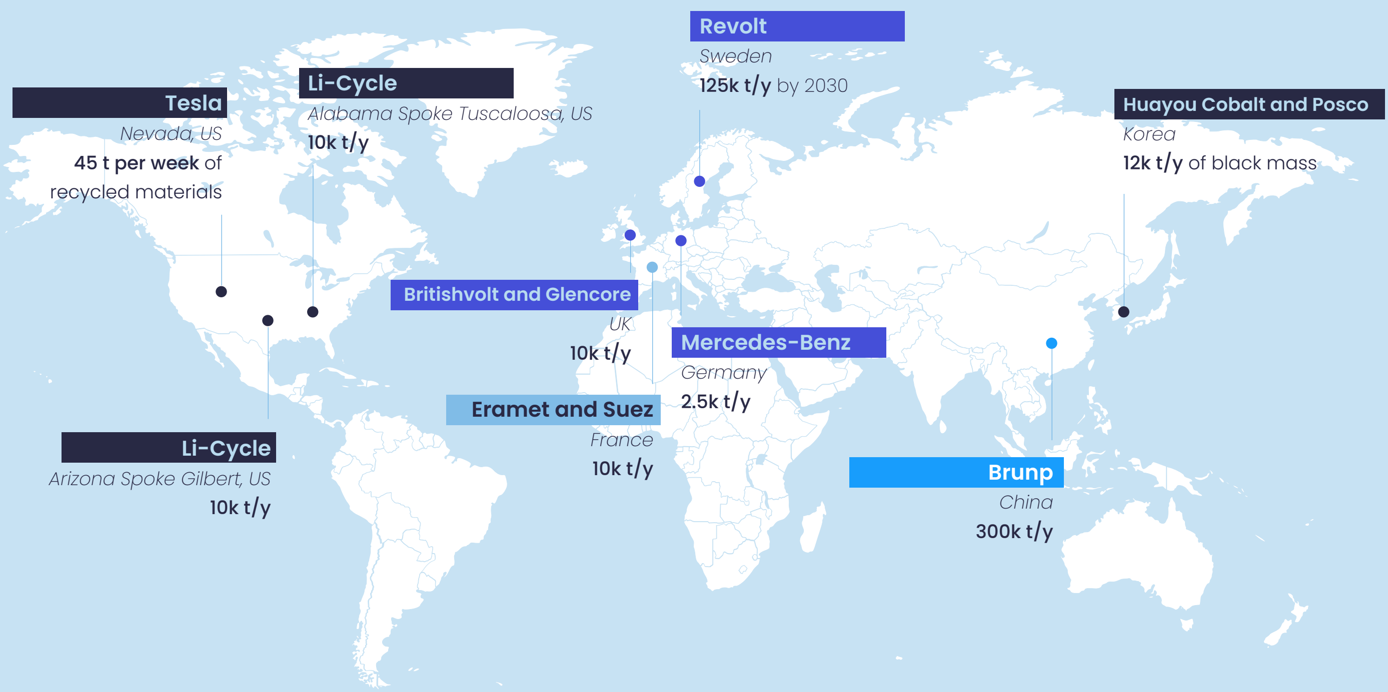
Battery recycling: EV battery value chains evolving towards long-term sustainability

Mina Ha
Research Analyst, Rho Motion

The battery recycling market is set to grow as EV battery value chains from mining companies to battery manufacturers and OEMs invest in battery recycling through joint ventures, acquisitions, and partnerships to reach long term sustainability goals. While the trend is expected to continue largely driven by battery recycling legislation and the need to secure feedstock supply for battery production, there are challenges in meeting legislative requirements and achieving financial sustainability.

Chart: Global battery recycling capacity is expected to expand as EV market builds toward closed-loop value chains

Recent announcements on EV battery recycling plants coming online between 2022 and 2025



This is a non-exhaustive representation of EV battery recycling plants in 2022

One of the great challenges the EV market currently faces is securing a supply of raw materials, which appears to be scarce, as the EV market is expected to grow fast towards the end of the decade. Also, the supply of battery raw materials is dominated by several resource-rich countries where vast amounts of raw materials such as lithium, nickel, and cobalt are contained. The supply dominance often works towards pushing up the material prices especially when the market experiences a supply shortage.

Major battery producers and OEMs have been expanding their scope of business towards upstream value chains to mitigate the supply disruptions. In recent years, investments have been also building up around battery recycling to reach long term sustainability. The map above shows OEMs and battery cell producers that have entered the battery recycling market by setting up a joint venture, or own production plant, or investing directly in battery recycling companies.

In Europe, Northvolt built its recycling pilot plant in Västerås, Sweden, in 2019 under the recycling programme called Revolt. The battery producer recently announced that its first giga-scale recycling plant is set to be operational in 2023, with its annual capacity ramping up to 125,000 tonnes of batteries by 2030. Also, its joint venture with Norsk Hydro, Hydrovolt is expected to start its commercial production for battery recycling in Fredrikstad, Norway in May this year. In Germany, Mercedes-Benz's new recycling plant is expected to come online with an annual capacity of 2,500 tonnes of batteries in 2023. Glencore and Britishvolt formed a joint venture in January this year to build a lithium-ion battery recycling plant with an annual capacity of 10,000 tonnes of batteries for EVs, laptops and mobile phones at the site of Glencore's facility in Kent, the UK by mid-2023. Battery manufacturing scrap from the Britishvolt's plant in Northumberland, the UK, which is also set to commence in 2023, will be used as feedstock. The partnership is considering developing a post-treatment process from black mass into battery-grade raw materials. In the US, Tesla aims to recycle batteries at all its Gigafactory locations. It completed the first phase of a battery recycling facility at Gigafactory Nevada in Q4 2020. According to its 2021 Impact Report released in May, the Nevada recycling plant reached a production rate of over 45 tonnes of recycled materials per week at the end of 2021 and achieved a battery cell recovery rate of 92%. LG Energy Solution (LGES) and LG Chem (LGC) completed its USD50 million equity investment in Li-Cycle upon completion of its off-take agreement on scrap and nickel sulphate supply in March 2022. Prior to the acquisition, the three companies also signed a scrap supply and nickel sulphate off-take agreement in December 2021. Under the agreement, LGES will supply Li-Cycle with battery production scrap while Li-Cycle supplies 20,000 tonnes of nickel contained in nickel sulphate to LGC and LGES for the period 2023-2033.

The EU battery legislation is still under development

Source: Rho Motion

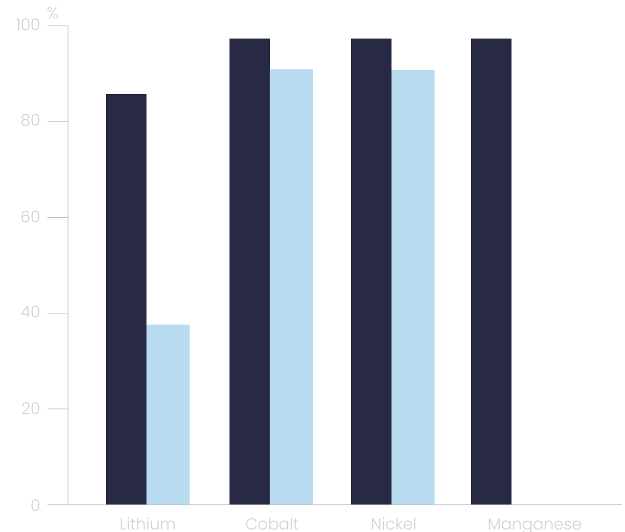
The EU Battery Legislative procedures

In Asia, CATL operates its battery recycling business through its subsidiary Brunp Recycling. Brunp has a battery recycling and CAM production plant in Hunan and its second recycling plant in Ningde, Fujian. It plans to invest USD5 billion (RMB32 billion) in Yichang, Hubei to build a large-scale CAM production and recycling plant by 2025. The recycling plant is expected to process 300,000 tonnes of batteries annually. In 2021, Huayou Recycling, a subsidiary of Huayou Cobalt, formed a joint venture called POSCO HY Clean Metal with the Korean raw material producer POSCO to build a battery recycling plant that processes 10,000 tonnes of black mass yearly. The plant construction is expected to be completed by the end of 2022.

China's EoL battery recycling recovery rate requirements are set higher compared to Europe

Source: Rho Motion

Battery recycling recovery rate requirements, China vs EU



Battery recycling legislation, the key driver of the battery recycling market, is expected to further reinforce the recycling capacity expansions. China's EV battery recycling legislation is more developed with its End-of-Life (EoL) battery handling systems and requirements such as targets for battery recycling recovery rates compared to other regions. In 2018, the Chinese Ministry of Industry and Information Technology published guidelines on handling EoL batteries including the battery collection and tracing service network set up by EV OEMs, and battery tracking system and requirements for whitelisted battery recycling and reuse companies. In Europe, the European Commission first proposed the EU Battery Directive in December 2020 to ensure the sustainable use of batteries covering the whole lifecycle of batteries from mining processing to battery production and recycling. There have been updates on the proposal in the past two years, and further procedures are expected to follow.

Unlike China and Europe, the US currently does not have battery recycling legislation established or under progress. The country focuses on developing the domestic EV battery supply chains including battery recycling through public funding. In early May this year, the U.S. Department of Energy announced that it will grant USD3.1 billion for expansions of battery manufacturing, raw material sourcing and recycling, USD60 million of which will be allocated to EV battery recycling and reuse projects.

The battery recycling market is in its infancy and faces challenges, i.e., meeting legislative requirements which vary by region. The EU and China have set their own targets for EoL battery collection and material recovery rates; China's targets for recycling recovery rates for cobalt, nickel and manganese were set at 98% in 2020 while the EU aims at 90% by 2025. Meeting the requirements is closely linked to whether EoL battery logistics and tracking systems are in place and how advanced recycling technologies are, and those areas are still under development and need investments going forward. Another challenge is financial sustainability. Feedstock for battery recycling currently comes mainly from production scrap, which is insufficient to achieve economies of scale. The financial performance of battery recycling operations is likely to show improvement as increasing volumes of EoL EVs come into recycling in the next five to 10 years.

rho motion

Battery Recycling Outlook

Our Battery Recycling Outlook provides a long-term outlook for global scrap material available for battery recycling. The outlook is presented by region, battery chemistry and feedstock and covers end-of-life EVs, battery manufacturing scrap and end-of-life energy stationary storage.

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Our forecast provides long-term outlooks for the following:

- GWh of BEV and PHEV scrap material available for battery recycling by feedstock, battery chemistry and region to 2040
- Tonnes of black mass available for battery recycling by feedstock, battery chemistry and region to 2040
- Battery recycling technologies
- Battery recycling OEM profiles
- Battery recycling legislation

The battery recycling market is gaining traction as EV value chains evolve toward long-term sustainability goals amid future raw material shortages and environmental, social, and governance (ESG) concerns.

The outlook provides an in-depth analysis of the current and future battery recycling market in aspects of the market dynamics, technologies, and key drivers. The report can be used as a tool to understand how the market grows at global, regional, and country levels on the back of EV demand, legislation, and recycling company strategies.

Black Mass and the Battery Revolution: An Overview of the Experimental Research Conducted by Alfred H Knight

ALFRED H KNIGHT

Dr Laurance Donnelly
Chief Geologist, Head of Technical Department, Alfred H Knight

As the global demand for batteries is projected to significantly increase in the decades to come, Alfred H Knight, a leading global testing and inspection organisation, is participating in the 'battery revolution' through innovative experimental research.

As we enter a new era known as the 'battery revolution', the number of lithium-ion batteries (LIB) in circulation is likely to increase significantly (Figure 1).

An anticipated shortfall in the availability of battery minerals is predicted by some investigators to result in a greater reliance on the recycling of end-of-life (EoL) LIB.

Experimental research commissioned and conducted by Alfred H Knight and our partners explores the phase characteristics of the commercially important intermediate material, known as 'black mass.'

What is black mass?

'Black mass' is the industry term used to describe a type of e-waste comprising crushed and shredded EoL battery cells. It contains mixtures of valuable metals including; lithium, manganese, cobalt and nickel.

Figure 1: Global annual scrap materials by market

Source: Rho Motion

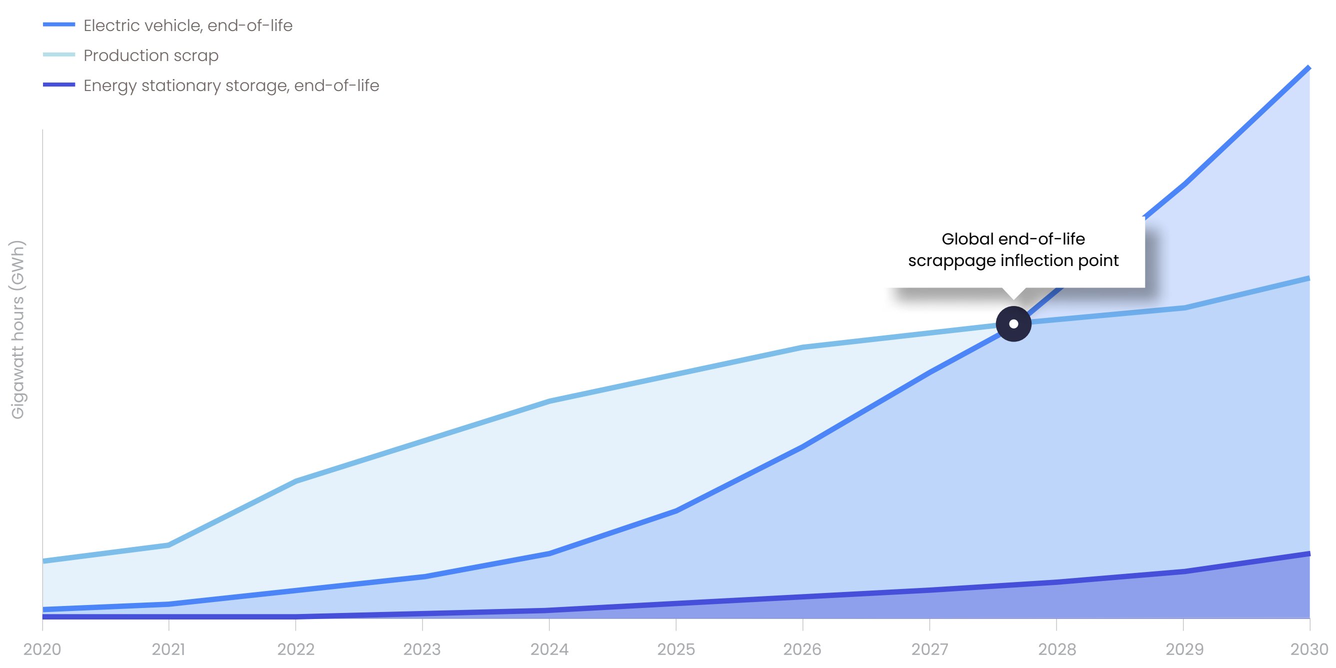
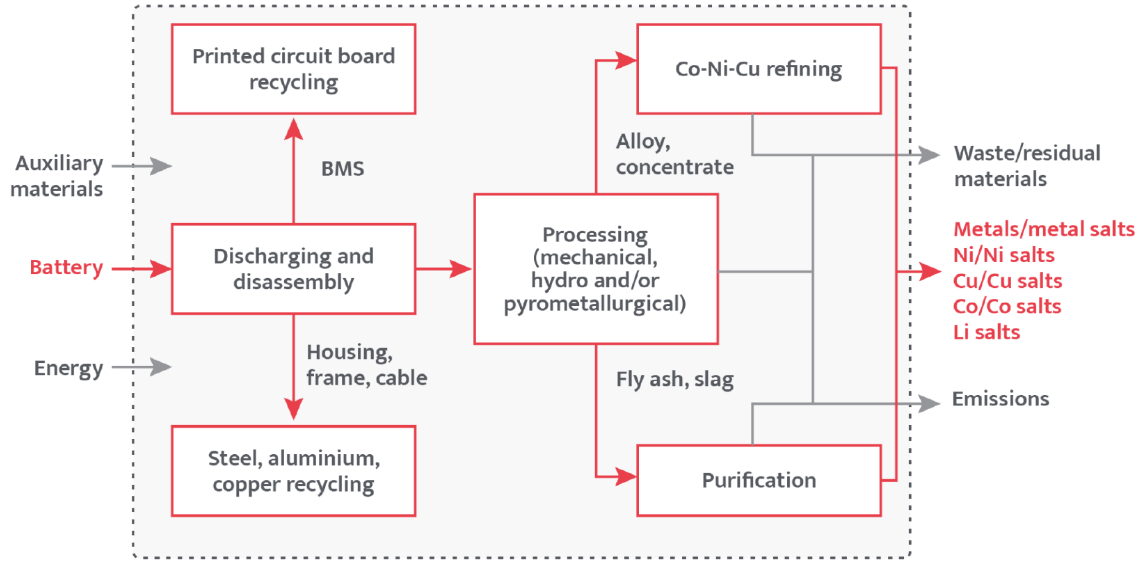


Figure 2: Initial stages in the recycling of LIBs. BMS is a battery management system utilised for the safe operation of the battery pack. It monitors the battery to make sure it doesn't operate outside the set safety limits.

Source: Donnelly et al., 2022, pending



Initially, waste batteries are collected, sorted, discharged and disassembled (Figure 2). This is followed by mechanical crushing, drying, sorting sieving and pyrolysis to 700°C to remove any remaining electrolyte and potentially hazardous to health fluorine-containing components (Figure 3). The resulting material is what is referred to in the battery recycling industry as 'black mass'.

The demand for future battery mineral supply and the associated metals relies on the availability of economically extractable geological mineral resources. The recycling market for LIBs is expected to expand significantly and black mass could provide strategically important metal resources that could make up part of the shortfall from conventional geological sources. The shift to a more circular economy creates the framework needed for collecting and recycling LIB into the supply chain.

According to research conducted by Circular Energy Storage, by 2030, it is estimated that around 1.2 million tonnes of LIBs will have reached EoL. This comprises an estimated potential recovery of 125,000 tonnes of lithium, 35,000 tonnes of cobalt and 86,000 tonnes of nickel, which could be recovered for use in new battery production.

Phase characterisation

The results of the assaying performed by Alfred H Knight found a sample of black mass from a European source to comprise; cobalt 15.79%, nickel 6.94%, manganese 4.82%, lithium 3.19%, copper 1.97%, aluminium 5.13% and other components.

Figure 3: Mechanical stages of LIBs recycling.

Source: Donnelly et al., 2022, pending

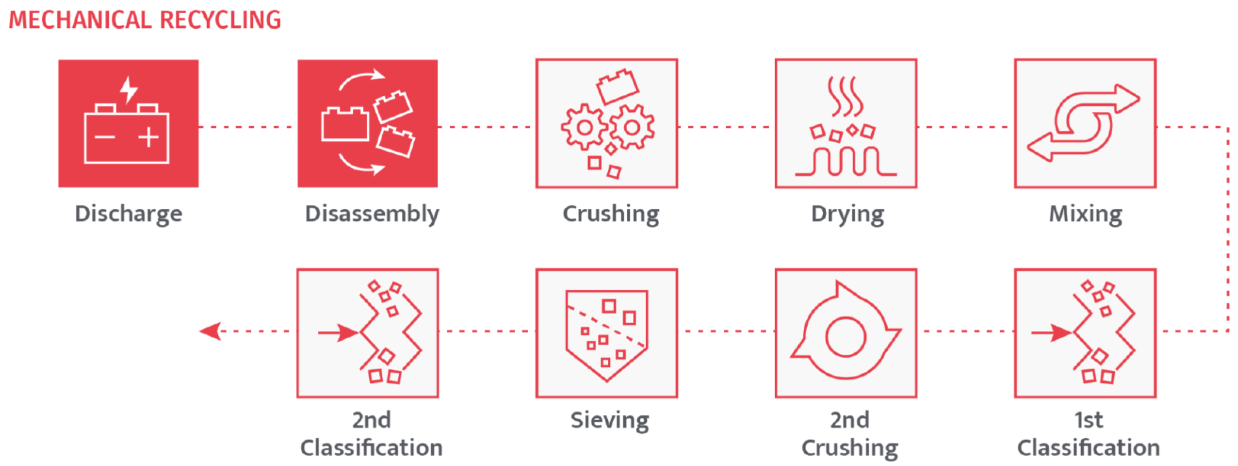


Figure 4: Automated mineralogy (AM) and SEM-BSE images for a sample of black mass. The bright phase in the SEM-BSE image is Cu foil, which in 2D sections looks like folded wire (upper). Enlarged micro X-CT image, from a video, showing the form of (A) the Cu foil particles in 3D and (B) the form of the cathode/aluminium foil components (lower).

Source: Donnelly et al., 2022 pending

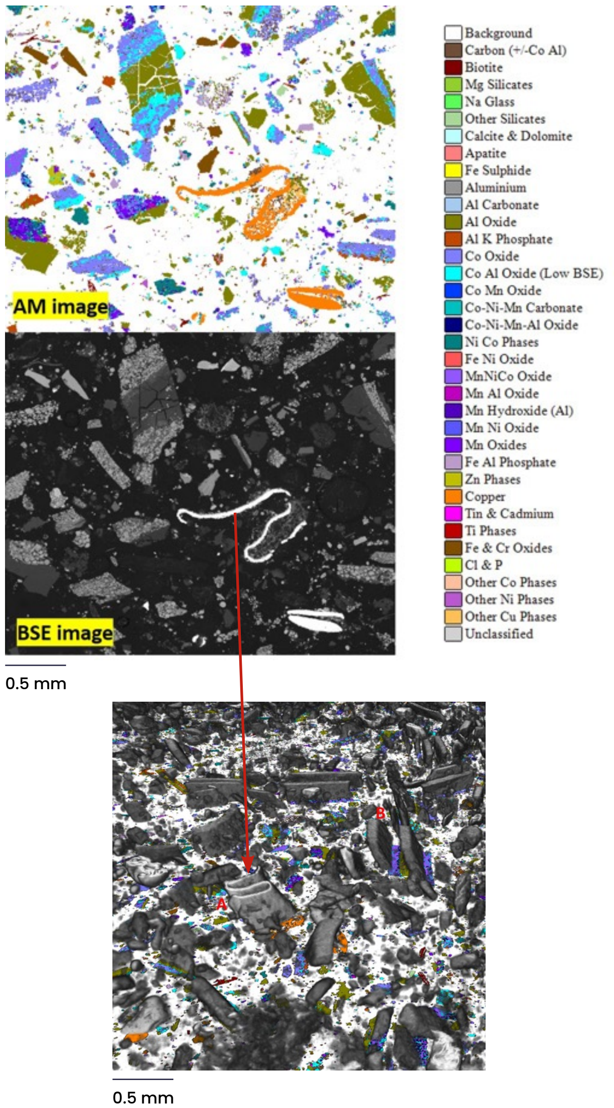
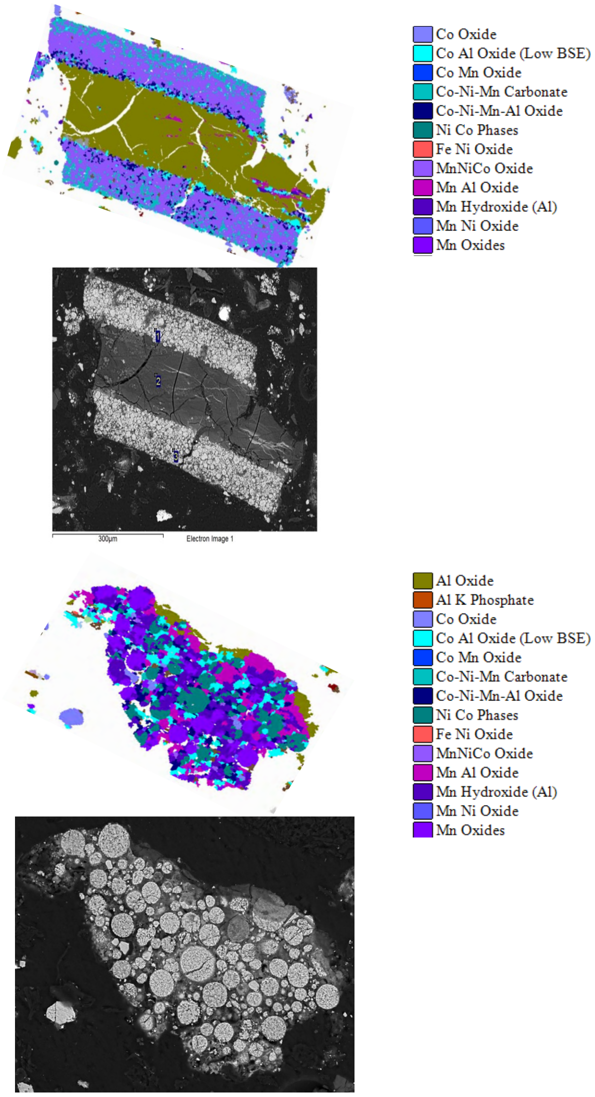


Figure 5: SEM-BSE image of black mass particles with showing complex and contrasting textures, the variable distribution of metals, grain sizes and morphology. Layered and stratified with metallic inclusions infilling fractures (upper) and globules of different metals in a single grain (lower).

Source: Donnelly et al., 2022 pending

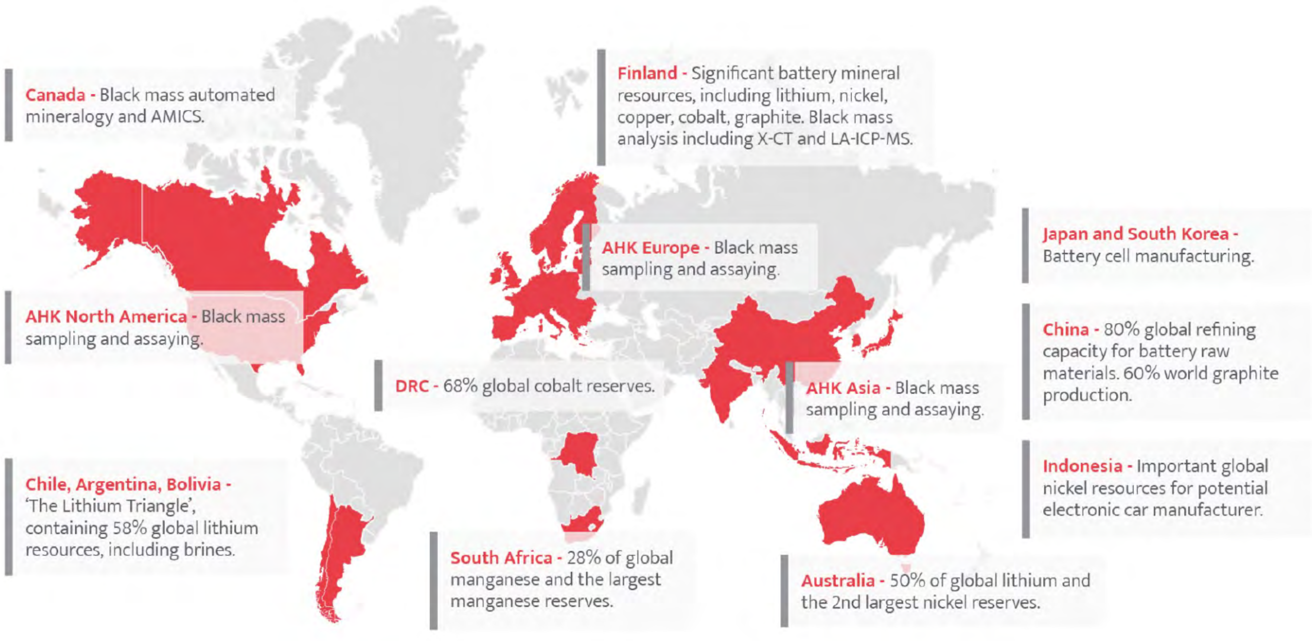


Following this, the Alfred H Knight Technical Department commissioned and conducted an innovative and experimental programme of 'phase characterisation' to determine the battery components, phase chemistry, and morphological characteristics, grain size, composition and textural variability for a natural state (unprepared) and prepared (crushed and dried) powdered sample. This was required to; develop a sampling strategy and standard operating procedure (SOP), to obtain a non-biased and representative sample, assist to determine a hydrometallurgical or pyrometallurgical processing route, detect valuable payable metals, assist with assay procedures, identify potential pollutant or penalty phases and for hazard identification and risk mitigation.

The black mass was investigated using expertise and instruments from the UK, Canada and Finland, which included the following:

- A visual examination and binocular microscopy.
- Manual scanning electron microscopy (SEM).
- Automated scanning electron microscopy with linked energy dispersive spectrometers (SEM-EDS).
- Advanced mineral identification and characterization systems (AMICS).
- X-ray computed tomography (X-CT).
- Laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS).

Figure 6: Alfred H Knight global reach. *Source: Alfred H Knight*



The results

The results of the automated and interactive SEM-EDS quantified the phases present and showed at high resolution, the chemical variability and phases that could be assigned to original battery components:

- The particles were found to be texturally complex, with mixed phases (Figure 4).
- Aluminium foils were coated with the different lithium metal oxide compounds.
- Copper foil appeared 'wire-like' in 2D, however, the X-CT imaging showed complex 3D textures and morphology of the particles, including deformed copper foil sheets (Figure 5).
- The light elements, such as lithium and 67 other non-metals and metals at a 20-micron scale with ppm to ppb level detection limits, were detected and quantified using LA-ICP-MS.

Why is this Important?

The technical research commissioned and conducted by Alfred H Knight provides a detailed understanding of the complex composition, particle structure and textural variability of black mass. This is enabling improved sampling and analysis techniques, which support a full understanding of the metal content. Alfred H Knight is providing a more detailed perception of black mass, in the recycling industry, to assist with the understanding of industrial processing and the recycling of battery waste.

Get in touch

Our team of highly-skilled subject matter experts, technical specialists, field inspectors and laboratory technicians operate from strategically located hubs around the globe (Figure 6.). This enables Alfred H Knight to deliver swift, accurate and reliable results at each stage of the battery materials supply chain.

If you would like further information on the research conducted by Dr Laurance Donnelly and the team at Alfred H Knight, email laurance.donnelly@ahkgroup.com, or visit ahkgroup.com.

Acknowledgments

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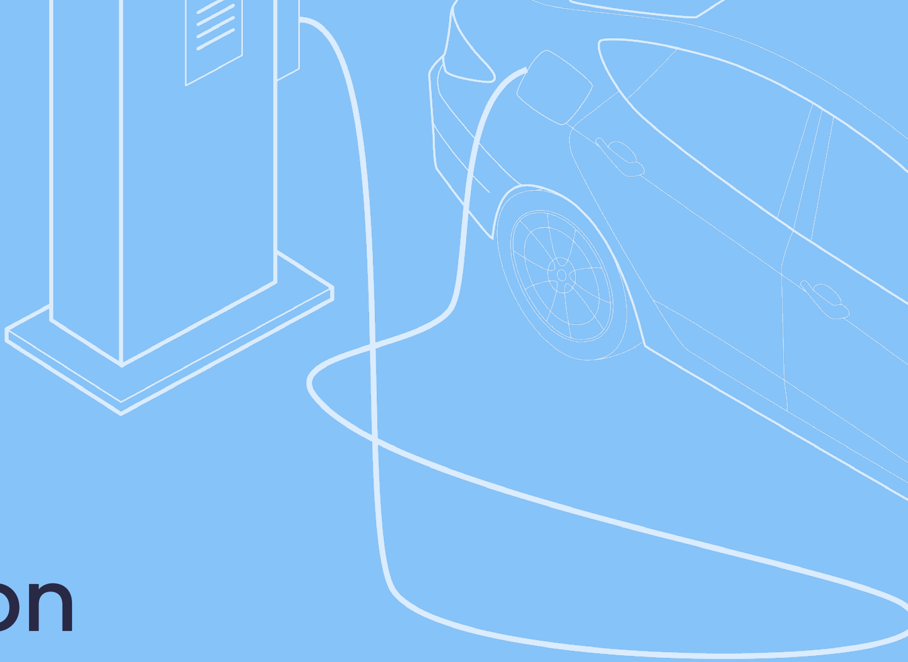

Rho Motion Consultancy and Advisory Services

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Rho Motion provides bespoke consultancy and advisory services, based on our clients' needs covering the EV and battery supply chains in the following areas:

- Competitor analysis
- Market entry strategy
- Business appraisal and strategy
- Battery chemistry and technology evaluation
- Techno-economic modelling
- Technology strategy
- ESG circular economy
- PFS/DFS

Our clients are diverse, global players and our research is relied upon in bankable feasibility studies, preliminary economic assessments and public finance raising including IPOs and debt issues.

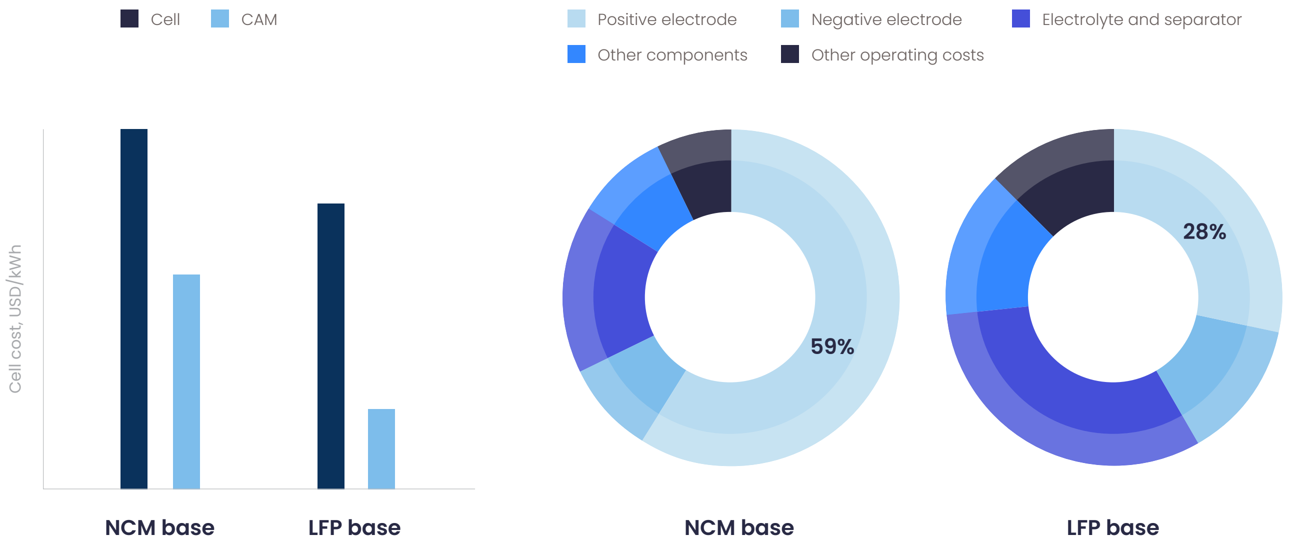
Strained value chains and the role of energy storage

Ulderico Ulissi
Battery Research Lead, Rho Motion

Photo: Adobe Stock

Figure 1: Cost structure of NCM and LFP battery cells. Lithium base cost scenario, assuming lithium hydroxide and carbonate cost parity at 17 USD/kg.

Source: Rho Motion



Strained value chains continue to be a significant headwind for the energy transition. It is unlikely the situation will ease anytime soon, as a major conflict in Europe and continued lockdowns in China are expected to cause extended supply crunches. The automotive industry has been badly affected.

The "just in time" approach to manufacturing doesn't cope well with parts pricing and availability fluctuations. To avoid these situations, with a long-term outlook towards electrification, OEMs now recognise that batteries will be one of the key components to secure. This should not surprise our readers. During the last quarter, we summarised complexities in the lithium-ion circular value chain. This article will discuss how price fluctuations of raw materials can affect battery cell costs by proposing two case studies for current and next-generation technologies.

We used Rho Motion's bottom-up battery cell cost model for this exercise. This tool, available to clients, is ideal for those who wish for more granularity to correctly estimate battery costs, e.g. USD/kWh, and battery material intensity, e.g., kg($NiSO_4$)/kWh. The model is

Figure 2: Solid-state battery cell cost split (top) and separator thickness versus cell cost linear, bi-variate sensitivity analysis for different solid-state battery chemistries

Source: Rho Motion

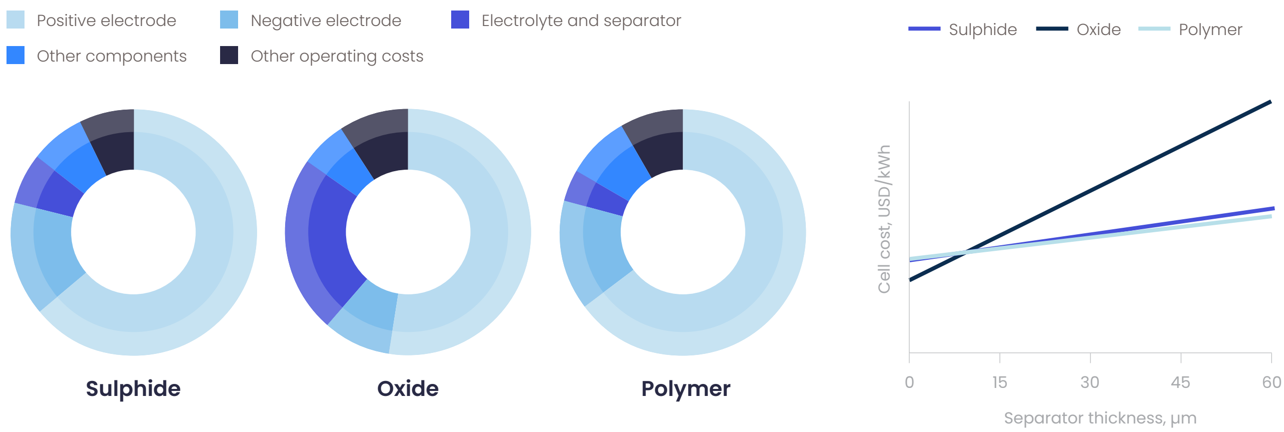


Photo: Sungrow EMEA

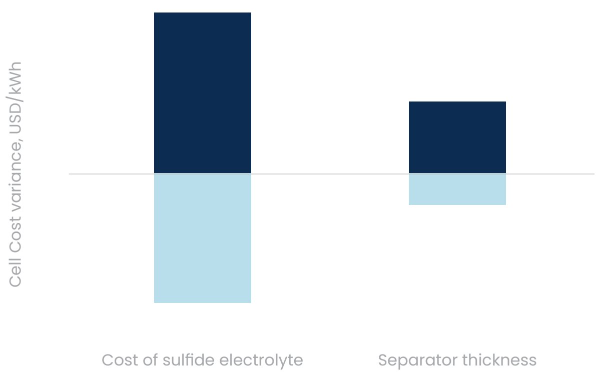
unique in the industry today, as all assumptions have been validated based on top-down data using detailed battery pack/cell teardowns.

Case Study 1: Nickel versus Iron-based, how does lithium price affect battery cell cost?

In this first case study, we modelled two different state-of-the-art battery cell chemistries, cells using $LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$ (NCM811) and $LiFePO_4$ (LFP) as the positive electrode, or cathode, active materials (CAM). We fixed other cell variables such as inactive components to make results comparable between the two cell chemistries, manufacturing plant location and size, and used a 11x31x1.2 cm^3 prismatic soft-case (pouch) cell design. We also modelled natural graphite as the negative electrode, or anode, active material (AAM) and a conventional organic, $LiPF_6$-based electrolyte. For NCM811, we assumed a positive electrode areal capacity of 4 mAh cm^{-2}. At the same time, for LFP, we modelled 3 mAh cm^{-2}. These values are comparable with current state-of-the-art cell designs. According to our model, these battery cells would be characterised by a gravimetric/volumetric energy of about 275 Wh kg^{-1} / 600 Wh L^{-1} (NCM811) and 200 Wh kg^{-1} / 400 Wh L^{-1} (LFP), respectively, and a lithium content, which is chemistry dependant, of about 0.1 kg kWh^{-1}. This represents our base case scenario, which is reported in Figure 1. For this analysis, we assumed the price parity of lithium hydroxide (LiOH) and lithium carbonate (Li_2CO_3), at 17 USD kg^{-1}. In this hypothetical scenario, LFP battery cells would be 21% cheaper than NCM811. The figure also evidences the different cost split of these two different chemistries. Whereas cathode for NCM-type represents 59% of the total cell cost, this goes down to 28% for LFP-type. These results highlight that the cost structure of cells using different CAMs is different, and as lithium price varies, we could see battery cell prices diverging.

Figure 3: Sensitivity analysis, the effect of varying cost of sulphide electrolyte and separator thickness

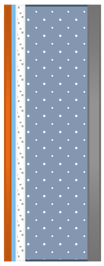
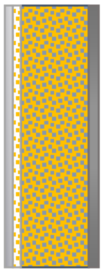
Source: Rho Motion



Case Study 2: Solid-state batteries, different technologies, different cost structures

The situation becomes more complex when trying to compare next-generation technologies, where the chemistry is not yet fixed and more, and potentially different, components need to be considered. To compare the cost structure of incumbent and next-generation chemistries, we considered solid-state batteries for our second case study. While keeping most variables fixed. We assumed NCM811 as CAM, natural graphite as AAM, and used a 11x31x1.2 cm^3 prismatic soft-case (pouch) cell design, we considered different electrolytes, such as sulphide, Li_2S-P_2S_5-type, oxide, $Li_7La_3Zr_2O_{12}$-type, and polyethylene oxide-type. In this case, we had to consider a certain amount of electrolyte at both the negative electrode (anolyte) and the positive electrode (catholyte), which we fixed for both at 15%, and will constitute part of the respective electrodes' costs.

Figure 4: Example of sulphide-type and oxide-type next generation battery cell chemistries *Source: Rho Motion*

QuantumScape		**Solid separator, liquid catholyte** QuantumScape uses an oxide-based solid-state separator, and a liquid electrolyte in the cathode ("catholyte"). The anode is a "lithium-free" current collector. Sintering and manufacturing of thin, oxide-based ceramic separators could be a barrier to scale-up. Li-free anode shows largest reversible swelling.	**Partners, investors** SAIC, QIA, CAPRICORN, TRIPLEPOINT CAPITAL, Continental, Fidelity, Breakthrough Energy, KENSINGTON, khosla ventures
Solid Power		**All-solid state** Solid Power uses a sulfide solid-state electrolyte. At the anode, it is proposing lithium metal (long-term) and silicon (short-term). The latter benefits from reduced swelling. This cell chemistry currently demands the highest pressure during cycling, (the use of silicon could reduce it). Manufacturing relatively compatible w/ standard li-ion.	**Partners, investors** BMW, KIA, Ford, A123 SYSTEMS, SOLVAY, SK, RIVER STONE, KOCH, SAMSUNG, VanEck, DCRC, VOLTA ENERGY TECHNOLOGIES, NEUBERGER BERMAN

This is a key difference, as compared to conventional lithium-ion batteries, which contain only a single electrolyte, solid-state batteries can contain anolyte, catholyte and electrolyte characterised by different nature and chemistry. The top part of Figure 2 highlights how sulphide/polymer-type and oxide-type cells are characterised by different cost structures. The latter, for example, can often employ lower cost catholytes, similar to conventional lithium-ion, as the oxide type electrolyte is relatively more compatible, from a chemical point of view, with conventional-type electrolytes. The bottom part of Figure 2 shows the results of our linear, bi-variate sensitivity analysis, highlighting the effect of separator thickness, which we varied between 1-60 μm. This is another variable specific to solid-state batteries. The results evidence that oxide-type cells can be more cost-effective compared to other solid-state chemistries at a low thickness (achievable for example via vapour deposition), but this specific chemistry does not scale well as the solid separator thickness increases.

Of course, solid-state electrolytes are expected to also be subject to price fluctuations. Today there is no value chain in place, but these chemicals will also be subject to potential supply crunches. Given sulphide-type chemistry (e.g., Li_2S-based), which is relatively lithium-intensive, we assumed a price for the LPS-type electrolyte of 28 USD/kg, and varied its cost between 10-50 USD/kg. The results, reported in the Figure 3 tornado plot, evidence that the increased electrolyte price could lead to a cost premium of 15%, or a cost reduction of circa 10% in the most optimistic scenario. As a reference, the figure also shows the effect of varying separator thickness between 10-40 μm.

All these calculations should be considered only as an example and serve to highlight the importance of rigorous and thorough cost analysis and technoeconomic modelling when considering current and next generation technologies. Two examples of other solid-state battery chemistries that we modelled are reported in Figure 4. To know more about our cost modelling tool, or to discuss the results reach out, and we'll be happy to set-up a discussion.

EV sales have grown by almost two-thirds, despite significant headwinds to the industry

Photo: Adobe Stock

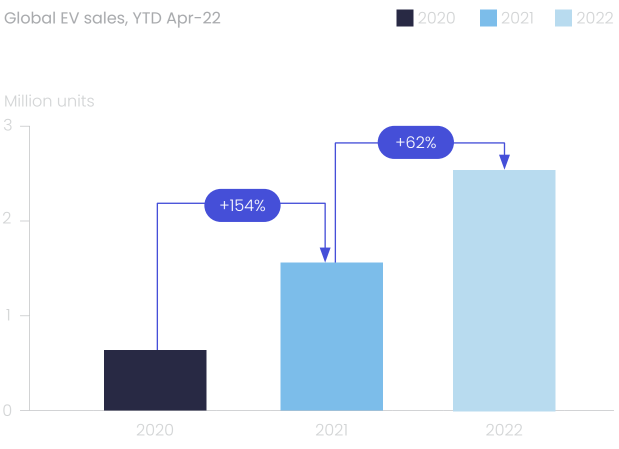
Charles Lester
Data Manager, Rho Motion

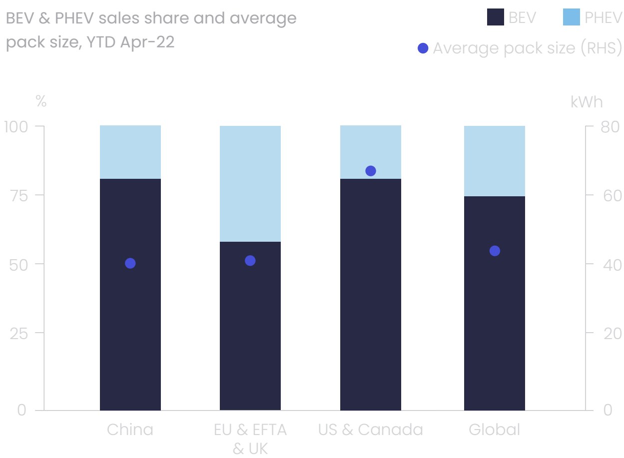
Sales of electric vehicles have grown by 62% for all vehicle classes in the opening four months of 2022, but not without significant headwinds facing the market. The impact of the Ukraine conflict, rising raw material costs, and the ongoing semi-conductor shortage have disrupted supply chains and affected many players across the EV value chain, with OEMs looking to find ways to absorb the burgeoning demand.

Global EV sales are at 2.6 million YTD

In the opening four months of 2022, global EV sales for all vehicle classes have reached 2.6 million. There has been significant growth in Chinese EV sales which have more than doubled over the same period. Despite the 30% reduction in the EV subsidy in China, many OEMs have ramped up production capabilities y-o-y. Most notably, BYD has increased its EV sales y-o-y in 2022 by more than four times to reach around 400,000 vehicles sold. Tesla has also increased its production capabilities in China, supplying both the domestic market and export market, especially in Europe.

Graph 1 *Source: Rho Motion*

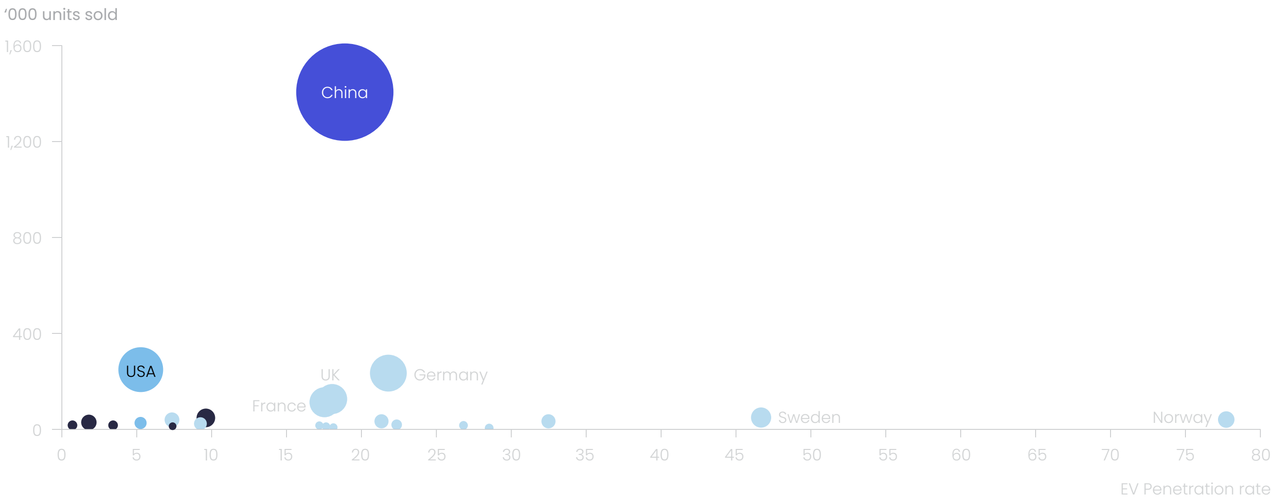




In Europe, YTD EV sales have increased by 18% y-o-y with the strongest growth from Tesla, Hyundai Kia, and Stellantis. For Tesla, Giga Berlin will ramp up to volume production throughout the year with the aim to switch to the new structural pack architecture with 4680 format cells. For Hyundai Kia, there has been a strong European demand for the EV6 and Ioniq 5 since their release, due to the attractive price point and fast charging capabilities. Alongside this, the Niro has also been the third best-selling EV in Europe YTD, behind the Model 3 and Model Y. Finally, Stellantis has boosted its sales after several new releases under its many brands, including many light commercial vehicles. Stellantis is now selling over 30 unique models, aligning with its plan to have 75 BEVs by 2030.

EV penetration rate growth is still highest in the Nordics, with YTD Apr-22 Norway EV sales approaching 80% penetration. Looking at the larger EV markets, China's EV penetration reached a record high of 25% in April 2022 following a weak total vehicle market combined with strong maintained EV sales. In Europe, the EV penetration rate in Germany has been at 22% YTD. This is lower than the total penetration for EVs in Germany in 2021, but we expect the number of EVs sold to increase towards the end of the year in Europe driven by the emissions legislation. In the US, EV penetration is around 5%.

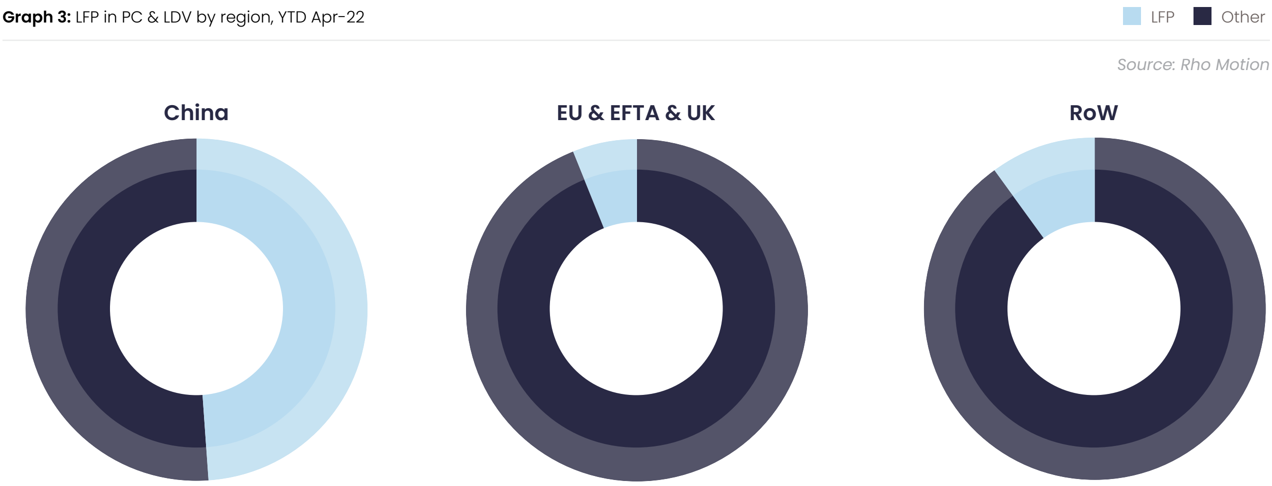
Graph 2: BEV & PHEV penetration rates and market size by country, YTD Apr-22 *Source: Rho Motion*



LFP has been dominating the headlines in China

The opening months of 2022 have also highlighted chemistry developments. LFP is in Standard Range Tesla models exported from China, with most shipments heading to Europe. North American Standard Range models also have LFP batteries from China. NCMA has started to enter the market on a larger scale following General Motors' models with its 'Ultium' Battery, including the GMC Hummer and BrightDrop EV600.

Graph 3: LFP in PC & LDV by region, YTD Apr-22



The market share of LFP continues to grow in China. So far in 2022, 60% of EVs sold (all vehicle classes) in China have an LFP battery. For Passenger Cars and Light-Duty Vehicles, LFP is at 49% YTD Apr-22.

We forecast greater than 10 million EVs to be sold in 2022, with some supply challenges alleviated toward the end of the year. Below, we will discuss the opportunities and challenges the global market is facing as supply attempts to align with demand.

Leading the charge

The EV market has been thrown into the eye of a storm in 2022 but EV sales have still grown by 62% y-o-y. With the limiting factor in EV sales ultimately down to supply issues, the EV market is still progressing in terms of policy, OEM commitments, and consumer choice.

EU emissions legislation will be tighter in 2022 due to a reduction in the credit system. However, with fewer overall sales in Europe, it may be easier for OEMs to meet their targets. In April, the European Parliament passed an EU plan to ban new ICE car sales from 2035, a commitment that some OEMs had already previously announced in Europe, such as Volkswagen.

There has also been a significant increase in the number of EV models available to consumers. In the EU & EFTA & UK, there have been over 200 unique EV models sold so far in 2022. In the US & Canada, there have been around 70, and in China closer to 250.

Many players across the EV value chain have also been looking to manage long-term supply constraints and price volatility through vertical integration, most recently with Stellantis and LG Energy Solution agreeing to establish a 45GWh battery facility in Canada by 2024.

Tough challenges for the automotive market in 2022

The EV market has faced unexpected challenges in 2022. The rising prices of the key raw materials since Russia invaded Ukraine, lockdowns in China following COVID-19 cases, and a continued lack of semi-conductors has resulted in an EV production constraint. With this combination, OEMs have been raising their prices.

The COVID-19 lockdowns and restrictions in China have resulted in several EV plants shutting down or operating at a reduced capacity since April. This is discussed in detail in this Magazine, by Frank Du, Rho Motion, and Jessie Xu, Rho Motion.

As for the semi-conductor issue, many producers in Taiwan have been increasing investment to capture the demand disparity. However, we expect these capacity expansions to settle down the demand problems towards the end of 2023.

Several nations have and are expected to reduce EV subsidies. China reduced its EV subsidy by 30% in 2022 but this has had little impact on the maturing EV market in the region. As for Europe, there will be a subsidy reduction in Germany, France, and Sweden, in 2022.

Overall, the EV market has still been growing at a rapid pace y-o-y, despite the significant headwinds that will continue to impact the market during 2022. Many of these longer-term issues are being addressed through the means of increased investment and deeper levels of vertical integration.

Mitra Chem

Building the North American battery materials supply chain champion

With mass adoption of electric vehicles and renewable energy (solar, wind, nuclear, etc.), electrification is a top national priority to reduce America's reliance on foreign energy and further our clean energy goals. However, the lack of domestic battery materials manufacturing leaves us still vulnerable to sourcing the majority of battery supply chain steps from outside the U.S.

Mitra Chem is a U.S.-based lithium-ion battery materials product company focused on developing manufacturing capability in the U.S. – with a focus on shortening the lab-to-production timeline by > 90% using its proprietary machine learning process.

Vivas Kumar
Co-Founder and CEO of Mitra Chem

Top three problems Mitra Chem is solving:

1. **China currently dominates the global battery market.**
   - Today, China accounts for **62% of all cathode material production** (the critical component to manufacture batteries) and will **increase to 81% of upcoming capacity by 2030.**
   - Over-reliance on China could become our "Achilles' heel" to achieving clean energy independence.
   - Mitra Chem is building large-scale manufacturing capacity in the U.S. and working directly with domestic champions (like cell makers and Auto OEMs) to bring its products to American consumers.
2. **Current manufacturing techniques are too dependent on metals sourced from overseas.**
   - Today, China controls the vast majority of the world's cobalt and nickel processing capabilities, including vital trade access to mining suppliers in Africa and Australia/New Zealand.
   - Mitra Chem is prioritizing **iron-based cathodes** to power lithium-ion batteries. This shifts production to **conflict-free minerals** sourced locally in the U.S., offers a **less expensive alternative** to Chinese metals, and ultimately results in a **safer battery** for the consumer.
   - But, currently **100% of the iron-based cathodes are produced in China,** so Mitra Chem aims to build this important capability in the U.S.
3. **Current methods use decades-old processes that make battery innovation slow and difficult.**
   - Today's industry standard to design, build, and test new batteries can take approximately **18 months,** making it difficult to innovate and scale quickly.
   - Mitra Chem has developed a proprietary method (first developed at Stanford University) to reduce the production timeline to **less than one month.**

Learn more at mitrachem.com

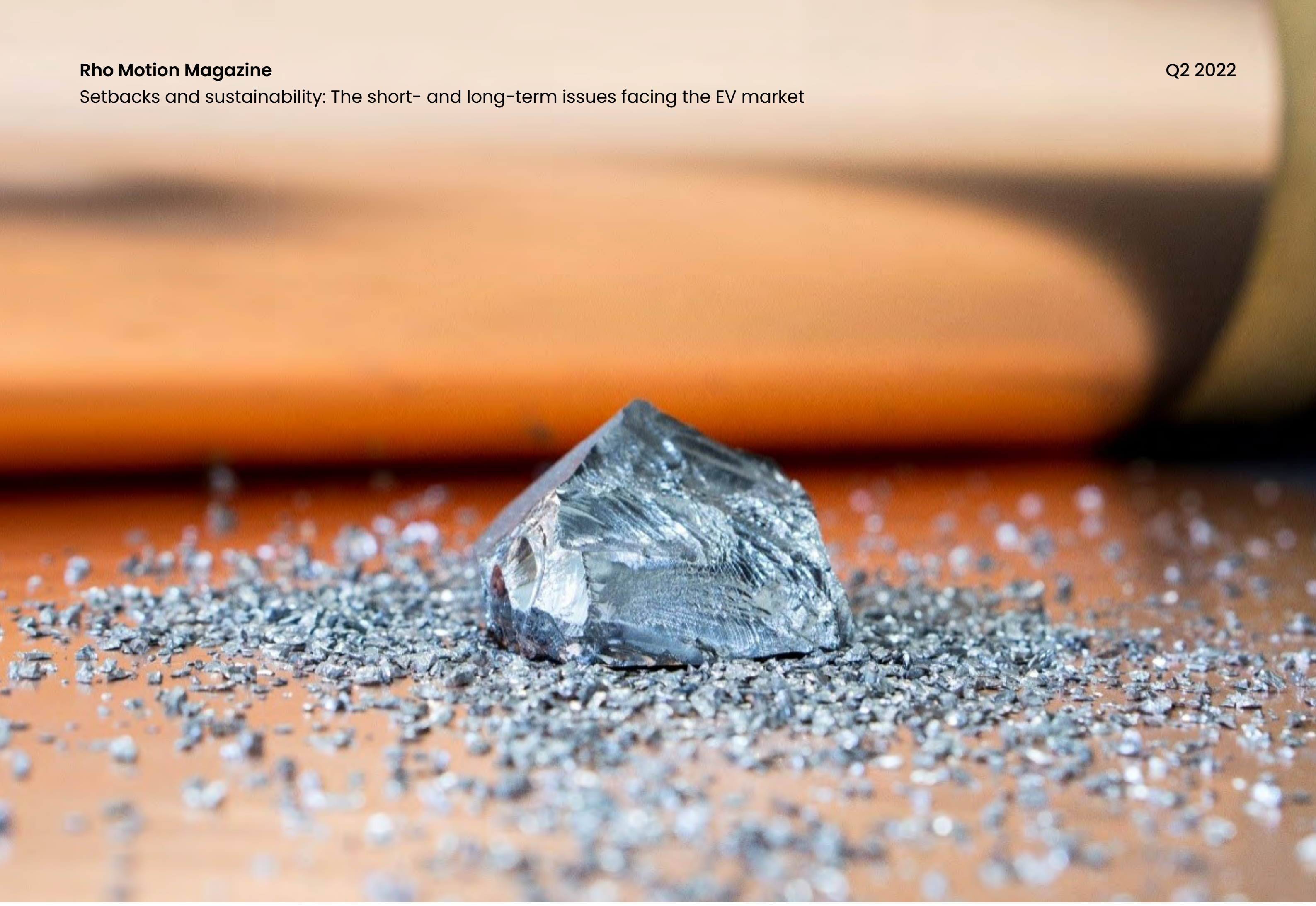


Photo: E-magy

The power of silicon: how silicon boosts EV battery performance

Lukas Malinowski
Senior Business Development Manager, E-magy

A prospective buyer of an electric vehicle usually wants four things at once: a longer range, faster charging, more energy efficiency, and a lower price tag. Batteries have, however, proved to be a limiting factor. What if there was a way to solve this problem? E-magy has developed silicon materials for batteries that will revolutionize the electric vehicle battery market.

The customer is always right, but sometimes they can also be a little too demanding. If you'd ask any potential buyer of an electric vehicle what they want from their new vehicle, you'd get an answer along the lines of: I want a car that can drive from London to Berlin on a single charge, with batteries so light that it does not affect my car's performance and so small that I sacrifice no cabin space. The batteries should be lightweight, fast charging and extremely efficient, so that the car has an excellent Wh/km-ratio and a small carbon footprint. And oh yes, the vehicle should be reasonably priced, please.

This utopian dream of the perfect EV is something every EV manufacturer is familiar with, mostly because it is exactly the car we wish we could build.

Next generation EV batteries

What if we could produce cost-effective batteries that store more energy and charge faster, hence significantly reducing the battery pack size? That's the challenge E-magy set itself. And it believes it has found the answer.

Enter silicon-dominant batteries. Silicon has long been recognized as a promising active anode material. It is the second-most abundant mineral in the earth's crust, is widely available and has ten times the capacity of graphite. Using it as an active anode material could make batteries hold more energy and charge faster, enabling EV range to grow vastly. Lithium-ion batteries (Li-ion) batteries, the most common type of batteries in current electric vehicles, use graphite as an active anode material. But graphite's physical and chemical properties are struggling to keep up with EV application requirements: they are considerably limited in how much energy they can store and have limited fast charging capabilities. These issues can be solved by silicon-dominant batteries (batteries with anodes that are more than 80 percent silicon).

The use of silicon in batteries, however, has long been dismissed because of a technical problem: when charged and discharged, it swells and breaks over time. This has long frustrated battery makers: here is a solution to make batteries with a higher capacity and lower charging times—if only there was a way to prevent the swelling and breaking.

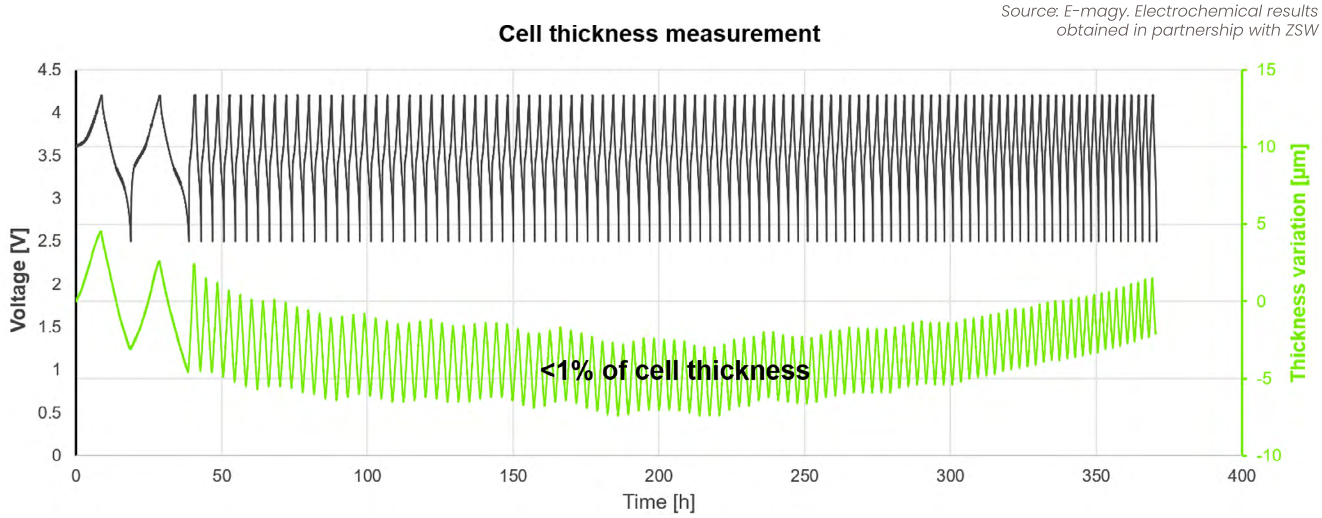
The innovation: Nano-sized pores

E-magy has found a solution. It has invented a method to create new kind of silicon material with nano-sized pores. This nanoscale porous structure prevents the swelling and breaking completely, by actually containing the swelling within the nanopores themselves. After one hundred charge and discharge cycles, the swelling of a pouch cell with E-magy silicon has been found by the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) to be less than 1 percent, well under the 10 percent that the battery industry deems acceptable. Furthermore, the company designed its solution for silicon-dominant application in high-performance Li-ion batteries without using low-capacity graphite as active material. This delivers 40 percent more energy density and enables faster charging compared to existing graphite solutions.

The real world

Throughout history, many scientific discoveries have been hailed as ground-breaking by researchers. It's all well and good to produce a solution in the lab, but if it is too costly to be practical in the real world, then it will only remain an interesting academic case study.

Source: E-magy. Electrochemical results obtained in partnership with ZSW



E-magy pilot production line *Photo: E-magy*

E-magy puts the metrics and concerns of the real world front and center of its technology. Its patented nano-porous silicon can be produced in large volumes and its production process is ready for gigafactories' anode manufacturing lines – E-magy's inhouse pilot production line, in its facility near Amsterdam, is capable of providing the nano-porous material in ton scale.

A short foray into the technical side of things: E-magy's nano-porous silicon uses micrometer-sized powder and low-cost metallurgical silicon as opposed to costly engineered particles and difficult-to-process nano-powder. The casting process is efficient, with no need for CVD coating with silane gas or slow metal-assisted etching. This means exceptional energy density compared to graphite-anode batteries at a comparable cost per kWh to graphite.

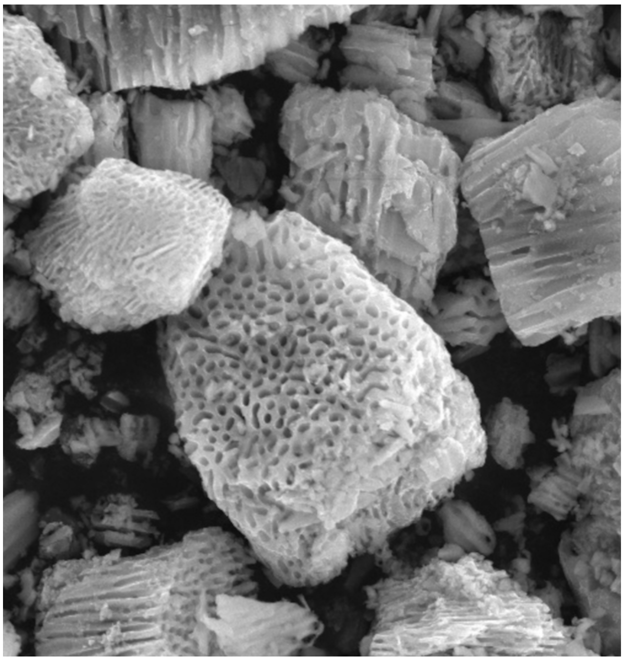
But that's not all. Silicon will also be a stepping stone towards solid-state batteries. Recently, some of the world's most innovative battery developers are working on solid-state batteries with high content silicon anodes. This combines the safety of solid-state batteries with the high energy density of silicon.

Leading cell makers

And it's not just the R&D departments that are excited, the entire market is quickly waking up to the power of silicon. Tesla, looming large over any discussion about EV, uses silicon in its batteries for the Model 3, though to a very limited extent as an anode additive: it merely slightly boosts the graphite anode. Leading cell makers such as LG Energy Solution, Samsung SDI and CATL are already increasing the amount of silicon in the anodes of their newest battery models. Various automotive OEMs such as Porsche, VW and Mercedes have already announced that they are working on high-performance silicon-anode batteries.

Silicon truly is the next-generation anode material for high-energy batteries. It is already effectively used as an anode material in other commercial batteries, for example in power tool batteries and other commercial batteries such as wearable devices. Market research firm IDTechEx forecasts that the silicon anode material market would grow at a rate of over 36% annually until 2032.

E-magy is an integral part of this awakening: in close cooperation with leading cell makers, research institutes and automotive manufacturers, the company is rapidly improving the cycle life of its silicon. In less than two years, it has been able to increase the cycle life of its product by a factor of 3.5, bringing it closer to the demands of the EV industry.



E-magy nano-porous silicon *Photo: E-magy*

For decades, battery capacity and weight have caused range anxiety and bugged the shift towards the mass adoption of truly electric mobility. Now, the industry is ready to take the next step towards truly efficient electric mobility.

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The impact of COVID-19 lockdowns and restrictions on the EV value chain in China

Photo: Adobe Stock


Yu (Frank) Du
China Research Lead, Rho Motion


Jie (Jessie) Xu
Research Analyst, Rho Motion

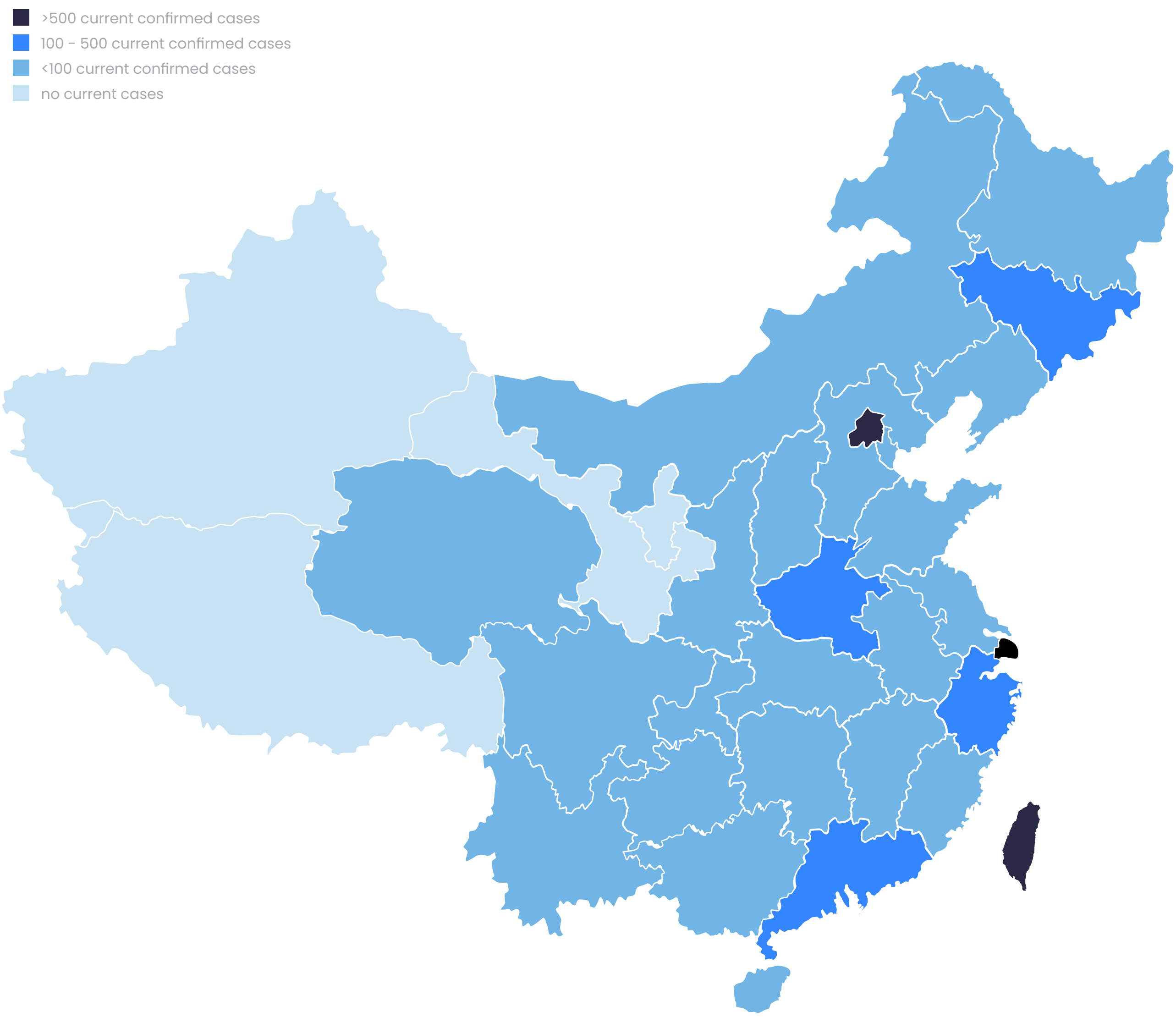
The Omicron variant has posed a great challenge to China's Zero-COVID policy. Shanghai entered a weeks-long strict lockdown while some other cities tightened their restrictions due to reported local cases. Shanghai is one of the centers of China's automobile industry, with many local OEM factories ceasing production and the automotive supply chain largely halted. This article will analyse the impact of the 2022 COVID lockdowns and restrictions on the automotive industry at a national level.

In Q2 2020, COVID cases were cleared in China and the Chinese government implemented a nationwide Zero-COVID strategy. Up to the end of 2021, there had been no severe COVID outbreak, and society has been functioning normally. However, due to its highly infectious nature, the Omicron Variant hit China very hard and caused several large outbreaks in Jilin, Shanghai, and Shenzhen.

Figure 1 provides a snapshot of cases at time of writing (mid-May) in all provinces and territories. After weeks of battling against the Omicron Variant under the Zero-COVID policy, the number of areas with severe outbreaks is no longer increasing. According to the daily reports from the local healthy committees, in April, the reported new cases are mostly located in controlled areas where lockdowns or strict restrictions are already in place. For the two weeks since 1st May 2022, the daily new cases have remained in the several hundreds.

Figure 2 demonstrates the timeline of lockdowns/ restrictions in major cities. Most lockdowns happened at early stages and lasted for around one week. Whereas almost all the long citywide lockdowns happened in the

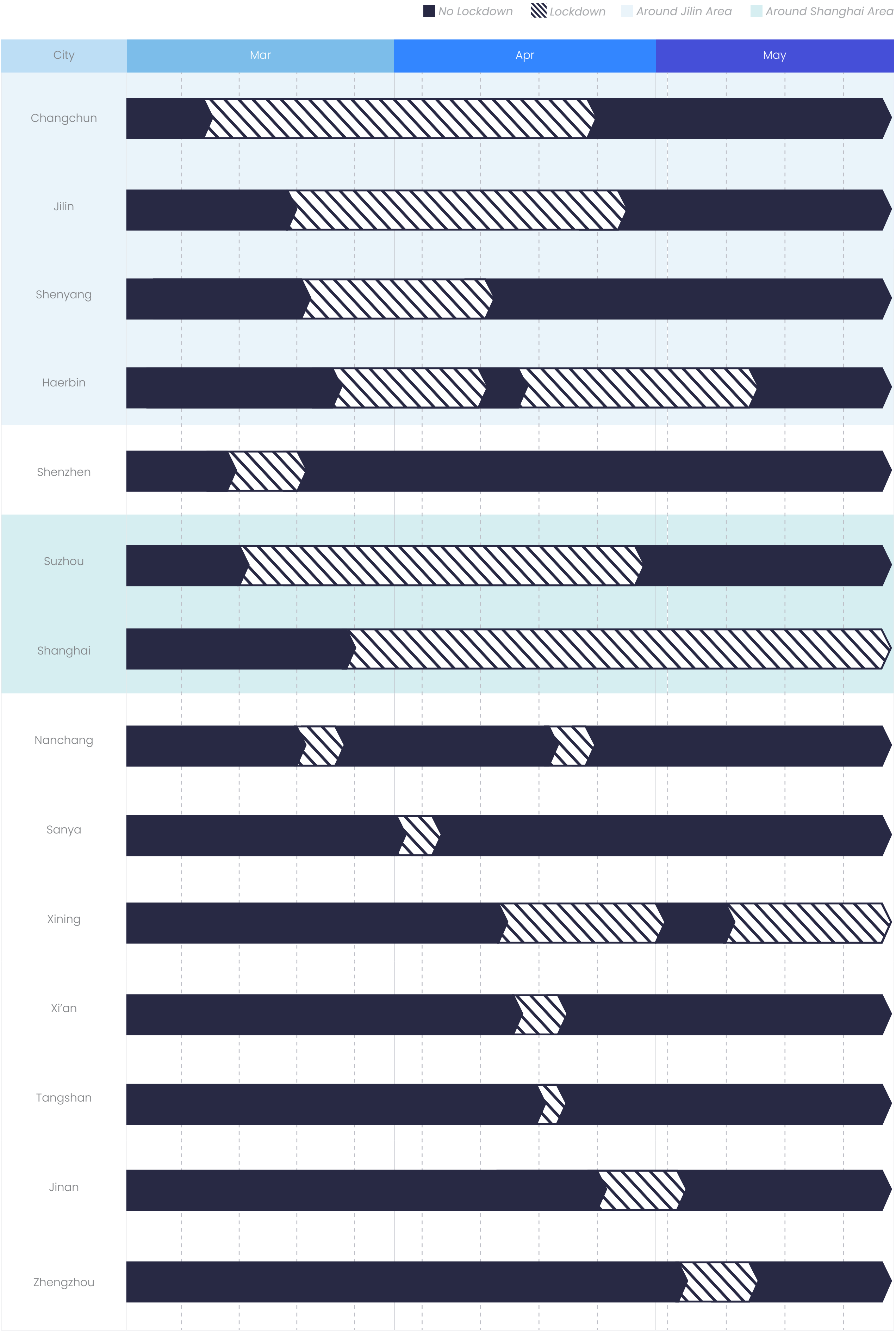
Figure 1: Existing Confirmed COVID Cases in China (13/05/2022) *Source: National Health Commission*



Yangtze River Delta (Shanghai and neighbour regions, marked in blue) and Jilin province (marked in grey). Fortunately, the two most affected areas have both made progress in containing the virus. The whole Jilin province was reopened on 28th April 2022 and the Shanghai lockdown, according to officials, is now close to an end as well.

Figure 2: Timeline of Restrictions and Lockdowns in Major Cities

Source: Provincial Health Commissions

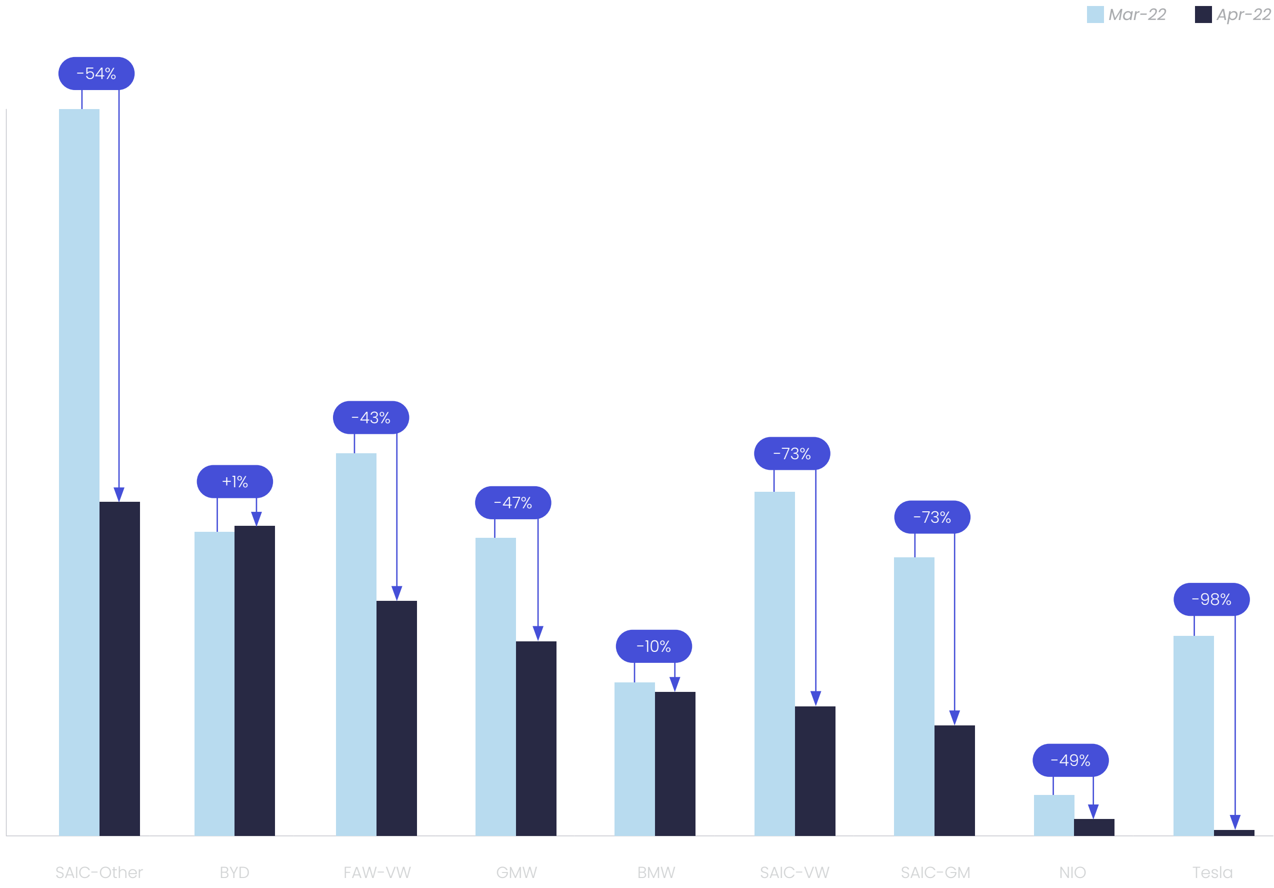


However, the challenge remains for the automotive industry. Jilin province and the Yangtze River Delta region are the centers of China's automobile value chain. Shanghai is also one of the largest auto markets in China. Because of the lockdowns, Chinese Automobile sales slumped by 47% m-o-m in April. Figure 3 shows the performance of some affected OEMs.

Tesla's sales dropped by 98% in April from the previous month as Tesla was forced to halt production at Giga Shanghai for most of April. Similarly, SAIC ceased production at its six plants in Shanghai, including the joint venture factories with VW and GM. FAW-VW joint venture factory and BMW's joint venture factory were also closed until early April because of the Jilin lockdown. BYD is the one rare exemption. The production and sales of BYD were not greatly affected because BYD's strategy is to invest in the full auto supply chain and its factories are outside of the restricted areas. Figure 4 outlines the operation situation for key factories.

Figure 3: 2022 March to April Auto (All Types) m-o-m Sales Growth

Source: Rho Motion Database

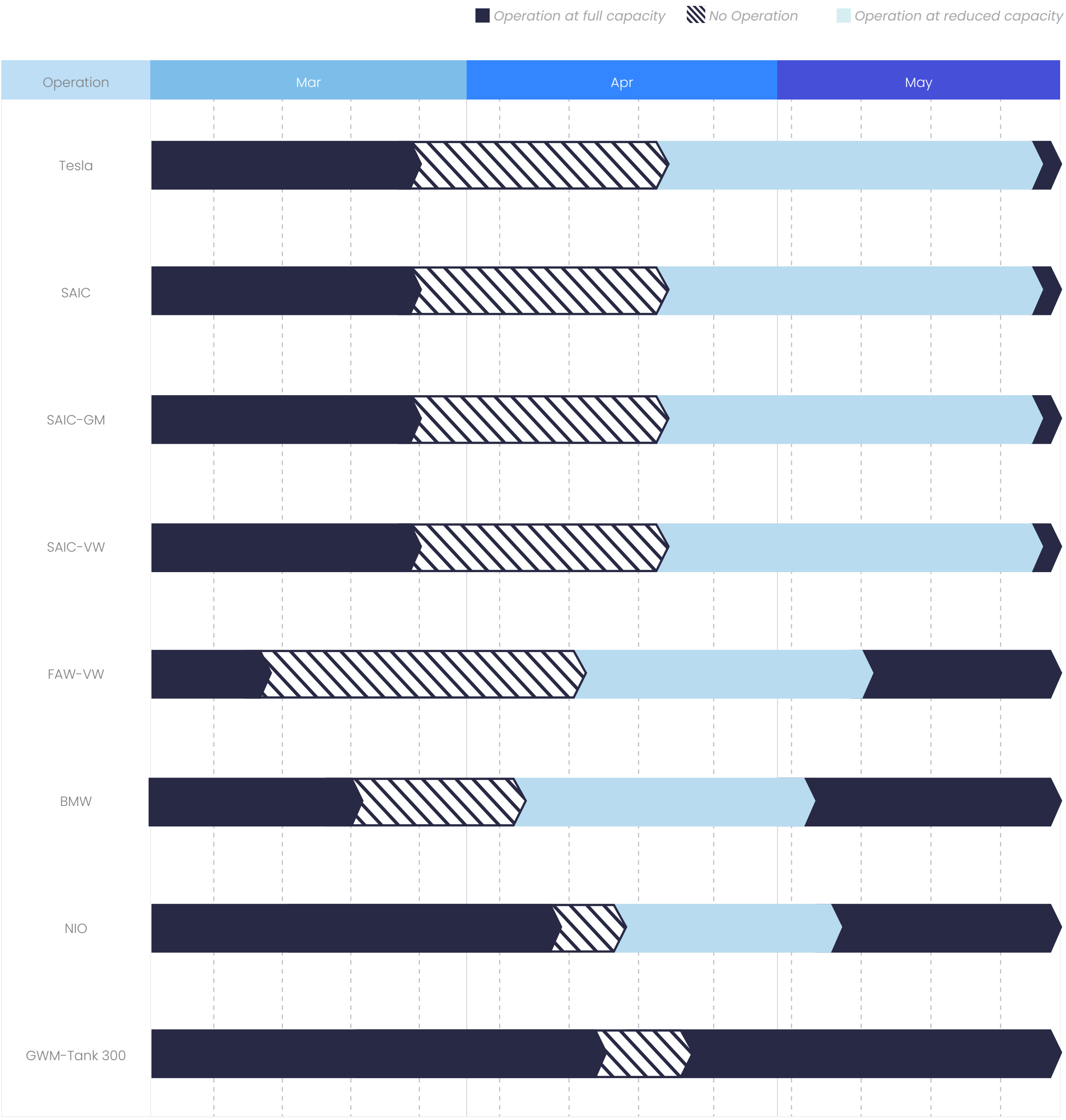


The blue highlight reflects the expected recovering period before the plants can be operated at full capacity. Theoretically, plants can restart at full capacity immediately with sufficient labour and feedstock. However, the lockdown is still in place in the Yangtze River Delta region and will greatly reduce the efficiency of logistics, leading to limited feedstock for factories. As a result, it will take much longer before the factories can fully recover to the pre-lockdown production level.

OEMs outside of the controlled areas can still face significant production challenges. Neither NIO nor GWM-Tank has production plants in Shanghai or Jilin. However, as shown in Figure 4, they still suffered from closed factories for several days due to the shortage of auto parts. Normally, auto part suppliers, such as seat manufacturers and window providers, open their production sites next to the OEM factories to reduce the time and the cost on logistics. The lockdowns in Shanghai and Jilin affected those suppliers as well and paralyzed the whole supply chain. If the missing component is easy to install, the OEMs can choose to manufacture the vehicles first and then install the missing parts later when they arrive. This can also cause delay as OEMs must adjust and test the assembly line. In the case of a large essential part that is missing, no car can be produced at all.

Figure 4: Timeline of the Key Factory Shutdowns

Source: Provincial Health Commissions



For the whole automobile industry, April 2022 was a very difficult month. The pressure comes from two aspects. On one hand, the factories in the lockdown areas must follow the government policy and stop operation for most of April. On the other hand, some of the auto part suppliers were closed during the lockdowns as well. Combined with the reduced logistics, the industry faces extremely tight supply because of the supply chain interruption.

As factories in Shanghai and Jilin reopen, the automobile value chain is recovering slowly. Cui Dongshu, secretary of the CPCA, estimated that the 2022 car production in China will be lower than the production projected at the beginning of 2022. However, he still maintains the NEV sales forecast of 5.5 million units in 2022. Tesla is still confident that Giga Shanghai's production capacity will recover fully in the near future. Despite the difficulties, China's automotive industry, especially the electric vehicle sector, is still promising. Lately, Beijing has been reporting around 50 new cases daily and caused some concerns. Rho Motion will continue to monitor the outbreaks in China and provide updates about the Chinese EV value chain in Rho Motion's weekly China Briefing.

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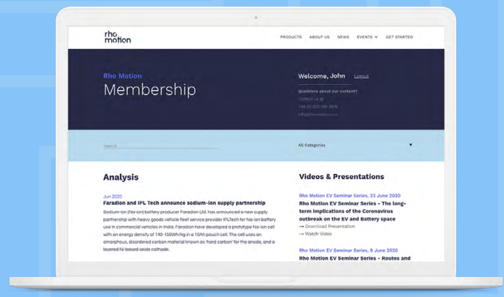

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The rise of BESS integration and market update

Photo: Adobe Stock

Iola Hughes
Research Manager, Rho Motion

The Battery Energy Stationary Storage (BESS) market has rapidly evolved over the last five years, with technology improvements and cost reductions largely driven by developments and investment in the electric vehicle market. More recently however we have seen a shift, battery manufacturers are looking to technologies that are best fit for stationary storage applications, choices are no longer being made based on availability, i.e., BESS application suitability instead of EV battery surplus. Similarly, we have seen a ramping up of cell manufacturers both moving into and building out technologies for the BESS space.

Vertical integration

The BESS market is diverse with many small players manufacturing the many system components, the market can however broadly be split into three main groups; cell manufacturers, BESS system integrators, and BESS developers. BESS system integrators are those manufacturing BESS units by combining a number of subcomponents from battery cells and modules to power conversion systems (PCS) and battery management systems (BMS). Players in the BESS integrator market have historically been limited to companies specialising in BESS

Graph 1: Battery energy stationary storage value chain example, Q2 2022

Source: Rho Motion

This is a non-exhaustive representation of the value chain, as of Q2 2022

systems such as Tesla Energy, Fluence, and Flexgen, More recently however, we have witnessed an increasing trend for market players to integrate and consolidate along the supply chain. Major players entering the BESS integrator market include battery cell manufacturers launching BESS products, and solar inverters manufacturers, such as Sungrow, looking to capitalise on their position in the booming solar and storage market.

In recent months we have seen LG Energy Solution, Samsung SDI, BYD, and CATL integrate by adding BESS products to their range, setting them in direct competition with system integrators. SVOLT also joined the growing list of vertically integrated BESS manufacturers by announcing it will begin producing a line of LFP based energy storage systems, having until now predominantly focused on the EV space. Similarly, Northvolt announced plans for ESS production facility in Poland with an initial output of 5GWh per year estimated to start production in 2023.

Whilst we have seen a growing list of cell manufacturers move into the BESS integrator space, particularly in China where all major cell suppliers are also manufacturing BESS, some cell manufacturers have opted to keep focus on the production of cells and modules for their customers instead. In the last year Freyr has announced four offtake agreement with ESS integrators, 28.5GWh with Powin, 19GWh with Honeywell, 31GWh with an undisclosed ‘leading global systems integrator’, and a further 10GWh with an undisclosed ‘major US renewables company’. These offtake agreements represent a significant portion of their planned capacity demonstrating Freyr’s position as a supplier instead of moving into the BESS integrator space.

BESS developers fall into a number of groups, energy and utility companies and developers, BESS integrators and private equity firms. Integration from BESS integrator to developer is commonplace, with several players working across both positions. Full integration from cell manufacturer to developer is rare, with LG Energy Solution’s recent acquisition of NEC Energy Solutions creating the first fully integrated BESS player. NEC is a previously leading energy storage subsidiary of NEC Corporation that went out of business in 2020. Under the deal, LG ES will establish a new corporation, LG Energy Solution Vertech. Inc., to run its stationary storage and systems integration business, including system, installation, and maintenance. NEC ES achieved annual growth of 60% when still operational between 2018 and 2020, LG ES plans to turn this growth into profit, with hopes the high level of vertical integration between cell, system and project development will relieve some of the typical supply chain issues.

While vertical integration comes with some benefits such as those cited by LG ES, others such as Fluence and Powin have opted to not integrate adopting instead a technology agnostic approach. These players cite the lack of vertical integration allows them to switch between chemistries based on material availability and supply chain and shipping logistics. These BESS integrators are increasingly looking to sure up their position in the market, with offtake agreements with multiple cell suppliers and component vendors increasingly being announced.

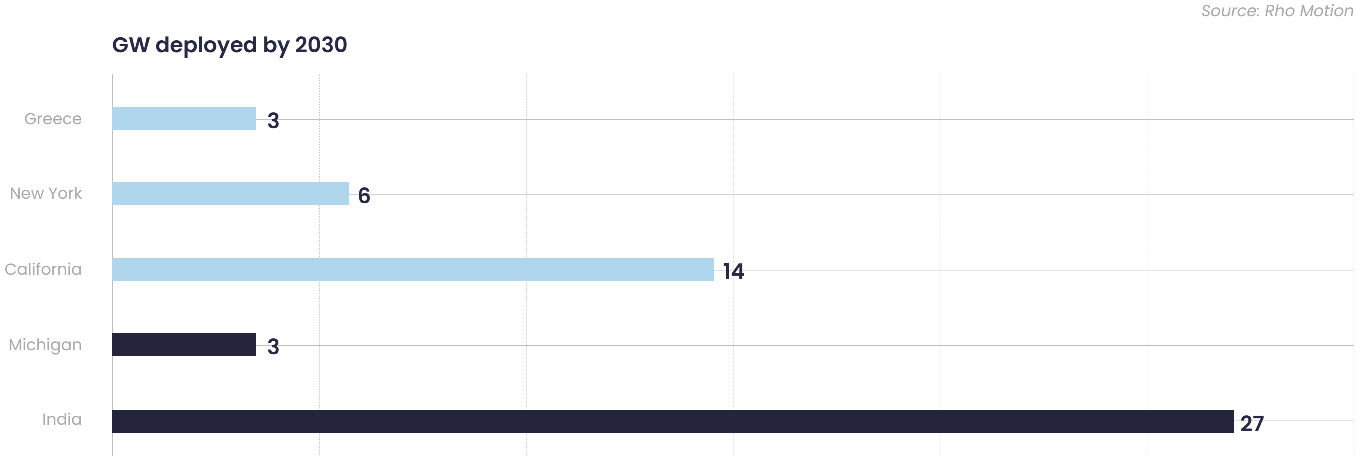
While vertical integration comes with some benefits such as those cited by LG ES, others such as Fluence and Powin have opted to not integrate adopting instead a technology agnostic approach.

Alongside the commitments we have seen from cell and BESS manufacturers, we continue to see countries and regions increase legislative support and remove some of the barriers for energy storage.

In Europe, Greece doubled its energy storage target to 3GW by 2030, to support over 20GW of targeted renewable capacity, making up over 70% of the country's electricity generation capacity. Spain increased its energy storage target to 20GW by 2030, rising to 50GW by 2050, with batteries set to make up a significant portion. The Netherlands, meanwhile, took steps to remove the double taxation law that faces the majority of European nations. In the US, Michigan announced a new environmental state roadmap, including 3GW of storage by 2030. This target when approved will make Michigan the tenth US State to adopt an energy storage target. California and New York also took steps to increase existing energy storage targets. New York announced it would double its energy storage target from 3GW to 6GW by 2030 as part of a collection of clean energy announcements. New York has had the most ambitious energy storage target for the last decade, and with the upgrade looks to maintain this position. The new target will be accompanied by "needed market reforms and cost-effective procurement mechanisms". The State plans to make the target achievable through State support and incentives for private customers to install storage. In California, the California Public Utilities Commission approved its new USD49 billion clean energy plan to add more than 25.5GW of renewables and 14.75GW of battery storage to the state's grid by 2032.

The Indian battery market, as featured in the Q1 2022 Magazine, has been gaining pace, since the recent issue the Indian Central Electricity Authority set out a report identifying the level of required pumped hydro and battery storage, projecting an ambitious 108GWh/27GW installed battery capacity in 2029-2030.

Graph 2: New energy storage targets



Project spotlights

Here, we examine the dynamics of a several BESS projects that have recently been commissioned from our [Battery Energy Stationary Storage Monthly Assessment.]()

PROJECT	Battery cell manufacturer	BESS integrators (system manufacturers)	BESS Developer
Elkhorn BESS	CATL	TESLA ENERGY	Pacific Gas and Electric Company
Dalian Vanadium Flow	RKP	RKP	国家能源局 National Energy Administration
Alaminos Solar + Storage	Saft a company of Total	Saft a company of Total	ACEN

Elkhorn BESS	
Power	183MW
Capacity	730MWh
Duration	4 hour
Battery	LFP
Paired resource	Grid
Commission date	Apr-22

Dalian Vanadium Flow	
Power	200MW
Capacity	800MWh
Duration	4 hour
Battery	Vanadium Flow
Paired resource	Grid
Commission date	Phase 1 2022; Phase 2 2025

Alaminos Solar + Storage	
Power	40MW
Capacity	60MWh
Duration	1.5 hour
Battery	Lithium ion
Paired resource	120MW Solar
Commission date	Feb-22

PROJECT SPOTLIGHT 1

Elkhorn BESS, California

Elkhorn BESS was commissioned in April by Pacific Gas & Electric (developer), at the site of the Moss Landing substation. The project sits alongside the larger Moss Landing Energy Storage Facility commissioned by Vistra in 2021. Elkhorn is made up of 256 Tesla (integrator) Megapacks for a combined power of 183MW at four-hour duration, with cells supplied by CATL (cell manufacturer). The battery will participate in the CAISO wholesale electricity markets, also providing ancillary services. PG & E now operated just under 1GW of BESS across California, with a further 1.4GW expected to come online in 2022.

PROJECT SPOTLIGHT 2

Dalian Vanadium Flow Battery Energy Storage Project, China

Dalian Vanadium Flow Battery Energy Storage Project is the first large-scale vanadium flow battery energy storage demonstrational project approved by the National Energy Administration (developer). The designed capacity is 800MWh/200MW and the project will be completed in two phases. The first phase (400MWh/100MW) is under testing and will be put into full operation in June 2022. The total investment is around RMB3.8 billion (~USD0.6 billion). The construction of the project began in November 2016 and the first phase was supposed to be completed by 2018. Technology for the project is provided by Rongke Energy Storage Technology (integrator & cell manufacturer).

PROJECT SPOTLIGHT 3

Alaminos Solar + Storage, Philippines

AC Energy (developer) switched on the first solar and storage project in the Philippines in February. The 1.5-hour duration 60MWh/40MW pilot battery will support a 120MW solar farm in Alaminos. The construction of the battery began in October 2020, with development and construction costs of USD42.8 million. The BESS consists of two 20MW facilities, provided by TotalEnergies-Saft (integrator & cell manufacturer). The batteries will both charge from the solar farm when demand is low and participate in ancillary services for the national grid.

*Rho Motion's **BESS Quarterly Outlook** and **BESS Monthly Assessment** provide up to date insight with all developments in this space. The assessment provides analysis of project announcements, updates, and commissions, tracking the development of key battery stationary storage metrics over time, as well as monthly news and market updates. Our outlook provides long-term outlooks for battery demand and battery chemistry, by application and region, based on robust and informed methodologies.*

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Charging & Infrastructure

Our EV Charging and Infrastructure research provides flexible and dynamic analysis on both the current state of the market and the technological and commercial outlook for the sector

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Global EV Charging Outlook

Our Global EV Charging Outlook provides an electric vehicle market analysis of the current and planned technologies at both the vehicle and charger level, and profiles the major players in the market and their relative competitive position and plans for the future. The report can be customised to cover as many or as few countries or regions as needed.

EV Charging Monthly Assessment

The assessment provides an analysis of the maximum charging capacity of global and regional passenger car and light duty vehicle sales and fleets, as well as a fleet energy demand.

EV Charging Monthly Database

Our EV Charging database with model-by-model sales and analysis of vehicle charging capabilities and battery pack size and chemistry.

Our Charging & Infrastructure market analysis is delivered in flexible, dynamic formats that can be customised for the user.

Find out more, contact us +44 (0) 203 960 9986, info@ rhomotion.com

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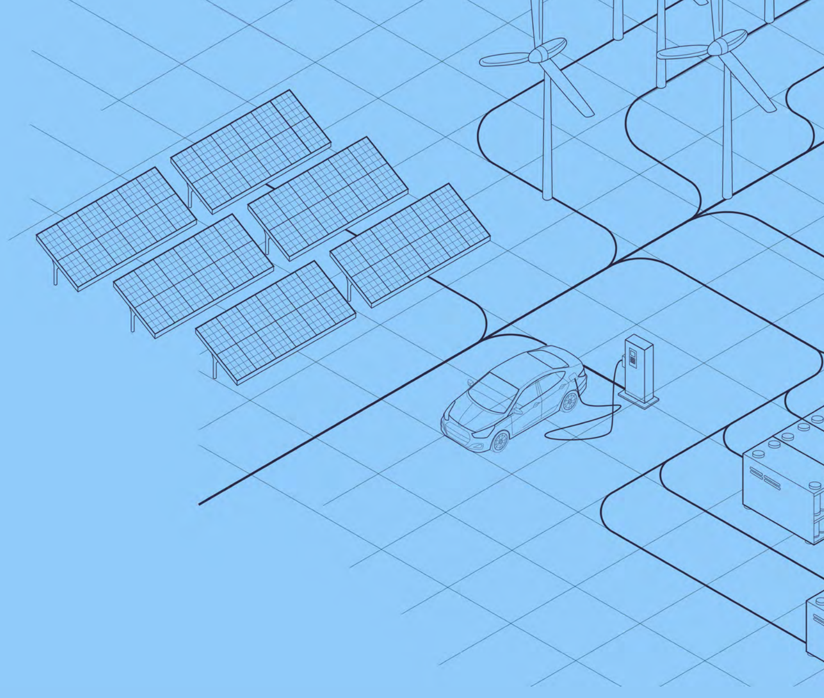
Battery Demand Service



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The Battery Demand Service combines all our battery outlooks and assessments in one place.

	Pro	Plus	Premium
Battery Demand Service: Outlook Excel file • Updated in line with outlook report releases	✓	✓	✓
EV & Battery Quarterly Outlook PDF and Excel File • Quarterly releases	✓	✓	✓
HEV Outlook PDF and Excel File • Quarterly releases	✓	✓	✓
Battery Energy Stationary Storage Outlook PDF and Excel File • Quarterly releases	✓	✓	✓
Fuel Cell Electric Vehicle Outlook PDF and Excel File • Annual releases	✓	✓	✓
Electric 2&3 Wheeler Outlook PDF and Excel File • Annual releases	✓	✓	✓
Electric Micro Mobility Outlook PDF and Excel File • Annual releases	✓	✓	✓
Monthly EV Battery Chemistry Assessment PDF and Excel File • Monthly releases		✓	✓
Monthly Battery ESS Assessment PDF and Excel File • Monthly releases		✓	✓
Monthly EV & Battery Database Excel File • Monthly releases			✓

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Photo: Ather Energy

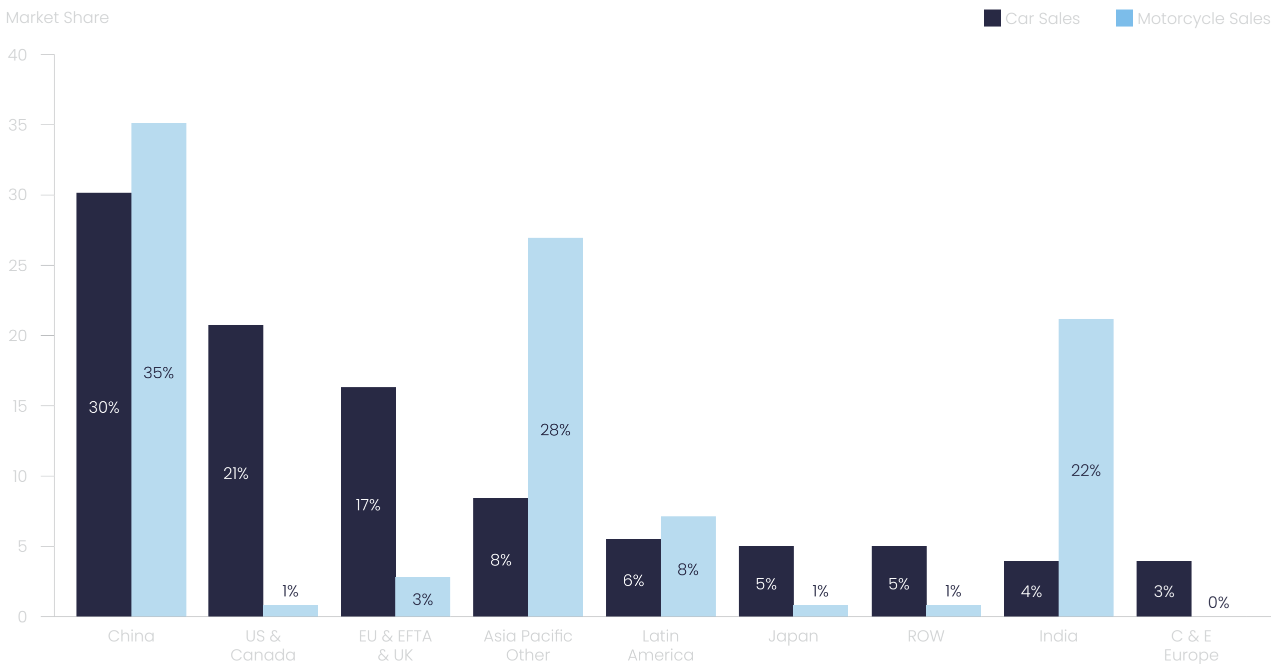
Why we need to see electrification of the two-wheeler market too

William Roberts
Research Analyst, Rho Motion

Electric vehicles are now on an irreversible path to becoming the dominant passenger car technology, but in the parts of the world likely to be the last to join this revolution motorcycles are the transport mode of choice. The dangers of this sector's vehicle emissions may be even more urgent.

Figure 1: Market share of car sales and motorcycle sales in 2021 by region.

Source: Rho Motion



In 2021, there were 57 million sales of two and three-wheelers globally, compared to a total vehicle market for passenger cars and light duty vehicles of 80 million units. This highlights exactly how important these vehicles are to the world's transportation needs. However, the distribution of these sales differs massively from that of passenger cars, where Europe and North America command 17% and 21% respectively of the global car market, they only account for 3% and 1% of motorcycle sales. Conversely, India and the Asia Pacific region account for just 4% and 8% of 2021 car sales but 22% and 28% of motorcycles respectively. China is the only major region to be consistent in both categories with a 30% share of car sales and a 35% share of motorcycles.

The driving force behind electrification is the need to decarbonise our transport system, stop burning fossil fuels and therefore mitigate the climate crisis. With smaller engines, lighter weight, and lower annual mileage, intuitively motorcycle dense regions may already be ahead of the curve in terms of CO_2 emissions from personal transportation. However, this does not tell the whole story. Motorcycles can be far worse than passenger cars for the other pollutants coming from the exhaust of an internal combustion engine. In 2018, The Real Urban Emissions Initiative (TRUE) took measurements of real-world NO_x, particulate, and CO_2 emissions from over 180,000 vehicles in Paris.

The results of these measurements on L-Category vehicles (Mopeds, motorcycles, etc.) found for Carbon Monoxide (CO) emissions for motorcycles were 2.3-11.1 times worse than like-for-like fuelled cars. For Nitrous Oxide (NO_x), motorcycle emissions were 1.2-6.1 times the average for like-for-like fuelled passenger cars. For the most up to date vehicles (Euro 4 compliant at the time), CO emissions were nearly 10 times greater than the most up to date cars.

The European emission standards for motorcycles have lagged those for cars with Euro 5 standards coming into effect in 2020, four and a half years after Euro 6 was introduced for passenger cars. Furthermore, the level of emissions standards in the regions which dominate two and three-wheeler sales are much weaker. In India, for example, Bharat Stage IV emissions were introduced in 2016, equivalent to Euro 4, although slightly more relaxed. Indonesia enforces only Euro 2 or 3 (depending on cc), and in Vietnam Euro 3 has been applied since 2016.

The emissions targeted by these standards are far more related to local air quality, CO and NOx are both key pollutants contributing to the formation of smog in dense urban areas.

Where are we with electrification and what is the outlook?

With the regions with the worst levels of air quality and highest per capita sales of motorcycles largely overlapping, the benefits of electrification of this sector could be hugely beneficial to the health of residents in these areas, especially in dense urban environments. It is those dense urban environments too where the switch to electrification is most feasible.

An obvious challenge to the electrification of mopeds and motorcycles is the battery size, and therefore the range of the vehicles. There are many reasons why

The driving force behind electrification is the need to decarbonise our transport system, stop burning fossil fuels and therefore mitigate the climate crisis.

average pack sizes are in the range of 1-4kWh in most of Asia. Firstly, cost - ICE mopeds are incredibly cheap, and adding too much battery power will make EVs uncompetitive. Secondly, is space in the vehicle. However, this weakness can also be one of the strengths of the segment as a small battery pack that can be easily carried opens the door for infinitely more flexible charging and battery swapping options.

The best proof so far of this concept comes from Gogoro in Taiwan which has grown in just a few years to hold not just a strong position among electric OEMs but a significant market share of the total sales.
In 2021 it sold nearly 10% of all motorcycles in Taiwan and held over 90% of the EV market. Gogoro's success so far has been due to its 'Gogoro Network' a series of battery swapping stations where riders can arrive, remove the batteries from their scooter, insert them into

Figure 2: (a) shows a global map coloured by the annual average PM2.5 concentration, (b) shows the same map coloured by 2021 motorcycle sales per 1,000 of the population.

Source: IQAir World Air quality report 2021 and Rho Motion

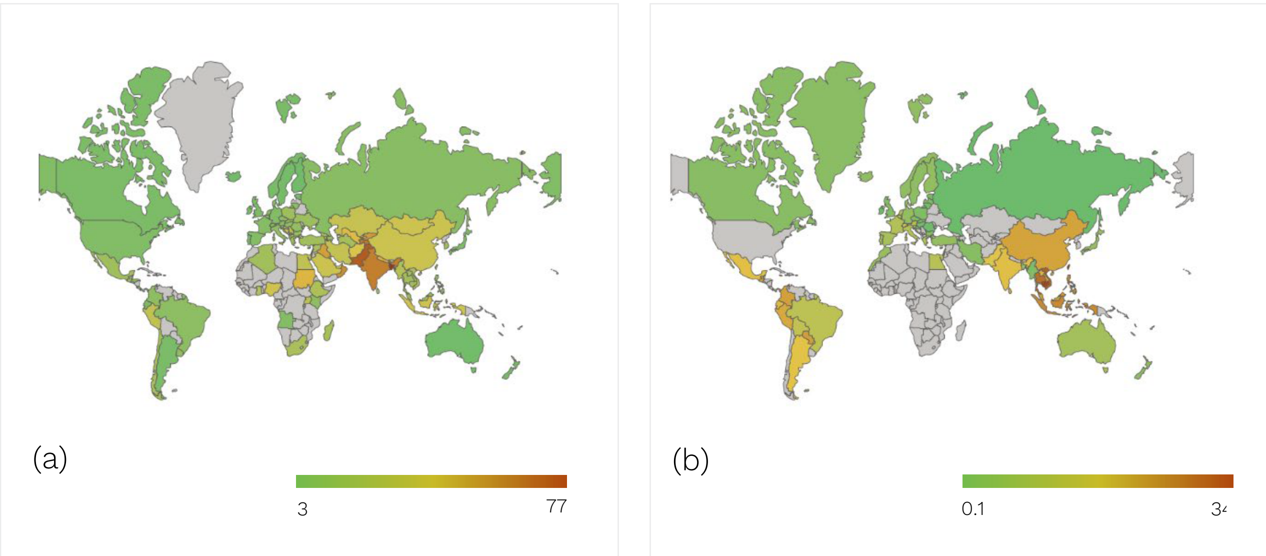
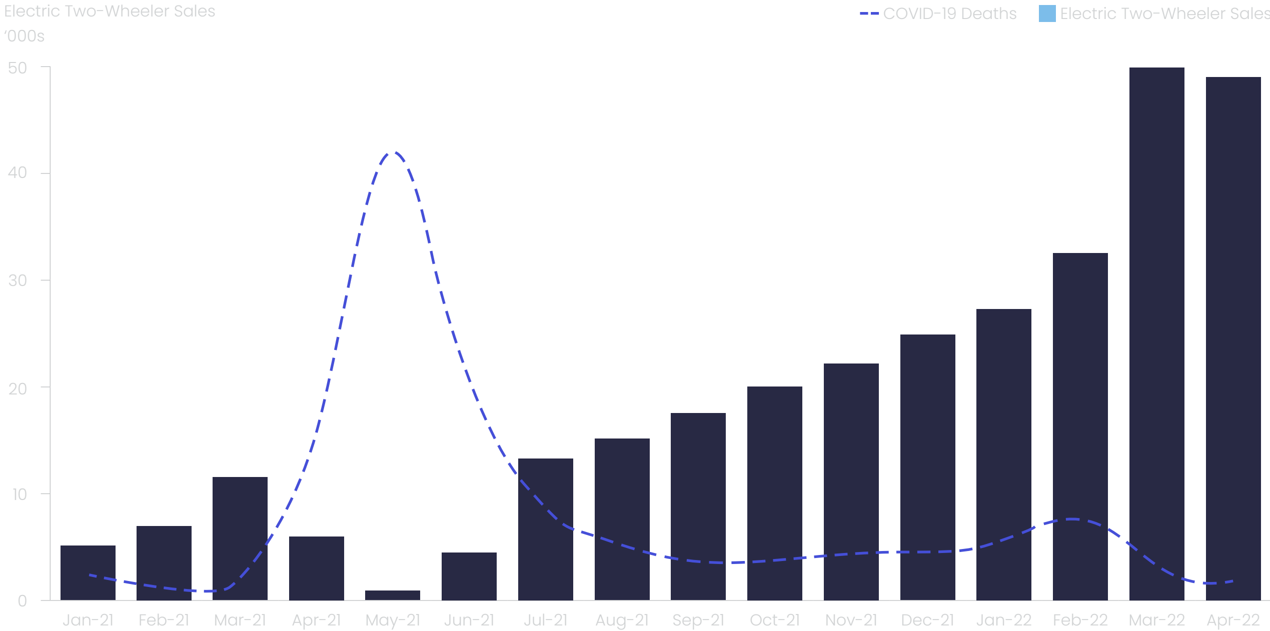


Figure 3: Monthly sales of electric two-wheelers in India from January 2021 to April 2022. When subsidies were revamped in June 2021 a dramatic change in the pattern is seen. COVID-19 deaths are included to explain the decline in April, May and June of 2021.

Source: Our World in Data



the station and receive two new fully charged ones in a matter of seconds. This all requires no additional input or payment on site as the network recognises the bike which it has received batteries from and can then invoice the owner appropriately for the power depleted from them.

Gogoro now looks to expand the use of its technology and has signed agreements with Hero in India and DCJ in China, both the largest OEMs of ICE vehicles in their respective countries. Other battery swapping initiatives such as from the big four in Japan (Gacheco) and telecoms giant China Tower in China look to emulate this model.

In India, one of the next targets for extensive two-wheeler electrification, the government has had a stuttering start in encouraging the industry. In 2019 the FAME II subsidy was introduced offering Rs10,000 (USD143) per kWh, capped at 20% of the vehicle cost for electric two-wheelers. This failed to gain the traction that was hoped for and by 2021, as the planned end of the funding came into sight, only a fraction of the available cash had been used. In June 2021 the scheme was remodelled raising the subsidy amount per kWh by 50% and doubling the limit to 40% of a vehicle's price. The effect was immediate with sales rising to a new record level in July and rising since.

The situation in India highlights how important the correct level of subsidy is. This has also spurred an influx of new electric two-wheeler start-ups in the Indian market such as Ola Electric, which only began selling in December 2021 yet sold nearly 15,000 vehicles in Q1 2022. These start-ups are now facing a challenge to convince the public of safety after several highly publicised battery fires. Voluntary recalls have been issued for some vehicles. Due to this, it is not yet certain that electrification will take hold in India in the immediate future, highlighted by the slight fall in sales in April 2022.

Our current outlook for the electric two and three-wheeler market sees the global penetration rate only creeping over 50% as we approach 2040. This is despite some ambitious targets set not only in India but in other motorcycle-dense nations such as Indonesia and Pakistan which are aiming for 90-100% penetration by 2040. So far little progress has been made to show that this can happen.

A Greater number of targeted incentive schemes are needed, recreating the success that FAME II is now having in India. Western markets can also play their part, despite being far smaller in terms of sales, Euro emission standards have become the de-facto standard worldwide and even though the effect on emissions in the EU may be negligible, pushing manufacturers forwards here will help pull forward emissions standards in the rest of the world too.

For a full view of the electric two and three-wheeler market get in touch to ask about our outlook by region to 2040 including battery chemistry splits and average pack size.

Energy Transition Tracker

Q2 2022

Our Energy Transition Capital Tracker provides an analysis of energy transition related companies going public through IPO or a merger with a SPAC each month, the full report is made available as part of our Membership. Below we provide a summary of the highlights so far in Q2 2022.

In April 2022, Gogoro closed its SPAC deal with Poema Global and listed successfully. Zhongyi Technology completed the traditional IPO process and also went public. Gogoro is a world leading two-wheeled EV manufacturer and battery swapping (for two-wheelers) provider. Valued at USD2.35 billion, Gogoro received at least USD335 million in cash from the SPAC deal, including an oversubscribed PIPE (Private Investment in Public Equity) of USD295 million. Some top tier institutional investors participated in the PIPE offering, such as Hon Hai (Foxconn) Technology Group and Temasek. Zhongyi Technology is a leading copper foil producer, mainly supplying CATL. Through the IPO deal, Zhongyi Technology raised RMB2.8 billion (~USD420 million).

Also in April, six companies announced their plans to go public. Renault is considering spinning off its EV business by H2 2023. Solid-state battery producer ProLogium is also planning an IPO in America or in Europe in the next two years. Sinosynergy and Vinfast have filed the IPO applications to SZ Exchange and SEC, respectively. Two charging start-ups, Charge Amps and FreeWire, have completed the pre-IPO funding round and are expected to start the IPO process later this year.

In May 2022, NIO, a fast-growing Chinese EV OEM, went public in Singapore by Way of Introduction. The shares are traded on the Main Board of the SGX-ST and are fully fungible with NIO's ADS listed on the NYSE. On 10th March 2022, NIO was also listed on the Hong Kong Exchange by Way of Introduction. NIO is now listed on three stock exchanges (NYSE: NIO; HKEX: 9866; SGX: NIO) while the primary listing remains on the NYSE.

Also in May, Sprixin, a smart grid and ESS solution provider, issued 17.73 million units of shares, accounting for 25% of the total outstanding shares. The issuing price was RMB45.13 per unit and the highest price on the issuing day was RMB61.8 per unit. Sprixin raised RMB800 million (~USD120 million) in the IPO deal.

We tracked another six companies announcing plans to go public in the same month. CH-Auto, Amprius, and Dragonfly will go public through SPACs and all aim to close the deals towards the end of this year. SungEel HiTech will soon IPO and potentially be the first and largest public recycling provider in South Korea. NeoVolta is pursing uplisting to the NASDAQ. And Wanxiang Group confirmed that it has started the process to spin off the battery business Wanxiang123 (A123) in preparation for a spin-off IPO.

Company	Company Area	Transaction type	SPAC	Date
April 2022				
Renault EV	EV	IPO	-	H2 2023
ProLogium	EV	IPO	-	Q4 2023
Sinosynergy	Hydrogen & Fuel Cells	IPO	-	Q4 2022
Vinfast	EV	IPO	-	Q1 2023
Charge Amps	Charging	IPO	-	2023
Freewire	Charging	IPO	-	Q4 2023
Hozon Auto	EV	IPO	-	Q4 2022
Forza X1	EV	IPO	-	2023
CALB	Batteries	IPO	-	Q2 2022
REV Renewables, Inc.	ESS	IPO	-	Q2 2022
Polestar	EV	SPAC	Gores Guggenheim Inc.	Q2 2022
Gogoro	EV	SPAC	Poema Global	05/04/2022
Zhongyi Technology	Battery Materials	IPO	-	21/04/2022
May 2022				
SungEel HiTech	Recycling	IPO	-	H2 2022
CH-Auto	EV	SPAC	Mountain Crest Acquisition Corp IV	Q1 2023
Wanxiang123	Batteries	IPO	-	2023
Amprius	Batteries	SPAC	Kensington Capital Acquisition Corp IV	H2 2022
Dragonfly	ESS	SPAC	Chardan NexTech Acquisition 2 Corp	Q4 2022
NeoVolta	ESS	IPO	-	H2 2022
Charge Amps	Charging	IPO	-	2023
Freewire	Charging	IPO	-	Q4 2023
Hozon Auto	EV	IPO	-	Q4 2022
Forza X1	EV	IPO	-	2023
CALB	Batteries	IPO	-	H2 2022
NIO	EV	IPO	-	20/05/2022
Sprixin	ESS	IPO	-	29/04/2022

Rho Motion's Energy Transition Capital tracker tracks companies going public through an Initial Public Offering (IPO) or special purchase acquisition companies (SPAC), SPACs are blank cheque companies designed to bypass the traditional IPO process.

Pre Merger/IPO

Post Merger/IPO

Seminar Series

Live & Online

Our Live event is invite only for Members and key partners. Scan the QR code to view the event agenda and to register to watch the recordings of the seminars.

When

Friday 24th June 2022

Where

Bank of America,
One Bryant Place,
New York, USA

Program

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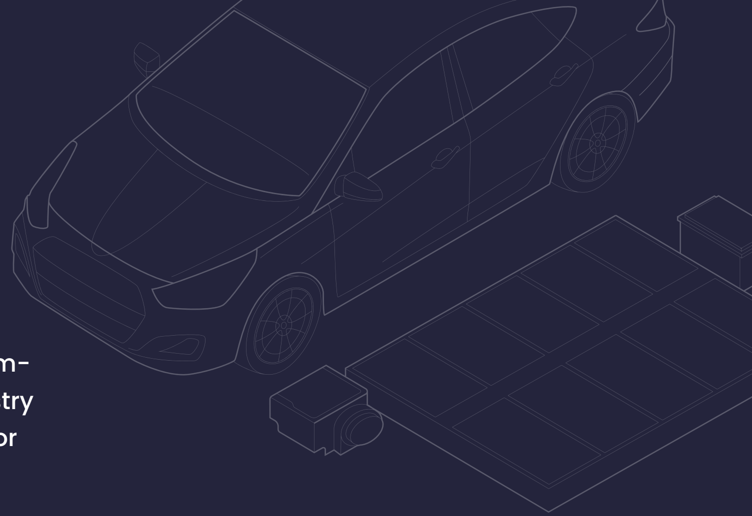

EV & Battery

Our EV & Battery market analysis is based on bottom-up model-by-model analysis, combined with industry leading insights into the future direction of the sector

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EV & Battery Quarterly Outlook

Rho Motion is an industry leader in EV market analysis. Our forecast provides long-term outlooks for EV penetration, battery pack size and chemistry by vehicle class, based on robust and informed methodologies.

EV Battery Chemistry Monthly Assessment

The assessment provides monthly sales weighted average of battery pack sizes and battery demand by chemistry market share for the EV industry across vehicle classes.

EV & Battery Monthly Database

Our core EV & Battery database, tracking sales, vehicle and battery development on a by-model basis

EV Motors Monthly Assessment

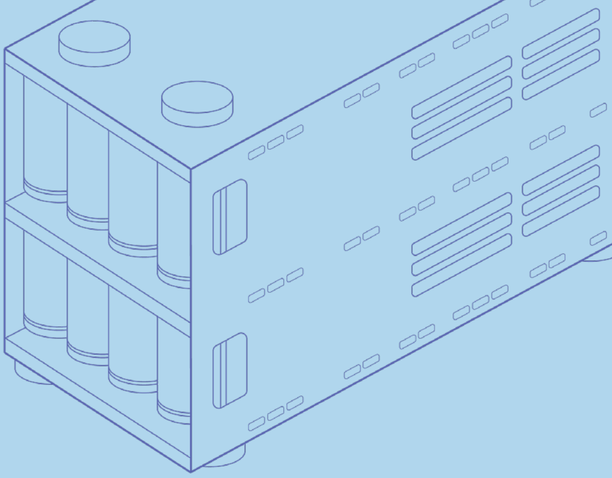
The assessment provides monthly weighted averages of motor technology demand across vehicle classes, detailing the power and quantity deployed regionally and by vehicle segment.

Hybrid EV & Battery Quarterly Outlook

Our Global HEV forecast provides a long-term outlook for HEV penetration, battery pack size and chemistry by vehicle class. Alongside our EV & Battery Quarterly Outlook it sits as an essential tool for tracking the total vehicle markets battery demand.

Our EV and Battery market analysis is delivered in flexible, dynamic formats that can be customised for the user.

Find out more, contact us +44 (0) 203 960 9986, info@ rhomotion.com



Energy Stationary Storage

Our analysis tracks storage projects around the world and examines use cases for different technologies to provide a robust and balanced outlook for the industry, at both the grid and behind the meter

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Battery Energy Stationary Storage Quarterly Outlook

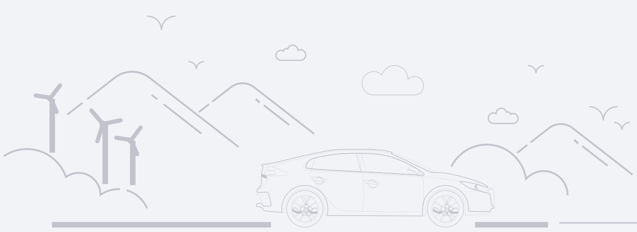
Our forecast provides long-term outlooks for battery demand and battery chemistry, by application and region, based on robust and informed methodologies.

Battery Energy Stationary Storage Monthly Assessment

The assessment provides analysis of project announcements, updates, and commissions, tracking the development of key battery stationary storage metrics over time, as well as monthly news and market updates.

Battery Energy Stationary Storage Monthly Database

Our core Battery Energy Stationary Storage database, tracking status updates, capacity, duration and technology trends.



Our Energy Stationary Storage market analysis is delivered in flexible, dynamic formats that can be customised for the user.

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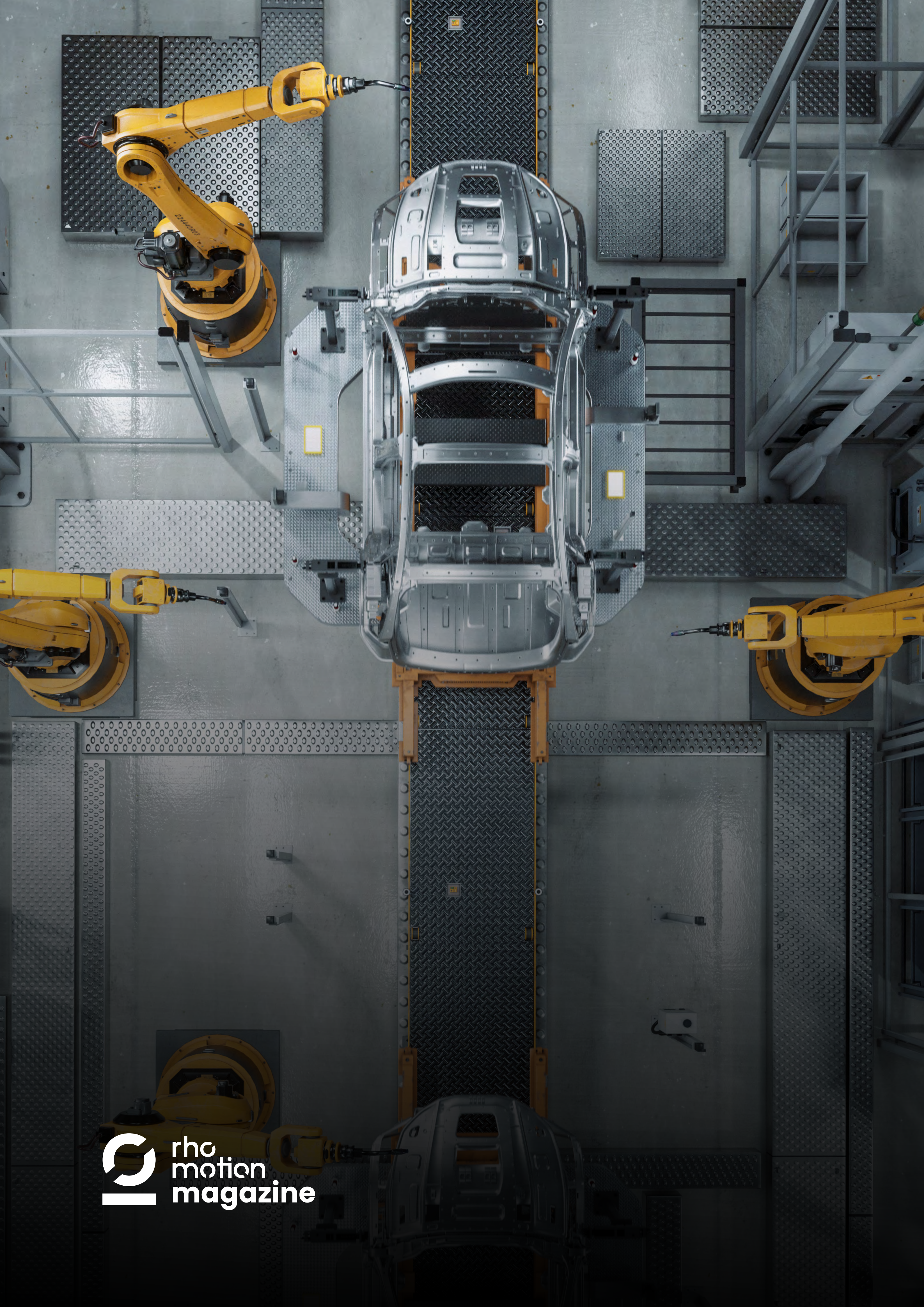
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