HCSS Geo-economics

Batteries require battery minerals, should Europe ramp up its efforts to secure them?

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Introduction

The EU's goal is to have 10 million electric vehicles (EVs) sold in the EU by 2030.[1] In order to hit this target, the number of EVs built and sold in the EU needs to ramp up drastically. Meeting this goal is important to Europe for several reasons. First, Europe will need to increase the number of EVs driving on European roads relative to the number of vehicles with an internal combustion engine (ICE) to meet the targets it has committed itself to under the Paris Climate Agreement.[2] Technological advancement is another reason. By pushing an agenda of electrification in the transportation sector the EU stimulates European car manufacturers (also referred to as *original equipment manufacturers* or *OEMs*) to innovate in green technology products (i.e. EVs). The OEMs are encouraged to put more effort into research and development of batteries and battery components within Europe. Increased efforts to develop these (new) technologies contribute to reducing the EU's dependence on technology and products imported from East-Asian countries like China, which currently dominate large parts of the Lithium ion Battery (LiB) supply chain (see ***Figure 1***).[3] Europe also emphasises securing its independence as a producer of LiBs through the construction of so-called battery gigafactories.[4] Though gigafactories are absolutely required to supply the most important part of a battery electric vehicle (BEV), the manufacturing of battery cells is just one link in the battery manufacturing chain. Securing the right set of battery minerals upstream and turning them into battery chemistries that meet the quality requirements of OEMs is equally, if not more, important. This article describes the impact that battery minerals have on the production costs of LiBs, how this echoes through the entire LiB supply chain and eventually the EU's chances to create a mass market for BEVs on European soil.

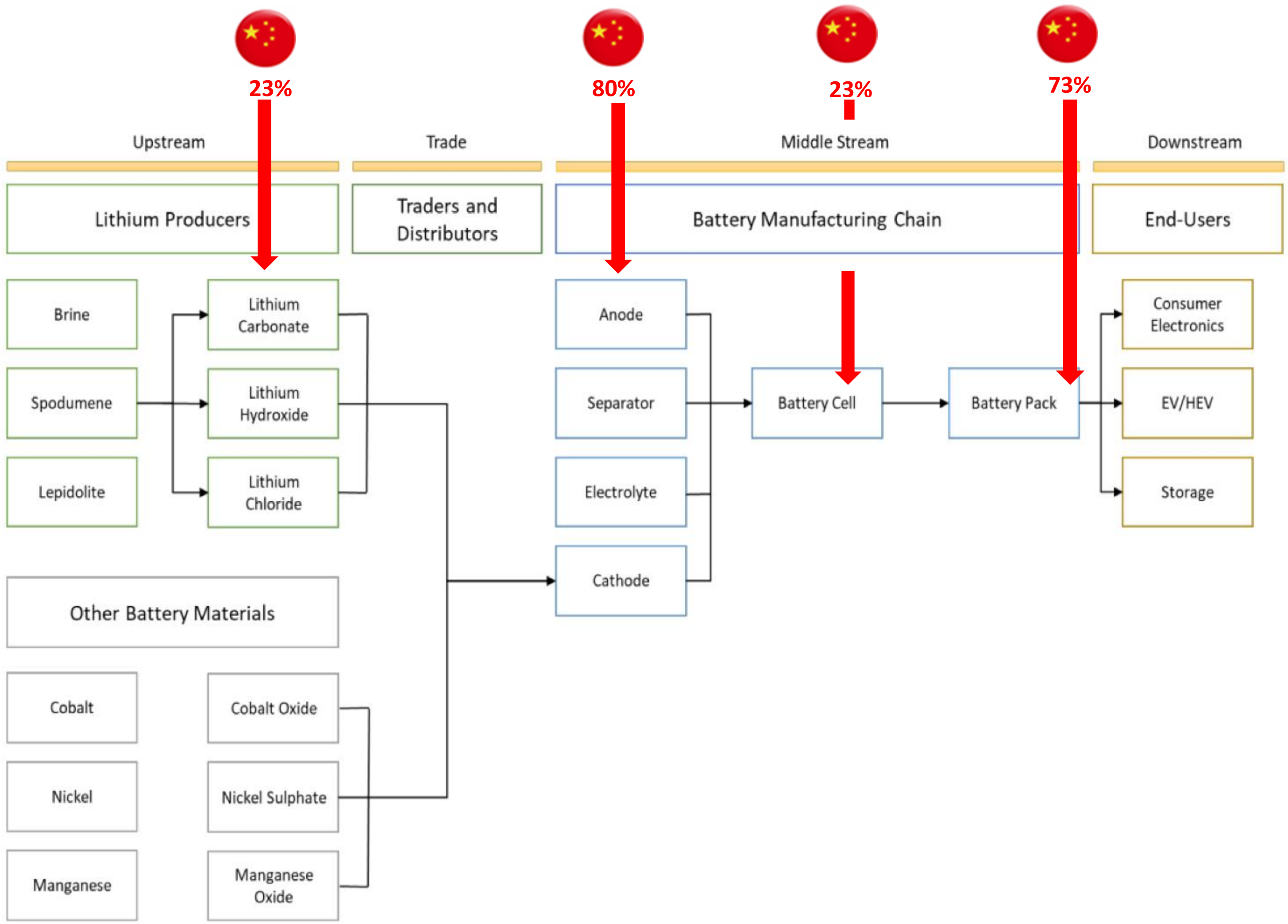
[1] Sources: BNEF EV Outlook 2020 and Fraser, Jake; Anderson, Jack; Lazuen, Jose; Lu, Ying; Heathman, Oliver; Brewster, Neal; Bedder, Jack; Masson, Oliver, *Study on future demand and supply security of nickel for electric vehicle batteries*, Publications Office of the European Union, Luxembourg, 2021.

[2] The CO2 emission reduction target for passenger cars set by the EC for 2030 is 59 g CO2/km. Source: Regulation (EC) No. 443/2009, Regulation (EU) 2019/631.

[3] In this article I will use the terms *Lithium ion Battery*, *LiB* and *battery* interchangeably.

[4] A gigafactory is a factory that is capable of producing batteries with a total combined capacity to store at least 1 Gwh of energy. 1 Gwh equals 1 million kWh.

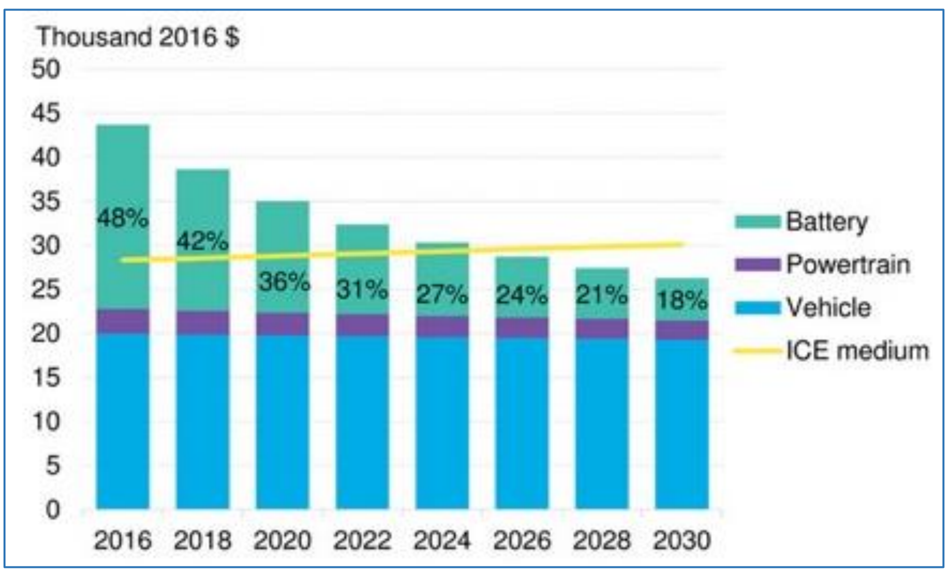
Figure 1: An overview of China's contribution in the production of the various products in the LiB Supply Chain. Sources: The Centre for Research on Multinational Corporations (SOMO) for the graph and Benchmark Minerals Intelligence for the numbers on China.



Understanding the drivers behind BEV production costs

A breakdown of the production cost for an average BEV shows that between 30 to 40% of that cost relates to producing the car's battery cell and pack (*Figure 2*). Bringing down the production cost of the battery cell and pack means bringing down the cost of a major BEV component, allowing OEMs to offer BEVs at prices where BEVs can compete with ICE vehicles. The US Department of Energy (DoE) and other industry experts believe that LiB prices need to drop below $100/kWh to enable BEVs to reach price parity with ICE vehicles. [5] As illustrated in the Bloomberg New Energy Finance (BNEF) graph in *Figure 3*, the average price of battery packs (this includes the cell) per kwh has come down significantly over the past seven years and BNEF recently broke the news that for the first time in history Chinese manufactured li-ion batteries (cell+pack) were sold at prices below $100/kwh. [6] Other factors that influence the attractiveness of BEVs relative to ICE vehicles are: (i) managing the concerns around the safety of li-ion batteries and (ii)'range anxiety' (the fear of your car having a limited range and ending up stranded with your BEV without the proximity of an EV charging point). If OEMs like Tesla succeed in offering BEVs at a price of $25,000 while also meeting the other concerns of consumers the chances of creating a mass-market for BEVs will improve significantly.[7]

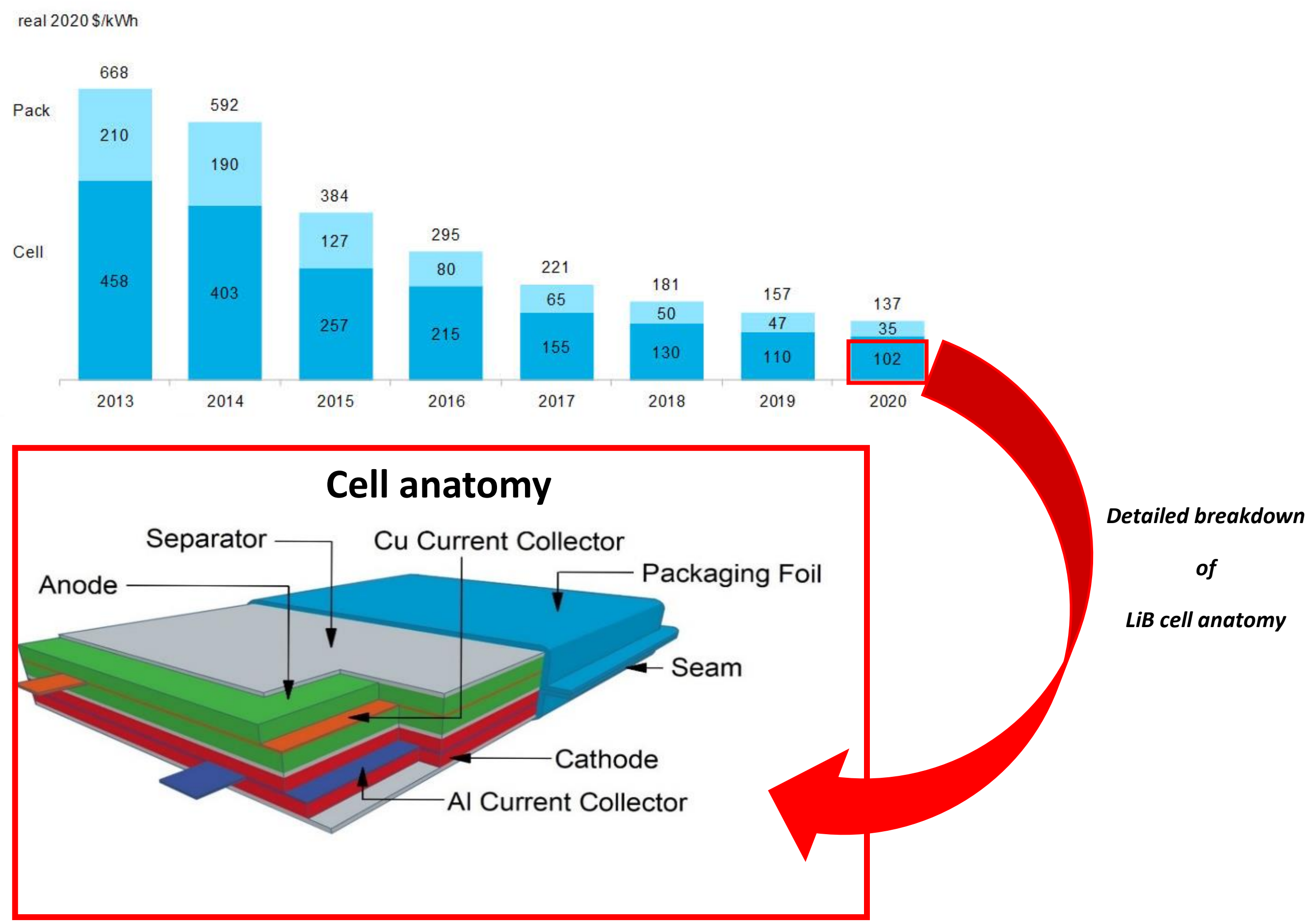
Figure 2: Cost breakdown of BEVs and price comparison with ICE cars in the US sedan segment. Price parity with ICE sedans is expected by 2024. Source: Bloomberg New Energy Finance (BNEF), 2016.



[5] For more information on the target that the Department of Energy has set for battery maker, please see: https://www.energy.gov/eere/vehicles/batteries
[6] Source: Bloomberg New Energy Finance (BNEF) battery prices fall below 100 USD per kWh.
[7]During Tesla's *2020 Annual Meeting of Stockholders and Battery Day* Tesla's CEO Elon Musk indicated that the company aims to produce a $25,000 BEV by 2023. For more information see: https://www.tesla.com/2020shareholdermeeting

Since roughly 80% of the cost of a LiB relates to the production of the LiB cell it is worth understanding more about what's happening in this essential component of the battery. Figure 3 offers a detailed look into the anatomy of a li-ion battery cell. The key components of a battery cell are the *cathode* (the battery's positive electrode), the *anode* (the battery's negative electrode) and the separator. When a battery is charging, lithium ions flow from the cathode to the anode where the Li-ions are stored in Graphite layers. When the battery is used (discharged), the lithium ions are released from the Graphite layers and sent back to the cathode. This reversed flow release the energy and generates power.

Figure 3: *Weighted average price of Battery Cell and Pack in combination with a detailed breakdown of cell costs. Source: BNEF 16 December 2020.*



Currently the most commonly used battery minerals are: Lithium, Nickel, Cobalt, Manganese, Aluminium, Iron and Phosphor for cathodes and Graphite (synthetic and natural) for anodes.

Battery minerals cannot be put into batteries fresh from the mine. They need to be chemically processed before being useful to LiB manufacturers and their customers (the BEV OEMs). This chemical process is not an easy task. BEV OEMs dictate the quality requirements for the batteries that are used in BEVs. LiBs require elaborate cooling systems to control the release of energy, preventing early thermal runaway, to make them safe enough for day to day use in transport.[8] Different battery chemistries react differently when charged and discharged multiple times and it's extremely important for OEMs to find battery chemistries that strike the right balance between safety, range, longevity and price to comfort the consumer that BEVs are ready for adoption by the masses. High performing, reliable batteries require cathode materials that have extremely high purity levels and are almost entirely free of metal impurities. Metal impurities cause damage to the LiB, which eventually may compromise the safety of the user. Today, metal impurity levels often need to be lower than 0.01% in order to be useful to makers of cathode active materials (CAM).

Therefore, next to the improvements that OEMs can make to the production processes of BEV components and the role that the EU can play through its strategic policy decisions, it is the continuous development and improvements of battery chemistries and CAM in particular that determines the success of BEVs relative to ICE vehicles. Since 30 to 40% of a BEV's production cost relate to producing the battery cell and pack and the production cost of a cell in turn depends on the chemistry used in the cathodes and anodes placed in a cell, a closer look into the cost impact of battery minerals on the different battery chemistries will be a useful exercise to understand how to potentially mitigate price risks in the future.

Understanding what determines the price of a BEV means understanding the entire supply chain for batteries, from downstream to upstream, and perhaps more importantly understanding the latest technological advancements in cathodes that determine which of these minerals will be in high demand for the coming years and in which chemically processed form. Battery gigafactories alone will not enable Europe to achieve its ambitions to set up its own, regionalized supply chain. Mega investments in the mining, processing and chemical engineering of battery minerals are required to produce li-ion batteries with the highest standard to provide BEV buyers with BEVs that are safe, affordable and have a practical range. Only then will BEVs be able to truly compete with ICE vehicles and will the EV revolution unfold.

[8] Thermal runaway occurs in situations where an increase in temperature changes the operating conditions in a way that causes a further increase in temperature, often leading to a detrimental effect on operations.

The Cathode: the LiB cell's key component

The three main CAM chemistries used by BEV OEMs today are: (i) NMC, (ii) NCA and (iii) LFP.

Nickel Manganese Cobalt (NMC) cathode chemistries

NMC chemistries distinguish themselves from other chemistries because they provide a high energy density and charge rapidly.[9] Nickel provides high energy density but poor stability which is why it is combined with battery minerals like Manganese or Cobalt as these minerals have a stabilizing effect on the chemistry. Over the recent years LiB makers have put a lot of R&D effort to thrift the Cobalt content in cathodes, something encouraged by OEMs and NGOs given the sensitivity around Cobalt's production methods and its supply risks.[10] Currently there is a trend to increase the Nickel content relative to the other constituents in the cathode chemistry. Whereas the original NMC cathode contained Nickel, Manganese and Cobalt in the same proportionate share (expressed in the name of this cathode: NMC 111), the newer NMC cathodes hold three times as much Nickel content compared to Manganese and Cobalt contents (hence the name NMC 622). In 2020, Swedish cathode and battery maker Northvolt announced that it is working on the mass production of cathodes with eight times more Nickel content (also known as NMC 811). These higher Nickel content cathodes offer two important benefits: first, being able to increase the Nickel content means increasing the energy density. Second, it reduces the exposure to Cobalt which is considered the battery mineral with the biggest price risk.

Nickel Cobalt Aluminium Oxide (NCA) cathode chemistries

Although NCA chemistries have a higher cost of production, they offer (i) a higher energy density then most of the other chemistries, (ii) a long battery life (of over 15 years) because the battery is able to perform more charge / discharge cycles whilst (iii) being able to perform well under very extreme outside temperatures.[11] Currently the main producers of NCA cathodes are Japanese with Sumitomo Metal Mining taking a very significant market share due to its supply agreement with Panasonic who are the exclusive supplier of NCA batteries to Tesla for their Model X and S.

Lithium Iron Phosphate (LFP) cathode chemistries

LFP based cathodes are in high demand because they offer some big advantages for battery makers: (i) they do not contain Nickel and Cobalt (the two most expensive battery minerals used in cathode chemistries), (ii) they have a long charge / discharge cycle life and (iii) they have an excellent stability even if kept at high voltage for a prolonged time. Unfortunately, the downside of these cathodes is that

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[9] Wired Magazine: https://www.wired.com/story/this-cobalt-free-battery-is-good-for-the-planet-and-it-actually-works/

[10] According to the 2020 Cobalt Data Sheet of the US Geological Survey the DRC produced approximately 70% of the world's Cobalt in 2019. Although large multinationals like Glencore play an important role in the export of the DRC's Cobalt production, many smaller mines contribute to these exports too. These smaller mines are sometimes romantically referred to as 'artisinal mines' but the reality is far from romantic. Child labor, bad working conditions and poor waste management are the main reasons for the EU to incentivize players in the li-ion battery supply chain to either switch to mines with a good ESG track record or steer away from using Cobalt completely.

[11] Yuan-Li Ding; Zachary P. Cano; Aiping Yu; Jun Lu; Zhongwei Chen, *Automotive Li-Ion Batteries: Current Status and Future Perspectives*, Dpt. of Chemical Engineering Waterloo Institute of Nanotechnology and Waterloo Institute for Sustainable Energy University of Waterloo, Canada, 2019.

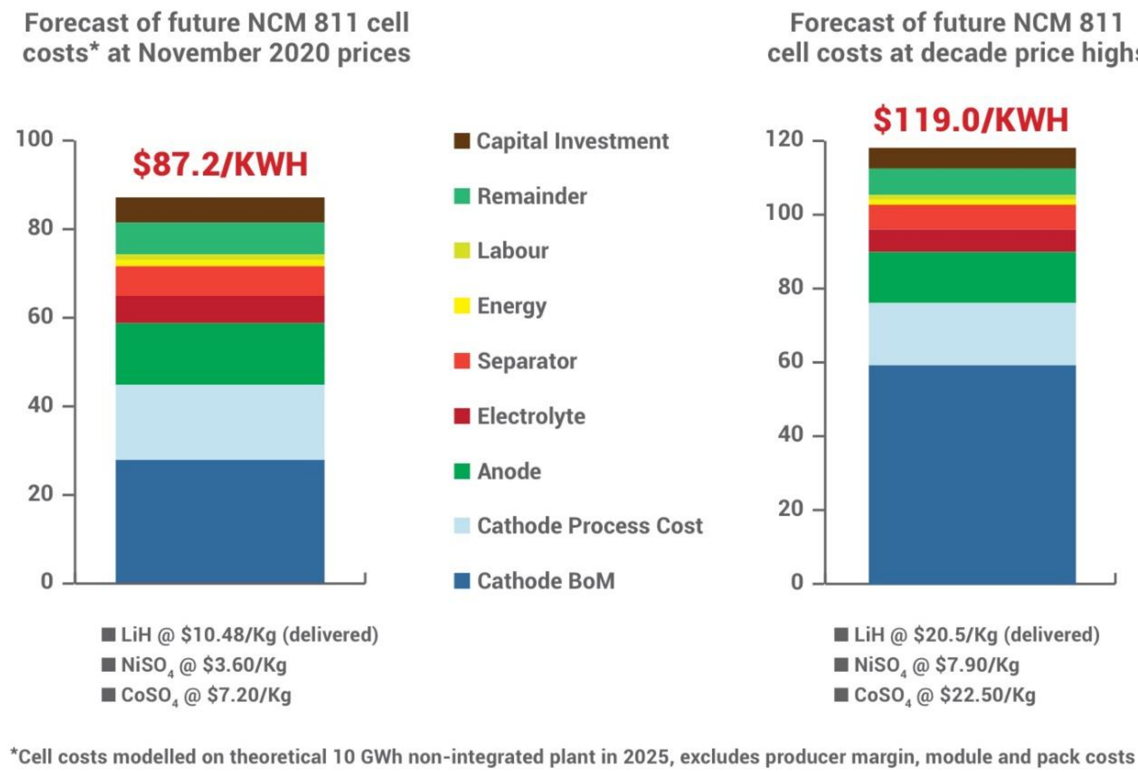
(partly due to the absence of Nickel) they have a lower energy density. Because of their longevity and stable performance, LFP batteries are traditionally used in E-buses and electric heavy-duty vehicles. These vehicles typically do not require a sudden release of intense power by the battery in comparison to the more luxurious high performing BEVs like the Tesla Model S. With the intellectual property rights over LFP batteries set to expire in 2022 and the performance of LFP based batteries continuously improving, LFP based batteries could rapidly gain market share in BEV growth markets[12]. In Europe, the French gigafactory startup Verkor (backed by the energy services giant Schneider Electric) announced that they will centre their battery production around LFP based batteries to serve lower cost BEV models meant for Mediterranean markets like Spain, Portugal and Italy.

Different cathodes, different bill of materials

Since the LiB cell constitutes approximately 80% of the LiB's production costs it is key to understand what contributes to the cost of making a LiB cell. The *bill of materials* (*BoM*) is a list of all the raw materials, components, sub-components and the quantities of each needed to manufacture a LiB cell. ***Figure 4*** illustrates the cost breakdown for a NMC 811 LiB cell for two different price scenarios. Looking at Figure 4 three things become clear. First, cathode BoM cost could easily double if prices of battery minerals were to return to decade highs. Second, the overall costs related to cathodes (i.e. BoM costs plus process costs) is large, more than 50% of the LiB cell's cost is related to making the cathode. Third, cathode and anode together constitute 65-75% of total LiB cell costs (depending on which scenario you look at). This last point illustrates the importance of the battery minerals that constitute the anode and cathode BoMs as well as the chemical processes required to upgrade these minerals to high purity so that they can be used into a battery cell. But there is another conclusion to be drawn here, one that is not directly visible in Figure 4. This cost breakdown is made on the assumption of the BoM for a NMC 811 cell. This is a high Nickel and low Cobalt content cell. As explained earlier, different cathodes have different battery minerals and therefore different BoMs. Exposure to a supply sensitive battery mineral like Cobalt can be reduced by using Cobalt free cathodes, such as LFP. But Cobalt is not the only battery mineral with an uncertain future supply. Nickel, Manganese and Lithium can all become supply sensitive battery minerals too, unless the industry (and government stakeholders) is willing to expand the scope of its investments in the LiB supply chain. LiB Gigafactories alone will not be enough for Europe to realize its ambitions set under the Paris Climate Agreement or as part of its Green Deal. More investments will be needed in the upstream and midstream (i.e. processing of battery minerals) sections of the supply chain as well. After all, batteries require battery minerals.

[12] Source: Roskill, 25 June 2020. See: *The true drivers behind LFP demand*.

***Figure 4:** Cell cost breakdown for NMC 811 cell based, November 2020 prices vs Decade High prices. Source: Benchmark Minerals Intelligence Q4 Review 2020.*



How does this impact Europe's EV ambitions?

A next price hike, especially for Nickel and Cobalt metal prices, can stagnate the downward trend of LiB cell prices. In the two scenarios illustrated in Figure 4, the total LiB cell production cost increases with almost 36.5% to $119/kWh. Assuming that an average BEV in Europe will have a 100kWh energy unit inside it, a 36.5% increase of a NMC 811 LiB cell price could easily lead to a $3,000 price increase for a BEV. This does not yet include the margin that the BEV OEM will want to make on the car. And we have to bear in mind that in the two scenarios illustrated in Figure 4 above, price hikes for Manganese have been left out. ***Table 1*** below indicates the percentage increase in cathode raw materials used in Volkswagen's EVs over the period 2018-2020. Note the dramatic increase in the use of all battery minerals, including Cobalt. Within the next decade, Volkswagen alone intends to increase its LiB output almost tenfold (from 24 Gwh to 240 Gwh, in Europe alone). We have to bear in mind that Volkswagen is not the only BEV OEM with big ambitions. All the major OEMs have announced similar ambitions within the next decade, which can lead to only one thing: an upward pressure on the prices of battery minerals. The outlook becomes even grimmer if we take into consideration that battery cells do not simply require battery minerals, but chemically processed battery minerals that meet the chemical requirements of battery (component) makers. This part of the LiB supply chain is still in its infancy in Europe. Today, Europe does not have a single Lithium refining facility for instance.

Table 1: *VW Group percentage increase in cathode raw material used in EVs over 2018-2020. Source: Roskill, VW Power Day Review, March 2021*

	Nickel (t)	Lithium (LCE t)	Cobalt (t)	Manganese (t)
2018	543	660	204	282
2020	7,047	7,080	1,868	2,047
% increase	1,198%	973%	816%	626%

Battery mineral price increases will detrimentally affect the ability of BEVs to reach the aspired price parity with ICE vehicles, one of the prerequisites to create a mass market for BEVs. Without the creation of a mass market, many investments in LiB technology will be deferred or even cancelled creating a negative spiral that will keep Europe in the grip of the current forerunners (i.e. East Asian players) in the LiB supply chain.

How can policymakers mitigate the price risks related to battery minerals?

Diversification. That's the key word to mitigating the risks associated to hikes in metal prices. First, by diversifying the investments in the LiB supply chain. Second, by diversifying the materials used for batteries. Third, by diversifying the places where these materials are sourced and fourth, by diversifying the marketing of LiBs and BEVs. I will explain each form of diversification briefly.

Diversification of investments in the LiB supply chain

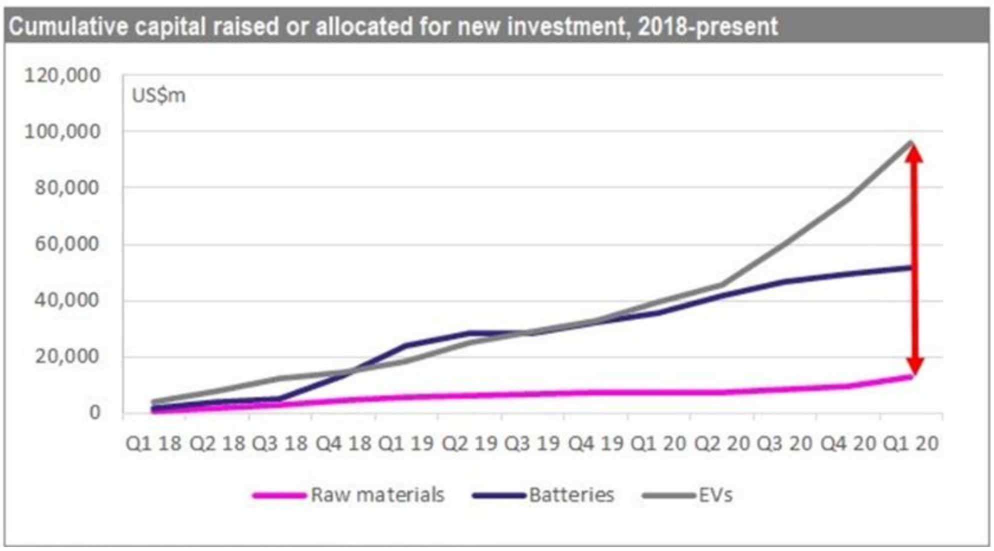
Figure 5 illustrates the issue well. Yes, green tech is hot amongst investors but if we take a closer look at where funds are flowing to, we see that the larger part is flowing to projects downstream (i.e. EV and battery factory roll out). In Europe, most of the attention is going to the LiB gigafactories. In 2020 Europe had 500 Gwh of new gigafactory capacity in the pipeline. Recently, Volkswagen announced that it will be increasing its LiB production from 24 Gwh to 240 Gwh, in Europe alone that is. [13] It will however not invest funds in projects upstream (i.e. mining) or midstream (refining and processing). The gap between cumulative downstream investments and cumulative investments upstream over the past two to three years is a whopping 80 billion US Dollar. Inconceivable, if one realizes that without raw materials there will be no BEV or LiB rolling out of a factory. Although these numbers are reflecting global industry investments, the picture for Europe is no different. General analysts might point to the fact that the European Commission has set a target to identify and invest in upstream projects that can be operational by 2025.[14] However, Europe will need multiple projects with the size of the *Cinovec* project to start production within the next 5 years if it wants to meet its goal of selling 10 million EVs

[13] On 15 March 2021, Volkswagen held its 'Power Day' event during which the company laid out its BEV strategy for the next decade. See Power Day Live Stream

[14] See action 5 of the European Commission's Communication on Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability, 3 September 2020

in 2030[15]. Current developments in Europe do not indicate that that will happen soon. Depending on the size of the energy unit in each of these 10 million EVs, Europe will require a multiple of today's entire global production of Lithium compounds (roughly 360,000 tonnes). Since it takes five to seven years to get the average mine into commercial production and Europe is renowned for its long permitting and stakeholder participation procedures, chances are that Europe will not be able to meet its own demand in battery minerals in the next decade at least not from local production alone contrary to what former Executive Vice-President Šefčovič of the European Commission announced in his speech at the inauguration of the European Raw Material Alliance (ERMA). [16]

Figure 5: Allocation of investments in sections of the LiB supply chain. Source: Battery Minerals Review, 17 March 2021.



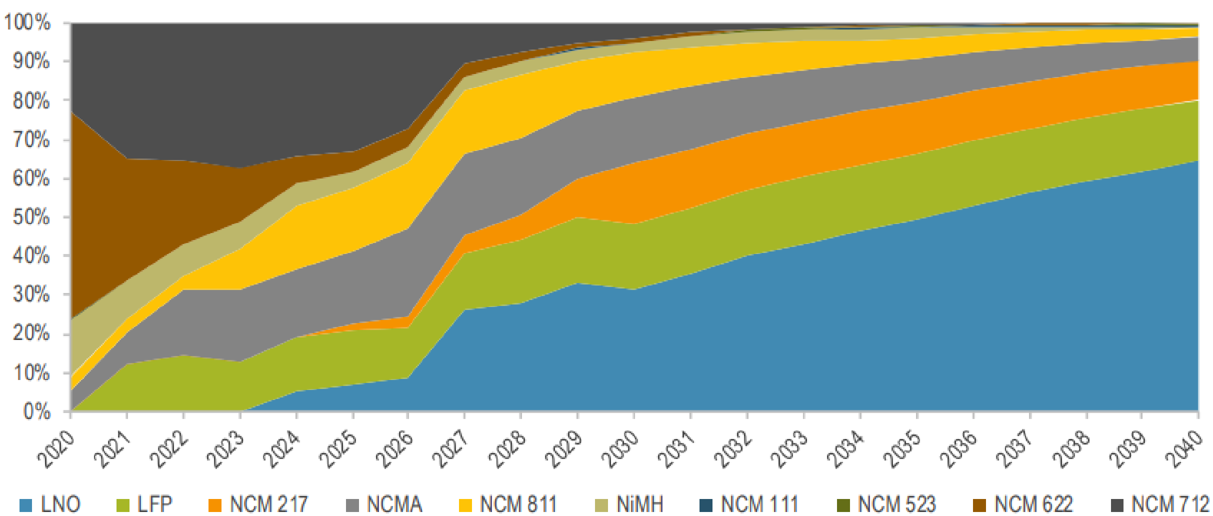
The message that Figure 4 and 5 convey to European policymakers is clear: allocate more funds to secure a steady supply of battery minerals from multiple sources. This can be achieved by (i) pursuing an active and focused trade policy with countries outside of the EU under which European diplomats are trained and well equipped to understand the importance of each battery mineral in the EU's masterplan of creating a European LiB supply chain and (ii) encouraging and, where required, even incentivizing European corporations to 'go global' and create partnerships with entities abroad to secure not only raw materials but also processed compounds required for the manufacturing of LiB cells and BEVs. In short, Europe needs to create *virtual airlifts* allowing battery minerals and other critical minerals to flow into the EU's own LiB supply chain.

[15] The Cinovec project is one of Europe's largest integrated Lithium mining and refining projects. The project is supported by the Czech government and has the potential to become a significant supplier of Lithium compounds to the EU and its automotive industry. See: https://www.europeanmet.com/cinovec-lithium-tin-project/
[16] Speech by Vice-President Šefčovič at the launch of the European Raw Materials Alliance, 29 September 2020

Diversification of materials used for batteries

The EU has the power to encourage or discourage the use of certain materials by producers in the LiB supply chain. Demanding ESG certifications from producers to show where their Cobalt comes from is a good example. By making it clear that Cobalt from so called 'artisanal' mines are not in compliance with the EU's ESG requirements, producers and users across the battery supply chain are encouraged to look for better alternatives since there is a risk that the market for 'non-compliant' Cobalt becomes smaller over time and their products might get rejected. The market is currently behaving in this manner and has started to thrift the use of Cobalt in favour of Nickel and Manganese. This is not to say that Cobalt will disappear entirely as a cathode active material, to the contrary, Cobalt still has a role to play given its benevolent properties as a stabilizer in LiBs. However, over the next decade there will be a new equilibrium in which the balance of power will shift in favour of high Nickel, high Manganese and low Cobalt chemistries for batteries. ***Figure 6*** illustrates the cathode forecast for Europe by market intelligence company Roskill:

Figure 6: *Cathode forecast for Europe, expressed as a percentage of volumes purchased by LiB makers. Source: Roskill, 2020* as part of the study performed for the JRC. *See:* Fraser, Jake; Anderson, Jack; Lazuen, Jose; Lu, Ying; Heathman, Oliver; Brewster, Neal; Bedder, Jack; Masson, Oliver, *Study on future demand and supply security of nickel for electric vehicle batteries*, Publications Office of the European Union, Luxembourg, 2021.

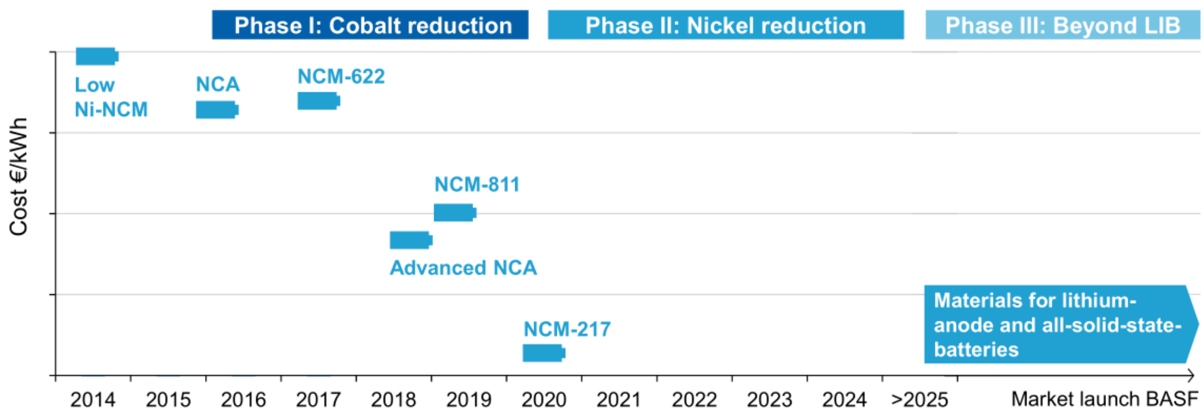


Broadening the scope of cathode chemistries that can be used in LiB cells for BEVs is a good thing. Based on February 2021 metal prices, certain high Manganese, low Nickel and low Cobalt chemistries reduce cathode prices with more than 55% on a USD/kg basis and almost 50% on a USD/kWh basis.[17] Diversification can therefore lead to serious LiB cell cost reductions.

[17] Roskill, *Volkswagen Power Day Review*, 18 March 2021.

Diversification of materials also means looking beyond current LiB technology. ***Figure 7*** is an example of how corporations in the battery supply chain are constantly optimizing battery (cathode) chemistries. BASF's NCM 217 high Manganese (and ultra-low Nickel and Cobalt) cathode is a great example of this optimization as Nickel too has its geopolitical restrictions. [18]

Figure 7: *BASF's cathode evolution roadmap.*



Diversification of sources

Using more Nickel and thrifting Cobalt in LiB cells doesn't mean that all of a sudden the EU's ESG standards are met and all producers and suppliers in the LiB supply chain are in compliance with the EU's ESG requirements. Nickel too has its challenges. Nickel Sulphates (the specialty chemical product used in CAM for LiBs) require intermediate Nickel products such as Nickel matte, Mixed Sulphate Precipitate (MSP) or Mixed Hydroxide Product (MHP). As illustrated in ***Figure 8*** by the end of this decade 40% of these intermediates will be produced and processed in Indonesia, Russia and China.[19] The association of Russia and China with (geopolitically motivated) supply risk seems apparent for EU policy makers, but ever since Indonesia announced an export ban of Nickel ore, EU off-takers have become aware that it is not only China and Russia that they need to worry about. Indonesia's aspirations to become a vertically integrated Nickel producer make absolute sense. Gone are the days that countries in Southeast Asia supplied raw materials to European corporations who would add value to these raw materials in their home countries, upgrade them into intermediate and end products only to sell them back with higher margins to people and corporations in the country where these raw materials came from in the first place. Instead of pursuing its legal battles with Indonesia at the World Trade Organisation (WTO), the EU could perhaps consider an approach similar to Chinese and Japanese firms who bring the much needed technology and funding into the country and lift the skills of local people. [20] The additional benefit of such approach is that European corporations have a real chance to ensure that production processes meet the ESG and quality standards of the EU back home.

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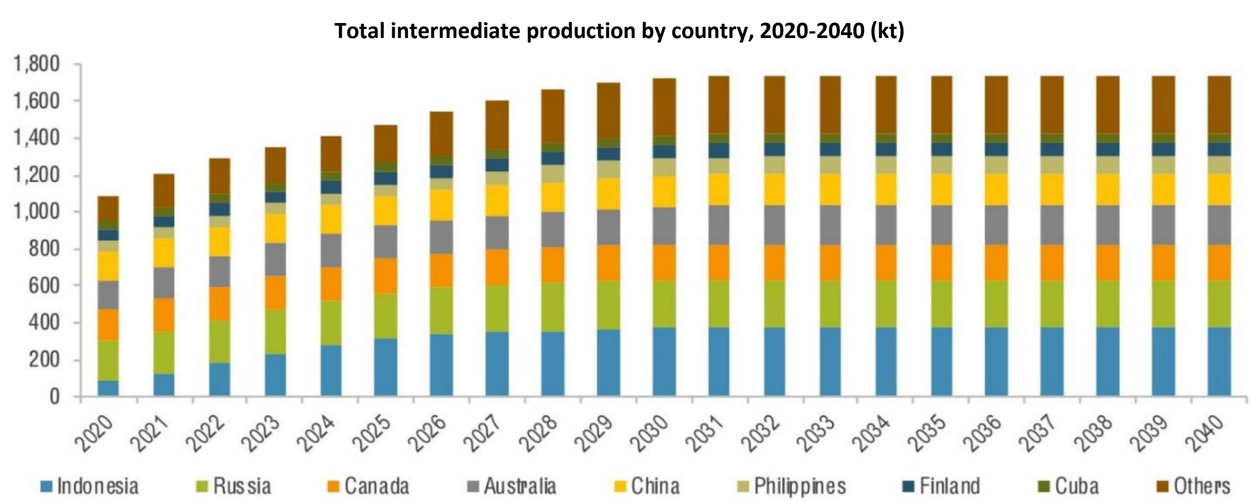
[18] During Volkswagen's Power Day on 15 March 2021 Volkswagen announced that ultra-high Manganese cathodes play a significant part in its LiB strategy for the next decade.
[19] Fraser, Jake; Anderson, Jack; Lazuen, Jose; Lu, Ying; Heathman, Oliver; Brewster, Neal; Bedder, Jack; Masson, Oliver, *Study on future demand and supply security of nickel for electric vehicle batteries*, Publications Office of the European Union, Luxembourg, 2021.
[20] https://www.reuters.com/article/us-eu-indonesia-trade-idUSKBN2AQ0GO

Although some good initiatives are currently developed by some European corporations, the big players in the mining and processing of Nickel in countries like Indonesia and the Philippines are non-European players like Vale (Brazil), Sumitomo (Japan) and Tsingshan (China).[21]

And similar risks apply to Manganese. High purity Manganese Sulphate is required as feedstock for CAM and a shift from high Cobalt to high Nickel or high Manganese content cathodes will create an upward pressure in the demand for high purity Manganese, a mineral that is not even listed on the EU's list of critical minerals. Again quite difficult to understand if you realize that high purity Manganese Sulphate has a limited feedstock at the moment. Today, it is only economically viable to extract high purity Manganese from ores containing Manganese Carbonate. Only 2% of all Manganese holding orebodies in the world are Manganese Carbonate ores. And there is literally only a handful of projects outside of China that have the potential to produce Manganese Carbonate.[22] The EU needs to increase its efforts in co-developing or co-owning Manganese Carbonate (ore) projects outside of China. Through pre-payment arrangements with local producers, EU funders can try to secure access to part of the Manganese Carbonate. EU companies can help set up integrated facility to refine and process the Manganese Carbonate further to Manganese Sulphate. If it there is no or little local demand then perhaps it makes sense to set up supply agreements or joint ventures to jointly market the end product in more mature markets on the basis of profit sharing so that local miners have the feeling that they still benefit from the value added to their product downstream. Securing a foothold in (part of) foreign supply chains is essential if the EU wants to establish a steady supply of much needed battery minerals for the European LiB production chain.

Figure 8: *Total intermediate production by country until 2040 Source: Roskill 2021.*



[21] BASF and Eramet joint study for HPAL Nickel in Indonesia
[22] Fernley, Matt, *Some Manganese is more equal than others*, Battery Minerals Review, 2 November 2020

Diversification of product marketing

Market differentiation is not a new phenomenon. Different consumer groups have different needs and producers will always look for different ways to sell their products, optimizing their marketing strategy to ensure that the targeted groups are approached in the most effective way. The market for BEVs is no exception. BEV OEMs will adopt their marketing to meet the needs and purchase power of consumers in each geography and even each demographic group in the most effective way. It is no coincidence that Tesla's first product in China is a Tesla Model 3, the least expensive model in the Tesla product portfolio. Due to new safety regulations becoming effective in China, OEMs in China are now encouraged to use the safer LFP batteries in their BEVs.[23] In a country where the central government is actively pushing the roll out of EV infrastructure by adding 600,000 new EV charging stations on top of the 1.2 million existing ones, range anxiety becomes less of an issue and people can be comfortable with LFP powered BEVs even if they have a smaller range than the more energy dense LiBs with high Nickel content cathode chemistries.[24]

In Europe, the big BEV OEMs and notably the German ones, will have a more diversified fleet of BEVs with high Nickel and high Manganese cathode chemistries. European consumers demand higher standards for energy density, range and overall performance of the car. Because of their superior performance and range, NMC or NCA powered BEVs tend to be sold at a premium compared to LFP powered BEVs. In Europe, we will see a differentiated market for BEVs with NMC / NCA powered BEVs leading the charge in the North(west) of Europe and LFP powered BEVs leading BEV sales in the South and East of Europe where the purchase power of the average consumer tend to be lower.

The European Commission has set itself a very ambitious target of having at least 30 million zero carbon emission cars on European roads by 2030. A large number of those zero emission cars will be BEVs. Having such a large number of BEVs on the road requires sufficient public charging stations (according to some sources almost 2.2 million) and it's a positive development to see that the European Commission has set ambitious targets for this as part of its *Green Deal.* [25] The more public charging stations for BEVs, the quicker range anxiety will disappear as a concern for consumers and the more diverse the portfolio of LiB cathode chemistries can become. Driving electric in Europe will not be for the happy few who can afford a BEV with high performing, expensive LiBs but there will be a real mass market for BEVs with a diverse set of products OEMs can offer to different types of consumers with different needs and spending power. This diversification contributes to reducing the exposure to high Nickel and high Cobalt cathodes, making BEVs less sensitive to large fluctuations in battery mineral prices. With the release of the IP for LFP technology in 2022, I expect that more battery producers in the EU (and the USA) will invest in improving LFP technology which will greatly benefit the European consumer as it will offer a wider range of quality products to choose from.

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[23] A reference to the new safety standards for LiBs as introduced by China's Ministry of Industry and Information Technology (MIIT) on 12 May 2020 can be found here: https://www.chinadaily.com.cn/a/202005/18/WS5ec1e22aa310a8b241156558.html

[24] Greenbiz: https://www.greenbiz.com/article/look-inside-chinas-timely-charging-infrastructure-plan

[25] *Recharge EU: How many charging points will Europe and its member states need in the 2020s,* European Federation for Transport and Environment, Brussels, January 2020.

Conclusion

Battery materials price hikes adversely affect the price of LiBs and since LiBs constitute almost 40% of a BEV's production cost, price hikes upstream will echo through downstream. Depending on the size of the energy unit in the BEV, a 36.5% increase in a LiB's production cost can easily lead to a price increase of more than $3,000 per BEV. This steers BEVs away from price parity with ICE vehicles, an important incentive for consumers to switch from ICE vehicles to BEVs. Policymakers should be aware of this impact and consider investing in more than just the downstream part of the LiB supply chain. Educating Europe's diplomats and trade envoys on the importance of battery minerals and processed intermediates like Nickel matte is crucial in order to secure a steady supply of these materials. Europe's battery gigafactories will need feedstock and Europe will not be able to supply this feedstock from European soil alone. Active partnerships with producers abroad need to be set up, preferably on a 'China plus one' approach to create more alternative supply routes as the vast majority of today's supply routes all cross China at one point. So, diversification of supply routes will be key.

Other ways to mitigate the risk of price hikes are: diversification of materials used in LiB cathode chemistries and diversification of marketing activities. Volkwagen's announcement to make high purity Manganese cathodes their priority (and to thrift the use of Cobalt and Nickel) is a good example of how diversification of materials can further reduce the exposure of BEV OEMs to price hikes upstream. Equally, by differentiating marketing activities for different regions and demographic groups, BEV OEMs will be able to diversify their portfolio of energy unit chemistries and reduce their dependence on only a limited number of LiB cathode chemistries. LFP based cathodes for LiBs will become the product of choice for markets in which consumers have less to spend and are less concerned with high performance and quick charging capabilities of their car. This does however require the EU member states to actively push the roll out of BEV infrastructure at a higher pace in order to remove any anxiety over range restrictions.

Finally, sudden increases in battery mineral prices also have a positive effect. They encourage more R&D in alternatives or even substitutes. That's what currently happens in the case of Cobalt. If prices reach an extremely high plateau that lasts for too long we will see the same developments as we have seen in a commodity market like oil and gas: high prices make projects (that were not deemed economically viable before the price increase) become economically attractive. The US shale gas boom is a good example of this. Perhaps it will then become economically attractive to extract Lithium from seawater. I want to make it clear that I do not consider battery minerals commodities. Absolutely not. Claiming that battery minerals are commodities would display a misunderstanding of the complexity and amount of scrutiny involved in getting these minerals to the point where they meet the rigid quality requirements of battery makers and BEV OEMs. However, if prices are high enough, for long enough, battery makers will steer away from LiB technology and develop alternative technologies. Although this is not the case now, all signs in the market show that this is likely to happen in the next five years and Europe should endeavour to engage more actively in the global LiB supply chain, from upstream to downstream, to make sure it comes close to achieving the targets it has set for itself. Batteries require battery quality minerals so you better make sure you have a foot (or two) in all sections of the LiB supply chain. Not just the fancy ones.

Jeff Amrish Ritoe, Bangkok, 13 April 2021