LONDON POLITICA

Powering the future: Lithium in the EV battery value chain

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Overview

By Sharif Fatourehchi

Lithium, known as “white gold”, is a metal identified as an essential material to the green energy transition. The metal is a fundamental component of lithium-ion batteries employed as the primary energy storage system in electric vehicles (EVs).

Technical characteristics

EV batteries have a superior energy per unit mass storage capacity, energy efficiency, high-temperature performance, power-to-weight ratio, and low self-discharge relative to other methods of storing electrical energy (lead-acid or nickel-cadmium). Lithium-ion batteries have been used in portable consumer devices for many years now, however, those in EVs are slightly different. Instead of the singular battery, they form a pack that compounds the power of thousands of lithium-ion cells.

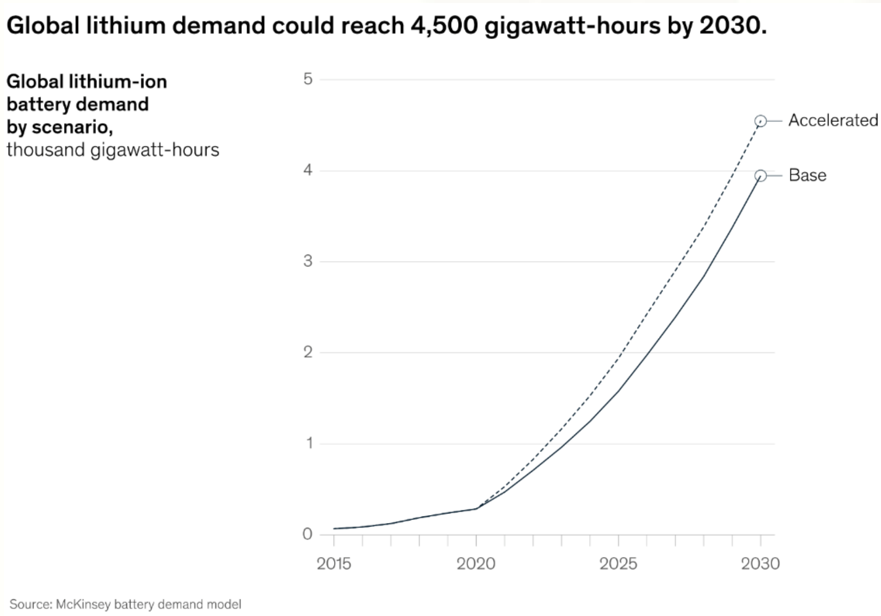
Lithium provides a great benefit to car manufacturers as it is the lightest metal and its chemical and physical characteristics, in its ionised form, make it safer than the available alternatives. EV manufacturers also have faith in the longevity of lithium-ion batteries, for example, Elon Musk claims that the batteries manufactured for use in Tesla’s vehicles will last 1500 battery cycles (22-37 years of use for the average individual). One of the key focuses of research on these batteries is the method of recycling. Seeing that they are presented as the key to a green future, scientists see it necessary to develop efficient methods of recycling to reduce the quantity of metals used – tens of kilograms of valuable metals including 8 kg of lithium in a single car. The World Economic Forum forecasts that 54% of batteries would be recycled in 2030. However, that is if technological development makes it cost-effective to recycle in lieu of mining a greater quantity. A tangible example of the developments is Volkswagen’s announcement of a new pilot plant in Salzgitter for battery recycling.

Projected demand

1. *Medium-term demand*

Lithium-ion battery demand has been rising and is destined to dramatically increase in the medium term. The uptake in demand seen in recent times is predominantly a function of the replacement of petrol and diesel fuelled cars with plug-in EVs with forecasts estimating over 50% of new vehicles produced globally by 2035 to be EVs (without further policy changes). This trend will lead to global lithium-ion battery demand reaching 4500 gigawatts by 2030, thus presenting a large gap to be filled by increases in supplies and improvements in the efficiency of the entire supply chain. By the year 2030, it is projected that 95% of all global lithium demand will be for battery production, presenting a 70% increase from 2015. According to IEA projections, the concentration of demand will be in the United States (US), the European Union (EU) and China. The production of these batteries, and consequently the drivers of lithium demand, will be the operators of gigafactories. Tesla Inc. already has 5 operative gigafactories, however, other car manufacturers are also launching new projects in that regard, such as Honda Motor Co. and LG Energy Solution's joint venture announced in 2022.

Figure 1: Global lithium demand projections (2015-2030)



Source: Marcelo Azevedo, Magdalena Baczyńska, Ken Hoffman and Aleksandra Krauze, "Lithium mining: How new production technologies could fuel the global EV revolution," *McKinsey*, 12 April 2022.

2. *Long-term demand*

Long-term demand for lithium is set to continue to be maintained at high levels for the coming years. The price of lithium has dropped to such low levels that the use of any other material will likely not be cost-effective. Currently, it is 30% cheaper than when it initially entered the market in the 1990s whilst performance and scale have improved. Therefore, whilst supply-side lags are being tackled and alternatives are unlikely to be discovered, the demand for lithium will be maintained at the least in the long term with aid for developments in the recycling sphere and the plan to construct 30 new gigafactories in Europe.

Lithium in the EV battery value chain

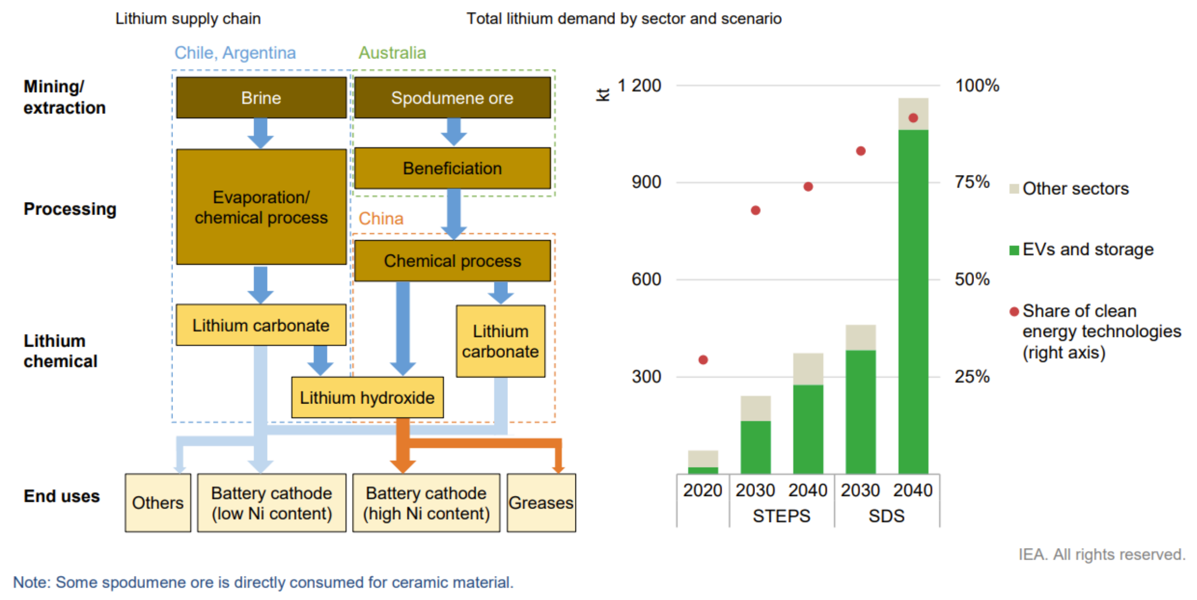
By Nathan Alan-Lee

With production of EV batteries rapidly increasing, lithium has been identified as a potential bottleneck resource. Shortages of lithium are estimated to impact the EV supply chain as early as 2025, with the rate of supply increase being outstripped by demand. Understanding the opportunities and risks of the lithium supply chain has become strategically vital, beginning with raw ore extraction, refining and final battery manufacturing.

1. Extraction

Lithium is commercially mined or extracted through two different processes. The first option uses lithium brine, which is saline ground water with high concentrations of lithium which can be extracted. This method of extraction is typical of South American deposits in the "Lithium Triangle" of Chile, Argentina and Bolivia but also in western China. The second option is lithium hard rock or spodumene (found in pegmatite) mining, this option is generally considered more efficient and likely to be the primary method moving forward. This process is currently employed in Australian lithium production, with potential application in areas such as sub-Saharan Africa.

Figure 2: Lithium from resource to consumer



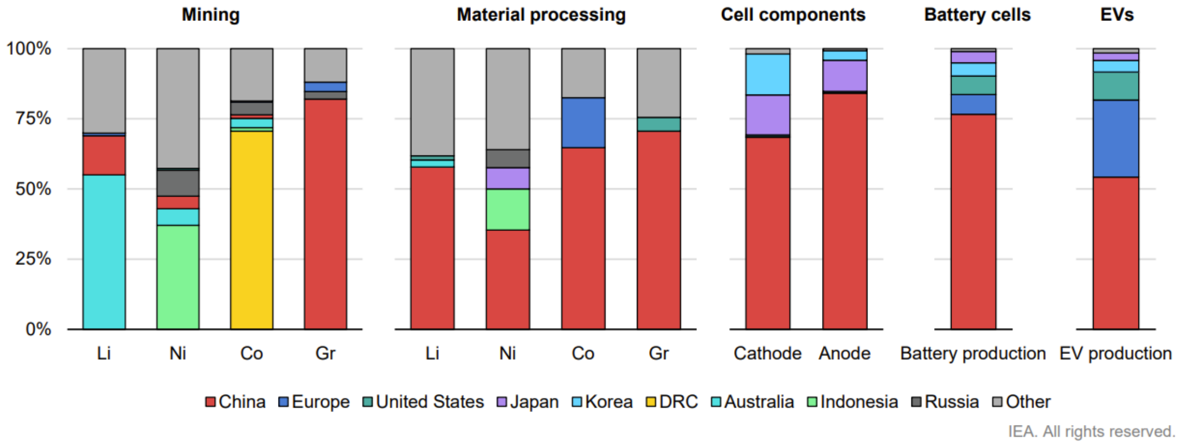
Source: International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, 138 (Paris: IEA Publications, 2022).

Currently, lithium production is dominated by a few key countries: as of 2021 Australia produced 55,000 tons, Chile, 26,000 tons and China 14,000 tons, followed by Argentina and Brazil. The current production does not however, reflect the potential of current estimated lithium reserves. According to the United States (US) geological survey, estimated reserves have been rapidly expanding as lithium exploration takes global priority, in 2022 they increased from roughly 22 million to 89 million tons. As this trend continues, lithium mining looks to diversify into North America (US and Canada), sub-Saharan Africa (Congo, Mali, Namibia, and Zimbabwe) and even Europe (Germany, Czechia, Serbia, Austria). One of the largest known reserves has been found in Bolivia, reaching at least 21 million tons. However, as with many of these newer discoveries, effective extraction will require significant investment and infrastructural development.

2. Refining

The second stage, after extraction and ore processing, is refining the lithium bearing ores into two key lithium chemicals: lithium carbonate and lithium hydroxide. This stage has also become one of the key bottlenecks in the lithium supply chain. With lithium hydroxide, as of 2021, only 5 companies controlled three quarters of global production capacity, 80% of which was produced in China. Overall, China has been responsible for supplying some 60% of these two lithium based chemicals. This degree of market control represents a key risk to industry and to the global push for a green transition.

Figure 3: Geographical distribution of the EV battery supply chain



Source: International Energy Agency, *Global Supply Chains of EV Batteries*, 5 (Paris: IEA Publications, 2022).

There are several Chinese companies which standout in the lithium mining and refining process: Ganfeng Lithium Group Co Ltd, Chengxin Lithium Group, Zhejiang Huayou Cobalt and Tianqi Lithium. The largest producer of refined lithium salts, Ganfeng Lithium, currently has a market capitalisation around $22 billion, and has been looking to expand across the production chain, most recently looking to acquire lithium deposits in Argentina. Chengxin Lithium Group, with a market capitalization of roughly $5.6 billion, also focuses on refining lithium salts and rare earth metals. In November 2021, Chengxin Lithium Group, also expanded its stake into primary extraction by acquiring the majority share in a Zimbabwean mining operation. The third Chinese lithium giant, with a market capitalisation of roughly $15.5 billion, is Zhejiang Huayou Cobalt, which, as the name suggests, began in the production of cobalt, another key resource in the EV battery manufacturing. Zhejiang Huayou Cobalt also made headlines in late 2022 as it announced its acquisition of a new mine “Arcadia” in Zimbabwe, a deal worth $422 million on its own but also requiring the construction of local refining capacity. Tianqi is the largest company in terms of market capitalization, around $25 billion, but has been more focused on primary extraction of “hard rock” lithium in Australia, rather than refining of lithium salts. In a recent expansion (2022), Tianqi Lithium began producing refined lithium hydroxide in a new plant in Australia, indicating their potential to become a major lithium refiner.

There are also a number of key non-Chinese companies in the lithium salts production chain, noteworthy examples are the US based Albemarle Corporation, and the Chilean Sociedad

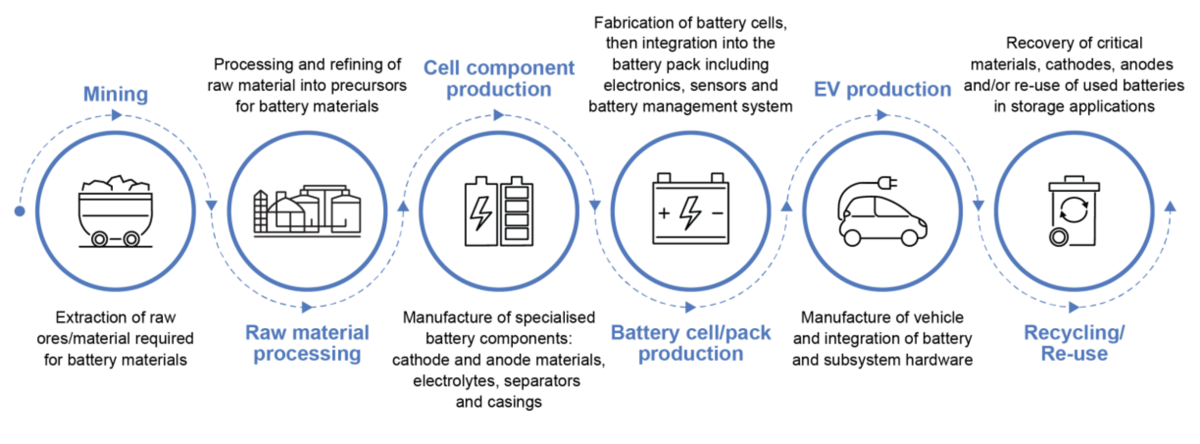
Química y Minera (SQM). Albemarle operates a number of refineries in Chile, near Antofagasta, and is currently developing refining capacity in Australia. In addition, there are several smaller companies which may become larger players as the lithium industry grows, these include: Australia based Allkem and Pilbara Minerals as well as US based Livent.

Albemarle as a company is the largest player in terms of overall value, with a market capitalisation of around $32 billion, but does not rely solely on lithium products. That being said, Albemarle holds stake in several key lithium extraction and refining operations, in the US Australia, Chile, Germany and China. Similarly, SQM is the second largest lithium producer by value with a $25 billion market capitalisation, but also produces other chemical products. SQM's lithium products are largely produced domestically in Chile. The remaining, smaller companies, all with market capitalisations below $10 billion, look to expand as diversifying the lithium supply chain becomes an increasingly prescient concern for the industry, and even a question of energy security.

3. *EV battery manufacturing*

After lithium has been refined to a "battery grade," it can be used in the construction of battery cell components most importantly the cathode and anode. While lithium is required for both of these components, the cathode is the most complicated and expensive component in EV batteries. There are several dominant cathode types including lithium cobalt oxide, lithium nickel manganese cobalt oxide (NMC), lithium nickel cobalt aluminium oxide (NCA) and lithium iron phosphate (LFP), while each type requires lithium in its construction the quantity is variable.

Figure 4: EV battery life cycle



Source: International Energy Agency, *Global Supply Chains of EV Batteries*, 19 (Paris: IEA Publications, 2022).

Much like other stages of lithium in the EV value chain, battery cell manufacturing is highly concentrated to specific companies and countries. China is again a key player producing well over 50% of EV battery cathodes and roughly 95% of LFP cathodes. Some of the key companies are Tianjin B&M Science and Technology, Shenzhen Dynanonic and Ningbo

Shanshan. Outside of China, the Japanese company Sumitomo is a key producer as well as the South Korean company EcoPro BM.

The final stage of the process is the actual assembly of components into EV batteries. While this stage is less concentrated in a single country, roughly 65% of EV battery manufacturing is done by three companies: CATL (China), LG Energy Solution (Korea), and Panasonic (Japan). Other key companies in this area are BYD (China), SK Innovations (South Korea) and Samsung SDI (South Korea). While other countries look to break into this stage of the market it may be years before competitors emerge.

Projected risks and trends

By Ojus Sharma

Medium-term risks

The lithium industry has experienced rapid growth in recent years, yet the medium-term outlook for the industry is highly uncertain, with various risks that could impact the demand for lithium and its price. This section aims to assess the medium term (5-10 year period) risks in the lithium industry, covering the supply chain, demand, and market dynamics.

1. *Supply-side risks*

Exploration risks: The lithium industry relies on the exploration and development of new lithium deposits to meet the growing demand for the metal. Exploration and development activities are highly risky and capital-intensive, and there is a risk that some lithium projects may not be economically viable. Additionally, exploration risk in lithium mining is heightened by the uncertainty surrounding the size and grade of lithium deposits. Lithium exploration projects involve drilling and sampling to determine the quantity and quality of lithium resources, and there is a risk that the results may not meet expectations. For example, a company may invest significant resources in exploring a lithium deposit, only to find that the deposit is smaller or lower in grade than expected. This could result in a reduction in the potential profitability of the project and impact the company's ability to secure financing for development. In addition, exploration projects also face the risk of regulatory delays and social opposition, which could impact the development timeline and costs.

Processing risks: Lithium production involves complex and capital-intensive processing operations, and there is a risk of technical and operational difficulties that could impact production volumes and costs. Lithium production involves various stages of processing, as covered previously. Technical difficulties in any of these stages could impact production volumes and costs. For instance, if a production facility experiences a breakdown in its processing equipment, this could result in a temporary halt in production, causing significant financial losses. In addition, the production process also requires significant amounts of water and energy, and there is a risk of water scarcity and rising energy costs, which could impact production volumes and costs. This could be a deal-breaker in China for instance, where a looming water crisis could make extraction processes difficult, and lead to social upheaval, causing challenges at the policy making level as well. The environmental damage related to lithium processing is another potential risk source. In 2022, the activities of lithium producer Livent Corp. were found negatively impacting mines in Argentina, in the salt lake at the Salar del Hombre Muerto. The company had invested significant resources in exploring a lithium deposit in the Salar de Atacama region, but regulatory delays and social costs and opposition seemed to force the company to abandon mining plans there. This case highlights the risk of regulatory challenges in lithium exploration projects and the impact on the development of lithium resources.

Transportation risks: Transportation risks refer to the potential disruptions to the supply chain that could impact the delivery of lithium from producers to consumers. The lithium industry is dependent on the transportation of lithium over long distances, from the production site to key markets, and there is a risk of disruptions along the way. Some examples of transportation risks include:

Logistical issues: The transportation of lithium requires careful management and coordination, and there is a risk of logistics issues, such as lost or damaged shipments, that could impact the delivery of lithium.

a. **Geopolitical tensions:** Lithium is transported to key markets across the world, and there is a risk of geopolitical tensions and trade disputes that could impact the ability to transport lithium. For instance, a trade dispute between two countries could result in restrictions on the import or export of lithium, disrupting the supply chain. These will be further covered in the following section.

b. **Port congestion:** Lithium is transported through major ports, and there is a risk of congestion at these ports, causing delays and impacting the delivery of lithium. This is particularly important at a time when lithium supply is stalling due to inflation and pandemic driven supply chain vows, straining trade infrastructure.

These transportation risks could impact the cost and availability of lithium, which could impact the growth of the lithium industry in the medium term. Companies in the lithium industry will need to manage these risks effectively to ensure the reliable delivery of lithium to key markets. Methods such as diversification of supply chains, via several reliable and resilient channels, could be adopted to potentially mitigate risks.

2. *Demand-side risks*

Electric vehicle adoption risks: The lithium industry is dependent on the growth of the electric vehicle market, and there is a risk that the adoption of EVs may not meet current expectations. Factors that could impact the growth of the EV market include the availability of charging infrastructure, the cost and range of EVs, and consumer preferences.

Price volatility risks: The lithium market is highly volatile, and there is a risk that fluctuations in demand and supply could impact the price of lithium. Price volatility could impact the profitability of lithium producers and the viability of lithium projects. In 2018 for instance, the lithium market experienced overcapacity due to a surge in new lithium production from Australia and South America. This resulted in a decline in lithium prices and impacted the financial performance of lithium producers. This case highlights the risk of overcapacity in the lithium market and the impact on lithium prices and the financial performance of producers. Despite a risk of supply-side economics taking over, today we see a deficit of lithium supply in terms of demand. This can certainly be subject to change if investors flock and inflate the market too much, creating a bubble.

3. *Geographies associated with greater risk*

South America: South America is a major producer of lithium, with significant production in countries such as Argentina, Chile, and Bolivia. However, there are also challenges in the region, such as regulatory delays, social opposition, and infrastructure constraints, which could hamper the development and production of lithium resources.

China: China is a major producer and consumer of lithium, but there are also risks associated with the country, such as trade tensions and environmental regulations. For example, in 2019, China imposed stricter environmental regulations on lithium production, which impacted the production of lithium and resulted in a decline in lithium prices.

Africa: Africa has potential lithium resources, but there are also risks associated with the development of these resources, such as political instability, regulatory challenges, and infrastructure constraints. For instance, in 2020, lithium production in Zimbabwe was impacted by regulatory changes in the country, which resulted in a ban on raw lithium exports in an attempt to limit illegal artisanal mining and relocate refining capabilities.

Australia: Australia is a major producer of lithium, but there are also risks associated with the country, such as competition from other mineral producers, regulatory challenges, and infrastructure constraints. Lithium production in Western Australia was impacted by competition from iron ore producers for rail transport, which resulted in higher transportation costs for lithium producers. Going forward, more erratic climate effects can downgrade the lucrative incentives for supplies to choose it.

These regions are associated with greater risks in the lithium industry due to a combination of factors, such as political and economic instability, regulatory challenges, infrastructure constraints, and competition from other mineral producers. Companies in the lithium industry will need to carefully consider these risks when exploring and developing lithium resources in these regions.

Long-term risks

By Suraj Rajesh

This section aims to assess the long term (10+ year period) risks in the lithium industry, spanning geopolitics, technology and dependencies with other areas of the EV battery value chain.

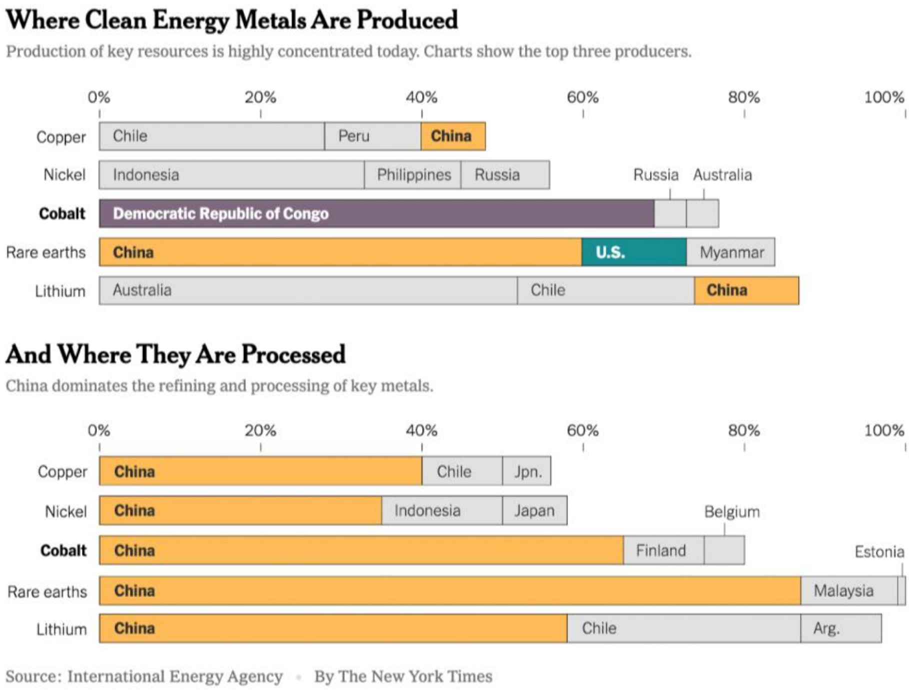
1. *Geopolitical risks*

The demand for lithium is set to hit 1.5 million tonnes by 2025 and 3-4 million tonnes by 2030. However, supply is unlikely to reach such levels; in 2021, lithium production only stood at 106k tonnes, and demand will likely outpace supply by 2025. The biggest geopolitical risks come from its strategic rival and a close ally.

China : Currently, the manufacturing of lithium is concentrated in Australia (52%), Chile (25%), China (13%), and Argentina (6%). Europe and the US produced around 2% of the world's lithium combined. China also refines and processes more than 50% of lithium and other key resources used in EV batteries. China is also moving faster; for one gigafactory equivalent built in the US in 4 months, China builds in a week. Even if investment is made to expand capacity, regulation and other time-consuming costs would create reliance on imports until they become functional. This presents a clear potential risk of overdependence for lithium-ion battery production well into the 2030s.

Russia's war on Ukraine has highlighted the short-term effects of detaching from existing supply chains. If such a need arose with China, the costs would be much steeper and it would be more challenging to create additional capacity. If China uses its leverage, future conflicts will be fought with minerals rather than tanks.

Figure 5: Geopolitical risk hotspots in the EV battery value chain



Source: Dionne Searcey, Michael Forsythe and Eric Lipton, "A Power Struggle Over Cobalt Rattles the Clean Energy Revolution," The New York Times, 20 November 2021.

United States: The Inflation Reduction Act also hurts the EU's investment goals in EVs and would require member states to flesh out more fiscal capacity to support domestic production. As a result, the EU may have to primarily depend on imports for the foreseeable period. The US also has one of the world's largest lithium deposits and is keen to ramp up EV production. Under the IRA 40% of critical components used in EV batteries need to be extracted in the US (or its free trade partners), This further increases to 80% in 2026. Secondly, 50% of the batteries must be assembled in the US, which rises to 100% by 2028. This will incentivise producers to set up factories in the US to be more competitive in international markets. For example EU startup Marvel Fusion, a company which hopes to create clean fusion energy is being pressured by investors to move to the US. Tesla also announced in September 2022 that they are pausing plans to create battery cells in the US to take advantage of tax credits.

It is also unlikely that the US will provide many concessions to EU businesses. So it may not be a question of whether the EU will win this new race; rather, it would be a question of whom it would lose to.

However, the EU has taken steps to avoid this scenario, investing in several mining projects, including in Germany, France and Portugal. Swedish company Northvolt also opened Europe's first battery gigafactory. What the EU does to attract enough investment given the US and China's involvement may decide the future of EV production.

Moving wheat from point A to point B is vital in itself, but some points in the global transport system prove more critical than others. These points are transport junctures through which exceptionally large volumes of trade pass – also known as chokepoints. The global food system is reliant on several of these chokepoints, which are outlined in Figure 2. Disruption to these points could drive up food prices and threaten food security. The blockage of the Suez-Canal and the more recent Russo-Ukrainian war highlight the importance of these chokepoints to our global food trade system.

2. *Technological risks*

Lithium mining is harmful to the environment, associated with exploitation, does not last very long and is sensitive to temperature changes. Therefore, researchers are looking at alternatives to lithium which may disrupt the commodity's demand in the long run. In particular large-scale energy storage (for electricity grids) may move away from lithium in the long run. “The grid scale battery storage technologies market was valued at US$7,058 million in 2021 and is projected to grow at a compound annual growth rate of 15.6% during the forecast period 2022-2032.

Some of the alternatives include:

Sodium-ion batteries: Sodium ion has the most significant chance of replacing its lithium counterpart. It mimics lithium's chemical properties and is closer to commercialisation than alternatives. This is especially true for large-scale energy storage capacity. It holds heat much longer and is much more abundant. It is also 20-40% cheaper than lithium.

However, sodium-ion batteries are less energy dense and will require larger-sized batteries. It may be an issue for EVs, but it will affect lithium's demand for large-scale energy storage.

Pumped Hydro Storage: It comprises 96% of utility-grade energy storage capacity in the US. It relies on simple gravitational principles to store energy. However, it is challenging to build as it takes up enormous space and needs specific geography. Therefore it does not pose as considerable a risk as other alternatives.

Thermal heat: This alternative uses molten salt to store thermal energy and convert it into electric energy. Again, using sodium's heat storage properties to its advantage, holding heat for 6 hours compared to lithium battery’s 4 hours (discharge duration which is economically viable). Malta is building a thermal heat plant in the US which will go into operation in 2025.This technology is scalable but lags behind in efficiency compared to lithium ion.

Other technologies, such as flow redox batteries, show much promise but are not yet ready to be commercialised. It is unclear which technology might replace lithium for grid storage, but there are many contenders to look out for.

3. *Value chain risks*

A likely fundamental long-term risk for EV battery value chains stems from cobalt, another major constituent in EV batteries. A standard lithium-ion battery pack contains about 14kg of cobalt. Cobalt is vital in creating Lithium-ion batteries as it enables improved range and reduces volatility.

The risks associated with cobalt can be categorised as follows.

Cobalt Red: Two thirds of cobalt reserves are located in the democratic republic of Congo. The mines are hotspots of hazardous working conditions. Thousands of labourers are crammed to work in tight spaces for just a few dollars. Moreover, they inhale and contact the toxic effluents from the mining process. In addition, militias traffic children, sometimes from hundreds of miles away and force them to work in these mines. These artisanal cobalt mines are illegal but still run due to rampant corruption in the country. Beyond the suffering of the Congolese people working in the mines, the extraction methods are not sustainable. This would lead to public pressure to move away from cobalt in the DRC. This means already high prices will skyrocket, necessitating investments in alternatives such as Lithium Iron batteries.

Supply-side risks: China owns 15 of the 19 mines in the DRC. It also refines and processes 60% of the world's cobalt. This creates a direct dependence on China for cobalt supply chains. The international emergency agency expects a cobalt shortage by 2030, further amplifying dependence on Chinese production. China's control of the cobalt supply chain is even tighter than Lithium. If China decides to control supply for its cobal transition, the rest of the world, particularly the EU and the US, will struggle to circumvent Chinese cobalt production.

Demand-side risks: Cobalt makes up 10-30% of the costs of a typical battery and its demand will likely outpace supply. Cobalt is usually found as a by-product of Nickel and copper mining, therefore, its price is tied to those minerals and is volatile, adding to the woes of rising lithium prices.

Therefore, the difficulty in importing and processing cobalt may damage the supply for standard Lithium-ion batteries. The battery industry would have to evolve and there is no guarantee that Lithium will still be a part of the evolution.

Conclusion

Overall, the lithium industry faces a range of medium- and long-term risks that could impact the demand for lithium and its price, as well as the ability of EV battery manufacturing countries to acquire refined lithium. These include operational risks such as exploration and processing risks, transportation risks, as well as external risks such as competition from alternative energy storage solutions, price volatility, geopolitical tensions. In fact, the high concentration of reserves, refining capabilities and EV battery manufacturing capabilities creates bottlenecks in the supply chain that are highly vulnerable to the aforementioned risks. Given the expected steady demand for EV batteries (in the medium term at least), the industry will need to manage these risks effectively to ensure sustainable growth and the success of the green energy transition in the long term. ■