The Hague Centre
for Strategic Studies

Europe’s Strategic Access to Battery Minerals in a Changing Geoeconomic Landscape

Irina Patrahau and Ron Stoop

August 2025

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Executive Summary

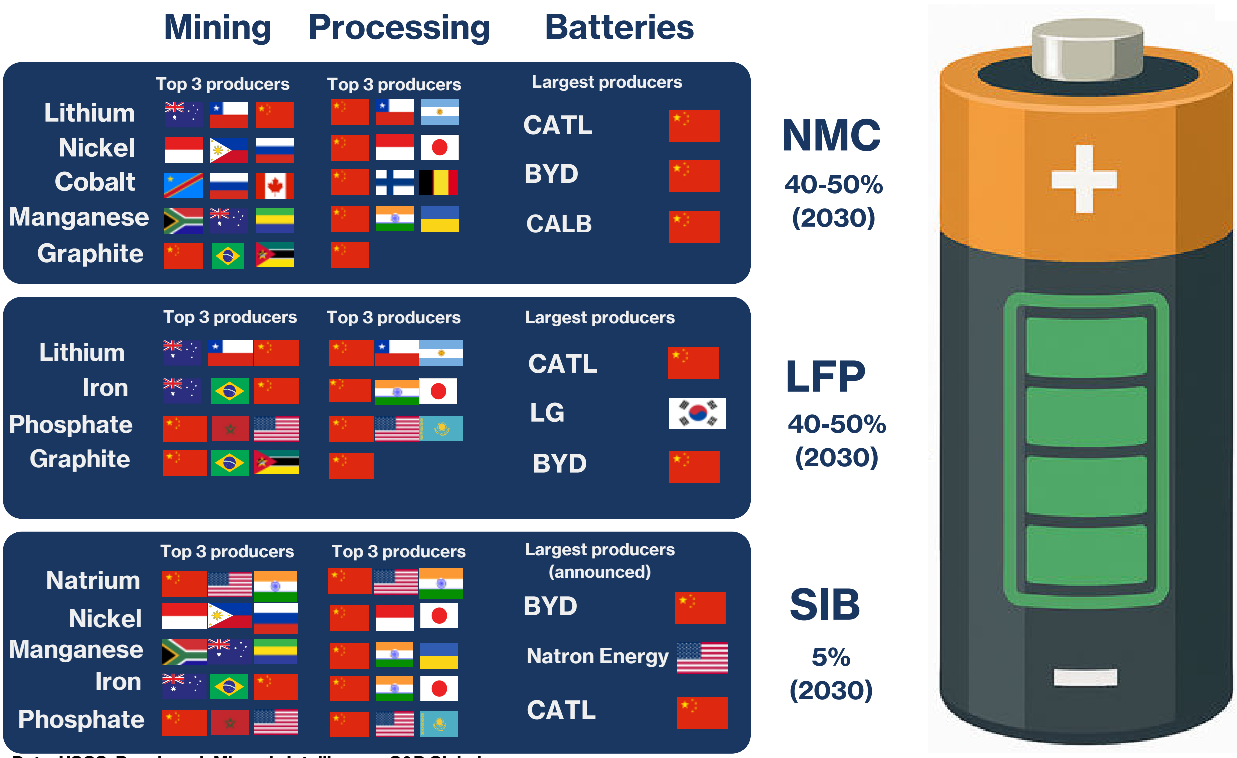
Europe's transition to a low-carbon economy hinges on the rapid deployment of battery technologies. Batteries are essential for stabilising electricity grids powered by renewables and for enabling the shift from internal combustion engine (ICE) cars to electric vehicles (EV), especially after the European Union's (EU) 2035 ban on new ICE cars. As of 2025, lithium-ion (li-ion) batteries dominate the energy storage market. Li-ion batteries can be produced using different chemistries, the two most widely deployed being the Lithium Nickel Manganese Cobalt Oxide (NMC) and the Lithium Ferro Phosphate (LFP) types.[1] Their dominance is expected to continue towards 2030.

The successful deployment of batteries in Europe depends on secure supply chains, which are heavily concentrated (see Figure 1). China plays a dominant role across the entire battery supply chain. It produces most of the world's batteries and controls large shares of battery material mining and processing capacity, including graphite, lithium, manganese and phosphate. The Chinese government can use its control over battery supply chains to exert geopolitical pressure on other countries. Europe's energy transition could be slowed down because of this.

To reduce its vulnerability, Europe could choose to look into types of batteries that rely less on raw materials whose supply chain is dominated by China. A third battery chemistry that is becoming increasingly relevant is the Sodium Ion Battery (SIB). This battery avoids the use of critical raw materials (CRM) like lithium, cobalt and (depending on the chemistry) nickel and manganese, thus reducing the supply chain risks (Figure 1). At the manufacturing stage, China has already captured a significant portion of the market. In 2024 China was home to around 90-95% of sodium-ion battery factories, with the EU and the US both capturing a share of between 1-5%.

1 International Energy Agency, 'Trends in Batteries – Global EV Outlook 2023 – Analysis', IEA, 2023, https://www.iea.org/reports/global-ev-outlook-2023/trends-in-batteries.

Figure 1. Battery Supply Chain by Chemistry



Data: USGS, Benchmark Minerals Intelligence, S&P Global

This paper compares three battery chemistries – Nickel-Manganese-Cobalt (NMC), Lithium-Ferro-Phosphate (LFP) and Sodium-Ion (SIB) – in terms of the geopolitical vulnerabilities they bring to the EU. This research informs policymakers in Brussels as well as member states about domestic industrial development plans. It can also support businesses in incorporating geopolitical considerations in their strategic decision-making.

A supply chain vulnerability score for 2025 is calculated for each of the battery material based on supply concentration, recyclability, substitution potential, and geopolitical ties between the EU and exporting countries of both raw and processed materials. Based on these dimensions, an overall vulnerability score per chemistry is being calculated, reflecting the risks associated with these battery chemistries. The results of the supply chain vulnerability analysis are as follows:

- **LFP has the highest supply vulnerability score.** LFP batteries use fewer types of CRM than NMC but remain dependent on processed phosphate and graphite, which are the analysed materials with the highest associated vulnerabilities. The very high supply chain concentration makes them susceptible to geopolitical tensions. Natural graphite has been added to the Chinese government's export restriction list, and so is the preparation technology for battery cathode materials for LFP manufacturing.
- **NMC has a medium supply vulnerability score.** NMC depends on several CRM, all of which facing significant supply chain risks, but their supply chains are slightly more diversified than those of phosphate and natural graphite. Lithium, manganese, and cobalt have a diversified mining landscape, and China's dominance in processing is under 60% of the global market for all three.

- **SIB has the lowest supply vulnerability score,** although there is variation between the subtypes within the SIB chemistry. These lower scores reflect the lower usage of critical minerals with high vulnerability scores. Moreover, sodium is a highly abundant, low-risk material. However, manufacturing is still dominated by China, and some variants include CRM such as nickel and manganese.

These supply vulnerabilities may change after 2030 considering the EU's efforts under the Critical Raw Materials Act (CRMA) and Battery Regulation. Goals include mining 10% of materials domestically, processing 45% and recycling 25% by 2030. The announced European CRMA strategic projects focus on lithium, graphite, cobalt, manganese and nickel – all essential materials for lithium-ion batteries, especially for the NMC chemistry. The Battery Regulation furthermore encourages the recycling and recovering of the raw materials in the NMC battery chemistry. This shows that the EU is focused on establishing a resilient domestic NMC battery supply chain in the coming years.

There are no EU-based strategic projects for phosphate, which is critical for LFP batteries. Some phosphorous projects exist in neighbouring Norway. One of the largest European phosphate rock deposits has been found there, and production is expected to start by 2029.[2] Still, the EU's phosphorous import dependency in 2025 is high and the recycling rate 0%. This calls for additional efforts to address supply risks by 2030 and reduce the exposure of EU-based LFP manufacturers to potential disruptions.

SIB technologies may offer a strategic opening, particularly if Europe accelerates domestic production and targets variants with minimal CRM dependence.

Bringing together the 2025 supply vulnerability analysis and the post-2030 assessment, three main takeaways emerge:

- **The NMC market brings opportunities to EU manufacturers post 2030, even though from both a material supply and a manufacturing perspective, the 2025 situation remains vulnerable.** China's dominance in the manufacturing sector and over the global market furthermore makes it difficult for emerging EU producers to stay competitive and sustain operations. The higher cost of NMC chemistries may also bring competitive issues to European manufacturers compared to LFP and SIB batteries. Yet from a material security perspective, vulnerabilities could be reduced by 2030-2035 considering the EU's strategic projects on lithium, nickel, manganese, graphite, cobalt, pointing to a good opportunity to start investing in this value chain.
- **LFP batteries are emerging as a more affordable chemistry than the NMC, but current supply chain vulnerabilities and the limited efforts to address them point to continued geopolitical challenges for European manufacturers.** If the EU wanted to develop its LFP manufacturing base, it would have to think about de-risking the graphite and phosphate supply chains. Additionally, it would have to consider the challenges associated with recycling LFP batteries compared to the more established NMC recycling practices.
- **The SIB battery chemistry is a nascent and promising technology that brings notable opportunities for the EU, but significant investment is needed to reach full potential**. As China is set to dominate the SIB manufacturing landscape in the coming years, significant investment and strategic support by the EU are needed to make the SIB market in Europe a success.

2 Caliber, 'Europe's Raw Materials Crunch: Struggling to Secure Resources amid Rising Military Needs', 19 juli 2025, https://caliber.az/en/post/europe-s-raw-materials-crunch-struggling-to-secure-resources-amid-rising-military-needs; Frédéric Simon, '"Great News": EU Hails Discovery of Massive Phosphate Rock Deposit in Norway', Energy, Environment & Transport, *Euractiv*, 29 juni 2023, https://www.euractiv.com/section/energy-environment/news/great-news-eu-hails-discovery-of-massive-phosphate-rock-deposit-in-norway/.

Our recommendations for EU policymakers and industrial actors are:

1. **Ensure that the strategic projects on the NMC supply chain move forward as soon as possible.** The high supply chain risks in 2025 can be mitigated by 2030-2035 through the different CRMA strategic projects. In addition, showing that this mechanism works and projects do become operational brings more trust and certainty to investors in the European market.

2. **Invest in risk mitigation measures for the LFP supply chain**, including domestic EU projects and partnerships with other suppliers on both the supply chain resilience and circularity. LFP demand is growing, so more manufacturing capacity should be built in the EU to mitigate long-term risks.

3. **Invest in research and scale up SIB battery chemistries**. Especially for stationary storage, SIB is a fast-growing alternative. This could give the EU a (co-)leadership position in a key technology in the energy transition.

1. Introduction

In the 21st century, two significant trends have altered the geoeconomic landscape. First, geopolitical shifts like the rise of China as a great power, the changing geopolitical priorities of the US towards the Indo-Pacific, and the Russian aggression in Ukraine have had far-reaching implications for the global balance of power. In turn, this has affected the setup of trade relations and global value chains. Countries increasingly prioritise relative national gains at the expense of international collaboration. Trade relations have shifted away from economically efficient global value chains to those designed for greater geopolitical security. The emerging geoeconomic landscape is one of political and economic fragmentation.

Second, the energy transition has been reshaping relations between energy producers and consumers. Unlike the fossil fuel system, in which countries in the Middle East, the United States and Russia dominated world production and maintained leverage towards their consumers, the low-carbon system is differently organised. It depends on critical raw materials (CRM) and the production of clean technologies like wind turbines, solar panels, electrolysers and batteries. In this new system, countries like China, Indonesia, and South Africa dominate production.

These global shifts pose challenges for the European Union (EU) and its technological choices in strategic sectors like batteries. Growing trade tensions, weaponised dependencies and technological competition negatively impact the EU, whose welfare has been shaped by open trade relations and globally integrated value chains. These also affect the bloc's technological choices, particularly in strategic sectors such as batteries.

Batteries are central to the EU's transition to a low-carbon economy. They have two main applications. First, batteries play a vital role in balancing the electricity grid. In a renewable energy system this is essential, given that both solar and wind power are intermittent power sources and have a volatile output. Batteries store excess energy when supply exceeds demand and release it when demand exceeds supply, ensuring a stable and reliable power system. Second, batteries are central to the decarbonisation of road transport. Electric vehicles (EV) are the most promising alternative to internal combustion engines, which from 2035 will no longer be sold on the EU market.[3] Without batteries, the European energy transition cannot be fulfilled.

The effective and secure scale up of batteries in the EU hinges on de-risked supply chains, from the extraction and processing of critical raw materials (CRM), to the production and, later, recycling, of batteries. Each type of battery depends on different combinations of CRM, with different types of vulnerabilities associated with their supply chains. As of 2025, lithium-ion (li-ion) batteries dominate the energy storage market. Li-ion batteries can be produced using different chemistries, the two most widely deployed being the Lithium Nickel Manganese Cobalt Oxide (NMC) and the Lithium Ferro Phosphate (LFP) types.[4] The main

3 'EU Ban on the Sale of New Petrol and Diesel Cars from 2035 Explained', European Parliament, 3 november 2022, https://www.europarl.europa.eu/topics/en/article/20221019STO44572/eu-ban-on-sale-of-new-petrol-and-diesel-cars-from-2035-explained.

4 International Energy Agency, 'Trends in Batteries – Global EV Outlook 2023 – Analysis', IEA, 2023, https://www.iea.org/reports/global-ev-outlook-2023/trends-in-batteries.

CRM used in these batteries are mentioned in the name. Most of these have been added to the EU's 'Critical Raw Materials List' in 2023 due to their high economic importance and potential supply risks. A third battery chemistry that is becoming increasingly relevant is the Sodium Ion Battery (SIB). This battery avoids the use of CRM like lithium, cobalt and (depending on the chemistry) nickel and manganese, CRM which the li-ion batteries are heavily dependent on, thus reducing the supply chain risks.

To have access to these materials, natural resources need to be exploited, ores need to be refined, and highly specialised materials need to be produced and turned into components and final products. In 2025, the EU imports most of the materials and components used for batteries. Despite attempts to build more industrial capabilities by 2030 under the European Critical Raw Materials Act and the Battery Regulation, issues around permitting, industrial competitiveness and social acceptance still hamper the successful development of a European supply chain. This means that, at least in the short term, the bulk of critical raw materials will have to be imported from other continents. Outside of Europe, unfriendly regimes with unstable institutions and/or weak protections for human rights and the environment can pose challenges to the EU's secure and responsible procurement of critical raw materials. Furthermore, the increasing fragmentation of the global trade system has put pressure on supply chains, increasing the likelihood of trade restrictions and price spikes, with the risk of ultimately destabilising European industries that depend on CRM and battery imports.

From these challenges follows the question: What are the geopolitical vulnerabilities associated with the different battery chemistries and how can the EU address these?

In order to answer the question, this paper analyses the geopolitical vulnerabilities arising from the three most widespread battery chemistries as of 2025 – NMC, LFP and SIB. The analysis is two-fold. First, it focuses on the geopolitical vulnerabilities associated with the extraction and processing of eight minerals and draws implications for the three battery chemistries between 2025-2030. Second, it provides an assessment of developments expected at the extraction, processing and manufacturing levels post-2030. This two-part analysis ultimately leads to an assessment of the different vulnerabilities associated with the three battery chemistries before and after 2030. This research informs policymakers in Brussels as well as member states about domestic industrial development plans. It can also support businesses in incorporating geopolitical considerations in their strategic decision-making.

This paper starts by providing insights into the battery sector and the materials used for their manufacturing, resulting in a selection of the most relevant battery chemistries and materials for analysis. After explaining the methodology, the supply chain vulnerability assessment is included in section four. Finally, conclusions and recommendations are developed for European policymakers and industry players to mitigate vulnerabilities associated with current and future battery manufacturing.

2. Battery chemistries and critical raw materials

This section provides an overview of the main battery chemistries used as of 2025, the global distribution of manufacturing capabilities, and the required materials for each chemistry. As explained below, there are three dominant battery chemistries on the market, which are also the focus of this paper: NMC, LFP and SIB. Some of the required materials overlap for different chemistries, but notable differences remain. The material composition for each chemistry is explored in the paragraphs below, leading to a final list of materials to be analysed in the next sections.

2.1. The battery production landscape in 2025

The most used battery systems for EVs and stationary storage are the Nickel Manganese Cobalt (NMC) chemistry and the Lithium-Ferro-Phosphate (LFP) chemistry.[5] The NMC chemistry is more stable and has a slightly larger energy density, meaning that it can store more energy in comparison to other batteries of similar dimensions. This made NMC the preferred option for EVs. The main competitor of the dominant NMC battery chemistry is the burgeoning LFP battery chemistry. One of the main competitive advantages of LFP batteries is their lower cost. LFP-based batteries are on average about 30% cheaper than NMC-based batteries.[6] The split between the chemistries differs by use case. For stationary storage LFP had a market share of 80% in 2023, versus a market share of 40% for EVs in that same year.[7] With advances in LFP manufacturing leading to increased energy density, this gap is quickly closing.[8]

China has established itself as a dominant player across all three battery chemistries, as seen in Table 1. According to the Fraunhofer Institute, in 2023 China dominated both NMC (~65%) and LFP production (~90%) globally. For the NMC chemistry, the dominance of China is projected to diminish considerably in 2030 due to other countries' attempts at de-risking this supply chain, translating into significant investments outside of China.

5 International Energy Agency, 'Trends in Batteries – Global EV Outlook 2023 – Analysis'.

6 BloombergNEF, 'Lithium-Ion Battery Pack Prices Hit Record Low of $139/kWh', Uncategorized, *BloombergNEF*, 26 november 2023, https://about.bnef.com/blog/lithium-ion-battery-pack-prices-hit-record-low-of-139-kwh/.

7 International Energy Agency, 'Executive Summary – Batteries and Secure Energy Transitions – Analysis', IEA, 2024, https://www.iea.org/reports/batteries-and-secure-energy-transitions/executive-summary.

8 McKinsey, 'The future of electric vehicles & battery chemistry', 17 december 2024, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-battery-chemistries-powering-the-future-of-electric-vehicles.

The EU has for the last decade prioritised the buildup of the European battery manufacturing landscape, especially in the NMC chemistry. Countries such as Germany, France, Sweden and Hungary have relevant battery sectors.[9] However, since 2022 several battery companies have decided to downscale their battery production or move their production to the US.[10] Furthermore, one of the largest domestic battery producers in Europe – Northvolt – filed for bankruptcy in early 2025 due to a combination of issues, including quality and a drop in revenue.[11]

The US was expected to play a large role in battery manufacturing following the tax incentives for clean technology production in the Inflation Reduction Act (IRA) of 2022.[12] Nevertheless, the Trump presidency has cast considerable doubt on the state of many clean technology investments in the US due to tariff policies and uncertainty over incentives and policy priorities with regards to the energy transition.[13]

Moreover, China is projected to produce more LFP batteries in 2030 than NMC batteries.[14] For LFP batteries there are also serious plans to scale up production capacity in Europe, like the project between EU-based Stellantis and Chinese CATL to build a large LFP battery factory (up to 50 GWh) in Spain.[15] Still, the dominance of China in 2030 is projected to persist due to the prioritisation of LFP production by Chinese battery manufacturers.[16]

Table 1. Battery production landscape by chemistry in the EU, China and the US in 2024

Chemistry	EU	China	US
NMC[17]	15%	65%	15%
LFP[18]	5%	90%	3%
SIB[19]	1-5%	90-95%	1-5%

9 Transport & Environment, 'An Industrial Blueprint for Batteries in Europe', T&E, 2 juli 2025, https://www.transportenvironment.org/articles/an-industrial-blueprint-for-batteries-in-europe.

10 Alex Janiaud, 'Explainer: The IRA Begins to Attract Overseas Battery Manufacturers to the US', 20 mei 2024, https://www.sustainableviews.com/explainer-the-ira-begins-to-attract-overseas-battery-manufacturers-to-the-us-320ef7a9/.

11 Northvolt, 'Northvolt Files for Bankruptcy in Sweden', 12 maart 2025, https://northvolt.com/articles/northvolt-files-for-bankruptcy-in-sweden/.

12 Rebecca Bellan, 'Tracking the EV Battery Factory Construction Boom across North America', *TechCrunch*, 6 februari 2025, https://techcrunch.com/2025/02/06/tracking-the-ev-battery-factory-construction-boom-across-north-america/.

13 Jonathan Gifford, 'Tariff Uncertainty Grips US Battery Development', *Pv Magazine International*, 24 april 2025, https://www.pv-magazine.com/2025/04/24/tariff-uncertainty-grips-us-battery-development/.

14 Fraunhofer Institute for Systems and Innovation Research, 'Analysis of Global Battery Production: Production Locations and Quantities of Cells with LFP and NMC/NCA Cathode Material', Fraunhofer Institute for Systems and Innovation Research ISI, 12 juni 2023, https://www.isi.fraunhofer.de/en/blog/themen/batterie-update/globale-batterieproduktion-analyse-standorte-mengen-zellen-lfp-nmc-nca-kathoden.html.

15 Cora Werwitzke, *Stellantis & CATL Officially Confirm LFP Battery Cells Plant in Spain - Electrive.Com*, Battery, 10 december 2024, https://www.electrive.com/2024/12/10/stellantis-catl-official-confirm-plant-for-lfp-battery-cells-in-spain/.

16 Fraunhofer Institute for Systems and Innovation Research, 'Analysis of Global Battery Production'.

17 Fraunhofer Institute for Systems and Innovation Research, 'Analysis of Global Battery Production'.

18 Fraunhofer Institute for Systems and Innovation Research, 'Analysis of Global Battery Production'.

19 Statista, 'Na-Ion Batteries Capacity Forecast by World Region', Statista, september 2023, https://www.statista.com/statistics/1417860/sodium-ion-capacity-forecast-by-region-worldwide/.

A smaller but rising share of battery manufacturing can be attributed to the emerging Sodium Ion Battery (SIB) chemistry.[20] Their main benefit is the substitution of lithium by natrium as a cathode material and an electrolyte (in solvent form). Natrium chloride (salt) is inexpensive and abundantly available across the globe, making it an attractive option for low-cost batteries.

SIB is the smallest of the three in terms of global share of the battery market, with only 4% in 2023, but the production numbers are expected to grow.[21] The estimates for sodium ion production capacity in 2030 have increased sharply between 2023 and 2024, from 150 GWh to an expected 335.4 GWh.[22] This is a significant increase from the current capacity of around 50 GWh, but still relatively small compared to the global lithium-ion battery market, which is estimated at around 6,700 GWh in 2030.[23] With the first large scale factories producing SIB in China, the US and Europe, the chemistry is poised to become an important technology, especially in the stationary storage field.[24]

China was home to around 90-95% of sodium-ion battery factories in 2024, with the EU and the US both capturing a share of between 1-5% (see Table 1). BYD is currently building the largest project with a 30 GWh SIB factory in Xuzhou.[25] Other Chinese companies are also operating large-scale projects, like CATL expecting 20 GWh in 2030 and HiNa, 5 GWh. Investments outside of China are not as significant but include Natron Energy (24 GWh) and Acculon (2 GWh) in the US, and Tiamat (5 GWh in 2029), Moll Batterien (5GWh in 2027) and the Altris pilot plant in the EU.[26] Neither the EU nor the US had any gigawatt-scale battery factories in 2024.

Besides the three above-mentioned chemistries, alternatives include lead-acid, Nickel-Cobalt-Aluminium (NCA), Nickel-Ferro-Aluminium (NFA), Lithium Manganese Rich (LMR), solid-state and flow batteries. The lead-acid battery chemistry, the first rechargeable battery ever invented and the most widely used one, maintains a large global market value but is used less and less for EVs and stationary storage due to lower energy density and higher

20 Fraunhofer Institute for Systems and Innovation Research, 'Analysis of Global Battery Production'.

21 Statista, 'Na-Ion Batteries Capacity Forecast by World Region'.

22 PV Magazine, 'Sodium-Ion Batteries – a Viable Alternative to Lithium?', *Pv Magazine International*, 22 maart 2024, https://www.pv-magazine.com/2024/03/22/sodium-ion-batteries-a-viable-alternative-to-lithium/.

23 International Energy Agency, 'Lithium-Ion Battery Manufacturing Capacity, 2022-2030 – Charts – Data & Statistics', IEA, 22 mei 2023, https://www.iea.org/data-and-statistics/charts/lithium-ion-battery-manufacturing-capacity-2022-2030.

24 Business Wire, 'Natron Energy Achieves First-Ever Commercial-Scale Production of Sodium-Ion Batteries in the U.S.', 29 april 2024, https://www.businesswire.com/news/home/20240428240613/en/Natron-Energy-Achieves-First-Ever-Commercial-Scale-Production-of-Sodium-Ion-Batteries-in-the-U.S.
Marija Maisch, 'New Sodium-Ion Developments from CATL, BYD, Huawei', *Energy Storage*, 28 november 2024, https://www.ess-news.com/2024/11/28/new-sodium-ion-developments-from-catl-byd-huawei/.
'Pioneering Work for Europe', https://moll-batterien.de/en-gb/news/02-news/pioneering-work-for-europe.

25 Cameron Murray, 'BYD Launches Sodium-Ion Grid-Scale BESS Product', *Energy-Storage.News*, 27 november 2024, https://www.energy-storage.news/byd-launches-sodium-ion-grid-scale-bess-product/.

26 Marija Maisch, 'Acculon Launches Production of Sodium-Ion Battery Modules, Packs', *Pv Magazine International*, 11 januari 2024, https://www.pv-magazine.com/2024/01/11/acculon-launches-production-of-sodium-ion-battery-modules-packs/.
Sam Krampf, 'Top Global Leaders in Sodium-Ion Battery Technology', *SodiumBatteryHub*, 15 november 2024, https://sodiumbatteryhub.com/2024/11/15/top-global-leaders-in-sodium-ion-battery-technology/.
Ennes en Ennes, 'Sodium Ion Set to Impact Thriving US Battery Market'.
Randall Randall, *Tiamat to Build a 5 GWh Factory for Sodium-Ion Batteries in France - Electrive.Com*, Battery, 12 januari 2024, https://www.electrive.com/2024/01/12/tiamat-to-build-a-5-gwh-factory-for-na-ion-batteries-in-france/.
Lei Kang, 'World's First GWh-Class Sodium-Ion Battery Production Line Sees First Product off Line', *CnEVPost*, 2 december 2022, https://cnevpost.com/2022/12/02/hina-gwh-sodium-ion-battery-production-line-first-product/.
'Pioneering Work for Europe'.

environmental costs.[27] NCA, NFA and LMR batteries are relatively similar to the NMC chemistry in terms of raw materials used and can therefore be considered variants of the NMC chemistry.[28] Finally, solid-state and flow batteries have not yet reached full commercial maturity.[29] Therefore, these chemistries are not taken into consideration in this analysis.

2.2. Critical raw materials in NMC, LFP and SIB batteries

This section maps the chemical composition of the three battery chemistries selected for analysis. This is restricted to the raw materials that are used for the cathode (the part of the battery that attracts electrons and sends an electrical current), anode (the part of the battery that sends electrons and receives the electrical current) and electrolytes (the material that makes it possible for electrons to flow between the two parts). Although battery cells and packs contain additional materials such as copper and aluminium, these materials fulfil the same function (wiring, casing), regardless of the specific cathode-anode chemistry.[30] Since they do not impact the comparative analysis of the three batteries, they are left out of the analysis.

The materials used in NMC chemistries are shown in Table 2. The cathode of NMC batteries consists of lithium nickel-manganese-cobalt oxides. Lithium electrolytes move electrons from the anode to the cathode. For the anode, the most commonly used materials are graphite and silicon, with the former being the industry standard.[31]

Table 2. Raw materials used in the NMC battery chemistry[32]

NMC Battery Chemistry	
Battery component	**Raw Materials**
Cathode	Lithium, Nickel, Manganese, Cobalt
Anode	Graphite

27 Ryutaka Yudhistira e.a., 'A comparative life cycle assessment of lithium-ion and lead-acid batteries for grid energy storage', *Journal of Cleaner Production* 358 (juli 2022): 131999, https://doi.org/10.1016/j.jclepro.2022.131999; 'Lead Acid Battery - an overview | ScienceDirect Topics', https://www.sciencedirect.com/topics/engineering/lead-acid-battery.

28 Maria Guerra, 'Why GM Is Betting on LMR Battery Technology', 13 mei 2025, https://www.batterytechonline.com/lithium-ion-batteries/why-gm-is-betting-on-lmr-battery-technology.

29 Marija Maisch, 'New Sodium-Ion Developments from CATL, BYD, Huawei', *Energy Storage*, 28 november 2024, https://www.ess-news.com/2024/11/28/new-sodium-ion-developments-from-catl-byd-huawei/.

30 There are some notable exceptions, such as in some SIB batteries, where aluminium can be used instead of copper as a current collector.

31 Alex K. Koech e.a., 'Lithium-ion battery fundamentals and exploration of cathode materials: A review', *South African Journal of Chemical Engineering* 50 (oktober 2024): 321-39, https://doi.org/10.1016/j.sajce.2024.09.008.

32 AquaMetals, 'What Are Battery Anode and Cathode Materials?', *AquaMetals*, 26 april 2023, https://www.aquametals.com/recyclopedia/lithium-ion-anode-and-cathode-materials/.

The LFP chemistry is based on lithium-iron-phosphate oxides in the cathode, as seen in Table 3. The main difference between NMC and LFP is the usage of different types of iron-phosphates, -oxalates and -oxides as an input for production.[33] Finally, phosphate – often in the form of phosphoric acid, ammonium dihydrogen phosphate or iron-phosphate – is used as an input, completing the LFP cathode. Variations of the LFP chemistry exist, such as the lithium iron manganese phosphate (LFMP) chemistry and the lithium cobalt phosphate (LCP) chemistry.[34] However, these are less common and will not be considered in this analysis. LFP chemistries generally use graphite as the anode material, although researchers are also studying the possible benefits of replacing it with silicon.[35]

Table 3. Raw materials used in the LFP battery chemistry

LFP ($LiFePO_4$) Battery Chemistry	
Battery component	**Raw Materials**
Cathode	Lithium, Iron, Phosphate Rock
Anode	Graphite

SIB batteries involve a large variety of possible chemistries, out of which three main categories emerged: sodium-ion layered oxides (with natrium-nickel manganese cathode), Prussian blue analogues (with natrium-iron-carbon-nitrogen cathode) and phosphate-based polyanionic compounds (with natrium-iron-phosphate cathode).[36] These three are also selected for the analysis, as seen in Table 4. Industry developments suggest that natrium-nickel-manganese oxides are most common, alongside natrium-iron-phosphate polyanions.[37] The natrium-manganese-phosphate oxides chemistry is also being considered, although it suffers from several technical challenges as well as higher costs due to the presence of pricier manganese.[38]

There is also considerable interest for the Prussian Blue Analogues (PBA) chemistry, due to its potential simplicity, large storage potential and possibility of using inexpensive materials for the cathode. The natrium-iron-carbon-nitrogen compound has been mentioned as a

33 Yanying Lu en Tianyu Zhu, 'Status and Prospects of Lithium Iron Phosphate Manufacturing in the Lithium Battery Industry', *MRS Communications* 14, nr. 5 (2024): 888-99, https://doi.org/10.1557/s43579-024-00644-2.

34 Donguk Kim e.a., 'Boosting both electronic and ionic conductivities via incorporation of molybdenum for LiFe0.5Mn0.5PO4 cathode in lithium-ion batteries', *Journal of Alloys and Compounds* 989 (juni 2024): 174396, https://doi.org/10.1016/j.jallcom.2024.174396.
Jessica Manzi en Sergio Brutti, 'Surface chemistry on LiCoPO4 electrodes in lithium cells: SEI formation and self-discharge', *Electrochimica Acta* 222 (december 2016): 1839-46, https://doi.org/10.1016/j.electacta.2016.11.175.

35 Binke Li e.a., 'Enabling high-performance lithium iron phosphate cathodes through an interconnected carbon network for practical and high-energy lithium-ion batteries', *Journal of Colloid and Interface Science* 653 (januari 2024): 942-48, https://doi.org/10.1016/j.jcis.2023.09.133.

36 Yujie Yang e.a., 'Prussian blue and its analogues as cathode materials for Na-, K-, Mg-, Ca-, Zn- and Al-ion batteries', *Nano Energy* 99 (augustus 2022): 107424, https://doi.org/10.1016/j.nanoen.2022.107424.

37 Adrian Yao e.a., 'Critically assessing sodium-ion technology roadmaps and scenarios for techno-economic competitiveness against lithium-ion batteries | Nature Energy', 13 januari 2025, https://www.nature.com/articles/s41560-024-01701-9.

38 Wenhua Zuo e.a., 'Layered Oxide Cathodes for Sodium-Ion Batteries: Storage Mechanism, Electrochemistry, and Techno-economics', *Accounts of Chemical Research* 56, nr. 3 (2023): 284-96, https://doi.org/10.1021/acs.accounts.2c00690.

promising PBA cathode material.[39] If we look at commercial development: US-based Natron Energy and China-based CATL use the Prussian Blue Analogy chemistry for their new battery types.[40] Swedish company Altris AB is developing the Prussian White variant of this chemistry.[41]

In nearly all instances, SIB use Hard Carbon as an anode material instead of the more traditional graphite used in NMC and LFP batteries.[42]

Table 4. Raw materials used in the SIB battery chemistry

SIB Battery Chemistry[43]		
Battery component	**Chemistry**	**Raw Materials**
Cathode	Sodium ion layer oxides[44]	Natrium (Salt) + Transition Metal (Titanium/Vanadium/ Chromium/Manganese, Iron, Cobalt, Nickel and Copper)[45] + Oxide
	Phosphate-based polyanionic compounds	Natrium, Phosphate Rock, Iron, Manganese, Vanadium, Cobalt
	Prussian blue analogues (PBAs) / Prussian White	Natrium, Iron, Carbon, Nitrogen[46]
Anode		Hard Carbon, Soft Carbon

[39] Yang Xiao e.a., 'Prussian Blue Analogues for Sodium-Ion Battery Cathodes: A Review of Mechanistic Insights, Current Challenges, and Future Pathways', *Small* 20, nr. 35 (2024): 2401957, https://doi.org/10.1002/smll.202401957.
Yifan Huang e.a., 'Modification of Prussian blue analogues as high-performance cathodes for sodium-ion batteries', *Chemical Engineering Journal* 499 (november 2024): 156410, https://doi.org/10.1016/j.cej.2024.156410.

[40] Cameron Murray, 'Upstream: Prussian Blue Production for Natron Sodium-Ion Batteries Starts; Mitra Chem Hires Bechtel to Design LFP Cathode Facility in US', *Energy-Storage.News*, 19 oktober 2022, https://www.energy-storage.news/upstream-prussian-blue-production-for-natron-sodium-ion-batteries-starts-mitra-chem-hires-bechtel-to-design-lfp-cathode-facility-in-us/.
'Beyond the Lithium-Ion Battery: A Look Into China's Sodium-Ion Boom', Powerhouse, geraadpleegd 19 mei 2025, https://www.powerhouse.fund/beyond-the-lithium-ion-battery.

[41] 'Altris 2.0', https://www.altris.se/news/altris-presents-world-leading-prussian-white-cathode-material.

[42] Yao e.a., 'Critically assessing sodium-ion technology roadmaps and scenarios for techno-economic competitiveness against lithium-ion batteries | Nature Energy'.

[43] Lu en Zhu, 'Status and Prospects of Lithium Iron Phosphate Manufacturing in the Lithium Battery Industry'.

[44] FutureBatteryLab, *The Big Beginner's Guide to Sodium-Ion Batteries – FutureBatteryLab*, 28 januari 2024, https://futurebatterylab.com/the-big-beginners-guide-to-sodium-ion-batteries/.

[45] Hanqing Gao e.a., 'Advances in layered transition metal oxide cathodes for sodium-ion batteries', *Materials Today Energy* 42 (juni 2024): 101551, https://doi.org/10.1016/j.mtener.2024.101551.

[46] Muhammad Fayaz e.a., 'Prussian blue analogues and their derived materials for electrochemical energy storage: Promises and Challenges', *Materials Research Bulletin* 170 (februari 2024): 112593, https://doi.org/10.1016/j.materresbull.2023.112593.

The complete list of materials analysed in this paper is shown in Table 5 below.

Table 5. Raw materials analysed in this paper and their use in NMC, LFP and SIB battery chemistries. 'x' means that the material is always used in the chemistry.

Material	NMC	LFP	SIB		
			Sodium ion layer oxides	Phosphate-based polyanionic compounds	Prussian blue analogues / Prussian White
Cobalt	×				
Iron / Steel		×		×	×
Lithium	×	×			
Manganese	×		×		
Natrium (Salt)			×	×	×
Natural Graphite	×	×			
Nickel	×		×		
Phosphate rock / Phosphorous		×		×	

Note: This analysis takes into account some materials that are not Critical Raw Materials, such as iron and salt, due to their importance in battery manufacturing.

3. Methodology

Three main battery chemistries have been chosen for the geopolitical risk analysis based on the assessment in the previous section – NMC, LFP and SIB. Other chemistries were excluded because their market size or potential were limited compared to these main three chemistries.

To establish the geopolitical risks for battery manufacturing in Europe up to 2030, a two-step supply chain analysis will be used. First, mapping the supply chain of raw and processed materials will provide insight into the relative position of states/regions with regards to the battery materials space. Based on this mapping, geopolitical relations are analysed between the EU and countries that dominate production capabilities in different parts of the supply chain. This offers insights into the geopolitical vulnerabilities of different battery materials for Europe. In the second step, vulnerability scores are calculated per chemistry by averaging individual material scores. This results in a vulnerability assessment per battery chemistry.

After that, the paper also takes into account developments that would point to an increase in the EU's industrial capabilities for extracting and processing materials as well as manufacturing batteries, in line with policies like the Critical Raw Materials Act and the Battery Regulation.

This pre- and post-2030 assessment helps conduct a comparative analysis between the three battery chemistries. It is used to develop recommendations for European policymakers and industrial actors to reduce geopolitical risks and increase resilience in its emerging battery industry. The methodology is described in more detail below.

3.1. Assessing material vulnerabilities for battery chemistries 2025-2030

This paper analyses the geopolitical risks associated with the supply chains of eight materials[47] used in NMC, LFP and SIB battery chemistries, as explained in the previous section.

In order to assess the likelihood of geopolitical disruption in these value chains and give insights into which battery chemistries currently pose the highest risks, the framework below is applied. This framework has been applied in previous HCSS work on critical raw materials supply chains in 2025.[48]

47 These are materials of mineral origin. Synthetic or bio-based materials are excluded as their supply chains are different than those of minerals, primarily because they are not so strongly geographically bound, meaning that the geopolitical vulnerabilities are not comparable.

48 Irina Patrahau en Benedetta Girardi, 'Raw Material and Supply Chain Vulnerabilities in the Dutch Defence Sector: An Analysis of the Air Defence & Command Frigate', *HCSS*, 2025, https://hcss.nl/report/raw-material-supply-chain-vulnerabilities-dutch-defence-sector-frigate/.

Table 6. Framework to assess the likelihood of disruption in raw material supply chains

	Indicator	Guiding question	Measurement of indicator	Data
SUPPLY CHAIN	**Supply concentration**	To what extent is global supply geographically concentrated?	Market share (%) of top three global producing countries (extraction and processing)	EU Study on the CRM list 2023
	Recyclability	What percentage of (European) demand can be supplied with secondary materials?	End of Life Recycling Input Rate	EU End of Life Recycling Input Rate (EoL-RIR) (Annex 1)
	Substitutes	Are there available substitutes to the material?	Substitution score	EU Substitution Index for supply risk (Annex 5 SR)
GEOPOLITICAL RELATIONS	**Supplier country stability**	To what degree are the top global suppliers stable countries or located in stable countries?	Fragile State Index (FSI) score	Fragile States Index
	Economic relationship with suppliers	What is the economic relationship between top global suppliers and the Netherlands/EU?	Trade Intensity score	Trade Intensity Index from the World Integrated Trade Solution platform of the World Bank
			Trends in bilateral foreign direct investment flows; (Regional) Investment strategies; (Content of) existing trade deals; Discourse of officials; Export controls/bans	Qualitative
	Political relationship with suppliers	To what extent can the top 3 suppliers realise its desired outcomes in the international system?	Global Power Index (GPI)	Global Power Index
		To what extent can the Netherlands influence the top 3 suppliers?	Relational power in the international system	Pardee Formal Bilateral Influence Capacity Index
		What is the political relationship between top global suppliers and the Netherlands/EU?	Regional strategies; Government official discourse; Political stability in both States (shift in domestic Political situation can result in different bilateral relations); Cooperation in global fora between States; Historical relations	Qualitative
	Military relationship with suppliers	What is the military relationship between top global suppliers and the Netherlands/EU?	Arms trade; Ongoing conflicts, Military alliances; Military exercises	Qualitative

The likelihood of disruption for each material is assessed by assigning scores from 1 to 3 to various indicators (with 1 indicating a low likelihood of disruption and 3 indicating a high likelihood). A weighted average is calculated as follows:

1. **Supply Chain Vulnerability**: Indicators were scored from 1 to 3, and an average score was calculated to represent overall supply chain vulnerability.

2. **Geopolitical Relations**: Indicators were scored from 1 to 3. These scores are then weighted according to the country's share of global production. For example, if Country X accounts for 70% of global production, its geopolitical score contributes 70% to the overall geopolitical vulnerability score.

3. The overall likelihood of disruption for each material was determined by averaging the supply chain and geopolitical vulnerability scores.

In cases where the material's supply chain is diversified across multiple producers, the material is considered to have a very low likelihood of disruption, and a score of 1 was automatically provided.

Finally, for each battery chemistry, an average vulnerability score is calculated by taking into account the scores of all minerals used in the manufacturing process.

3.2. **Outlook post-2030**

The pre-2030 analysis will be augmented by data about expected CRM capabilities by 2030, battery manufacturing and the growth potential of the chemistry. The analysis takes into account the 47 strategic projects announced as part of the CRM Act in the EU and assesses their potential of reducing EU dependencies on CRM efforts and thus reduce geopolitical vulnerabilities. It also looks at projections of battery manufacturing capacity in the EU. Taken together, this information provides a well-rounded perspective on the expected geopolitical vulnerabilities of each battery chemistry moving forward.

4. Geopolitical risks to the EU battery industry

4.1. Critical raw materials & battery chemistries 2025-2030

Based on the methodology presented in section three, the likelihood of supply disruption up to 2030 has been assessed for eight materials. The results are displayed in Table 7. The score is primarily driven by the relationship between European countries and the main suppliers of the materials, reflecting both their ability and willingness to disrupt supplies to the EU. An aggregate score is calculated for each battery chemistry to allow for comparison. The assessments are summarised below.

Critical raw materials

A key driver of a high likelihood of disruption is China's dominance in the supply chains, especially in the processing phase. This tends to be a larger bottleneck than mining in supply chains. Even though materials like lithium, manganese, cobalt, iron and nickel are mined across the world in the United States, Australia, South Africa, the Democratic Republic of Congo and Indonesia, most of them are exported to China to be processed. As seen in Table 7, China holds more than 50% of the global processing markets for all of these materials. Over-reliance on Chinese production is particularly problematic due to the growing economic, political and security tensions between the EU and China. This makes China not only able but also willing to use CRM as tools of geopolitical influence. The Chinese government has used this weapon over time, starting in 2010 in the dispute with Japan over rare earth elements, and especially since 2022 in the trade conflict with the United States. This conflict has affected the EU as well, as Chinese export controls are typically country-agnostic.

Table 7. Results of the assessment of the likelihood of supply disruption per material and top global producers

Material	Score	Part of 2023 EU CRM list	Top producers of raw materials (2023)	Top producers of processed materials (2023)
Natural Graphite	2,59	Yes	China 67% Brazil 8% Mozambique 5%	China 100%
Phosphate rock / Phosphorous	2,38	Yes	China 43.6% Morocco 14.2% United States 9.5%	China 78.5% United States 10.6% Kazakhstan 6.4%
Lithium	2,04	Yes	Australia 53% Chile 24,1% China 10,2%	China 56,2% Chile 32,1% Argentina 10,5%
Manganese	2,04	Yes	South Africa 29,3% Australia 16,3% Gabon 14,4%	China 58,2% India 13,1% Ukraine 4,4%
Cobalt	1,95	Yes	Democratic Republic of Congo 62,8% Russia 6,6% Canada 4,1%	China 59,6% Finland 11,4% Belgium 5,3%
Iron / Steel	1,94	No	Australia 37% Brazil 18% China 15%	China 52% India 6% Japan 6%
Nickel	1,90	Yes	Indonesia 26% Philippines 14% Russia 10%	China 33% Indonesia 12% Japan 9%
Natrium (Salt)	Very low risk / no score calculated	No		

Out of the battery materials analysed in this paper, natural graphite has already been affected by export barriers since 2022, showing the EU's vulnerability to dependence on China. China has a dominance over the extraction and processing of natural graphite. This includes spherical natural graphite, a highly purified form that is used in batteries. The EU has no capability of producing spherical graphite.[49] In addition, China dominates the supply of synthetic graphite, which is a key potential substitute for natural graphite in batteries.

Furthermore, the phosphate rock supply chain shows considerable vulnerabilities. LFP batteries need a very pure form of phosphoric acid, called purified phosphoric acid (PPA). Only a relatively small percentage of phosphate rock is suitable to be converted into PPA.[50] Currently, about 5% of PPA is used for the automotive sector. This percentage is expected to increase to 24% by 2030.[51] Nevertheless, within the phosphate mining sector it is expected that shortages could start as early as 2026.[52]

49 Jeff Amrish Ritoe e.a., *Graphite: Supply Chain Challenges & Recommendations for a Critical Mineral* (The Hague Centre For Strategic Studies, 2022), https://hcss.nl/report/graphite-supply-chain-challenges-recommendations-for-a-critical-mineral/.

50 Bruno Venditti, 'Phosphate Shortage Could Disrupt LFP Market as Early as 2026, Says First Phosphate CEO', *MINING.COM*, 6 juni 2023, https://www.mining.com/phosphate-shortage-could-disrupt-lfp-market-as-early-as-2026-says-first-phosphate-ceo/.

51 Benchmark Mineral Intelligence, 'More Phosphoric Acid Refining Capacity Needed as LFP Demand Increases', Benchmark Source, 4 oktober 2023, https://source.benchmarkminerals.com/article/more-phosphoric-acid-refining-capacity-needed-as-lfp-demand-increases.

52 Venditti, 'Phosphate Shortage Could Disrupt LFP Market as Early as 2026, Says First Phosphate CEO'.

Lithium, manganese and cobalt have been assessed with a similar likelihood score for supply chain disruption. Lithium has a relatively concentrated market, with Australia leading extraction followed by Chile. Australia is a key economic, political and military partner of European countries. In 2023, Chile became the first country in Latin America to sign an Advanced Framework Agreement with the EU, updating their 2002 Association Agreement.[53]

The EU is also investing in the stability of its relation with South Africa, the largest supplier of manganese. The EU is South Africa's first investment and trade partner, despite the country's simultaneous cooperation with other important power blocs under BRICS (Brazil, Russia, India, China, South Africa).

In the case of cobalt, the main producer is the Democratic Republic of Congo (DRC), whose relations with the EU have been advancing especially in the raw materials sector. The EU and DRC have signed a strategic partnership on sustainable raw materials value chains in 2023 and have been co-developing the Lobito economic corridor to enhance connectivity between the DRC's 'copper belt' and the Angolan port of Lobito.[54] Still, the DRC's internal instability and institutional weakness can negatively affect its ability to export materials. Lithium, manganese, and cobalt are therefore extracted in countries with whom the EU either already has really close relations or has been building them.

The processing of lithium, manganese and cobalt is a larger vulnerability as it takes place primarily in China, increasing the likelihood of disruption. The EU has 100% dependence on imported processed lithium, which is a key vulnerability for its emerging battery market.[55] Both lithium and manganese supply chains are therefore at risk of disruption.

Other materials like iron and nickel have lower likelihood of disruption due to a largely diversified supply base, strong domestic capabilities in Europe and relatively high end-of-life recycling rate. Iron is one of the largest global markets with enormous quantities being produced, traded and consumed on a daily basis. Even though the EU's import dependency for iron ore is 71%, most of it is processed into steel in Europe. This is also why iron ore is not on the CRM list. Still, China dominates more than 50% of global processing. If the EU's demand for steel grows faster than its production capabilities, thus relying in higher proportions on imports, this could turn into a vulnerability. The supply chain of nickel is also dominated by China, but its market share is relatively low. Europe also has quite some extraction capabilities and only imports 35% of its consumption. However, processing facilities are less developed, leading to an import dependency of 75%. As such, even though nickel and iron have a relatively lower disruption likelihood, there are still vulnerabilities that should be monitored and mitigated.

Finally, no score was calculated for salt given the wide geographical spread of production capabilities. In addition to China, the United States and India being the largest global producers, many European countries like Germany, the Netherlands and Poland have strong salt production capabilities. Much of this salt is produced and consumed domestically, meaning that import dependency is very low. The main consumer of salt in Europe is the chemical industry (more than 50% of the total), followed by de-icing (17.3%) and food (7%).[56] Geopolitical disruptions in the salt supply chains thus have a lower likelihood of disruption of European markets.

53 'EU-Chile Partnership', European External Action Service, 2023, https://www.eeas.europa.eu/eeas/eu-chile-partnership_en.

54 'Democratic Republic of Congo', European Commission, 2025, https://international-partnerships.ec.europa.eu/countries/democratic-republic-congo_en.

55 Bryan Bille, *Increasing Lithium Supply Security for Europe's Growing Battery Industry: Recommendations for a Resilient Supply Chain* (2024), https://hcss.nl/report/lithium-supply-security-europe-battery-industry/.

56 'EUsalt Roadmap 2024', EUsalt, 2024, https://eusalt.com/about/eusalt-roadmap/.

Battery chemistries

When combining the vulnerability analysis for each material in the battery chemistries, a general vulnerability score can be deduced. The results of the analysis can be found in Table 8.

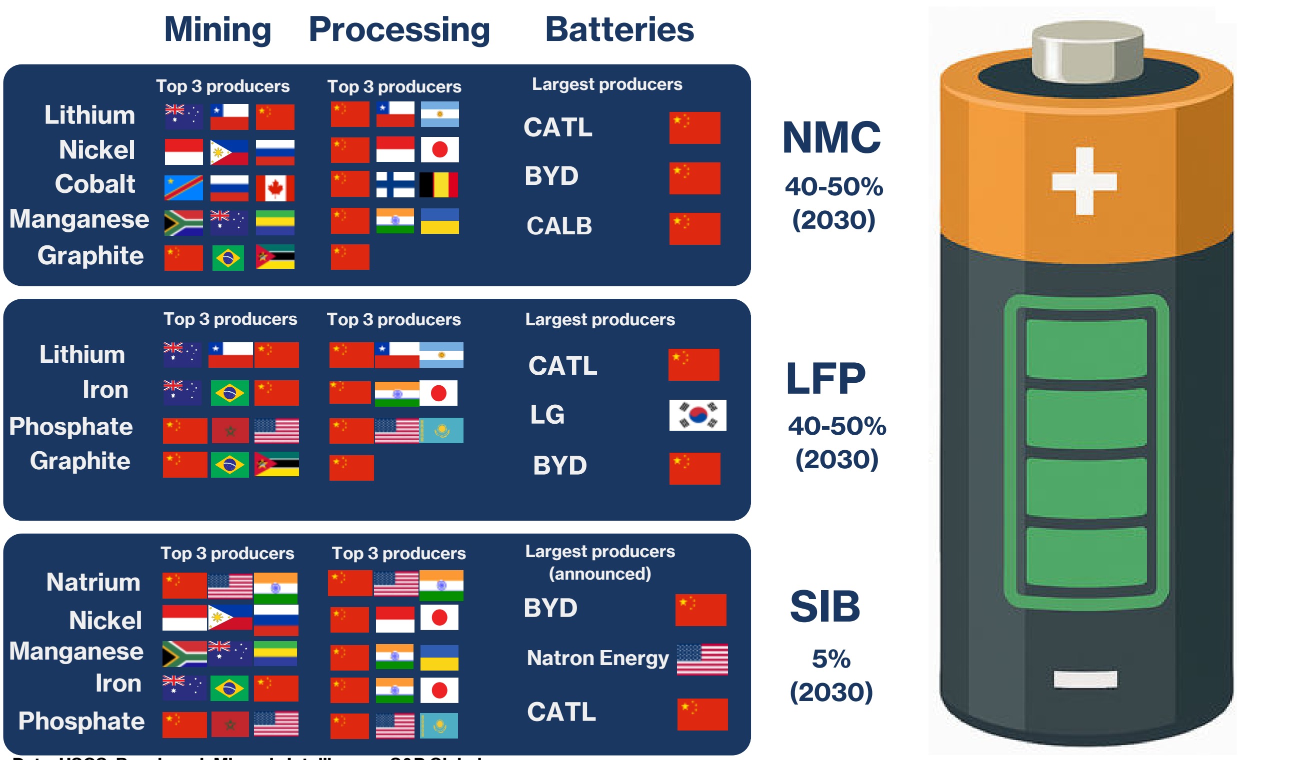
Table 8. Aggregate vulnerability scores per battery chemistry

Material	NMC	LFP	SIB		
			Sodium ion layer oxides	Phosphate-based polyanionic compounds	Prussian blue analogues / Prussian White
Cobalt	1.95				
Iron / Steel		1.94		1.94	1.94
Lithium	2.04	2.04			
Manganese	2.04		2.04		
Natrium (Salt)			1	1	1
Natural Graphite	2.59	2.59			
Nickel	1.90		1.90		
Phosphate rock / Phosphorous		2.38		2.38	
Total	**2.10**	**2.24**	**1.62**	**1.77**	**1.47**

The scores show that both NMC and LFP batteries have considerable vulnerabilities associated with their mineral supply chains, with LFP potentially incurring slightly more vulnerabilities. This is also shown in Figure 1. Although LFP uses less types of critical raw materials, the processing of phosphate rock and graphite, which are essential, are still highly concentrated in China. The downstream use of the battery minerals in production facilities is also highly concentrated in China, especially for LFP chemistries. In July 2025, the Chinese government restricted the export of preparation technologies for LFP materials used in batteries, showing the high vulnerability faced by the EU in this market.[57]

[57] Liu, John. 'China Puts New Restrictions on EV Battery Technology in Latest Move to Consolidate Dominance | CNN Business'. CNN, 17 July 2025. https://www.cnn.com/2025/07/17/business/china-new-export-controls-ev-battery-intl-hnk.

Figure 1. Battery Supply Chain by Chemistry



Data: USGS, Benchmark Minerals Intelligence, S&P Global

The assessment also shows that SIB contain more abundant raw materials (natrium) and less materials with high geopolitical vulnerabilities. This means that inputs for these battery minerals are easier to procure. This translates into a lower vulnerability score. China remains by far the most dominant on the SIB battery production landscape, meaning that the few budding EU-based SIB producers will have formidable competition in the scaling up of SIB production. Furthermore, it is projected that the sodium ion layer oxides chemistry will be the most common manufactured SIB variant.[58] This chemistry still contains two critical raw materials – nickel and manganese – which means that dependence on China for these materials will persist.

4.2. Outlook for battery minerals and manufacturing post-2030

Recognising its current vulnerabilities, the EU is making significant efforts to increase its domestic industrial capabilities in CRM value chains, among which is the battery sector. According to the Critical Raw Materials Act (CRMA), the EU aims to expand material extraction to 10% of its consumption, processing to 45%, and recycling to 25% by 2030.[59]

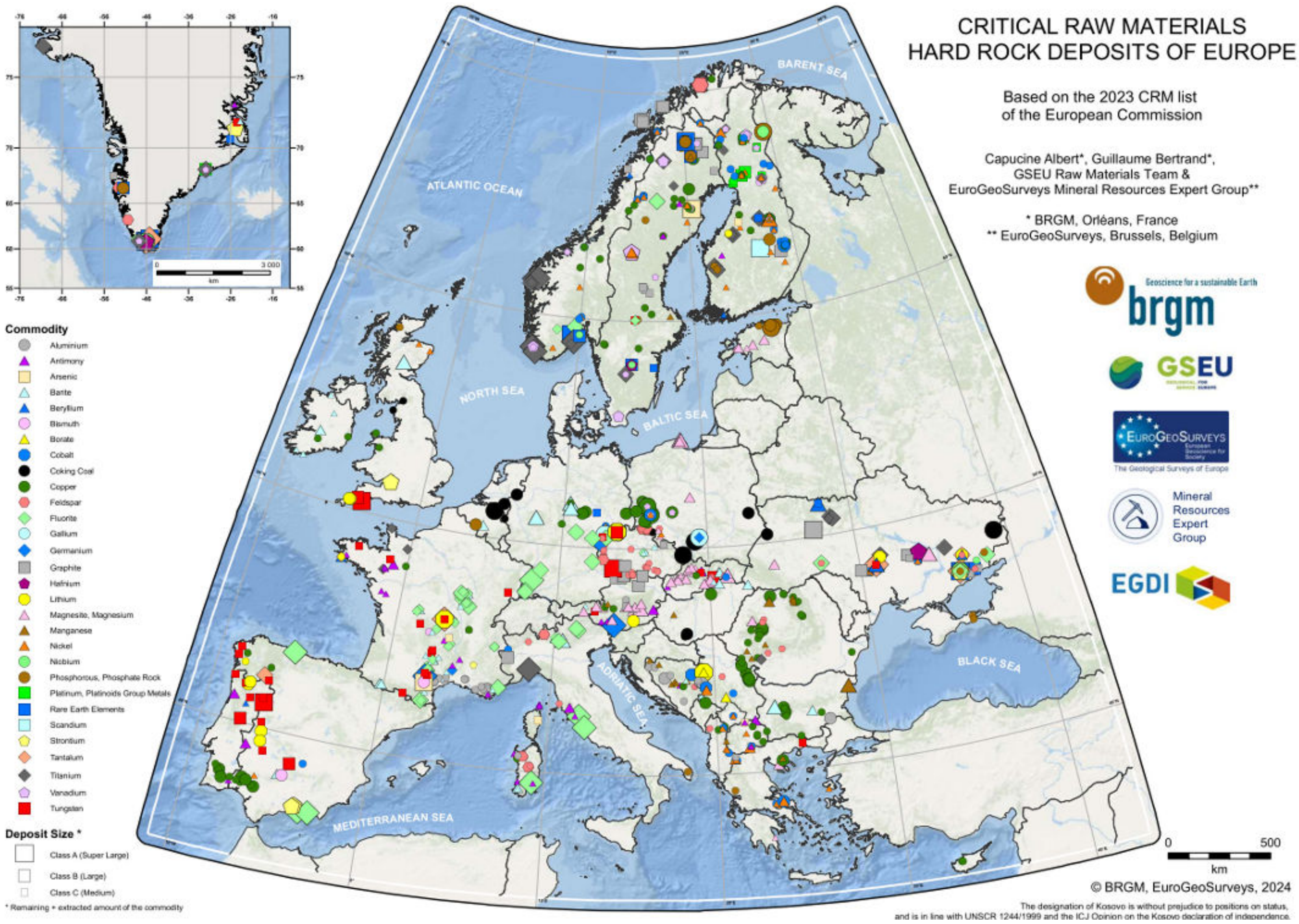
58 Benchmark Mineral Intelligence, 'Sodium Ion 2030 Pipeline Capacity Hits 150 GWh as Cathode Trends Emerge', Benchmark Source, 5 mei 2023, https://source.benchmarkminerals.com/article/sodium-ion-2030-pipeline-capacity-hits-150-gwh-as-cathode-trends-emerge.

59 European Commission, 'Critical Raw Materials Act', 3 mei 2024, https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en.

The EU Battery Regulation also mandates common EU standards for lifecycle emissions, recycled content, performance and safety.[60]

The expansion of material extraction in the EU is dependent on the reserves available within its own borders. In comparison to other geographies, the EU has relatively little reserves of battery materials, but some of these can still be exploited. Figure 2 shows an overview of Europe's CRM hard rock deposits. Scandinavian countries have a significant concentration of deposits, especially for cobalt, graphite and copper. Spain and France have notable lithium reserves, while Romania and Poland have copper. Austria and the Czech Republic could moreover exploit graphite reserves.

Figure 2. Critical raw materials hard rock deposits in Europe.
Source: EuroGeoSurveys, 2024[61]



60 The European Parliament en Council of the European Union, 'Regulation - 2023/1542 - EN - EUR-Lex', 12 juli 2023, https://eur-lex.europa.eu/eli/reg/2023/1542/oj/eng.

61 Geological Service for Europe, 'European Critical Raw Materials', december 2024, https://www.geologicalservice.eu/upload/content/1753/egs_gseu_all_crm_maps.pdf.

Many conditions must be fulfilled between having a reserve and an operating mine. In the EU, issues like permitting, competitiveness and public opinion make it difficult to open and operate mines. To overcome some of these issues, the European Commission selected 47 strategic projects under the CRM Act. These projects will get prioritised at European and national level to start operating as soon as possible and contribute to the CRM Act 2030 benchmarks. The full list of projects is included in Annex 1.

Table 9 shows the EU's import dependence on raw materials and processed materials as well as the strategic projects expected to materialise by or post 2030 in these two parts of the supply chain. This gives an indication of the potential for the import dependence to be reduced in the coming years, even though these projects would not ensure total independence. The expected size and output of each project are not yet entirely clear, but give an indication of the EU's policy priorities. Moreover, the most recent end-of-life recycling rate of each material is compared to the number of strategic projects for recycling to assess the extent to which secondary materials will contribute to a reduction in primary material imports post 2030.

Table 9. The EU's import dependence on battery materials as of 2023 and announced projects for 2030 benchmarks

Material	Import dependence raw materials (2023)	EU Strategic Projects on Extraction	Import dependence processed materials (2023)	EU Strategic Projects on Processing	End-of-Life Recycling Rate in the EU (2023)	EU Strategic Projects on Recycling
Natural Graphite	97%	2	100%	4	3%	2
Phosphate rock / Phosphorous	82%	0	100%	0	0%	0
Lithium	81%	9	100%	8	0%	4
Manganese	97%	1	66%	2	9%	4
Cobalt	81%	3	25.7%	3	22%	3
Nickel	31%	2	75%	2	16%	5

Note: Iron and salt were excluded from the table as they are not on the CRM list, and they therefore do not qualify for strategic projects.

The most strategic projects have been selected for lithium, graphite, cobalt, manganese and nickel – all essential materials for lithium-ion batteries, especially for the NMC variant. This shows that the EU is focused on establishing a domestic NMC battery supply chain in the coming years. It also points to the fact that emerging battery manufacturers will likely incur less supply vulnerabilities in the NMC sector compared to other emerging battery chemistries.

Lithium has the highest number of projects, and that is also where the EU's import dependencies are among the highest between critical raw materials. At the extraction level the EU is 81% dependent on lithium imports, while at the processing level 100%. The recycling rate of lithium is 0%, which is expected to grow with the four strategic projects in this sector.

Graphite and cobalt have a relatively similar number of strategic projects, expected to increase EU capabilities for extraction, processing and recycling. Graphite not only has the highest likelihood of disruption as discussed in the previous section, but also very high import dependency rates – 97% at extraction level and 100% at processing. Cobalt is very vulnerable at extraction level, but existing domestic capabilities are relatively strong. Its recycling rate is also relatively high, at 22%, meaning that the upcoming 3 strategic projects will significantly raise it.

Manganese and nickel have a notably high number of strategic projects in recycling, in addition to an already high recycling rate – 9% and 15% respectively. Their supply chains are not as vulnerable as those of graphite or cobalt, but the EU is clearly investing in the full range of battery minerals by 2030.

Finally, no strategic projects have been selected for phosphorous. Some phosphorous projects already exist in neighbouring Norway, as of the largest European phosphate rock deposits has been found there, with production expected to start by 2029.[62] For phosphorous, the EU's dependence on the raw material is 82% and on processed materials 100%, together with a 0% recycling rate. Projects across the world to increase phosphate production can be found in Australia, Brazil, Canada, Congo (Brazzaville), Guinea-Bissau, Kazakhstan, Mexico, Morocco, Russia and Senegal.[63] Not only are LFP vulnerability scores the highest, but LFP battery manufacturers will likely remain exposed to geopolitical threats.

[62] Caliber, 'Europe's Raw Materials Crunch: Struggling to Secure Resources amid Rising Military Needs', 19 juli 2025, https://caliber.az/en/post/europe-s-raw-materials-crunch-struggling-to-secure-resources-amid-rising-military-needs; Frédéric Simon, '"Great News": EU Hails Discovery of Massive Phosphate Rock Deposit in Norway', Energy, Environment & Transport, *Euractiv*, 29 juni 2023, https://www.euractiv.com/section/energy-environment/news/great-news-eu-hails-discovery-of-massive-phosphate-rock-deposit-in-norway/.

[63] U.S. Geological Survey, 'Phosphate Rock Statistics and Information', 31 januari 2025, https://www.usgs.gov/centers/national-minerals-information-center/phosphate-rock-statistics-and-information.

5. Conclusion and recommendations

This research shows that all three battery chemistries are prone to mineral supply chain vulnerabilities. The NMC and LFP chemistries generally exhibit higher levels of supply chain vulnerability. This is due to the larger presence of critical raw materials and materials that are mined and processed outside of Europe. The SIB batteries have lower vulnerability scores, pointing to the possible benefits of choosing these chemistries.

These global trends in CRM supply chains and batteries chemistries can help inform EU policymakers and emerging manufacturers' battery chemistry choices. The choice of battery chemistry to be manufactured in Europe could prove key in de-risking supply chains and increasing the EU's strategic autonomy. Below, recommendations have been formulated for each of the battery chemistries.

Firstly, the NMC market may bring opportunities to EU manufacturers post 2030, even though from both a material supply and a manufacturing perspective the 2025 situation remains vulnerable. The NMC has the second highest vulnerability scores out of the three analysed due to the high import dependence of battery minerals to the EU. China's dominance in the manufacturing sector and over the global market furthermore makes it difficult for emerging EU producers to stay competitive and sustain operations. The higher cost of NMC chemistries may also bring competitive issues to European manufacturers compared to LFP and SIB batteries. Yet from a material security perspective, vulnerabilities might be reduced by 2030-2035 considering the EU's strategic projects on lithium, nickel, manganese, graphite, cobalt, pointing to a good opportunity to start investing in this value chain. The Battery Regulation furthermore encourages the recycling and recovering of the raw materials in the NMC battery chemistry, meaning that there is institutional support for building resilient NMC supply chains.

Secondly, LFP batteries are emerging as a more affordable chemistry than the other two, but current supply chain vulnerabilities and the limited efforts to address them bring geopolitical challenges for European manufacturers. China is investing heavily in this chemistry, in addition to its pre-existing control of 90% of the market. In 2025 it restricted the export of technology for the production of battery materials for this technology. This means that European companies will incur risks if they start building capabilities individually rather through a more accelerated sector-wide approach, as they will remain in a highly dependent supply chain situation. When it comes to material risks, the LFP chemistry could continue to incur the highest risks post 2030.

Finally, the SIB battery chemistry is a nascent and promising technology that brings notable opportunities for the EU. Since the ramping up of production capacity is still in its early stages, there might be scope for the EU to build a competitive SIB sector. The chemistry is highly reliant on natrium, a widely available material, and some variants use relatively less vulnerable minerals. Still, not all SIB chemistries are being produced at the same scale.

Furthermore, even within certain SIB chemistries there are CRM's present, such as manganese and nickel.

The European Union is an open market economy and will to some extent always remain somewhat dependent on third countries. Raw material deposits are not evenly distributed across the globe, and significant trade flows are likely to occur in the future. This does not mean that the EU does not have any possibilities to lower its raw material vulnerabilities. The EU could work on diversifying its supplier base, collaborate with more 'friendly' countries and develop more strategic projects that could lead to at least some degree of self-sufficiency.

Based on the above-mentioned findings, three recommendations were developed for EU policymakers and industrial actors:

1. **Ensure that the strategic projects on the NMC supply chain move forward as soon as possible.** The high risks in 2025 can be mitigated by 2030-2035 through the different strategic projects. In addition, showing that this mechanism works and projects do become operational brings more trust and certainty to investors in the European market.

2. **Invest in risk mitigation measures for the LFP supply chain**, including domestic EU projects and partnerships with other suppliers on both the material and technological side. LFP demand is growing, so more manufacturing capacity should be built in the EU to mitigate long-term risks.

3. **Invest in research and scaling up of SIB battery chemistries**. Especially for stationary storage, SIB is a fast-growing alternative. This could give the EU a (co-)leadership position in a key technology in the energy transition.

Annex 1. EU Strategic Projects on Battery Materials

Project	Country	Material(s)	Type			
			Extraction	Processing	Recycling	Substitution
Ageli	France	Lithium (battery grade)	×	×		
Aguablanca	Spain	Cobalt, PGM, Copper, Nickel (battery grade)	×			
BAM4EVER	France	Graphite (battery grade)		×		
Barroso Lithium Project	Portugal	Lithium (battery grade)	×			
Chvaletice Manganese Project	Czech Republic	Manganese (battery grade)	×	×		
Cinovec Lithium Project	Czech Republic	Lithium (battery grade)	×	×		
CirCular	Spain	Copper, Nickel, PGM			×	
CO2Graphite	Estonia	Graphite (battery grade)		×		
EMILI	France	Lithium (battery grade)	×	×		
European Initiative for Strategic and Sustainable Graphite Production	France	Graphite (battery grade)		×		
GALLICAM	France	Nickel (battery grade), Cobalt, Lithium (battery grade), Graphite (battery grade), Manganese (battery grade), Copper		×		
Hycamite TCD Technologies Ltd	Finland	Graphite (battery grade)		×		
Hydrometallurgy	France	Lithium (battery grade), Cobalt, Nickel (battery grade), Manganese (battery grade), Graphite (battery grade)			×	
Jervois Finland Cobalt Refinery Expansion Project	Finland	Cobalt (battery grade)		×		
KELIBER LITHIUM	Finland	Lithium (battery grade)	×	×		
Kolmisoppi	Finland	Nickel (battery grade), Cobalt	×			
Las Navas	Spain	Lithium (battery grade)	×			
Lift One	Portugal	Lithium (battery grade)		×		
Lithium Hydroxide Converter Guben	Germany	Lithium (battery grade)		×		

Project	Country	Material(s)	Type			
			Extraction	Processing	Recycling	Substitution
MINA DOADE PROJECT	Spain	Lithium (battery grade)	×			
NorthCYCLE	Sweden	Manganese (battery grade), Lithium (battery grade), Graphite (battery grade), Nickel (battery grade), Cobalt			×	
POLVOLT	Poland	Nickel (battery grade), Copper, Cobalt, Lithium (battery grade), PGM, Manganese (battery grade)			×	
Portovesme CRM Hub	Italy	Lithium (battery grade), Manganese (battery grade)			×	
ProHiPerSi	Germany	Graphite (battery grade)				×
Project Fortum Hydromet	Finland	Lithium (battery grade), Graphite (battery grade), Copper, Nickel (battery grade), Cobalt				×
RECOVER-IT	Italy	Copper, Nickel (battery grade), PGM			×	
Romano Mine	Portugal	Lithium (battery grade)	×			
Sakatti	Finland	Cobalt, PGM, Copper, Nickel (battery grade)	×	×		
SALROM Baia de Fier	Romania	Graphite (battery grade)	×			
Talga Natural Graphite ONE	Sweden	Graphite (battery grade)	×			
Viridian Lithium	France	Lithium (battery grade)		×		
Zero Carbon Lithium	Germany	Lithium (battery grade)	×			

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