



RYSTAD ENERGY

# BATTERY MATERIALS WHITEPAPER

JUNE 2021

CAN THE BATTERY SUPPLY CHAIN MEET  
THE EXPECTED SURGE IN DEMAND?

This Whitepaper is an abstract of our Battery Materials Solution.  
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Battery demand is poised to skyrocket during the next half century, but will the supply chain be able to produce the raw materials, process them and deliver them in accordance with the ethical and sustainable standards that leading manufactures are set to demand?

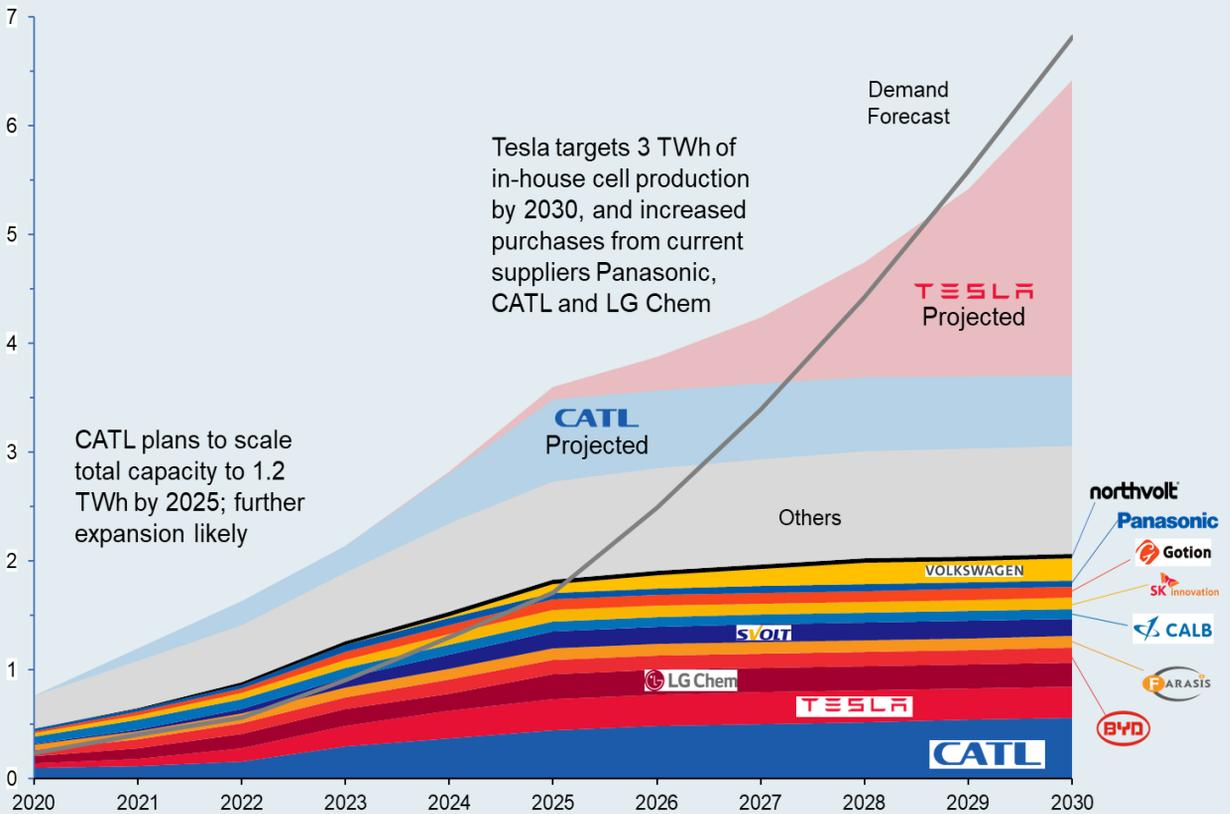


# Battery production this decade is poised to soar

A wave of planned battery plants have been announced in recent years, including for so called gigafactories – facilities able to produce an annual capacity of 1 gigawatt hour (GWh) or more – to supply the growing electric vehicle (EV) market. Global battery demand, however, is forecast to soar from 0.23 terawatt hours (TWh) in 2020 to 6.8 TWh in 2030.

Therefore, the supply of lithium-ion batteries will need to increase dramatically in order to keep up with the spiraling EV market, as current capacity plans fall short. Rystad Energy expects a supply-demand gap to emerge in the battery market towards 2030, potentially prompting significant investments in additional facilities.

**Figure 1: Cell production capacities by company and demand forecast**  
Terawatt hours (TWh)



Note: This excludes yield (plant utilization and scrap rate)

Source: Rystad Energy BatteryMaterialsCube Beta

The term gigafactory was originally coined by Tesla in reference to its Gigafactory 1 plant, which broke ground in Nevada in 2014. Numerous companies are following in Tesla's footsteps, boosting investments in the process. Total Li-ion cell production capacity worldwide in 2020 was 0.7 TWh, led by China's Contemporary Amperex Technology Ltd (CATL), which can produce 97 GWh per year.

Other large players in the market include LG Chem, BYD, Farasis and Tesla, as well as SK Innovation (SKI), Svolt and Panasonic – all planning to expand current production capacities. New players like

Volkswagen and Wanxiang will also add to the global output (see Figure 1), lifting total Li-ion cell production capacity to around 2.7 TWh per year in 2030.

CATL announced a capacity target boost to 1.2 TWh by 2025, and Tesla set a goal of 3 TWh by 2030 – potentially pushing total annual supply to around 6.1 TWh by the end of the decade. However, this might still not be enough. Should battery demand follow our projections, we see the need for incremental cell plants to be sanctioned and brought online after 2025.

## Significant European battery investment is on the cards

Europe accounted for 13% of the global battery manufacturing market in 2020 and is forecast to jump to 31% by 2030.

Increased financial support from development banks and the formation of the European Battery Alliance in 2018 (supported by a partnership between the European Commission and the European Investment Bank) has led to a rising wave of European project announcements in the last couple of years. The growth has also been supported by investment banks increasingly turning away from hydrocarbons.

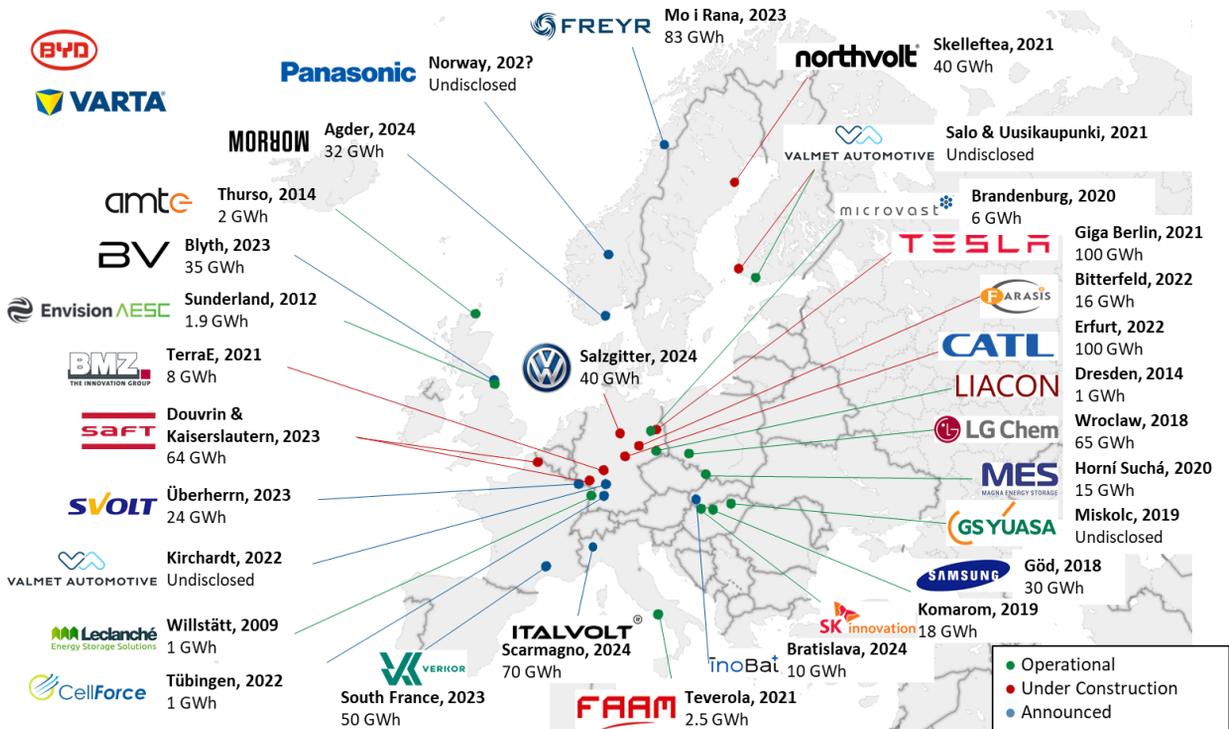
Northvolt raised capital to build its 40 GWh Skelleftea factory in northern Sweden to supply Volkswagen. The battery developer previously partnered with Volkswagen for another 40 GWh factory in Salzgitter, Germany, but sold its share in the project

to the car maker in March 2021. During its first quarter 2021 financials, Volkswagen also announced four other 40 GWh factories to be based in Europe, bringing its total capacity to 240 GWh by 2030.

With an estimated 330 GWh capacity by 2030, excluding additional projects where capacity is currently unknown or where no location is specified, Germany will likely become the central core of European battery production (see Figure 4). The largest facility in the country will be Tesla's Giga Berlin in the city of Brandenburg, and CATL's Erfurt plant, both of which are currently under construction and could reach 100 GWh individual capacity.

Total production capacity in Europe could reach 850 GWh by 2030, as more facilities are planned.

Figure 2: Map of European battery plants by status



Source: Rystad Energy BatteryMaterialsCube Beta

The US is the other country that is expected to see rising investment in battery manufacturing capacity. For example, Tesla’s pioneering Nevada Gigafactory 1 currently produces an estimated 40 GWh per year. The company is expanding its North American operations with a smaller plant close to its primary EV factory in Fremont, California. The facility, which will house the company’s Roadrunner line of 4680 cells, will see production ramp up to 10 GWh at peak. Tesla is also constructing the Giga Texas factory, just outside of

Austin. This project will be put into production in 2022 and will likely ramp up to an annual capacity of 100 GWh.

Indeed, the bold capacity ramp-up outlined by Tesla’s Elon Musk during the company’s 2021 Battery Day may further assist American ambitions to become a battery powerhouse. However, while Tesla announced a 3 TWh manufacturing capacity target by 2030, only around 700 GWh is currently accounted for.

# China will continue to dominate global battery demand

China dominated global battery manufacturing in 2020, accounting for 76% of worldwide capacity, and is forecast to still account for just over 50% by 2030. CATL leads the way both at home and internationally. Amid its aggressive 2025 1.2 TWh ramp-up strategy, the company has already started construction of its first overseas factory. Production is expected to begin in 2022 at its new plant in Erfurt, Germany, at 14 GWh, increasing later to 24 GWh and ultimately rising to 100 GWh. Chinese car manufacturer BYD and battery technology company Farasis, producing 59 GWh and 49 GWh, respectively, are both 100% domestically focused for now. Like CATL, however, these companies announced plans to expand their reach by building facilities in Europe, as BYD started

selling EVs in Norway in 2020 and Farasis signed a partnership agreement with Mercedes-Benz.

Other major expansions in production will come in China from Gotion High-Tech (formerly Guoxuan High-Tech). Tesla's Giga Shanghai plant began production in December 2019, just 12 months after breaking ground. While early output has been slowed by the Covid-19 pandemic, the factory will produce an estimated 35 GWh when full capacity is reached. Multinational corporation Wanxiang, meanwhile, is also set to emerge on the scene later this year when its Hangzhou factory comes online. Production is due to ramp-up from an initial 20 GWh to 80 GWh by 2023.



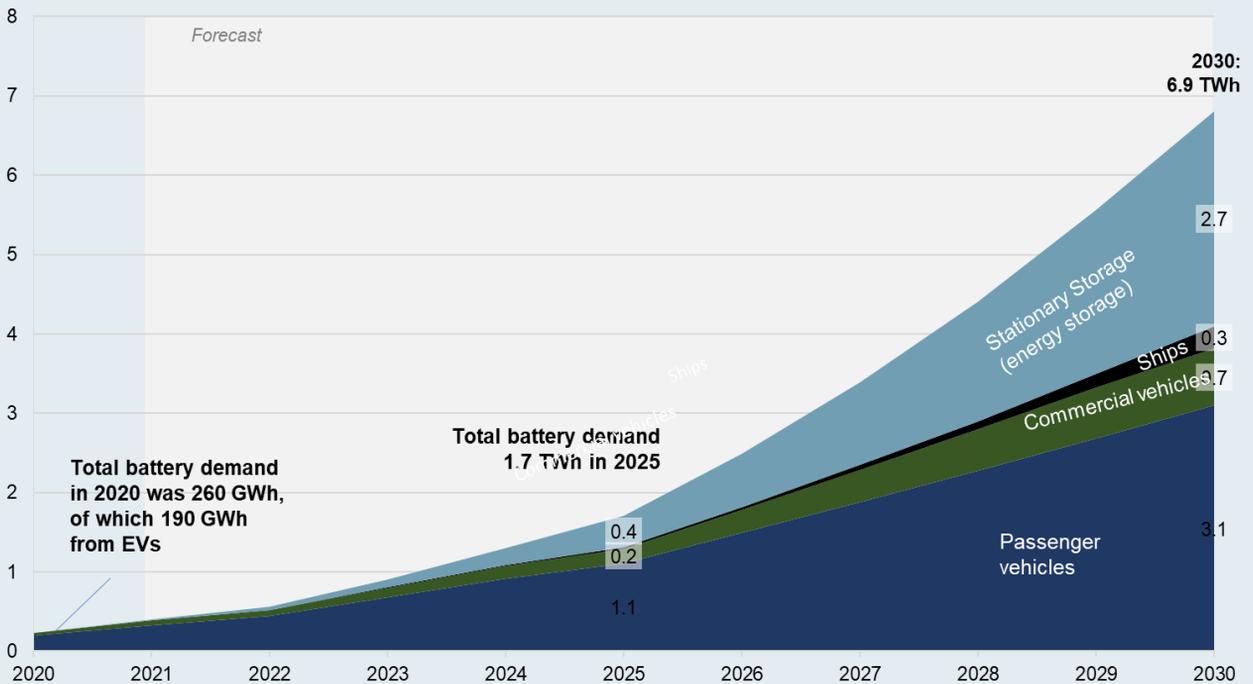
# Battery demand will be driven by more than just EVs

EVs continue to dominate the headlines regarding battery demand for the time being, but a market that is set to rival EVs over time is battery demand for stationary storage. Rising EV demand itself translates directly into increased attention for stationary battery storage. Furthermore, we believe the rising adoption of renewable energy could help drive annual demand for stationary storage beyond the battery needs of new passenger cars.

The key to the growth in stationary storage is the decarbonization of society, including both the power sector (high share renewables) and industry (increased electrification).

Figure 3 highlights the growth trajectory outlined for all battery demand, which is projected to reach 7 TWh by 2030. This demand forecast does not include demand for batteries from personal devices, electric bikes, drones, aviation etc. However, this growth projection does assume demand that is unconstrained by supply issues, which – as we will address later in this whitepaper – are in fact set to create problems. The demand scenario also assumes a 100% use of solar, wind and batteries in the power sector. Short-term issues are likely to emerge as the supply adjusts to the rapid growth in demand.

**Figure 3: Global annual battery demand potential in unconstrained scenario, by segment**  
Terrawatt hours (TWh)



Source: Rystad Energy research and analysis

# Can battery raw material supply meet these demand requirements?

A growing concern in the EV industry though, is that with surging demand forecast for batteries, will the supply chain be able to deliver the raw materials and components that will be required to manufacture these batteries? Some initial challenges were identified through Rystad Energy research. Key battery raw materials for cathodes include nickel, cobalt and lithium, while graphite is needed for anodes.

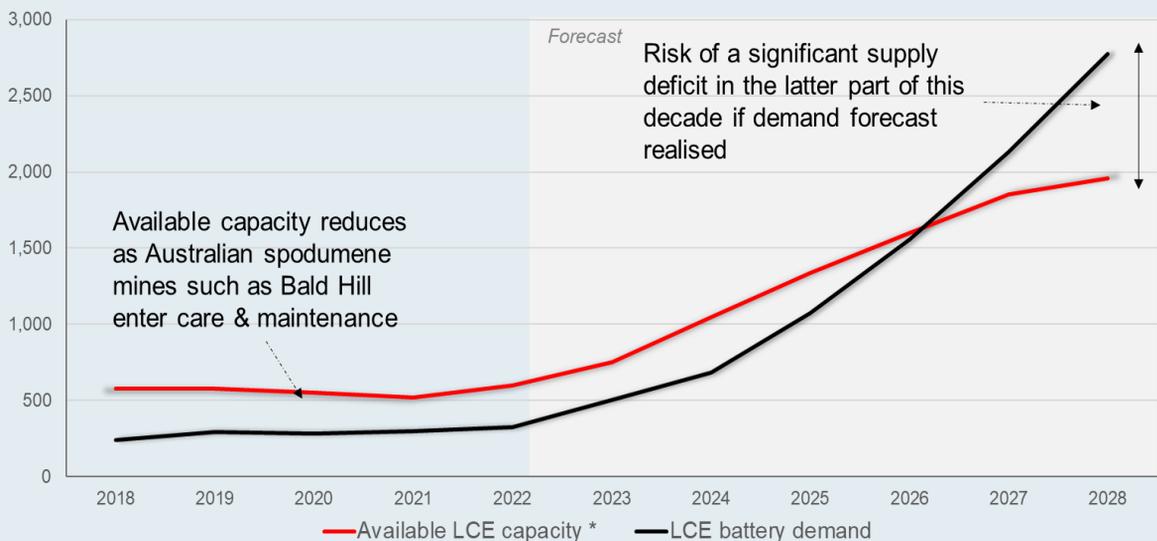
Taking a detailed look at the lithium market as an example, supply of this mineral will struggle to meet skyrocketing demand. The mining industry is unlikely to keep up with the expected demand spike, particularly after 2025, as battery recycling and other alternatives that could help reduce the shortage will take time to deliver results. Rystad Energy expects lithium prices will likely climb until further mining capacity becomes available, unless lithium extraction through other methods, like

geothermal brines, can be commercialized quickly. On the other hand, escalating lithium prices could prompt battery designers to seek ways to reduce the lithium content per battery.

There is no shortage of lithium in the ground to meet growing EV demand, but engineering, financing, building and then extracting the resource is not quick. The two primary routes for lithium extraction are hard rock mining and lithium evaporation from salt brines. We estimate that it takes around five years to finance and develop a hard rock mine, and around seven years for a brine deposit.

The volume of LCE required by the EV industry for battery manufacturing was around 280,000 tonnes in 2020. Rystad Energy expects that by 2025, based on our demand growth estimates for EV batteries, the industry will require almost 1.1 million tonnes of LCE (see Figure 4).

**Figure 4: Global LCE battery capacity and demand balance 2018-2028**  
Thousand tonnes



\* We assume each year that a certain LCE capacity enters non-battery markets i.e. glass, ceramics etc., Forecast LCE demand includes for both EV/Vehicles & storage requirements

Source: Rystad Energy research and analysis

There are more than 40 proposed projects and expansions of existing hard rock and brine assets that are set to come on stream in the next half decade. However, even if these mines were to come on stream as planned, global LCE available to the battery market will be around 275,000 tonnes less than required (see Figure 2) by 2027. This deficit will be even larger if no new mines are sanctioned in the coming years to meet the demand projections.

These supply constraints for battery raw materials in the latter part of the decade are not just limited to lithium; surging demand will put pressure on several other minerals as well. Once again, the problem here is not that the earth lacks the natural resources needed to meet demand, but rather that it will take a considerable amount of time to get these ever-increasing volumes of minerals out of the ground.

## Will re-used batteries and recycling provide an answer?

Structural changes will indeed be needed from the battery supply chain in order to make this industry sustainable in the long term. More mining appears to be the only short-term option to meet growing demand, but this runs the risk of derailing the EV industry's environmental credentials.

For example, looking again at lithium, hard rock mining requires large amounts of water and can release up to 15 tonnes of CO<sub>2</sub> for every tonne of lithium produced. Extracting lithium from brine deposits, while emitting less CO<sub>2</sub>, requires more water, and this process often takes place in parts of the world where water is scarce.

Environmentally friendly methods of lithium extraction from geothermal brines are being explored in the UK, Germany and the US. We expect to see these initiatives gain momentum in the coming years in an effort to keep lithium supply levels high while keeping prices low.

As the EV industry matures, industries will need to be established that promote second-life battery use and near 100% recyclability. Battery recycling has been slow amid technical constraints, economic

barriers, logistical issues and regulatory gaps. Current recycling methods require high-temperature melting and extracting or smelting processes that are energy-intensive and not environmentally friendly.

One key problem has been that batteries were not designed with material recovery in mind, but rather to produce energy for a long time, as cheaply as possible. With battery recycling growing increasingly important, start-up companies in North America and Europe are eyeing new technologies. The US Department of Energy, for instance, has set up a battery recycling research and development center in collaboration with nine UK universities, led by the University of Birmingham, and 14 industrial partners.

Rystad Energy believes there will be a push to tackle battery recycling as more projects approach the end of their service life. Widespread adoption of battery recycling may not be seen until after 2030, however, as EV batteries currently entering the system are designed to have a 15-year service life. Recycling is therefore unlikely to plug the gap between lithium supply and manufactures' demand after 2025.



# Are secure and carbon neutral supply chains achievable?

Alongside concerns about the supply of enough battery raw materials to meet the short-term demand projections, battery manufacturers and their vendors are also being challenged to ensure sustainable and carbon-neutral supply chains.

EV majors are coming to terms with the fact that there is a lack of transparency and a greater need for regulations within the supply chain – from the extraction of the raw materials used to manufacture lithium-ion batteries to the end of each vehicle’s service life. But the raw materials needed for battery manufacturing – cobalt, lithium and nickel – are often found in challenging regions where extraction is not done in an environmentally-friendly manner. As such, securing the supply of raw materials is likely to be a focal point for EV makers as they plan for increased production levels.

The specialized nature of each step of the battery supply chain means that carbon emissions, from logistical shipments of raw materials to finished batteries, pose issues for end-users. Many original equipment manufacturers (OEMs) plan to shift towards nickel-intensive cathodes in an effort to reduce the use of cobalt, which has been frequently associated with artisanal mining in the Democratic Republic of Congo (DRC). Cobalt, however, will continue to be a critical metal for batteries for years to come. Nonetheless, OEMs are keen to see a localization of supply chains, particularly across Europe and in the US, both of which continue to lag behind Asia on this front. North America and Europe struggle with a lack of local active mines and comparable processing facilities compared to Asia, particularly for lithium.

**Figure 5: Active battery raw material mines**



Securing raw materials remains a strategic concern for OEMs. With such ambitious growth rates and relatively subdued raw material prices, key EV manufacturers have pledged upstream investments in a bid to limit future bottlenecks.

Tesla, for instance, has taken greater ownership of upstream raw materials, most notably with the Piedmont Lithium deal for spodumene concentrate supply, thereby localizing the supply chain and securing raw material feedstock critical to lithium-ion battery production. This is likely to convince other players to consider strategic opportunities for long-term partnerships.

Of all the key battery raw materials, cobalt is the one that continues to raise the greatest concerns over its sourcing. Supply is dominated by the DRC – responsible for more than 70% of global output. The country has a history of instability and human rights violations, making it extremely difficult for many OEMs to achieve ethical sustainability of supply chains. OEMs are trying to mitigate this by pushing for battery models with lower cobalt content, like the NCA type (lithium nickel cobalt aluminum oxide) over the NMC type (nickel manganese cobalt).

One OEM taking steps to reduce its reliance on supply from the DRC is German car manufacturer BMW, which signed a five-year cobalt supply contract with Moroccan mining company Management Group last year. This, however, will only amount to one-fifth of the requirements of BMW's fifth generation EVs. The company therefore decided recently to start buying critical raw materials, including cobalt and lithium, directly from the mines. As such, Australia is now its primary source of cobalt and lithium. BMW will then sell these raw materials to the battery manufacturers that supply its models. BMW insists that all raw materials it uses must be extracted and processed in an ethical manner.

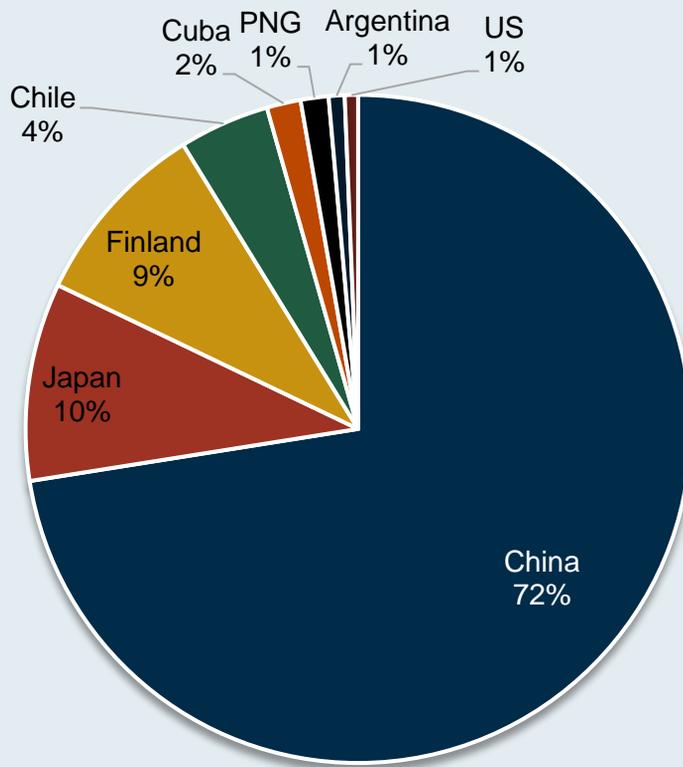
Nevertheless, most European OEMs could face greater challenges trying to localize raw material supplies, given limited local mining options and a rapid expansion of battery cell manufacturing plants.

## Reducing China's dominance in the supply chain?

The EU proposed to introduce a new set of battery regulations from 2022, which would revolve around the carbon footprint of production and sustainable supply chains. These regulations are poised to have a significant impact on raw material supply chains in Europe. There are currently just three precursor/cathode producers in Europe that will be able to capitalize on the EU's push for localization in 2022. The introduction of such local content requirements could spark a move into Europe by some Chinese and South

Korean producers of precursor chemicals for battery manufacturing. China continues to dominate the global battery raw material processing market that supplies cell manufacturers, which is an ongoing concern for battery manufacturers in Europe and North America. As can be seen from Figure 6, where we assess total processing capacity of lithium, nickel, cobalt and graphite into battery grades, China undertook nearly 75% of all processing in 2020, demonstrating dominance within this supply chain.

**Figure 6: Country undertaking battery raw material processing\* and precursor production in 2020**  
 Thousand tonnes



\*Total processing capacity of nickel, lithium, cobalt and graphite

Source: Rystad Energy BatteryMaterialCube

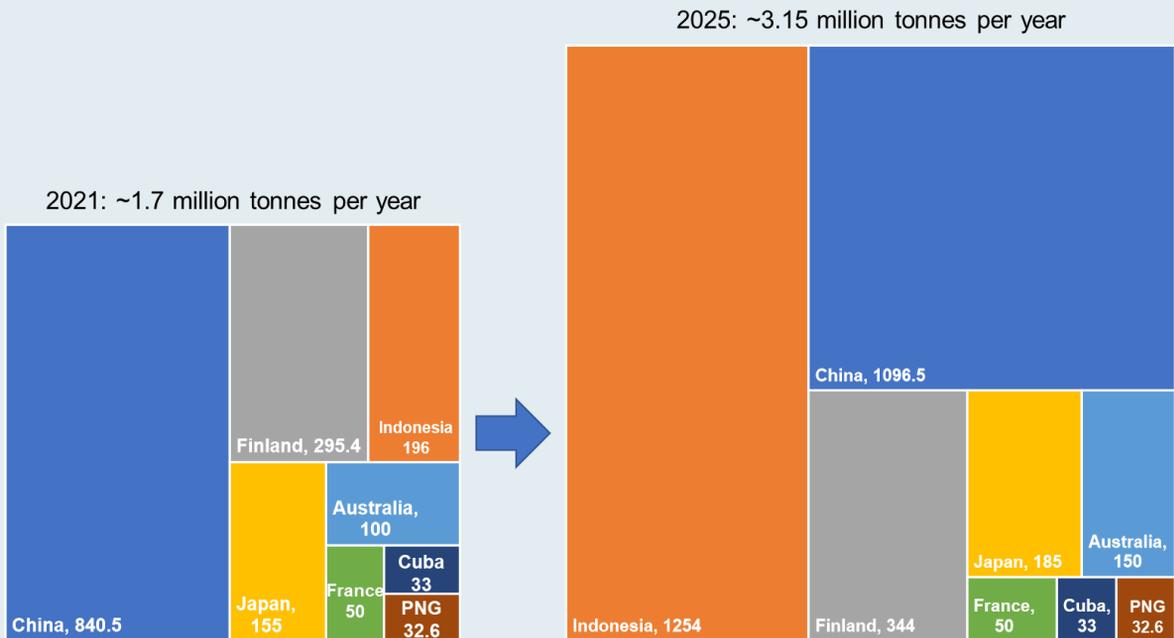
Certain countries, however, are looking to reduce China’s dominance in this part of the supply chain. Indonesia has banned export of nickel ore several times since 2014 in a bid to prevent capital from being extracted from the country. This was brought one step further in January 2020, when the country banned the export of all unprocessed nickel ore.

As the ban took hold, international players in the battery supply chain moved directly into processing in Indonesia. For example, European battery materials players BASF and Eramet have teamed up and are considering building a joint nickel and cobalt refining complex in Indonesia that would begin operations in the mid-2020s.

China currently holds a dominant position in the nickel refining market, with 840 kilotonnes of annual refining capacity for battery-grade nickel products, out of a total global capacity of about 1.7 million tonnes.

This is set to change as large greenfield investments are headed for new Indonesian refinery projects. By 2025, we expect Indonesia will have the world’s largest nickel refining capacity of 1.25 million tonnes per year, followed by China with nearly 1.1 million tonnes. A long-term sustainable supply of nickel will be vital for the development of EVs worldwide, and with its growing nickel processing capacity Indonesia is set to be a key player in this supply chain (Figure 7).

**Figure 7: Expected growth in nickel processing capacity from 2021 to 2025**  
 Thousand tonnes per year



Source: BatteryMaterialsCube; Rystad Energy research and analysis

The shift in global refining dynamics towards Indonesia could result in a vertically integrated upstream/midstream value chain in the country even though the shift itself comes from other factors, mainly its export ban on raw nickel products and the cost advantages for its smelting business. BASF and Eramet are following in the footsteps of several Chinese operators that have invested heavily in Indonesian processing facilities for both nickel sulfate and matte.

Six companies have set up processing facilities at the Morowali Industrial Park in Central Sulawesi, including Tsingshan Holding Group, China Ningbo Lygend Group, CNGR and Huayou Cobalt. The site offers mature infrastructure such as gas, electricity, pipelines and ports for the battery-targeting nickel projects – and even shipment services, which will be very convenient for exports in the future, especially for cathode production.

While Indonesia is expanding its market share in nickel processing, current market leader China is seeking other ways to strengthen its position in the growing market for battery materials, including a plan to convert low grades of nickel pig iron (NPI) into nickel matte for use in batteries.

Tsingshan, the world’s largest stainless-steel producer, sent shockwaves through the market earlier this year by announcing it would supply nickel matte from its Indonesian processing facilities to Huayou Cobalt and battery materials maker CNGR Advanced Material. The move triggered a slump in prices for battery-grade nickel on concern that use of cheaper, low-grade NPI could alleviate an expected supply shortage of the higher-grade product. The Chinese proposed conversion of NPI to nickel matte in Indonesia would follow the same process route of concentrated sulfide ores once the matte is produced.

Battery-grade nickel sulfate production via either route is not without environmental issues. Nickel produced from HPAL generates waste tailings that are often difficult to dispose of and are dumped in the sea, while production of nickel sulphate via NPI conversion into matte and the subsequent battery product have a significant carbon footprint via CO<sub>2</sub> emissions. Both production routes are a

cause for concern for OEMs keen to safeguard their ESG (environmental, social and corporate governance) scorecard, as the long-term environmental impact can be serious. As a result, some OEMs such as Volkswagen are pursuing a diversified battery approach by including lithium manganese nickel oxide (LMNO) batteries into their portfolios, in a bid to reduce both nickel and cobalt dependence.

## OEMs set to further take control of this supply chain?

Environmental pressures and security of supply remain the critical drivers pushing car manufacturers to take greater ownership of their respective supply chains.

There are several advantages for the automotive industry to move upstream. By developing battery systems internally, it enables players to customize the software for controlling the power systems that can have a direct impact on battery range over the service life of a vehicle. Also, given that batteries are the most expensive component of an EV, car makers can reap long-term cost advantages by manufacturing batteries themselves.

Although Tesla remains the pioneer in upstream investment, other major automotive companies have recently been considering their strategic options. BMW Group chosen to source cobalt directly for Samsung SDI and CATL, from mines in Australia and Morocco, in order to diversify and reduce dependence on the DRC for materials.

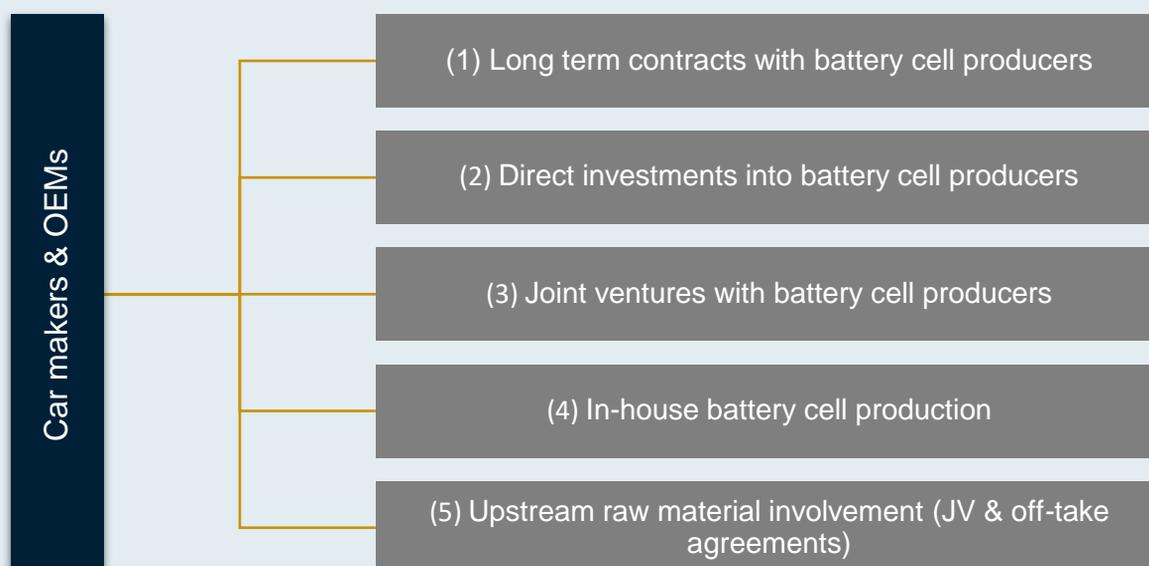
BMW has also partnered with Livent, at a cost of \$335 million, to extract lithium from a brine resource in Argentina, applying

methods that are more sustainable. In this technique, brine is not evaporated but returned directly to the ecosystem, thus minimizing water loss, which is a key environmental concern of traditional brine operations.

Interestingly some other auto makers have taken a slightly different approach based on the same principles, exploring the potential of blockchain in ensuring these credentials. Volvo, Ford and Volkswagen, to name a few, have all invested heavily in blockchain technology to bring greater transparency to the supply chain.

With environmental concerns high on the automotive agendas, some such as BMW Group have joined the Initiative for Responsible Mining Assurance to define requirements pertaining to environmental and social standards in connection with resource extraction. Ensuring raw material suppliers meet certain standards will be a growing theme in the supply chain as the push for greater transparency gains momentum.

There are several routes that OEMs can take to interact further with the supply chain, as shown in Figure 8.

**Figure 8: Different methods OEMs are using to access the battery raw material supply chain**

Source: Rystad Energy research and analysis

In conclusion, the battery raw material supply chain will struggle to deliver the projected raw materials that the battery manufacturers are projected to require. There are likely to be difficulties in providing, processing and resourcing these materials in an ethical and sustainable manner.

Raw material shortages are likely to become more frequent in the second part of the decade, as the mining sector seeks further significant injections of capital to ramp up capacity. Rapidly rising prices of raw materials, which are forecast due to this supply tightness, should help to free up capital and boost production capacity.

Longer term, after 2030, we believe efforts to close the loop in the battery raw material supply chain will be increasingly successful. As seen in other metals supply chains, such as steel, recycling will play an ever-greater role. This in turn will help to reduce dependence on freshly mined and processed battery raw materials.

Furthermore, European and American OEMs will likely push for more localized

supply chains in the next few years, in a bid to improve the environmental credentials of the EVs they produce – a critical requirement considering that these credentials have driven the adoption of EVs in the first place.

Nonetheless, our research suggests it will be very difficult for these companies to transform their supply chains quickly and circumvent the sourcing of key raw materials from challenging regions. This includes reducing dependence on cobalt from the DRC and materials from the lithium triangle in South America, as well as scaling back HPAL developments in the nickel markets in Indonesia.

However, later stages in the supply chain – such as processing and precursors, as well as anode and cathode manufacturing – are likely to become increasingly localized, with both Europe and America making a strong push to support their ever-expanding domestic battery manufacturing capacity.

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