No 48 – January 2025

Policy Brief

CEPII

Lithium-Ion Batteries: Dynamic Mapping of the Value Chain and Perspectives

Romain Capliez, Carl Grekou, Emmanuel Hache & Valérie Mignon

Summary

Accounting for more than 20% of global greenhouse-gas emissions, the transport sector plays a key role in the fight against global warming, alongside energy production. Decarbonizing mobility is a key lever in government strategies, making the electrification of transport, particularly the battery sector, one of the most strategic. The stakes are all the higher given that, while the lithium-ion battery sector has grown impressively over the past decade, this has mainly benefited China, which dominates the entire value chain. This *Policy Brief* provides an in-depth analysis of the positioning of the various players in the value chain, from minerals to batteries. By outlining industrial and institutional strategies, it also sets out how Europe can reduce its dependence on China. Finally, it focuses on sufficiency as a means of reducing dependence on critical materials and, by extension, on China.

RECHERCHE ET EXPERTISE
SUR L'ÉCONOMIE MONDIALE

With nearly 21% of global greenhouse-gas (GHG) emissions, the transport sector plays a key role in the fight against global warming, alongside energy production. Decarbonizing mobility, notably through the electrification of transport, is a major lever for government strategies. According to the International Energy Agency (IEA), approximately 14 million electric vehicles were sold worldwide in 2023 – 35 million over 2019-2023 – representing a market share of around 20% internationally and a 35% increase from 2022 (IEA, 2024a). However, geographic dynamics remain highly heterogeneous; China (8.1 million vehicles sold in 2023) is currently the most active market for this type of engine, followed by Europe (2.4 million) and the United States (1.4 million).

batteries are essential to both ecological and digital transitions

According to BloombergNEF (2024), the transport electrification segment (including charging stations and electric vehicles) became the leading sector for low-carbon technology investments in 2023, at approximately $630 billion. It now surpasses the renewable energy sector, accounting for 36% of global investments in low-carbon technologies, which reached around $1,800 billion last year. Considering climate goals and the notable decrease in battery costs over the past decade, this dynamic is expected to continue.

Providing affordable electrified mobility solutions to the general public is thus an ambitious goal for many governments. However, these strategies face various challenges throughout the entire electric vehicle production chain, especially in the battery manufacturing segment. Batteries are essential to both ecological and digital transitions.[1] From mineral extraction to transformation, integration into batteries, and ultimately electric vehicle production, the entire value chain is highly competitive between states (China, Europe, and the United States) and encompasses numerous issues, from industrial (value-chain resilience, industrial employment) and geopolitical (state sovereignty in securing supplies) to environmental (creating a circular economy in this sector to minimize impacts).

In addition to massive investments required for transport electrification and charging infrastructure, battery manufacturing requires large quantities of ores and metals, many of which are considered critical or even strategic.[2] Lithium-ion batteries – the most commonly used technology in electric cars – are very metal-intensive compared to lead-acid batteries in internal combustion engines.[3] In its Sustainable Development Scenario (SDS) – indicating what is required for a pathway compatible with the Paris Agreement –the IEA forecasts a 30-fold increase in global mineral demand by 2040. Electric vehicles and batteries account for half of this low-carbon energy-related demand growth.

lithium-ion batteries – the most commonly used technology in electric cars – are very metal-intensive

In recent years, electric vehicles have become a technology that symbolizes state competition in the ecological transition. From the 2022 Inflation Reduction Act (IRA) in the United States to the European Net Zero Industry Act (2024), industrial policies in developed countries all address electric vehicles in their productive or trade dimensions. These strategies aim to counter China's influence in this segment, as Beijing – through proactive policies for over two decades – has built and consolidated comparative advantages across the value chain.

This *Policy Brief* focuses on the issues and challenges raised by the electrification of the transport fleet, through the study of lithium-ion batteries. It provides an in-depth analysis of the positioning of various players across the value chain, from minerals to batteries. Given China's dominance across all value-chain segments, it also explores the pathways available to Europe to reduce its dependence on China.

1. Lithium-ion battery chemistries

Due to their high performance and reduced size and weight compared to other comparable technologies, lithium-ion batteries have become the leading technology for the energy transition, especially for electric mobility. Behind the common term lithium-ion batteries (or Li-ion) lies a multitude of technologies – different "chemistries"[4] – that differ in their performance and metal composition (see Figure 1 and Box 1). Generally, cobalt, graphite, lithium, manganese, and nickel are the main materials used in making a Li-ion battery. While graphite quantitatively stands out from other components, it is cobalt and nickel that lead in terms of component cost, with smaller quantities but high and/or highly volatile prices.[5]

behind the common term lithium-ion batteries lies a multitude of technologies

---

[1] In addition to the development of the Internet and digital mobility (smartphones, tablets, etc.), the explosion in the number of connected objects requires increased use of electricity storage technologies based on critical materials – first and foremost lithium. The role played by batteries is crucial here, given the challenges of energy performance (autonomy, size, etc.).

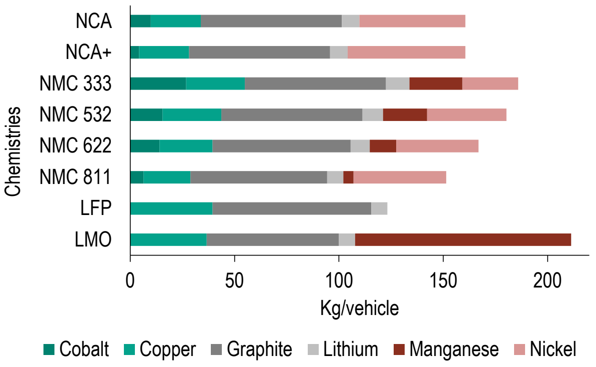
[2] The European Commission listed 34 critical raw materials in 2023, 17 of which were considered strategic because they were "*expected to grow exponentially in terms of supply*", had "*complex production requirements*" and "*thus face a higher risk of supply issues*". For more information, see Capliez *et al.* (2024).

[3] According to the 2023 WWF report carried out in collaboration with the Institute for Mobility in Transition (WWF, 2023), the manufacture of an electric vehicle requires an average of 394 kg of critical materials (mainly aluminum, cobalt, copper, graphite, lithium, manganese, and nickel), which is 2.2 times more than for the production of a thermal vehicle, which requires an average of 176 kg (aluminum, copper, and manganese).

[4] Battery chemistry refers to all the raw materials that make them up.

[5] For example, after increasing by 41% between 2021 and 2022, nickel prices fell by 18% in 2023 on an annual average; the decrease even reached 43% between January 2023 and January 2024. Prices then entered an upward dynamic, with growth of around 20% between February and May 2024, illustrating their high volatility.

Figure 1 – Main strategic metals in a lithium-ion battery



Notes: Illustration for a 75-kWh battery with graphite anodes. NMC: nickel-manganese-cobalt (numbers refer to respective element percentages); NCA: nickel-cobalt-aluminum; LFP: lithium-iron-phosphate; LMO: lithium-manganese-oxide. See Box 1 for more details.

Source: International Energy Agency (IEA, 2021).

Lithium-ion batteries are still very metal-intensive.[6] However, various chemistries and generations of batteries reflect a desire to combine performance and profitability through alternative and/or reduced-quantity minerals/metals. Market shares of batteries are thus expected to shift toward less intensive technologies. Figure 2 presents the current state and market share forecasts for different types of batteries in the automotive industry (IEA, 2024b). In 2021, the IEA (IEA, 2021) predicted a significant decline in LFP (lithium-iron-phosphate) batteries and remarkable growth in NMC (nickel-manganese-cobalt) chemistry batteries – particularly NMC 811 batteries – for light electric vehicles. However, the agency's forecasts have significantly evolved in 2024. A turnaround has been observed since 2019, with the resurgence of LFP chemistries. Several factors explain this dynamic. LFP batteries contain no nickel or cobalt, reducing exposure to high and volatile raw material prices. Cell-to-pack (CTP) technology has also reduced "dead weight" and packaging costs, thus increasing the energy density of LFP batteries.[7] Two other recent advances further contribute to the appeal of these chemistries: (i) a notable reduction in charging time (10 minutes for a 400 km range) and (ii) the development of LMFP chemistries, an improved version of LFP batteries containing manganese (M), which increases their energy density. Beyond Li-ion chemistries, new types of batteries, such as sodium-ion batteries, are expected to emerge by 2030. These are less intensive in critical materials than

Box 1 – Lithium-Ion Batteries in the Automotive Industry: An Overview of Technologies

Initially intended for consumer electronics, lithium-ion batteries have gradually found new applications in the automotive industry, establishing themselves as the standard for vehicle electrification. The principle remains unchanged: store electrical energy in chemical form and release it in a controlled manner. This is achieved through the movement of lithium-ions between two electrodes – from the anode (negative pole) to the cathode (positive pole) – immersed in a conductive liquid called electrolyte. Depending on the state of "charge" or "discharge", the cathode and anode alternately act as entry and exit points for the electric current. At the vehicle level, a lithium-ion battery is an assembly of individual battery units (called cells) connected together. The battery's voltage and capacity – the amount of electricity that can be stored, usually expressed in kilowatt-hours (kWh) – are determined by the number of cells, their size, type, and arrangement. Generally, the different lithium-ion batteries differ in their cells, composed of an anode, a cathode, a separator, and an electrolyte. While the anode is usually made of graphite, the cathode, on the other hand, consists of various chemical elements referring to different technologies, *i.e.*, different "chemistries"*. The main chemistries and their characteristics are briefly presented below.

NMC (Nickel – Manganese – Cobalt)

With a 72% market share in 2020 (see Figure 2), batteries using NMC chemistry are the most common in the automotive sector. This is due to their ability to achieve a very high specific energy (up to 220-240 Wh/kg), allowing them to store a large amount of energy with reduced volume and weight. NMC chemistry is available in 4 types: NMC 333, NMC 532, NMC 622, and NMC 811. The numbers refer to the respective percentages of elements in the cathode. The latest generation NMC 811 thus has a higher nickel concentration and lower manganese and cobalt content, enabling higher energy density at lower cost. This chemistry is expected to rapidly grow and replace older cells, particularly NMC 622, which were the most common in 2020.

NCA (Nickel – Cobalt – Aluminum)

Compared to batteries using NMC chemistry, those based on NCA chemistry have higher energy density (250-300 Wh/kg). However, they have a lower safety index. Due to the similarity between NMC 811 and NCA cells (low cobalt and aluminum content, and high nickel percentage), the latter are expected to be replaced by the former as a compromise between energy density, safety, and stability.

LFP (Lithium – Iron – Phosphate)

Using neither nickel nor cobalt, LFP chemistry batteries have a significant cost advantage (both economic and environmental). Added to this is high performance, particularly regarding safety and lifespan, which has supported the rise of LFP batteries. However, due to their lower energy density (thus requiring more volume and weight), LFP batteries have historically had limited applications in the industrial sector, stationary storage, agriculture, or special vehicle electrification.

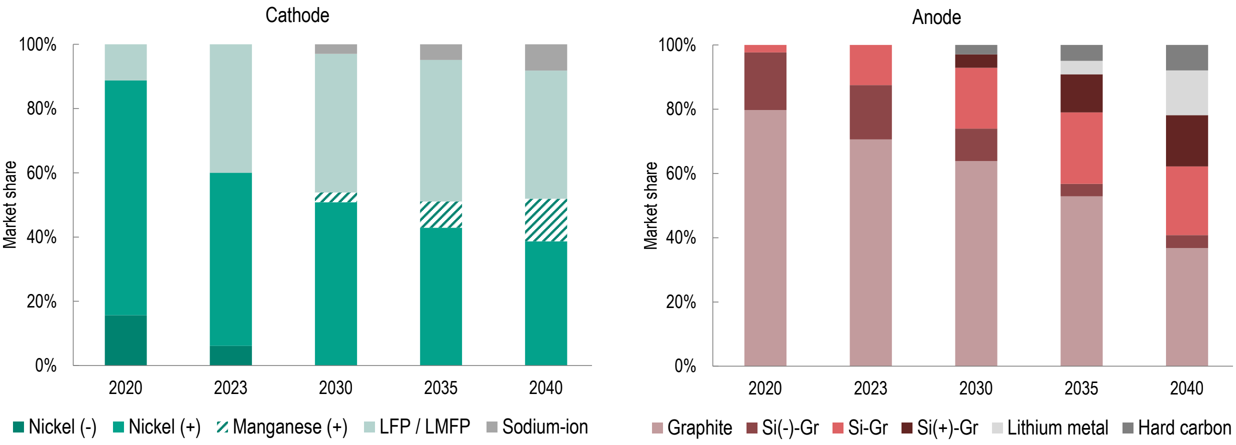
* "Solid-state" or "all-solid-state" batteries (ASSB), unlike other types, use a solid material for the electrolyte. The theoretical advantages associated with this developing technology include better energy density, increased safety, and shorter charging times.

---

(6) According to the IEA, based on a 75-kWh battery with graphite anodes, an average of 168 kg of mineral is needed per Li-ion battery, compared to less than 50 kg for a thermal vehicle battery.

(7) CTP batteries belong to the class of batteries without modules. Unlike batteries with modules, the cells of CTP batteries are positioned directly within the box, forming a uniform, continuous block. The proportion of active material is higher than in batteries with modules, which means greater energy storage capacity.

Figure 2 – Market shares of different battery chemistries for electric vehicles



Notes: LFP = lithium-iron-phosphate; LMFP = lithium-manganese-iron-phosphate; NMC = lithium-nickel-cobalt; NCA = lithium-nickel-cobalt-aluminum; NMCA = lithium-nickel-manganese-cobalt-aluminum; LNO = lithium-nickel-oxide; LNMO = lithium-nickel-manganese-oxide. Nickel (-) = low nickel content (includes NMC 333 and NMC 532, see Box 1); Nickel (+) = high nickel content (includes NMC 622, NMC 721, NMC 811, NCA, NMCA, LNO). Manganese (+) = high manganese content (includes LNMO and lithium-manganese-rich NMC (LMR-NMC)). Si(-)-Gr = silicon-graphite with low silicon content (5%); Si-Gr = silicon-graphite with medium silicon content (5%-50%); Si(+)-Gr = silicon-graphite with high silicon content (>50%).

Source: AIE (2024b).

their Li-ion counterparts, but their growth is highly dependent on lithium price dynamics. In other words, significant and sustained increases in lithium prices are required for the strong development of these chemistries. Finally, "solid-state" batteries (using the ASSB "All Solid-State Battery" chemistry), as opposed to current liquid electrolyte batteries, are also expected to emerge, even though they should not have a significant impact by 2030 (IEA, 2024b).

> *crucial role of technological changes in battery chemistries with fundamental issues concerning metals and recycling*

The evolution of IEA forecasts highlights the crucial role of technological changes in battery chemistries with fundamental issues concerning metals and recycling. LFP batteries, being nickel and cobalt-free, are relatively less economically viable for recycling compared to NMC batteries, as only lithium is recovered—particularly since it is present in smaller quantities (about 20%) in LFP chemistries compared to NMC chemistries. Cobalt and nickel are also materials that recycle well and have higher market prices than other metals. This increases the profitability of recycling NMC batteries compared to LFP chemistries.

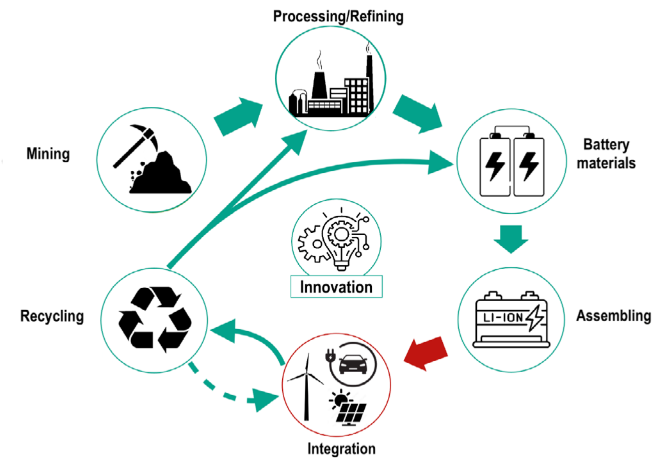
2. From minerals to lithium-ion batteries: reconstructing the value chain

With the expected rise of electromobility – over 730 million vehicles in circulation by 2040 (BloombergNEF 2023) – the entire lithium-ion battery value chain is expected to undergo a revolution. The aforementioned technological developments partially reflect the importance of the issues at stake. These issues are numerous and present at all levels of the value chain, from raw material extraction to battery production, and their potential recycling at the end of life. These steps are set to become increasingly strategic not only due to automotive manufacturers' desire for vertical integration but also due to broader industrial (*e.g.*, value-chain resilience) or state (*e.g.*, sovereignty) concerns.

Given their relative complexity, the manufacturing of lithium-ion batteries involves numerous steps. These are schematically represented in Figure 3.

The first step is raw material (ore) extraction. This step plays a crucial role in the value chain as the first – and primary – source of mineral supply, especially since mineral extraction is concentrated in a few countries (see Section 3). While many countries possess significant geological potential – such as Bolivia, Argentina, and Chile for lithium – the general awareness of the issues, particularly those associated with moving down

Figure 3 – Lithium-ion battery value chain



Source: Authors.

the value chain, coupled with lengthy and costly processes before new mines can be exploited, tends to reinforce the current advantages of producing countries. Added to this are numerous social, governance, and especially environmental challenges facing these countries.

Once extracted, mineral ores undergo treatment in a second step. This involves various phases ranging from basic transformations (*e.g.*, solidification) to mineral refining – *i.e.*, improving chemical purity. This key step of transforming into active materials adds about 50% value compared to the previous extraction step (see Sharova *et al.*, 2020, and Table 1). However, it also comes with a considerable environmental cost.[8]

recycling also addresses environmental concerns associated with the raw material value chain's upstream (extraction) and downstream (refining) stages

Table 1 – Value added at each stage of the value chain of a Li-ion battery (in %)

Mining	Processing/ Refinin	Manufacturing (battery materials)	Assembling	Battery pack (integration)	Recycling
~ 80	~ 50	~ 40	~ 50	~ 25-30	~ 10

Note: Value-added creation relative to the previous step.

Source: Sharova *et al.* (2020).

The middle segments of the value chain (third step) are equally value-adding. Various active materials are combined and associated with others to manufacture battery cell components. While the anode, usually made of graphite, may seem straightforward, mastering cathode production technology appears crucial as it significantly affects the final cell's performance. This primary role of the cathode is one of the reasons behind many battery manufacturers' desire for internalization.[9] This step adds about 40% value compared to the previous refining step (Mathieu, 2021). Further downstream, various processes related to cell assembly and certification generate an additional 50% value (Sharova *et al.*, 2020).

mastering cathode production technology appears crucial

The final steps before integrating "batteries" into the final product (*e.g.*, vehicles) involve grouping battery cells into modules, which are then assembled into "packs" or "battery blocks" equipped with an electronic system (Battery Management System, BMS) for controlling and managing the charge of different elements.

The final link in the value chain, recycling, is becoming increasingly important. By enabling a "loop" valuation of strategic metals contained in batteries, recycling would, ultimately, greatly contribute to securing supplies not only for battery metals but also, more generally, for those needed for the energy transition. Recycling also addresses environmental concerns associated with the raw material value chain's upstream (extraction) and downstream (refining) stages. The generic term "recycling" encompasses various paths and/or processes, primarily reusing production scrap and rejects. For batteries that are not directly reusable, those reaching end of life according to the automotive industry standards are offered a second life, particularly in stationary storage (solar and wind energy). If not, they are recycled in the true sense, and the recovered metals are fed back into the value chain.[10]

3. Global players

The raw material extraction necessary for lithium-ion battery production remains concentrated in a relatively small number of countries (Figure 4).[11] Australia and China stand out greatly from other countries due to both the diversity of their productions and the importance of some of them. Australia is the leading lithium producer, with 47.8% of global production in 2023, far ahead of Chile and Argentina, with 24.4% and 5.3%, respectively. These latter two countries, along with Bolivia, form the "lithium triangle", housing over 60% of the world's lithium resources.[12] Australia, for its part, holds about 21% of global reserves. It is also the world's leading bauxite producer (24.5%) and the third-largest manganese producer with 15% of global production, behind South Africa with 36% and Gabon with 23%.

China's subsoil is also rich in numerous minerals, giving it a predominant role among upstream players in the lithium-ion battery value chain. The leading producer of natural graphite, with 76.9% of global production (21.4% of global reserves), China is also the second-largest bauxite producer (23.3%) and a significant player in lithium, with about 18.3% of production and 7.4% of global reserves.

the raw material extraction necessary for lithium-ion battery production remains concentrated in a relatively small number of countries

Other countries also hold significant positions but with much less diversified production than Australia and China. This is particularly true for the Democratic Republic of Congo (DRC),

---

[8] See, in particular, the website of Vulcan Energy, a company that extracts lithium from geothermal springs in Germany.

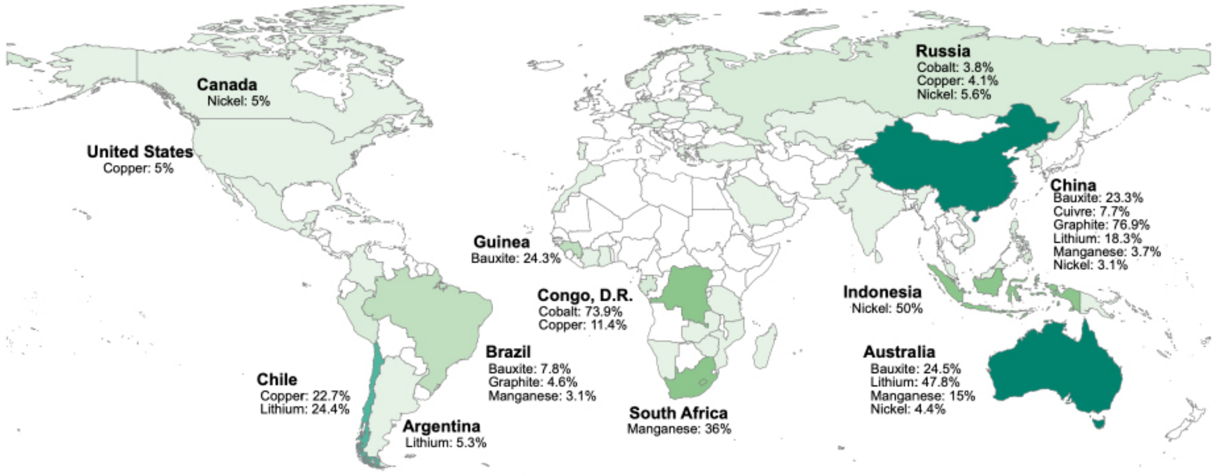
[9] For example, like Volkswagen, which plans to invest €20 billion in its PowerCo subsidiary by 2030, 14% of the world's manufacturing of NMC chemistries is internalized by cell-producing companies (Sharova *et al.*, 2020).

[10] Two types of processes are used to recycle metals in batteries: pyrometallurgical and hydrometallurgical processes. While the former are sources of GHG emissions, the latter require the use of chemicals and a large quantity of water, which must be cleaned up afterward.

[11] For details on methodology and data, see Box 2.

[12] Although Bolivia does not currently produce lithium, it is home to the largest lithiniferous deposit in the world, under the Uyuni salt flat.

Figure 4 – Major producing countries of minerals for lithium-ion batteries



Notes: Green shades indicate the importance of countries in producing minerals (2023) composing lithium-ion batteries. This importance is calculated as the average production (normalized between 0 and 1) of various minerals (*i.e.*, bauxite, cobalt, copper, graphite, lithium, manganese, nickel).

Source: USGS (*United States Geological Survey, Mineral Commodity Summaries*).

Box 2 – Dynamic Mapping of the Value Chain: Data and Methodologies

Dynamic analysis of the lithium-ion battery value chain requires a relatively large collection of data, ranging from raw material production to battery exports, and even electric vehicles. To cover the entire value chain, we rely on Blagoeva *et al.* (2019) and McMahon (2022), who provide six-digit identifiers in the harmonized system of designations and coding of goods (*i.e.*, HS6 code) for chain products. Besides ensuring relative comprehensiveness, the framework defined by Blagoeva *et al.* (2019) and McMahon (2022) allows for better traceability due to the internationally harmonized framework.

Unless otherwise indicated, data on raw material production and reserves are from the United States Geological Survey (USGS) Mineral Commodity Summaries. For downstream value-chain steps, we use data from BACI, the international trade database at the product level (Gaulier and Zignago, 2010). Analyzing trade flows of various identified products provides a precise view of key players and interdependencies. It is important to note that, due to the inability to identify final uses for intermediate goods, we consider flows "for all applications", not just for the automotive industry. The framework presented here is, therefore, general and focuses on key players for different products.

which produces 74% of the world's cobalt (2023) (its subsoil holds about 50% of global reserves), and Indonesia, producing 50% of nickel in 2023.

Analyzing national production, however, masks the reality of the role played by multinationals. The distinction between national and international players offers a different perception of global mineral production players, especially of China's importance.

While China's natural endowment gives it particular importance upstream in the value chain, it mainly played a leverage role in the country's rise. As documented by Bonnet *et al.* (2022), China became aware of the importance of strategic metals early on and especially perceived the potential of minerals and metals now considered strategic by all.[13] This desire to develop the mining sector was at the heart of an industrial agenda to "*change the resource advantage into economic superiority*",[14] an objective reaffirmed, among others, in the 10-year "Made in China 2025" plan (2015), projecting China as the industrial superpower by 2049, the centenary of the founding of the People's Republic of China. This Chinese domination objective involves a "decisive battle period" for the non-ferrous metal industry – the 13th Five-Year Plan (2016-2020) – aiming not only to secure China's supplies of strategic minerals and metals that it produces little of, or not at all, but also to strengthen its dominant positions. China has thus developed a broad strategy to establish control over a substantial portion of global production. With the "Go Global" policy in the early 2000s and the Belt and Road Initiative from 2013, Beijing has promoted the internationalization of its companies through various means: direct foreign investments, acquisitions, and stakes in local and/or global companies, new mining projects, infrastructure projects in exchange for raw materials, joint ventures, loans, etc. The most significant examples are lithium

analyzing national production, however, masks the reality of the role played by multinationals

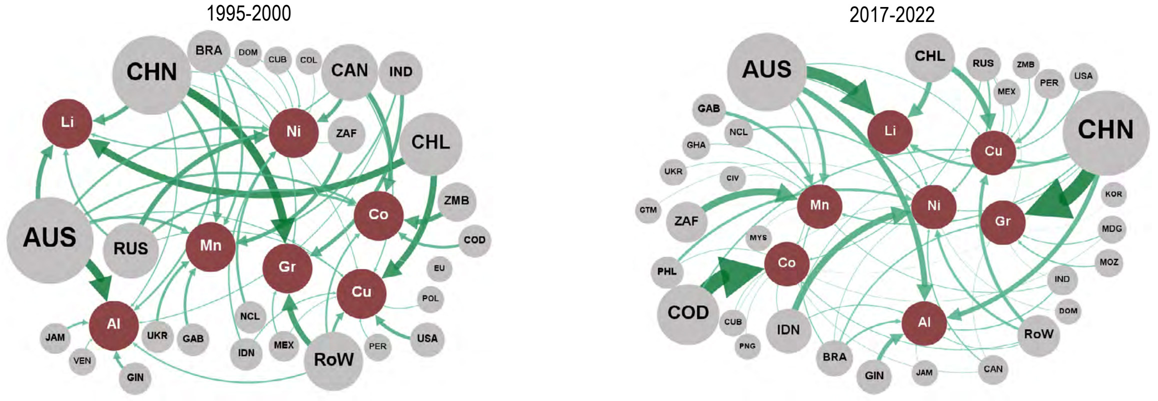
---

(13) The most telling example is undoubtedly that of rare earths. In the early 1980s, under the impetus of Deng Xiaoping, China undertook to establish a dominant position in the market despite negligible production compared to that of the United States, then the world's leading producer. By 1992 this was achieved; Chinese production exceeded that of the United States. In 1995, Chinese production was more than twice that of the United States; in the second half of the 2000s, 97% of world production was Chinese.

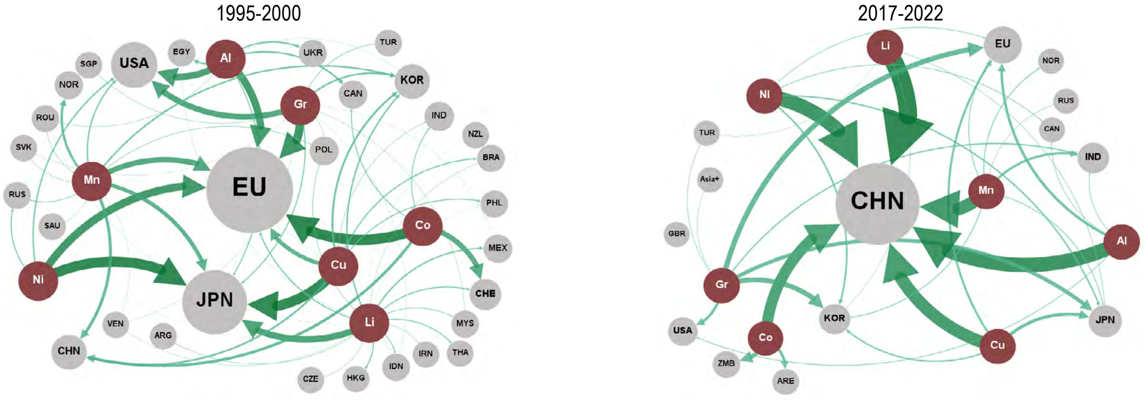
(14) "*Improve the development and applications of rare earth, and change the resource advantage into economic superiority*" (Jiang Zeminun, 1999).

Figure 5 – Mineral production and trade flows

5.a – Production



5.b – Trade flows (imports)



Notes: Minerals are indicated by ochre circles. "Al": aluminum/bauxite; "Co": cobalt; "Cu": copper; "Gr": natural graphite; "Li": lithium; "Mn": manganese; "Ni": nickel. Gray circles with ISO codes represent countries/groups of countries. "AUS": Australia; "CHL": Chile; "CHN": China; "COD": Democratic Republic of Congo; "JPN": Japan; "EU": European Union; "USA": United States. For readability, only major countries are represented. Arrow thickness indicates the market share of the concerned country. The country's "global" importance (sum of all market shares) is indicated by the size of its circle.

Sources: Authors from USGS (production) and BACI (imports) data.

and cobalt. Thanks to massive investments in Australia, but also in Argentina and Chile, China controls about 60% of global lithium production.[15] In the DRC, it controls a little over half of the official cobalt production.[16]

This substantial expansion of China has been accompanied by a general rise in its capacities, both upstream and downstream in the value chain. This is illustrated in Figure 5, which shows the national production and import trends of minerals, allowing for the representation of key players. While Figure 5.a shows some inertia in production,[17] Figure 5.b is more striking, demonstrating China's centrality in recent years.

In the period 1995-2000, China appeared as a minor peripheral player that imported relatively few minerals; it was primarily the European Union (EU), Japan (JPN), and the United States (USA) that were the main importers. This trend reflected the industrial dynamics in these countries, both upstream and downstream (refining, use as inputs) of value chains. Two decades later, these countries have been relegated to the background by a dominant China. In the period 2017-2022, China imported over 86.5% of global lithium production, 70% of bauxite and nickel production, 62.6% of worldwide manganese and copper, and 53% of cobalt. This structural transformation demonstrates the effectiveness of Chinese policies regarding strategic mineral supply and the

China has developed a broad strategy to establish control over a substantial portion of global production

---

(15) One example is the acquisition of Talison Lithium by Tianqi Lithium Corp. (Chengdu Tianqi Group), which gives the latter a majority stake in the Greenbushes mine (Australia), from which about 40% of the world's lithium production is extracted. Tiangi and its joint venture with Albemarle have also acquired a 26% stake in *Sociedad Química y Minera* (SQM), a Chilean company that controls about half of Chile's production, for the development of the *Salar de la Isla project*, Chile's second largest reserve.

(16) These include (i) the Sino-Congolese mining joint venture (Sicomines) – a case of bartering between infrastructure and access to raw materials –68% owned by Chinese companies and allowing them to extract up to 10 million tons of copper minerals and 420,000 tons of cobalt *(i.e.*, 12% of the DRC's estimated cobalt reserves) over a period of 15 years, (ii) the partnership signed with the state-owned company Gécamines, which holds shares in all mining projects in the country, and (iii) control of the Tenke Fugurume mine. See Foreign Policy (2019) and Bonnet *et al.* (2022) for more details.

(17) However, the DRC is growing in cobalt production, China in lithium production, and Indonesia in nickel production.

rise of “the Middle Kingdom” in industrial power, particularly its refining capacities (Table 2). In fact, alongside its international strategy for securing strategic materials, China has strengthened its weight in refining activities since the early 2000s, to the point that it is now the leading player in refining strategic minerals and metals (see Bonnet *et al.*, 2022). Regarding electric vehicle batteries, China refines, on average, 80% of the metals present in these technologies (CNCCEF, 2022).

Table 2 – Refining of electric vehicle battery minerals (in %)

	China	United States	European Union
Cobalt	82	0	17
Graphite	100	0	0
Lithium	59	4	0
Manganese	93	0	7
Nickel	65	1	13

Note: Data is not available for unreported minerals.

Source: Benchmark Mineral Intelligence (2020).

China’s dominance in refining activities gives it a second strategic lock to sustain its lead. Beyond upstream constraints related to mineral supply and industrial capacities, refining is associated with substantial environmental externalities that China has accepted to bear. Although less harmful than rare-earth refining,[18] refining minerals and metals in batteries has a considerable ecological and environmental cost. The best current technologies identify two main negative externalities: (i) significant CO2 emissions due to the highly energy-intensive refining steps (treatment, separation, concentration) and (ii) soil and water pollution or local water stress. For example, producing one ton of lithium requires just under 500 m^3 of water (about the equivalent of an Olympic pool for producing 5 tons) and emits an average of 5 tons of CO2 for lithium extracted from brine (45% of global production) and 15 tons of CO2 for lithium extracted from hard rock (55% of global production).[19] These negative externalities are further exacerbated by the increasing exploitation of lower-grade deposits, raising waste management issues that impact ecosystems.

alongside its international strategy for securing strategic materials, China has strengthened its weight in refining activities

China’s current hegemony in the upstream value chain reflects its dual strategy of internationalization – to control mining production – and foreign enterprise establishment on its soil, enabling skill and technology transfers. China now hosts numerous internationally important companies such as Ganfeng Lithium and Tianqi Lithium, the world’s first and third-largest lithium companies (Bonnet *et al.*, 2022), and Zhejiang Huayou, the world’s largest cobalt producer (Reuters, 2021).

Leveraging its upstream advantages, Chinese companies quickly moved downstream in the value chain. Figure 6 illustrates this evolution, showing China as dominant in the period 2017-2022 for cell component exports (58%) and lithium-ion batteries and battery components (76%).[20] This substantial part of global value addition stems from these elements that represent over half the cost of a battery. According to Benchmark Mineral Intelligence (Els, 2020), in 2019, China produced (i) 83% of anodes and 61% of cathodes[21] – representing about a quarter of the average lithium-ion battery production cost –and (ii) 73% of cells – about 30% of a battery’s cost –manufactured worldwide.

leveraging its upstream advantages, Chinese companies quickly moved downstream in the value chain

This large-scale production on Chinese soil also reflects the establishment of numerous foreign companies, notably the South Korean giant LG (Energy Solution), which produced about 50% of its production in China in 2019 (Lee, 2019). However, Chinese firms dominate the global market in the specific segment of electric vehicle batteries. In 2023, 52% of lithium-ion battery sales were made by Chinese companies, among which the global leader CATL (Contemporary Amperex Technology Company Ltd) accounted for 30.6% (see Figure 7). China has thus quickly eclipsed the primary actors of the past, such as the EU, the United States, and especially Japan, which exported 97% of batteries and battery components in the period 1995-2000 (Figure 6.a). Japan now ranks third behind South Korea, which has risen in the lithium-ion battery producer ranking, mainly due to LG’s rapid ascent since its founding in 1998.

the United States and the EU play a marginal role in the value chain

Conversely, the United States and the EU’s dynamics are now relegated to the background; they play a marginal role in the value chain (see Figure 6.a). While these two powers exported over 70% of battery materials and about 55% of cell components in the period 1995-2000, in the recent period cumulative shares

---

[18] In addition to the environmental externalities linked to the extraction of rare earths, the various refining stages are extremely polluting; this pollution is aggravated by the release of radioactive elements. The most telling example is the Bayan Obo mine in Inner Mongolia, whose waste is said to have a level of radioactivity 32 times higher than normal – compared to 14 times in Chernobyl (GEO).

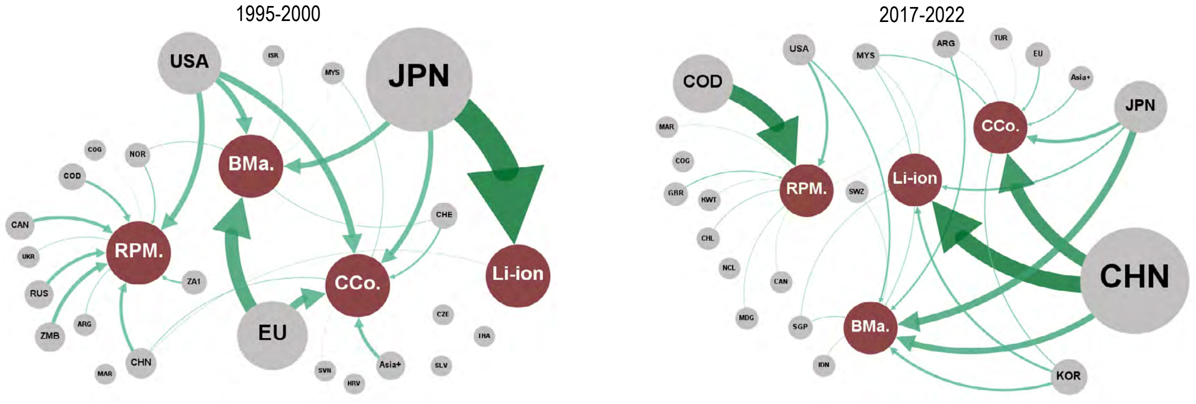
[19] In the case of lithium extraction from brines, there is also significant land use for evaporation ponds – just over $3000 m^2$/ton of lithium (see Hache *et al.*, 2021).

[20] Further down the value chain, let us mention that China is also the main market for sales of electric vehicles, most of which are produced in China (see Mayer *et al.*, 2024).

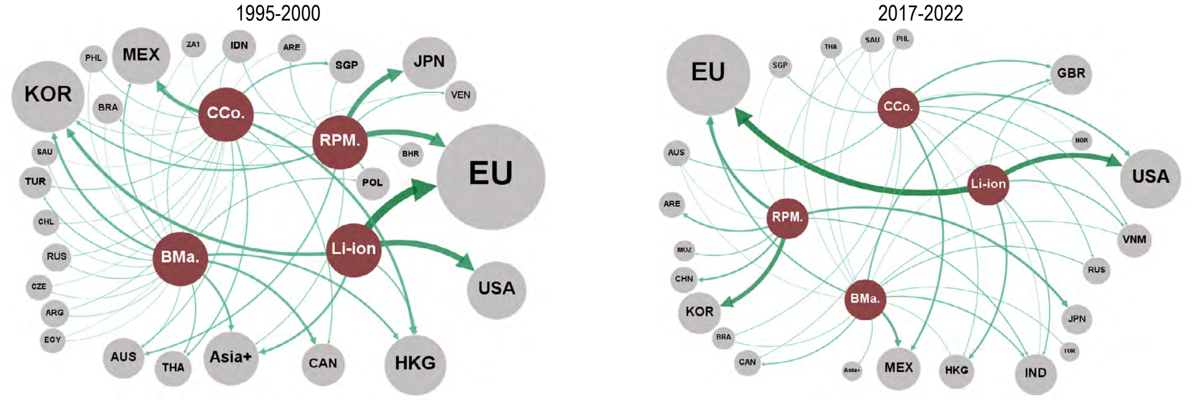
[21] Of the five largest NMC chemical manufacturing companies, three are Chinese and account for a combined market share of 31%: Hunan ShanSan (12%), Xiamen Tungsten (10%), and L&F (9%) (Sharova *et al.*, 2020).

Figure 6 – Exports and imports along the value chain

6.a – Exports



6.b – Imports



Notes: Trade flows of various products are grouped by value chain stages, indicated by ochre circles. Upstream to downstream, groups are: "RPM": refined and processed materials; "BMa": battery materials; "CCo": cell components; "Li-ion": lithium-ion batteries and components. Gray circles with ISO codes represent countries/groups of countries. "AUS": Australia; "COD": Democratic Republic of Congo; "CHN": China; "HKG": Hong Kong; "JPN": Japan; "KOR": South Korea; "EU": European Union; "USA": United States. For readability, only major countries are represented. Arrow thickness indicates the market share of the concerned country. The country's "global" importance (sum of all market shares) is indicated by the size of its circle.

Sources: Authors from BACI data.

are below 10%.[22] Among EU countries, only Poland, Hungary, and Luxembourg are net exporters of lithium-ion batteries today.

Regarding imports (Figure 6.b), however, the United States and the EU (mainly Germany and France) have retained their place as primary destinations for lithium-ion batteries and their components, to enable large-scale production. With a much lower presence in downstream value-added stages, this decline has substantial consequences for their economic prospects, given the issues associated with the lithium-ion battery value chain and, more broadly, those related to the energy transition.

China has become an essential player at all value-chain stages from minerals to batteries, making European countries – and many others – highly dependent

This overview shows the extent to which China has become an essential player at all value-chain stages from minerals to batteries, making European countries – and many others – highly dependent, especially for lithium-ion batteries. Given this situation, what options are available to Europe to reduce its dependence on China to mitigate supply shortages and not hinder its energy transition?

4. What perspectives for Europe?

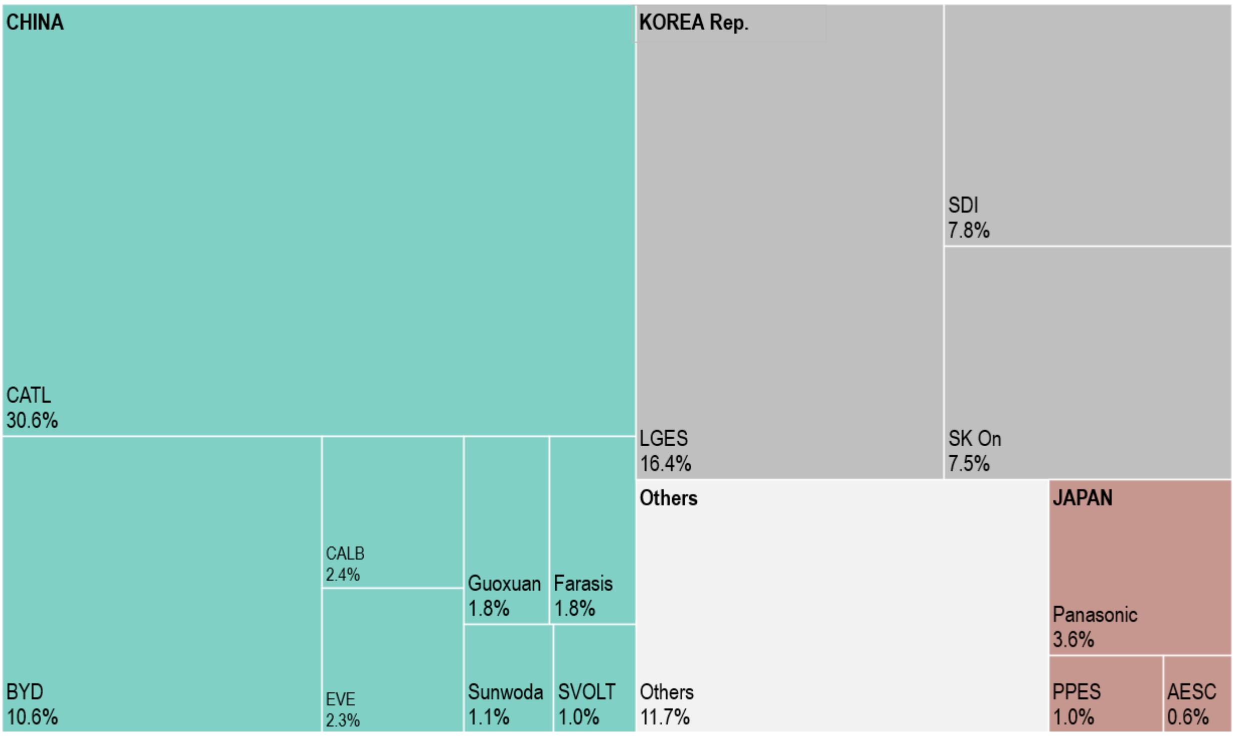
Europe's importance in the lithium-ion battery value chain has greatly weakened. In 2023, only 14% of these batteries were produced on European soil, concentrated in a few countries such as Germany, Hungary, Poland, and Sweden (Ratel Consulting LLC).

With a production capacity of 281.9 gigawatt-hours (GWh) in 2023, Europe closely follows North American capacities (295.3 GWh) but appears modest compared to China, which had a production capacity of 1290.2 GWh (4.57 times European

---

[22] Apart from the shares themselves, it should be remembered that exports and imports of batteries were much lower (in value terms) and/or of a different nature in that they did not concern electric vehicles.

Figure 7 – Market shares (sales in 2023) by lithium-ion battery manufacturer for electric vehicles



Source: Authors from SNE Research (2024) data.

capacities). However, as with mineral production, the localization of production units skews the actual measure of European capacities. Thus, although located on European soil, most production units are branches of non-European companies. More than half of European production is therefore attributed to South Korean or Chinese companies such as Samsung SSI, LGES, and CATL.[23] US companies (*e.g.*, Tesla Microvast) are also present on European soil, making more than 60% of production attributable to non-European companies.

more than half of European production is therefore attributed to South Korean or Chinese companies

While the European realization of its lag, and the resulting dependencies, may seem late, the response is significant. The European reaction is equally noteworthy, with a dual dimension.

The first part of the European response is industrial. By 2030, Europe aims to increase its production capacities sixfold (Figure 8). With a future capacity of 1784.9 GWh, Europe would have a production capacity 27% higher than North American capacities, greatly reducing the gap with China. Leading European industrialists such as Volkswagen Northvolt and FREYR should gain importance, reducing the share of foreign companies to 46.2%. Recent or new initiatives are also expected to emerge, such as the Automotive Cell Company (ACC), with a production capacity of 48 GWh in 2023.

by 2030, Europe aims to increase its production capacities sixfold

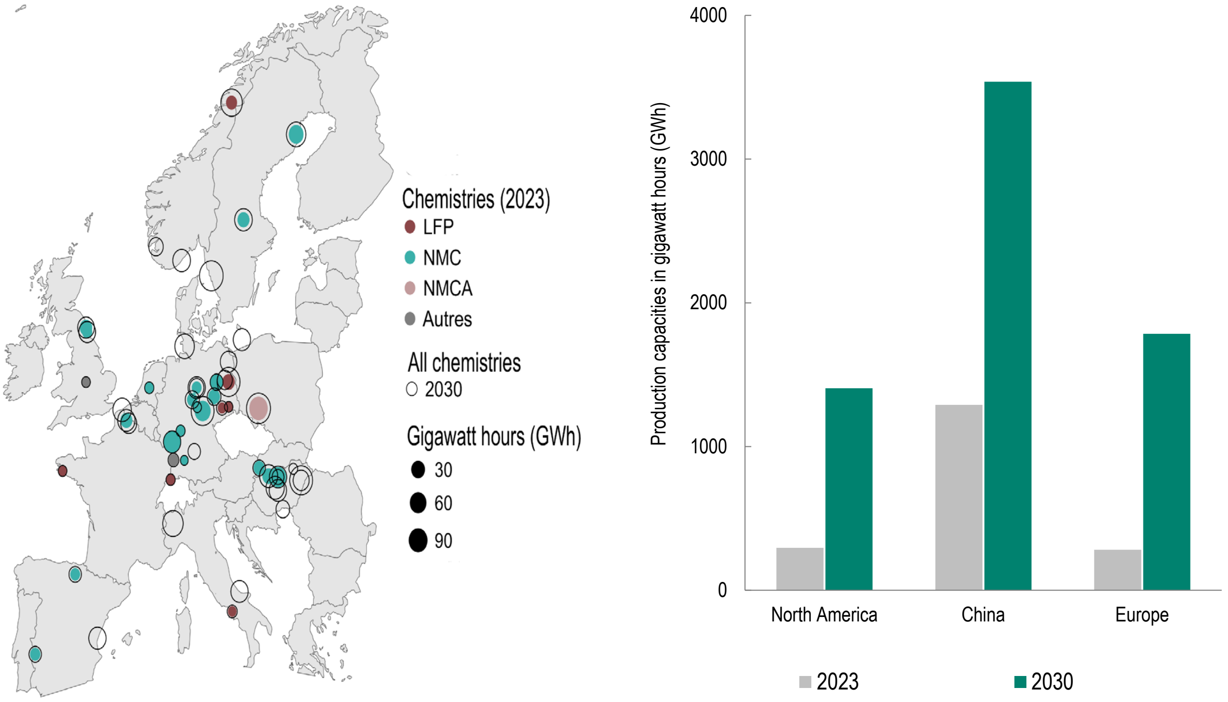
The second part of the European action plan is institutional and has a broader scope than just the lithium-ion battery sector. The EU has set up multiple actions and regulations across the entire value chain, aiming to reduce dependencies – notably on China – while regaining significant global importance. This is in line with the EU's Critical Raw Materials Act (CRMA), adopted in March 2023 and voted on in April 2024, which proposes "a comprehensive set of measures to ensure the EU's access to a secure, diversified, affordable, and sustainable supply of critical raw materials". This regulation aims to reduce dependency on foreign suppliers, avoid potential shortages, and minimize critical metal production's environmental and social impacts. It sets non-binding goals for 2030: "EU extraction should produce at least 10% of its annual consumption; EU processing should produce at least 40% of its annual consumption; EU recycling should produce at least 25% of its annual consumption; no more than 65% of the annual consumption of each strategic raw material at any relevant stage of processing should come from a single third country."

the EU's Critical Raw Materials Act aims to reduce dependency on foreign suppliers

---

[23] These three companies account for more than 41.5% of battery production in Europe.

Figure 8 – Evolution and location of European lithium-ion battery production capacities



Source: Authors, from Ratel Consulting (2023) data.

In many respects, these CRMA objectives appear ambitious.[24] This is especially true for mineral ore extraction in the EU. Despite the underused potential of European subsoil, the goal of 10% production on European territory seems unattainable, for three main reasons (Capliez *et al.*, 2024). First, Europe's metal reserves are insufficient and even non-existent for 13 critical metals listed by the European Commission in 2023. Second, the process from initial exploration to commercial production of a mine is lengthy, taking seven years for lithium to 17 years for copper, and requiring substantial financial investments. Finally, mines have a negative, outdated image, often facing strong local opposition (Box 3). Therefore, ensuring responsible exploitation practices to limit environmental impacts is crucial, a central point discussed in France during the National Public Debate Commission on Lithium in March 2024.[25]

the goal of 10% production on European territory seems unattainable

The objectives related to refining and processing also raise questions. These activities are very energy-intensive and polluting, and they require acceptance that they be relocated to Europe so as to achieve the EU's goal of producing at least 40% of its annual consumption through these processes. Competitive energy prices will also be essential to compete with the United States – in addition to China –which benefits from abundant unconventional gas reserves and relatively low electricity prices. Recycling, though less locally polluting and more acceptable, requires heavy investments. It could reduce dependency on mining resources but requires costly infrastructure for collection, sorting, pre-treatment and material processing, as well as constant technological adaptation – particularly to electric vehicle battery chemistries (Hache and Normand, 2024).

The EU also seeks to diversify its partnerships to reduce dependency on third countries and supply disruption risks. Recent bilateral agreements with Kazakhstan, Egypt, Namibia, Australia, and Canada aim to secure certain critical raw materials supplies. However, these agreements will not suffice, necessitating a dedicated European budget for investments in third countries and mandatory diversification of supplies imposed on companies (Hache and Normand, 2024). The "friend-shoring" strategy (partnerships with allied countries) is often mentioned but presents difficulties. Western countries with similar carbon neutrality and decarbonization goals for transport and energy compete for low-carbon technologies and the necessary materials. This competition could reveal conflicting interests and hinder agreement signing.

recycling, though less locally polluting and more acceptable, requires heavy investments

In addition to these bilateral agreements, the European Commission launched the European Raw Materials Alliance (ERMA) to no longer depend on more than 65% of a

---

[24] See Capliez *et al.* (2024) for more details.

[25] Also on the environmental front, the French government has granted the ecological bonus for the purchase of electric vehicles conditional since 2024 on a specific environmental level linked to their manufacture.

Box 3 – Emili: A “Project of Major National Interest” to Open a Lithium Mine that Sparks Debate

The Emili project for “*Exploitation de Mica Lithinifère par Imerys* (Lithium Mica Exploitation by Imerys)”, announced by Imerys in October 2022, involves exploiting a lithium deposit on an existing kaolin production site (Beauvoir site) in the department of Allier, in the Auvergne-Rhône-Alpes region. The goal is to produce a volume of lithium from 2028 onwards that would equip 700,000 electric vehicles annually for at least twenty-five years while minimizing environmental impacts. It is planned to extract 21 million tons of lithium-rich granite annually and distribute the activity across three sites: (i) Échassières for extraction, (ii) Saint-Bonnet-de-Rochefort, where the loading platform would be located, and (iii) Saint-Victor, where a conversion plant for refining mica (lithium-containing mineral) into lithium hydroxide would be established.

By decree published on July 7 in the *Official Journal*, Emili joined the list of “major national interest projects”, indicating administrative facilitation to expedite implementation procedures. While supported by the government and local officials who see it as an opportunity to create jobs, and with Imerys committed to minimizing environmental impacts, the Emili project raises concerns and opposition from a significant portion of the population. These concerns mainly involve four aspects: (i) a significant increase in water consumption, especially during periods of summer restrictions, (ii) fears of groundwater pollution, (iii) waste management, and (iv) the destination and use of extracted lithium—particularly whether it will be used for equipping highly polluting electric SUVs.

single third country. Achieving such a percentage seems complicated, given the EU’s exclusive dependence on China for rare earths, Turkey for boron, and Brazil for niobium. Specifically, regarding metals in batteries, about 68% of raw cobalt imported by Europe comes from the DRC, 87% of lithium from Australia, 79% of refined lithium from Chile, 41% of manganese from South Africa, and 40% of natural graphite from China (European Court of Auditors, 2023).

the European Battery Alliance aims to develop and produce batteries with a focus on environmental dimensions

The EU is also trying to move up the value chain, as illustrated by the launch of the European Battery Alliance in 2017, to retain as much value creation as possible in the automotive sector. This project aims to create an ecosystem in Europe that includes all automotive value-chain players, both European and foreign, to develop and produce batteries with a focus on environmental dimensions. The European Commission aims to create a comparative advantage in the environmental footprint of its batteries. These batteries represent a considerable amount of minerals that could be reused to meet Europe’s needs without having to mine on its soil.[26] By the end of 2020, over 500 industrial and research sector actors had joined this network, leading to about 15 lithium-ion battery plant projects and another 10 announced (Bonnet *et al.*, 2020). If all projects succeed, the EU will have nearly 25% of global lithium-ion battery production capacity by 2030, with about 50 factories.

China dominates the entire lithium-ion battery value chain, from upstream, where it controls raw material extraction and metal production, to downstream, where Chinese companies are at the heart of battery production

Conclusion

With carbon neutrality goals, many industrial sectors are undergoing profound changes. Among them, the mobility sector can be considered an epicenter of the forthcoming industrial revolution, whose early signs are already visible. With approximately 21% of global greenhouse-gas emissions, the transport sector, alongside energy production, plays a crucial role in combating climate change. Decarbonizing mobility is a major lever, making transport electrification, particularly the battery sector, one of the most strategic. The stakes are even higher because, as the lithium-ion battery sector has experienced explosive growth over the past decade, it has mainly benefited Asian players, particularly China.

the mobility sector can be considered an epicenter of the forthcoming industrial revolution, whose early signs are already visible

China dominates the entire lithium-ion battery value chain, from upstream, where it controls raw material extraction and metal production, to downstream, where Chinese companies are at the heart of battery production. This dominant position reflects a proactive policy implemented over more than two decades, combining the internationalization of Chinese companies for securing raw materials (Go Global) and establishing foreign firms on its soil to develop comparative advantages across the value chain.

Aware of its dependencies, Europe is firmly committed to catching up. On the industrial front, numerous initiatives have been launched to increase local battery production capacities, positioning Europe in the global competition. The industrial component is coupled with a new institutional framework, the European Critical Raw Materials Act (CRMA), defining, among other things, objectives for exposure to foreign suppliers and environmental impacts.

---

(26) We speak of “open mines”. Cobalt recycled in the EU already meets 22% of European demand (Bonnet *et al.*, 2020).

Beyond the CRMA, sufficiency, largely absent from the "institutional package", is gaining traction in European society. Highlighted as a central lever in combating climate change by the Intergovernmental Panel on Climate Change (IPCC, 2022), sufficiency is essential to reduce dependency on critical materials. By limiting metal demand, the EU could reduce its dependency on China. Initiatives such as lightening electric vehicles, lowering disposables, legislating against planned obsolescence, and displaying metal content in products would contribute to this effort. The EU could set an example by promoting lighter electric vehicles, reducing electricity consumption, and the environmental impacts related to production (Hache and Normand 2024). Sufficiency naturally has a global scope as it would relieve pressure on water resources, particularly in production regions already facing significant water stress.

sufficiency is essential to reduce dependency on critical materials

Achieving CRMA goals will require considerable efforts in terms of social acceptance, funding, and supply diversification. If metal sufficiency is an integral part of a sustainable and autonomous EU strategy for critical materials, it must be accompanied by support for citizens who generally do not perceive the notion of "low carbon" as involving a reduction in their metal consumption.

References

Blagoeva, D., Pavel, C., Wittmer, D., Huisman, J. & Pasimeni, F. (2019). "Materials dependencies for dual-use technologies relevant to Europe's defence sector", Publications Office of the European Union, JRC Technical Reports, KJ-1A-29889-EN-N (online).

BloombergNEF (2023). Electric Vehicle Outlook 2023.

BloombergNEF (2024). Energy Transition Investment Trends 2024.

Bonnet, C., Copinschi, P., Hafner, M. & Laboué, P. (2020). "L'alliance européenne des batteries : Enjeux et perspectives européennes", Observatoire de la sécurité des flux et des matières énergétiques, Rapport 6.

Bonnet, T., Grekou, C., Hache, E. & Mignon, V. (2022), "Métaux stratégiques : la clairvoyance chinoise", *La Lettre du CEPII*, no. 428, June.

Capliez, R., Grekou, C., Hache, E. & Mignon, V. (2024). "Matières premières critiques : vers l'autonomie stratégique européenne ?", L'Economie mondiale 2025, Repères, La Découverte.

CNCCEF (2022). "La Chine hors les murs", Lettre n° 46, CNCCEF.

Cour des comptes européenne (2023). "La politique industrielle de l'UE en matière de batteries. Un nouvel élan stratégique est nécessaire", Rapport spécial 15/2023.

Els, F. (2020). "CHART: China's stranglehold on electric car battery supply chain", Mining.com, April 16.

Foreign Policy (2019), "Mining the future: How China is set to dominate the next industrial revolution", FP Analytics Special Reports, May.

Gaulier, G. & Zignago, S. (2010). "BACI: International Trade Database at the Product-Level. The 1994-2007 Version", *CEPII Working Paper*, no. 2010-23,October.

Hache, E., Barnet, C. & Seck, G. (2021). "Le lithium dans la transition énergétique : au-delà de la question des ressources ?", Les métaux dans la transition énergétique, no. 4, IFPEN, February.

Hache, E. & Normand, E. (2024). "L'heure des choix pour la politique européenne sur les matériaux critiques", L'Economie politique, no. 101, pp. 52-62.

IEA (2021). The Role of Critical Minerals in Clean Energy Transitions. May.

IEA (2024a). Clean Energy Market Monitor, March.

IEA (2024b). Global Critical Minerals Outlook 2024, May.

IPCC (2022). "Climate Change 2022. Mitigation of Climate Change", Contribution to the Sixth Assessment report.

Lee, S. (2019). "50% of LG Chem's batteries made in China", The Elec, November 6.

Mathieu, C. (2021). "Green Batteries: A Competitive Advantage for Europe's Electric Vehicle Value Chain?", Études de l'Ifri, Ifri, April.

Mayer, T., Vicard, V. & Wibaux, P. (2024). "Will Chinese Auto Export Boom Transform into Local Production in Europe?", *CEPII Policy Brief*, no.45, June.

McMahon, K. S. (2022). "Trade Codes Related to the Lithium-Ion Battery Supply Chain for the United States, the European Union, and the People's Republic of China (2020-2021)", U.S. Geological Survey.

Ratel Consulting (2023). Global Battery Factory Database, Ratel Consulting LLC, January.

Reuters (2021). "China's Huayou buys lithium mine in Zimbabwe for $422 mln", Reuters, December 22.

Sharova, V., Wolff, P., Konersmann, B., Ferstl, F., Stanek, R. & Hackmann, M. (2020). "Evaluation of Lithium-Ion Battery Cell Value Chain", *Working Paper Forschungsförderung*, No. 168, Hans-Böckler-Stiftung, Düsseldorf.

United States Geological Survey (2024). Mineral Commodity Summaries 2024, USGS Publications Warehouse.

WWF (2023). "Métaux critiques : l'impasse des SUV. Quel scénario pour réussir la transition de nos mobilités ?", Rapport en collaboration avec l'Institut Mobilités en Transition.

About the authors

Romain Capliez is a master's student in Applied Economics at the University of Paris Nanterre and was an intern at CEPII at the time of writing.

Carl Grekou is an economist at CEPII.

Emmanuel Hache is scientific deputy and foresight economist at IFP Energies Nouvelles, associate researcher at EconomiX, and research director at IRIS.

Valérie Mignon is a professor at the University of Paris Nanterre, a researcher at EconomiX, and a scientific advisor at CEPII.

Contact: romain.capliez@parisnanterre.fr – carl.grekou@cepii.fr – emmanuel.hache@ifpen.fr – valerie.mignon@parisnanterre.fr

Policy Brief

CEPII

Centre d'études prospectives
et d'informations internationales
20, avenue de Ségur
TSA 10726
75334 Paris Cedex 07

contact@cepii.fr
www.cepii.fr – @CEPII_Paris
Press contact: presse@cepii.fr

CEPII Policy Brief
CEPII's insights on international economic policy

CEPII (Centre d'Études Prospectives et d'Informations Internationales) is a French institute dedicated to producing independent, policy-oriented economic research helpful to understand the international economic environment and challenges in the areas of trade policy, competitiveness, macroeconomics, international finance and growth.

Editor-in-chief:
Vincent Vicard

Editorial Director:
Antoine Bouët

Visual design and production:
Laure Boivin

ISSN 2270-258X

January 2025

To subscribe to
The CEPII Newsletter:
www.cepii.fr/KeepInformed

RESEARCH AND EXPERTISE
ON THE WORLD ECONOMY