Supply chain challenges signal a bumpy road ahead for electric vehicle adoption

With net zero ambitions now at the forefront of many governments' political agendas, electric vehicle sales are breaking new records. Soaring demand for EVs is driving the growing market for related critical minerals, and supply chains are rapidly expanding – but for now, China remains in the lead for battery manufacturing

Could supply chain issues slow down the pace of EV adoption?

Decarbonising the transportation sector is key for reducing greenhouse gas emissions – and with the global light-duty vehicles fleet of almost 1.29 billion cars reflecting the largest fraction of transport emissions, moving progress along has become more crucial than ever.

The EU aims to phase out almost all combustion engine-driven car sales by 2035, while over in the US, plans are already in motion for half of all sales to be electric by the end of this decade. With a growing coalition of countries now pledging to reach net zero by 2050, we take a look at the current state of global supply chains and the ways in which they could hinder progress moving forward.

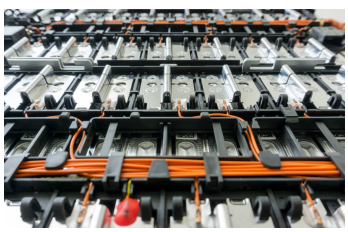
In this bundle

Energy | Transport & Logistics | Sustainability

Global electric vehicle supply chains struggle to keep up as demand surges

For electric vehicles, diversifying battery manufacturing and critical raw materials supplies will be key to ensuring secure and sustainable supply chains

By Coco Zhang, Ewa Manthey and Rico Luman



Energy | Transport & Logistics | Sustainability

Tightening supply shakes up battery metal dynamics

As battery manufacturers delve into new options in technology, the outlook for metals prices could complicate progress

By Coco Zhang, Ewa Manthey and Rico Luman

Transport & Logistics | Sustainability

Geopolitics, policy and sustainability to forge new electric vehicle partnerships

A glimpse into the future of the EV supply chain and the impact of geopolitical developments

By Coco Zhang, Ewa Manthey and Rico Luman

Article | 26 July 2023

Energy | Transport & Logistics | Sustainability

Global electric vehicle supply chains struggle to keep up as demand surges

Reaching net zero emissions will require massive amounts of critical raw materials, which are currently used in everything from solar panels to electric vehicles. For EVs, diversifying battery manufacturing and critical raw materials supplies will be key to ensuring secure and sustainable supply chains

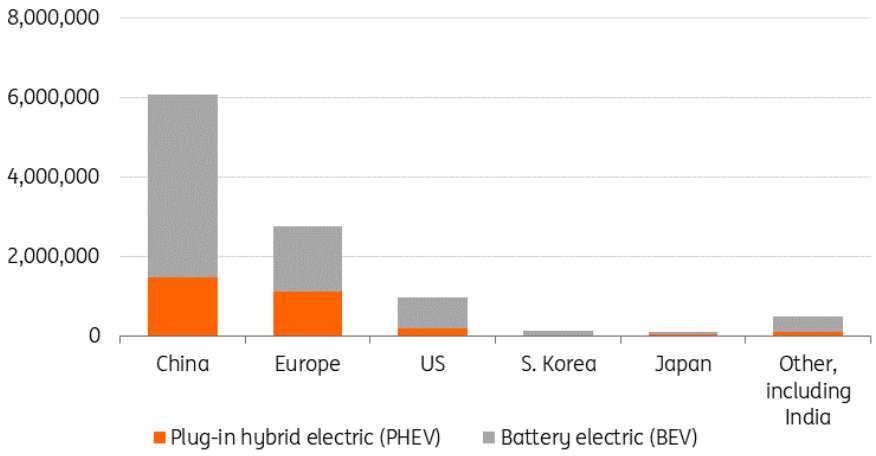
Almost one in five new cars sold worldwide will be an electric vehicle in 2023

Global EV sales are soaring, and the transition has only just begun

Electric vehicle markets are still showing great strength across the board, breaking new records as sales surge. A total of 14% of all new cars sold were electric in 2022, up from around 9% in 2021 and less than 5% in 2020. Global sales exceeded 10 million last year alone – and this level of growth isn't expected to slow any time soon, with almost one in five new cars sold worldwide this year set to be electric.

Global EV sales exceeded 10 million in 2022

Total electric vehicles sales (BEV + PHEV) per region in 2022



Source: IEA, BNEF, ING Research forecasts

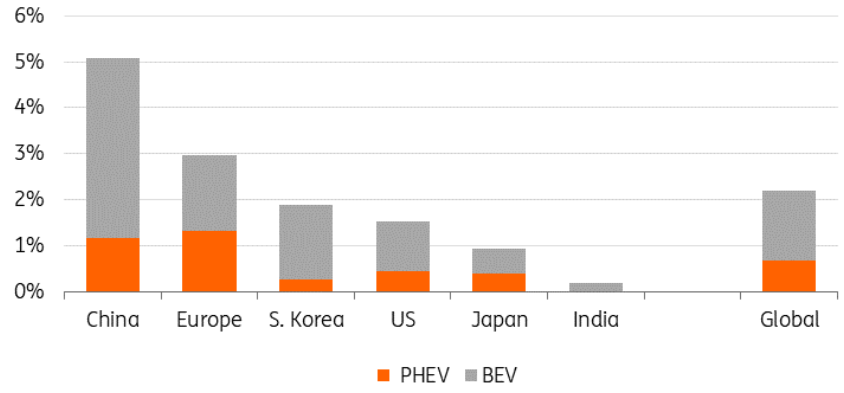
Despite surging EV sales, the transition has really only just begun

The acceleration in EV sales is gradually being reflected in car fleets across the globe but at a much slower pace, mainly due to production struggles over the last couple of years and consequently low replacement rates. The estimated EV share of the fleet – including plug-in hybrid electric vehicles (PHEVs) – reached just 2.2% in 2022.

Despite surging EV sales, the transition has really only just begun. This means that demand should continue to soar on the back of subsidies and future phase-out targets and regulations for internal combustion engine (ICE) vehicles. When total costs of EV ownership are on a par with those of ICE vehicles (and even begin to drop below them) in the second half of the decade, we can expect an extra upswing.

We're just at the start of the replacement and electrification of car fleets

Share of electric vehicles (BEV + PHEV) of the total car fleet per region in 2022



Source: BNEF, ING Research forecasts

Battery metals demand rises as EV market matures

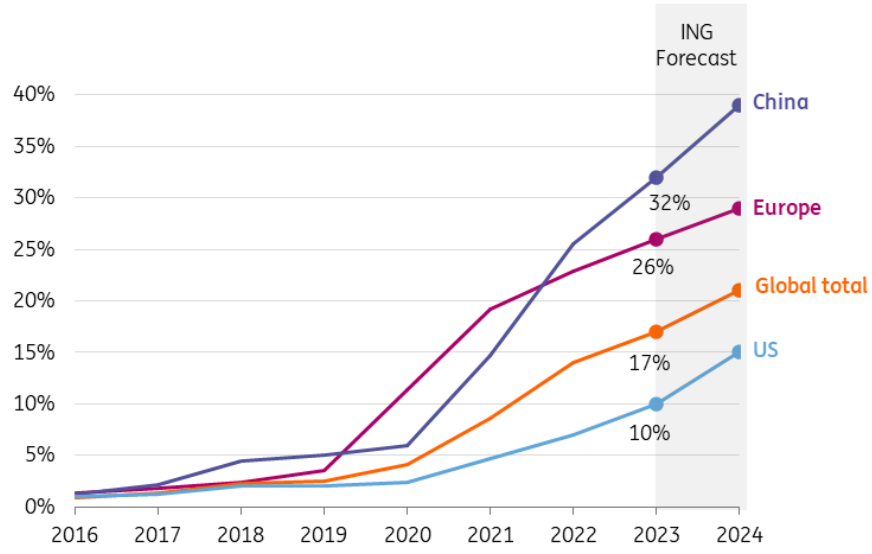
In 2019, only 2.5% of cars sold worldwide were electric, while in 2023 they're set to reach 17%.

China, the EU and the US are the leading markets, with electric cars set to surge to 60% of total car sales across these three economies by 2030 – that's if supply is able to keep up.

As the demand for EVs rises rapidly, so does the demand for the minerals inside their batteries. Until the market matures and the fleet reaches critical mass in various regions, recycling won't play a significant role just yet.

Expansion of EV sales is set to soar by 2030

Share of electric vehicles (BEV and PHEV) in total new car registrations per region



Source: IEA, BNEF, ING Research forecast

EV supply chains struggle to keep up with rapidly expanding end use markets

The expansion of EV sales is driving up demand for battery materials. Automotive lithium-ion (Li-ion) battery demand increased by about 65% to 550 GWh in 2022, from about 330 GWh in 2021. According to data from the International Energy Agency (IEA), this surge was driven primarily by growth in EV sales.

> *Squeezed supply chains and looming shortages of critical metals both present a major risk for the energy transition*

In 2022, about 60% of lithium, 30% of cobalt and 10% of nickel demand were for EV batteries. Five years prior, these shares were around 15%, 10% and 2% respectively. Lithium, rare earth elements, chromium, arsenic, cobalt, titanium, selenium and magnesium recorded the largest production volume expansions – ranging between 33% for magnesium and 208% for lithium – in the last decade. This still falls far short of the four to six-fold increases in demand projected for the green transition, according to a report from the Organisation for Economic Cooperation and Development (OECD). At the same time, global production of some critical raw materials, such as lead, natural graphite, zinc, precious metal ores and concentrates, as well as tin, declined over the last decade.

Squeezed supply chains and looming shortages of critical metals which are key for battery manufacturing present a major risk for the energy transition as we head towards 2030. Lagging investments in mining may also add another challenge to the mix as we begin to see the supply-demand balance grow increasingly fragile.

Author

Coco Zhang
ESG Research
coco.zhang@ing.com

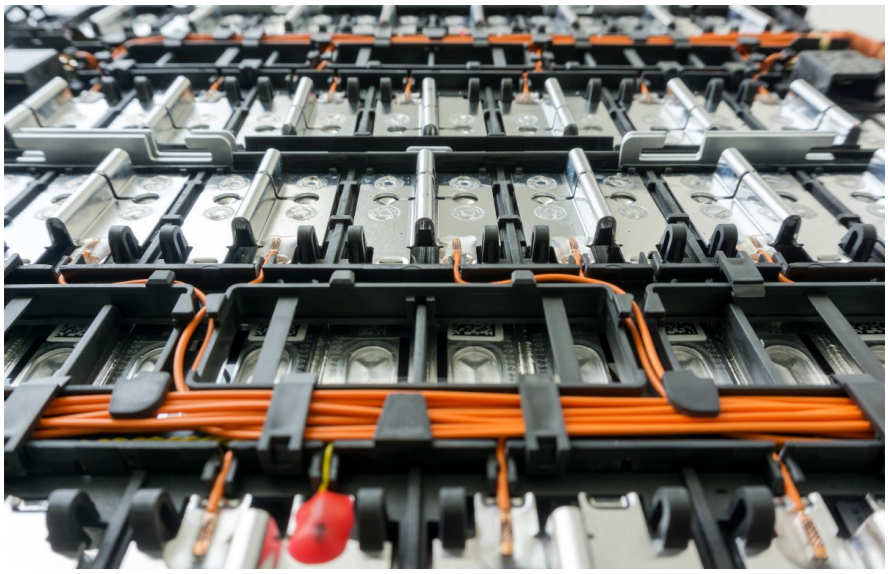
Ewa Manthey
Commodities Strategist
ewa.manthey@ing.com

Rico Luman
Senior Sector Economist, Transport and Logistics
Rico.Luman@ing.com

Article | 26 July 2023

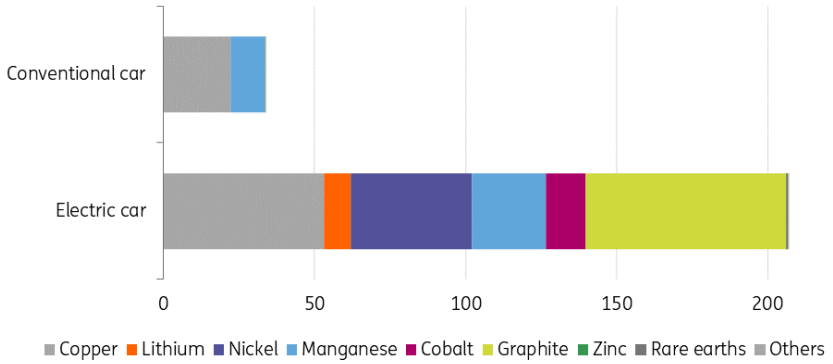
Tightening supply shakes up battery metal dynamics

The dynamics of tightening supply and soaring demand for electric vehicle batteries are becoming increasingly fragile. Battery manufacturers are now looking into new technology with advanced chemistry compositions to ensure long-term metals supply, but progress will be impacted by the outlook for metals prices



Battery technology is evolving rapidly as manufacturers transition away from nickel and cobalt, mainly as a result of high costs, scarcity, and mining ethics

More minerals are used in electric cars compared to conventional cars



Source: IEA, ING Research
Units: kg/vehicle

Surging battery metal prices pose challenges to the EV industry

The rapid increase in electric vehicle sales during the Covid-19 pandemic has exacerbated concerns over China's dominance in lithium battery supply chains. Meanwhile, the ongoing war in Ukraine has pushed prices of raw materials – including cobalt, lithium, and nickel – to record highs.

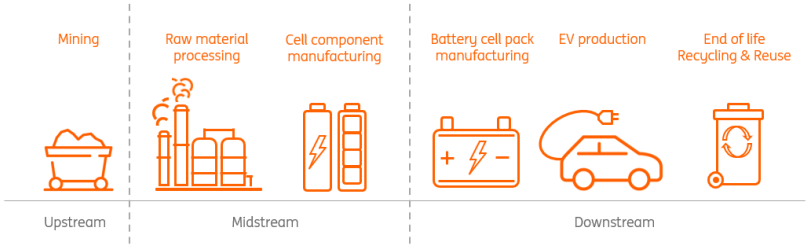
> *Rising demand for electric vehicles has pushed battery material prices to multi-year highs*

The dependence on specific suppliers is not the only concern. Batteries make up a big part of an EV's total cost and typically account for 30% to 40% of their value, but this proportion increases with larger battery sizes.

Rising demand for EVs amid tightening supply chains has also pushed prices of battery materials (including cobalt and lithium) to multi-year highs. This impacts prices, which in turn makes consumers more hesitant to make the shift to electric vehicles.

While prices for nickel and cobalt have come down in the first half of 2023, they are still higher than they have been in previous years. For example, Chinese prices of lithium carbonate (a refined form of the metal that goes into EV batteries) jumped more than 1000% from the end of 2020 to reach a high in November last year. They then lost more than two-thirds of their value through late April, according to data from Asian Metal.

What does the EV battery supply chain look like?



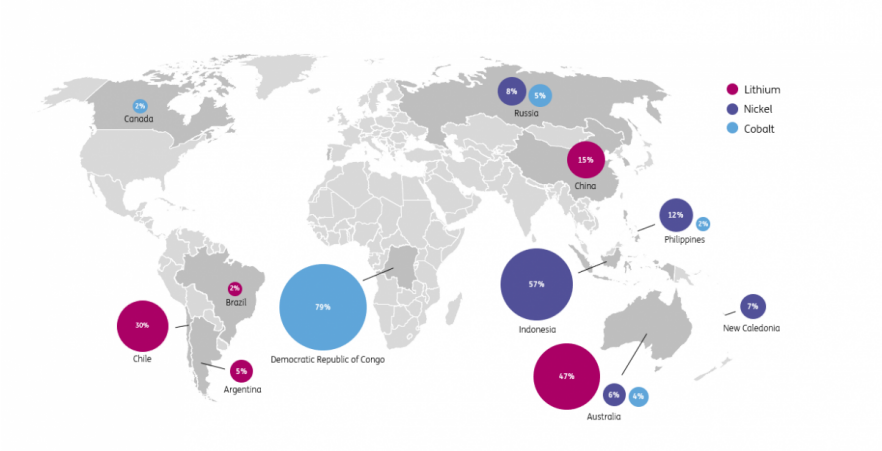
Source: IEA, ING Research

The five key materials for lithium-ion batteries (Li-ion) are lithium, cobalt, nickel, manganese, and graphite, all of which provide the battery with the power to store and release energy for boosting EVs.

Most of the key materials used in electric vehicle production are mined in resource-rich countries, including Australia, Chile and the Democratic Republic of Congo (DRC). There are likely sufficient reserves of minerals in the earth's crust to satisfy future demand for EV batteries, but scaling up mining is a long and expensive process.

For battery production alone, a conservative estimate from the International Energy Agency (IEA) suggests that by 2030, we will need 50 additional lithium mines and 60 for nickel. We will also need to add 50 new cathode and 40 new anode active material manufacturing plants to produce high-performance battery materials. Currently, it can take between two and seven years to build a new factory, depending on the technology and member state. It takes 10 years on average until a new mine comes online.

Top battery raw materials producing countries in 2022



Source: USGS, BNEF, ING Research

Lithium

Batteries are now the dominant driver of demand for lithium. For Li-ion batteries, lithium is irreplaceable. Over 70% of global lithium production comes from just two countries: Australia and Chile. Australia is the world's largest supplier and produces most of its lithium by mining hard rock spodumene, unlike Argentina, Chile and China, which produce it mostly from brine. Chile comes in second, holding more than 40% of the world's known reserves.

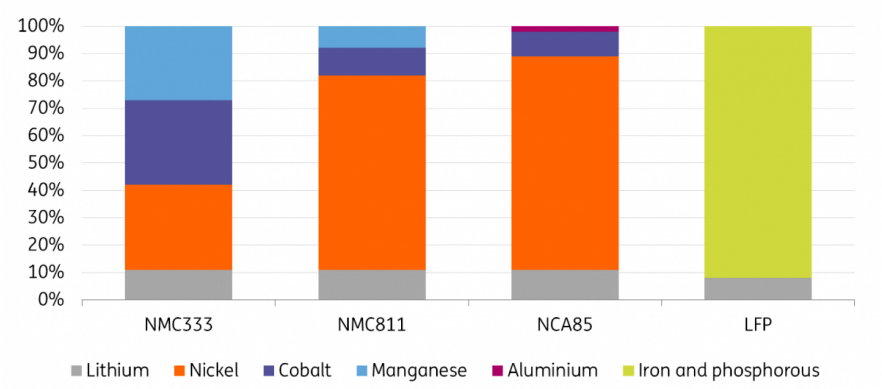
Cobalt

The intensity of cobalt in Li-on batteries has decreased significantly over recent years, with battery makers moving to higher nickel content chemistries. Cobalt is mainly mined as a by-product of copper or nickel mining, and more than 70% of it is produced in the DRC. Artisanal and small-scale mining is responsible for around 10-20% of the DRC's cobalt production. Refining is concentrated in China, accounting for around 80% of global capacity, although the country has little of the raw material.

Nickel

In Li-ion batteries, the use of nickel lends a higher energy density and more storage capacity to batteries. Class 1 nickel (>99.8% purity) is required in battery production, while class 2 nickel (<99.8% purity) cannot be used without further processing. Nickel is primarily found in two types of deposits: sulphide and laterite. Sulphide deposits are mainly located in Russia, Canada and Australia and tend to contain higher grade nickel. Russia is the world's largest supplier of Class 1 battery-grade nickel, accounting for around 20% of the global supply. Trade restrictions on Russia would therefore pile pressure on prices. Laterite, which contains lower grade nickel, is mainly found in Indonesia, the Philippines and New Caledonia. Indonesia, which holds almost a quarter of global nickel reserves, prohibited the export of nickel ore in January 2020 and is now attracting investments into higher-value processing, mostly from China.

Approximate mineral composition of different battery cathodes



Source: IEA, ING Research

Mineral content (%)

Impact of Russia's invasion of Ukraine on battery supply chains

Lithium and cobalt were relatively unaffected by the supply disruptions following Russia's invasion of Ukraine. For nickel, it's a different story. Russia is the third-largest producer, supplying around 9% and processing around 6% of global nickel in 2021 – but most importantly, it is the world's largest Class 1 nickel supplier and accounts for around 20% of global supply, most of which is

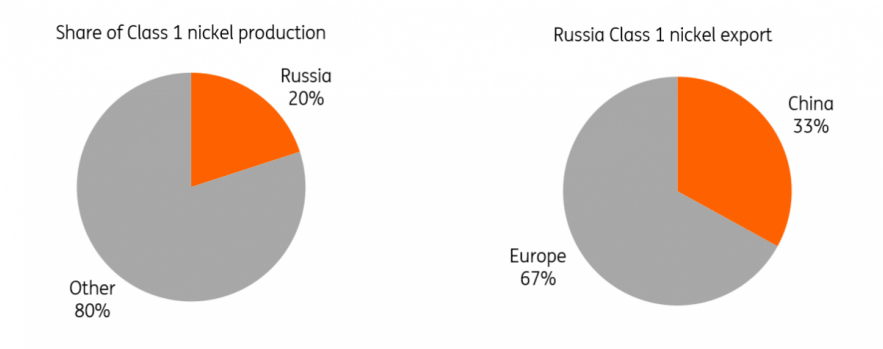
supplied by Norilsk Nickel.

Volatility in the nickel market has become increasingly common over the past year. We've seen reduced liquidity ever since the short squeeze seen back in March, when fears of sanctions on Norilsk Nickel (following Russia's invasion of Ukraine) coincided with a huge short bet by the world's largest stainless steel producer, Tsingshan. This caused prices to more than double in just a matter of days. The LME was forced to suspend trading for a week and cancel billions of dollars worth of nickel trades.

> *Volumes have stabilised, but remain at lower levels than before the nickel crisis last year*

LME volumes have declined since then, with many traders reducing activity or cutting their exposure due to a loss of confidence in the LME and its nickel contract in the aftermath of the March short squeeze. These low levels of liquidity have left nickel exposed to sharp price swings – even amid small shifts in supply and demand balances. But as the exchange introduced daily price limits and margin requirements fell, volumes started to pick up. The resumption of Asian trading hours has also encouraged more volumes and improved liquidity, which in turn has reduced volatility in the contract. While volumes have stabilised over the past few months, they remain at lower levels than before the nickel crisis last year.

Nickel production & exports (2021)



Source: IEA, ING Research

Battery chemistries are evolving amid tightening supply

Battery technology is evolving rapidly. Most electric vehicle batteries are Li-ion based and are light, small and store a lot of energy. While batteries can vary in composition, they generally rely on the same set of materials.

Li-ion batteries for EVs are either nickel-based – lithium nickel manganese cobalt oxide (NMC) and nickel cobalt aluminium oxide (NCA) or lithium iron phosphate (LFP). Nickel-based batteries have a higher energy density, which gives them more driving range, and they account for the majority of EV batteries outside of China. In general, the higher the nickel percentage in the battery, the higher the energy density that the battery can provide. Nickel-based batteries are also more expensive, mostly due to their use of cobalt and lithium.

In 2022, NMC remained the dominant battery chemistry with a market share of 60%, followed by LFP with a share of just under 30%, and NCA with a share of about 8%, according to the IEA. While nickel-based batteries remain the dominant battery chemistry, there has been a resurgence of LFP battery chemistries over the last few years, mostly driven by the increasing uptake of LFP in electric vehicles in China. Battery manufacturers have been transitioning away from nickel and cobalt because of their high costs, scarcity, and mining ethics. Nickel batteries require an environmentally damaging mining process, while cobalt artisanal mining lacks regulations.

Until now, production has been mostly limited to China but is set to increase on a global scale

LFP batteries differ from other chemistries in their use of iron (which is abundant and cheap) and phosphorus, rather than the nickel, manganese and cobalt found in NCA and NMC batteries. They have a lower energy density, but they are also cheaper to manufacture as they don't contain nickel, cobalt and magnesium. They do, however, remain exposed to expensive lithium prices. LFP batteries rely on lithium carbonate instead of hydroxide used for nickel-rich chemistries.

Until now, production has been mostly limited to China but is set to increase on a global scale. Chinese manufacturers, including BYD Co. and Contemporary Amperex Technology Co., accounted for as much as 99% of global production of LFP cathodes in 2022, according to Benchmark Mineral Intelligence. Tesla, Volkswagen and other major automakers are now already switching to LFP batteries in some of their EV models.

In recent years, alternatives to Li-ion batteries have also been emerging, notably sodium-ion (Na-ion). Na-ion relies on lower-cost materials than Li-ion, resulting in cheaper batteries. Na-ion batteries also completely avoid the need for critical minerals. Sodium is one of the most abundant and geographically spread resources on Earth, and the Na-ion battery developed by China's CATL is estimated to cost 30% less than an LFP battery. It's important to note, however, that these batteries do not have the same energy density as their Li-ion counterparts (75 to 160 Wh/kg compared to 120 to 260 Wh/kg).

With the dramatic rise in lithium and other battery materials prices over the last two years accelerating interest, several other cell manufacturers have now joined CATL in establishing a Na-ion supply chain. There are nearly 30 Na-ion battery manufacturing plants currently operating, planned or under construction for a combined capacity of over 100 GWh, and almost all of them are in China. For comparison, the current manufacturing capacity of Li-ion batteries is around 1,500 GWh, according to the IEA.

Na-ion cells are likely to be less sensitive to rising lithium, cobalt and nickel costs, with the lower pack cost providing a key reason to substitute Na-ion batteries for Li-ion applications. While lithium-ion continues to improve, BNEF expects that sodium-ion's energy density in 2025 will be comparable to that of LFP in the early 2020s when it took a significant share of global battery demand. BNEF anticipates sodium-ion deployment in cars will begin to take off in 2025, with over 15GWh set to be deployed that year.

Chemistry choice and the impact of material pricing

Battery materials play a key part not only in the performance of batteries but also in costs. In LFP cells, for example, materials account for 30% of battery pack prices. The price of lithium plays a relatively large role in determining the final cost of battery chemistries. In 2022, the most drastic increase seen in battery material prices was for LFP batteries at over 25%, while NMC batteries saw an increase of less than 15% according to IEA data. This can be explained by the price of lithium rising at a higher rate than that of nickel and cobalt. Even so, LFP batteries remain less expensive than NCA and NMC per unit of energy capacity.

The price of batteries also varies across different regions. China has the lowest prices on average and manufactures around 65% of battery cells and almost 80% of cathodes, according to the IEA.

Battery swapping can further shake up the EV supply chain

An alternative way of EV charging is emerging in the form of battery swaps, where a depleted battery is replaced by a fully charged one at a dedicated location. Battery swapping could be particularly attractive for trucks, as it can greatly reduce the time needed to charge a heavy-duty vehicle; it could also be useful for light-duty vehicles such as taxi fleets and personal cars because of the flexibility and, in some cases, the lower total cost of ownership (e.g., for two and three-wheelers).

Battery swapping could revolutionise the electric vehicle charging scene

China is leading in battery swapping for both trucks and passenger cars, with the number of swapping stations in China growing by 50% year-on-year to almost 2,000 at the end of 2022. EV manufacturer NIO covers two-thirds of that market, with its battery swapping-ready models and dedicated swapping stations. In the US, startup company Ample now operates 12 battery swapping stations in San Francisco, mainly serving Uber rideshare vehicles.

If it becomes mainstream, battery swapping could revolutionise the electric vehicle charging scene. At least one battery will be needed per vehicle, so the scale-up of such a business model could add even more pressure to the already tightening global EV metal supply chain. Companies providing such services would need more partnerships to secure an increased level of supply, or they will need to decrease each swappable battery's capacity as a compromise.

Smaller cars will reduce battery metals demand per unit

So far, the electric vehicle market has leaned on upper-middle-class models, such as Tesla's Model 3, as well as SUVs like the KIA EV6, Volvo C40 Recharge and BMW IX.

A regulatory incentive for smaller models could lower demand for battery metals significantly,

according to research from Transport and Environment for Europe. Analysis from the KiM Netherlands Institute for Transport Policy also indicates that a larger influx of smaller and more affordable middle-class electric vehicles – like the Volkswagen ID2 or the BYD Dolphin and Seagull models – is a requirement for a real breakthrough in the mass market. Ranges will also continue to develop, but given the extra weight, it's doubtful that efficiency will reach far beyond 500km.

Based on this, we believe that battery demand per unit is set to be lower than the current average as we head towards 2030.

Author

Coco Zhang
ESG Research
coco.zhang@ing.com

Ewa Manthey
Commodities Strategist
ewa.manthey@ing.com

Rico Luman
Senior Sector Economist, Transport and Logistics
Rico.Luman@ing.com

Geopolitics, policy and sustainability to forge new electric vehicle partnerships

Countries and companies are increasingly wary of possible shortages of raw materials going forward and seek to secure supply. Battery metal demand is also evolving as demand shifts between chemistries. Current interdependence is significant and actors seek to reduce supply risk in light of the energy transition

Source: Shutterstock

China dominates downstream EV battery supply chains

China has massively pushed electric vehicle (EV) sales in recent years which has helped to further develop the battery supply chain. China's dominant role in battery metals supply chains, as well as export restrictions in other countries, risk slowing down the pace of EV adoption.

EV supply chains are expanding, but for manufacturing, China remains the key player in the battery and EV component trade. In 2022, 35% of exported electric cars came from China, compared with 25% in 2021, according to the International Energy Agency (IEA).

The rapid increase in EV sales during the Covid-19 pandemic and increased geopolitical tensions have exacerbated concerns about China's dominance of lithium battery supply chains. The risks associated with the concentration of production are in many cases heightened by low substitution

and low recycling rates. For example, in EV batteries, there is no substitute for lithium.

More than 80% of the world's lithium is mined in Australia, Chile and China, the latter of which also controls more than half of the world's processing and refining.

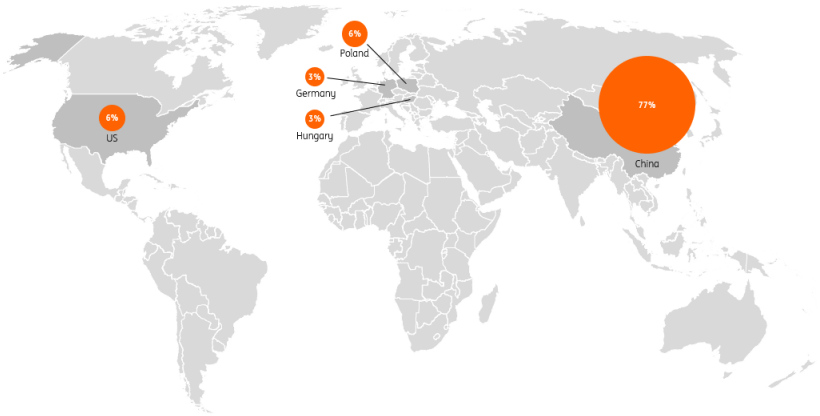
Chinese companies (including BYD and CATL) have also made significant investments in projects overseas; in Australia, Chile, the Democratic Republic of the Congo (DRC) and Indonesia. In Chile, the second-biggest lithium producer after Australia, only two companies produce lithium – US-based Albermarle Corp. and local firm SQM, in which China's Tianqi Lithium Corp. has more than 20% stake. They mainly make lithium carbonate – 90% of which goes to Asia.

China dominates many elements of the downstream EV battery supply chain, from material processing to the construction of cell and battery components. China only accounted for about 15% of global lithium raw material in 2022 but around 60% of the battery metal is refined there into specialist battery chemicals. China also produces three-quarters of all lithium-ion batteries. This is a result of Beijing's early push towards electrification, particularly through subsidising EVs.

Meanwhile, Europe is responsible for more than one-quarter of global EV assembly, but it is home to very little of the supply chain apart from cobalt processing at 20%. Like the US, Europe is currently pushing hard to develop its battery supply chain, but this takes time and sourcing dependencies remain.

China is the least expensive place to process lithium because of lower construction costs and an already large, processed chemistry engineering base. In 2022, 35% of exported EVs came from China, compared with 25% in 2021, according to the IEA.

Battery cell manufacturing is concentrated in China (2022)



Source: BNEF, ING Research

Rising trend of vertical integration of EV and battery production

With uncertainties from metal supply chains, some automakers – which have set EV sales targets – have been looking into expanding their businesses into mining in the hope of securing a long-term supply of raw materials. In January, General Motors (GM) announced that it had formed a joint venture with mining company Lithium Americas, which would give GM exclusive access to lithium from a mining site in Nevada, US.

Ford, through its joint venture with battery company SK Innovations, will receive a $9.2bn loan from the US Department of Energy (DoE), the largest single loan in the DoE Loan Programs Office history, to develop battery plants in Tennessee and Kentucky. Stellantis has entered separate joint ventures with Samsung SDI and LG Energy Solution to build battery plants in the US and Canada, respectively. Other firms such as Tesla, BMW, VW, Hyundai, and Honda are similarly investing in building battery manufacturing capacity.

In the coming few years, we are going to see more partnerships – not just trade partnerships, but strategic partnerships – made along the EV battery supply chain. The future of the EV industry is vertical, 'mine-to-wheel' collaboration. This means that early efforts of long-term planning and relationship building will become increasingly important.

Energy transition at risk as resource nationalism gains momentum

The energy transition has become a pillar of policy for many governments while global trade and political tensions have prompted a reconsideration of global supply lines.

The global incidence of export restrictions on critical raw materials has increased more than five-fold in the last decade. In recent years, about 10% of the global value of exports of critical raw materials faced at least one export restriction measure, according to a report by the Organisation for Economic Cooperation and Development (OECD).

The rise in resource nationalism could slow down the pace and increase the cost of the energy transition, impacting the scale of investments, supply and prices.

Export restrictions on ores and minerals, the raw materials located upstream in critical raw material supply chains, have grown faster than restrictions in the other segments of the critical raw materials supply chain, correlating with the increasing levels of production, import and export, as well as the concentration in a small number of countries, the OECD report found.

Chile's lithium move is the latest in the global resource nationalism trend

Earlier this year, Chile announced that it would nationalise its lithium industry to boost its economy and protect its environment. The move would in time transfer control of Chile's lithium operations from Albemarle and SQM, the world's number one and number two lithium producers, respectively, to a separate state-owned company, posing fresh challenges to EV manufacturers scrambling to secure supplies, with more countries seeking to protect their natural resources. Albemarle and SQM supply Tesla and LG Energy Solution, among other EV and battery manufacturers.

Chile is just part of the global trend with several other countries having taken greater control of their resources. Mexico nationalised its lithium deposits last year, while Indonesia banned exports of nickel ore in 2020.

Current efforts to strengthen EV battery supply chains

EU – The Critical Raw Materials Act (CRMA)

The EU's Critical Raw Materials Act is one of the cornerstones of the EU's Green Deal Industrial Plan,

together with the Net-Zero Industry Act, which sets a target for the EU to produce 40% of its own clean tech by 2030, such as solar power or fuel cells, partly by streamlining the granting of permits for green projects. The bloc also announced a goal for carbon capture of 50 million tonnes by 2030.

Europe is responsible for more than one-quarter of global EV assembly, but it is home to very little of the supply chain apart from cobalt processing at 20%, according to the IEA.

Global investment in the green energy transition is set to triple by 2030 from $1 trillion last year, the EU said. The bloc will need €400bn of investment a year to decarbonise and meet its target of net-zero emissions by 2050, it estimated.

As part of the Critical Raw Materials Act, the EU has set targets for the region to mine 10% of the critical raw materials it consumes, like lithium, cobalt, and rare earths, with recycling adding a further 15%, and increased processing to 40% of its needs by 2030. The EU also said that no more than 65% of any key raw material should come from a single third country. The EU is almost entirely dependent on imports of these raw materials, particularly from China, with 100% of the rare earths used for permanent magnets globally refined in China and 97% of the EU's magnesium supply sourced from China.

US – The Inflation Reduction Act (IRA)

The US IRA has established policies that aim to strengthen the entire domestic EV value chain. Under the IRA, battery cells can receive a tax credit of up to $35 per kWh of energy produced by a battery cell, while battery modules can get up to $10/kWh. In the case where battery modules don't use cells, a maximum of $45/kWh is provided. Moreover, the tax credits for EVs, with the highest level at $7,500, have important qualifying requirements that are tied to battery components and origins. This means that EV manufacturers looking to qualify for the tax credits will need to reroute supply chains and form new business partnerships with new suppliers.

The IRA can also encourage more battery recycling in the US because established battery recycling capacities can help EV manufacturers bypass any sourcing origin requirements for critical minerals. The government is also setting money aside to encourage the research and development of batteries and battery recycling.

It will be time and money-consuming, but the IRA's policies would in the long-run lead to a more resilient EV supply chain in the US. The IRA has spurred $45bn of announced private-sector investment in the entire value chain as of late March, with more to be expected in the future.

EV criteria: price, income, assembly and sourcing

- The retail price cannot exceed $80,000 for an electric van, SUV, or pickup truck, and $55,000 for any other type of EV.
- EV buyers' gross annual income cannot exceed $150,000 for a single taxpayer, $225,000 for a head of household, and $300,000 for a married couple filing jointly.
- Qualifying EVs' final assembly must be in North America.
- 50% of the value of the battery components must be manufactured or assembled in North America.
- 40% of the value of the critical minerals needs to be extracted or processed in the US or a country with which it has a free trade agreement (FTA), or be recycled in North America.

Source: US Treasury

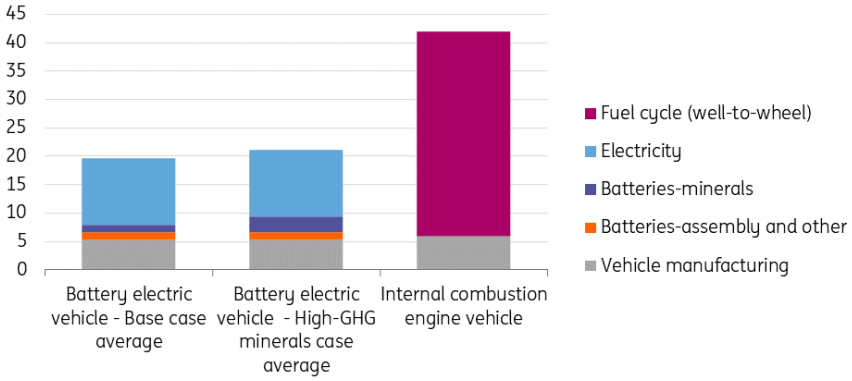
Investments key to combating China's dominance in EV supply chains

Investment is key to combatting China's crucial role in the EV supply chain. But even as the US and Europe continue to ramp up investment, China's dominance in processing and production is set to continue to grow. Bloomberg New Energy Finance (BNEF) is expecting China's dominance to continue, with the country accounting for 69% of the world's battery manufacturing capacity in 2027. Combating China's dominance in the EV supply chains will be an expensive process. According to BNEF, the US and Europe will have to invest $87bn and $102bn, respectively, to meet domestic battery demand with fully local supply chains by 2030.

More attention needed on battery recycling and emissions reduction

Recycling and emissions reduction along the EV battery supply chain is an area that has not yet received sufficient attention but will become increasingly important for companies to manage. Battery electric vehicles (BEVs) on average show significant environmental advantages compared to internal combustion engine (ICE) vehicles when life-cycle emissions are calculated. The portion of BEV life-cycle emissions coming from battery mining and processing is relatively low, but the pressure to decarbonise battery mining and production will only grow as the demand for EVs increases.

Comparative life-cycle GHG emissions of a mid-size BEV and ICE vehicle



Source: IEA, ING Research

There are several common practices to reduce emissions in EV battery mining and processing. First, companies are trying to use clean electricity to power their operations. This primarily includes buying Power Purchase Agreements (PPAs) from renewable developers. Second, mining companies are also taking initiatives to switch to low-carbon fuels – such as biodiesel – for their truck fleet.

Third, both mining and battery production companies have been engaged in boosting circularity for their product value chains. Today, the global capacity for battery recycling remains limited. In general, lithium-ion batteries' lifespan can last between 100,000 and 200,000 miles, or about 15 to 20 years of driving, after which it needs to be recycled in some way.

In the US, lower than 5% of lithium-ion batteries were recycled in 2019. For instance, US start-up Redwood Materials has been partnering with automakers Ford and Toyota, as well as battery producer Panasonic Holdings, to establish a closed-loop battery ecosystem. Redwood Materials recently obtained a $2bn loan commitment from the US Department of Energy to build and expand its pilot battery recycling facility. In Europe, Renault is collaborating with optimised resource management company Veolia and science-based company Solvay to advance EV battery metal closed-loop recycling.

Recycling EV batteries and decarbonising battery production will help companies boost company environmental, social, and governance (ESG) credentials. Recycling, specifically, can also help enhance supply chain security. Over the next few decades, we will see recycling become more mainstream among battery and EV manufacturers. McKinsey forecasts that EV battery recycling capacity will grow at 25% per year until 2040. Recycling lithium-ion batteries is increasingly becoming a priority for many countries and EV companies in order to reduce their dependencies on the mining of raw materials.

Policy and politics will continue to play a role in EV supply chains

Policy and politics will play an increasingly large role in the future of EV supply chains. To secure battery metal supply, we expect to see countries and regions such as the US and EU forge new trade partnerships. We expect governments' EV policies to focus more on batteries and metals, and we also expect EV companies to further partner up with battery manufacturers and mining companies. The sustainability of mining and battery manufacturing will affect company decisions in the long term, but its impact will be limited until there has been a huge uptake in EV adoption.

Author

Coco Zhang
ESG Research
coco.zhang@ing.com

Ewa Manthey
Commodities Strategist
ewa.manthey@ing.com

Rico Luman
Senior Sector Economist, Transport and Logistics
Rico.Luman@ing.com

Disclaimer

This publication has been prepared by the Economic and Financial Analysis Division of ING Bank N.V. ("**ING**") solely for information purposes without regard to any particular user's investment objectives, financial situation, or means. *ING forms part of ING Group (being for this purpose ING Group N.V. and its subsidiary and affiliated companies).* The information in the publication is not an investment recommendation and it is not investment, legal or tax advice or an offer or solicitation to purchase or sell any financial instrument. Reasonable care has been taken to ensure that this publication is not untrue or misleading when published, but ING does not represent that it is accurate or complete. ING does not accept any liability for any direct, indirect or consequential loss arising from any use of this publication. Unless otherwise stated, any views, forecasts, or estimates are solely those of the author(s), as of the date of the publication and are subject to change without notice.

The distribution of this publication may be restricted by law or regulation in different jurisdictions and persons into whose possession this publication comes should inform themselves about, and observe, such restrictions.

 ING Bank N.V. is authorised by the Dutch Central Bank and supervised by the European Central Bank (ECB), the Dutch Central Bank (DNB) and the Dutch Authority for the Financial Markets (AFM). ING Bank N.V. is incorporated in the Netherlands (Trade Register no. 33031431 Amsterdam). In the United Kingdom this information is approved and/or communicated by ING Bank N.V., London Branch. ING Bank N.V., London Branch is authorised by the Prudential Regulation Authority and is subject to regulation by the Financial Conduct Authority and limited regulation by the Prudential Regulation Authority. ING Bank N.V., London branch is registered in England (Registration number BR000341) at 8-10 Moorgate, London EC2 6DA. For US Investors: Any person wishing to discuss this report or effect transactions in any security discussed herein should contact ING Financial Markets LLC, which is a member of the NYSE, FINRA and SIPC and part of ING, and which has accepted responsibility for the distribution of this report in the United States under applicable requirements.

Additional information is available on request. For more information about ING Group, please visit www.ing.com.