Electric batteries and critical materials dependency: a geopolitical analysis of the USA and the European Union

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Abstract: This article estimates the import dependency of the USA and the European Union on the raw materials needed to produce batteries that equip electric vehicles. The dependency is very high on many critical materials and on batteries themselves. In a geopolitical context marked by the rising USA-China rivalry and new cold wars, it has prompted the USA and the EU to support local mining and processing of critical materials in an attempt to recover their strategic autonomy. They have also deployed raw material diplomacy to secure access to resource-rich countries by favouring allied countries whenever possible. Both decisions are difficult to implement, and progress is slow. China's dominance over the electric battery is difficult to circumscribe, especially since the USA, with the Inflation Reduction Act (IRA), does not hesitate to defend its interests at the expense of the EU. The result is a politicisation of business, forcing global production networks to align themselves with the opposing blocs.

Keywords: electric vehicles; lithium-ion battery; critical minerals; dependency; raw materials diplomacy; China; Inflation Reduction Act; IRA; European Battery Alliance; mining.

Reference to this paper should be made as follows: Jetin, B. (2023) 'Electric batteries and critical materials dependency: a geopolitical analysis of the USA and the European Union', *Int. J. Automotive Technology and Management*, Vol. 23, No. 4, pp.383–407.

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This paper is a revised and expanded version of a paper entitled 'Electric batteries and critical materials: a geopolitical analysis', presented at the 31st GERPISA International Conference, 'Toward Sustainability? The Electrification of the Automotive Industry', Université Libre de Bruxelles, 27–30 June 2023.

1 Introduction

Batteries are the core element of electric vehicles. They are made of rare earths and minerals and account for 58% to 77% of the total cost of a battery pack [Duffner et al., (2021), p.10].[1] With around 200 kg, the electric vehicle (EV) uses six times more minerals than the combustion-engine vehicle [IEA, (2022), pp.5–6]. The EV also needs a more extensive set of minerals compared to the internal combustion-engine vehicle.

Contrary to oil and gas, these minerals are not widely spread globally but are concentrated in a more limited number of countries. For instance, for lithium, cobalt and rare earth elements, the world's top three producers control well over three-quarters of global output [IEA, (2022), pp.30–32]. In the case of phosphate, five countries control 85% of world production (70% by Morocco alone).

Their demand is growing with the rise of the electric car (Alochet and Midler, 2019) and the progress in the energy transition towards net-zero emissions in 2050. According to the IEA, "… a concerted effort to reach the goals of the Paris Agreement would mean a quadrupling of mineral requirements for clean energy technologies by 2040. An even faster transition to hit net-zero globally by 2050, would require six times more mineral inputs in 2040 than today" [IEA, (2022), p.8]. Lithium demand would grow over 40 times by 2040, followed by graphite, cobalt, and nickel (around 20–25 times) [IEA, (2022), p.8]. This surge in material demand is structural. It reflects the transformation of the EV into a mass market in a context where renewable energies are also a growing source of minerals demand. It will not be matched over the next decade by a proportionate rise in supply, at least not for all minerals. A shortage will occur, leading to a strong price increase that may start to ease in the mid-2030s (Zeng et al., 2022; Liu et al., 2019). The average lead time of mining projects is over 16 years. Companies are interested in deferring their investment to minimise commodity price uncertainty (Foo et al., 2018), which is considered their most critical risk (Jiskani et al., 2022). The advent of an EV mass market and the energy transition is precisely what mining companies were waiting for, and they are now investing massively. The average lead time of mining projects being over 16 years means that added supply capacities will start to weigh down prices in the late 2030s. In the longer term, there is a risk of depletion of some minerals [Jetin, (2020), pp.163–164], even when recycling is taken into account, except to use increasingly destructive technologies of the environment with disastrous social consequences (Paulikas et al., 2022; Griffiths, 2022).[2]

The unbalance between supply and demand is already occurring (Fernyhough, 2022). It is compounded by the disruption of the global production networks (GPN)[3] (Henderson et al., 2002) provoked by the COVID-19 pandemic in 2020–2021, and the invasion of Ukraine in February 2022. It is reshaping the EV and battery global value chain (Economist, 2022b) with the following consequences.

Firstly, the relative scarcity has triggered a global scramble for critical minerals and components that involves mining companies, battery-and car makers. According to Renault's CEO Luca de Meo, "the persistent supply chains crises mean that 'the game has changed' and that 'carmakers have to play by new rules', which would make them more reliant on the efforts of energy and mining companies" (Miller et al., 2022). For instance, car makers must make direct off-take agreements with miners to secure material supply and be able to bargain in a good position with battery makers to get the best price (Dempsey and Campbell, 2022). Until recently, only battery makers and chemical companies were making raw material supply deals with mining companies. Car makers are also taking shares in mining projects (Great Wall Motor at Pilbara, Australia), are creating joint ventures with refiners (Toyota and Orocobre in Nahara, Japan), or also co-investing with battery makers in battery plants (VW with Northvolt, Germany) [Jetin, (2020), pp.167–168]. Tesla has even announced a plan to build a refinery in Texas to process lithium. However, it is considered a way to put pressure on chemical and mining companies (Sanderson 2020). Nonetheless, compared to the previous three decades when externalisation was the rule in the automobile industry, where carmakers conceived their role as 'architects' of GPN, the EV mass market in a context of shortage of materials heralds a new era of stronger involvement and direct relations between carmakers and all the actors of the value chains, including the more upstream, the mining companies. It is reminiscent of 'Ford Motors Company in the 1920s, which set up rubber plantation in the Amazon, a still mill in Michigan and coal mines across the USA to supply its growing automotive empire' (Dempsey and Campbell, 2022).

Secondly, there is a substantial increase and volatility in mineral prices that already spills over to the price of electric cars (Kawakami, 2022). More than 20 EV makers have bumped up prices in 2022 because of the soaring cost of raw materials used in batteries, among them nickel and lithium. Tesla raised its retail prices for its car between 5 and 10% and has decided to switch to lithium iron phosphate (LFP) batteries, which cost about 30% per battery cell less than their nickel-and cobalt-rich counterparts (Yoon, 2022; Opinion Lex, 2022). VW has done the same for some of its models. However, the significant drawback of these cheaper battery chemistries is their lower range which makes them adapted to entry models only (Yoon, 2022). The sudden rise of raw material prices has inverted the declining trend of the battery cost of these last decades from $1,200 per kilowatt-hour in 2010 to $132 in 2021. It is expected to rise to $135 per kilowatt-hour in 2022 (Bloomberg, 2021). According to other estimates, this translates into an increase of over 2,000 euros in the average EV price in 2022 (Punshi, 2022), which may discourage many potential customers. Cost parity with internal combustion engines may not be reached for mid-range EVs by 2025, which extends the need to subsidise EVs to make them affordable. According to the IEA (2022, p.11), "if both lithium and nickel prices were to double at the same time, this would offset all the anticipated unit cost reduction associated with a doubling of battery capacity". However, despite the raw material spike, a majority of studies expect a battery cost of $70 per kilowatt-hour in 2050 thanks to technological innovation, learning curve, and economies of scale (Mauler et al., 2021). These optimistic forecasts rest on the uncertain hypothesis that technological breakthroughs in new chemistries (lithium-sulphur and lithium-air batteries) will happen on time, between 2040–2050, and will reduce the demand for both cobalt and nickel (Xu et al., 2020) to avoid a burden-shifting from one to the other (Baars et al., 2021). Even a widespread adoption of the LFP battery (lithium ferro-phosphate, LFP batteries), which currently equips around 40% of EVs in China, would not avoid the price volatility issue. Phosphorus is made from phosphate and is also used in fertiliser and food. Because of its multiple uses, its price is highly volatile and may impact the LFP battery (Spears et al., 2022). Finally, the low price of LFP batteries and their material abundance rest on estimates based on light-duty vehicles. They are not confirmed when heavy-duty EVs are included. Heavy-duty vehicles' mass electrification would also increase lithium demand substantially putting additional strain on the lithium supply (Hao et al., 2019).

Thirdly, most of the scenarios that forecast a decline in material prices rest on the hypothesis that the recycling of spent batteries will become a significant alternative source of supply around 2035–2040 when a large number of EVs will reach their end of life. For instance, 'recycled quantities of copper, lithium, nickel and cobalt from spent batteries could reduce combined primary supply requirements for these minerals by around 10%' [IEA, (2022), pp.15–16]. The impact on primary supply is therefore limited. But moreover, achieving this result will not be easy because this scenario rests on very high levels of recycling capacities and collection rates. In contrast, the current level is very low, and most of the spent batteries end up in landfills (Mayyas et al., 2019). For instance, in the European case, 'recycling capacity must increase five times the current size by 2035, and 45 times by 2050, to recycle all LIBs' [Baars et al., (2021), p.74]. To reach these objectives, a strong state intervention is needed to make recycling mandatory. Otherwise, recycling will depend on its profitability, which makes it dependent on the relative prices of primary and secondary materials, the available technologies, the labour cost, and the state of environmental regulations in different parts of the world. In the case of the current lead battery that equips internal-combustion vehicles, 'low lead prices and stringent environmental regulations in the USA also led to some spent lead acid batteries being exported or dumped' [Mayyas et al., (2019), p.9]. This shows that an international agreement on recycling is needed to create a level playing field and ensure that the automobile industry is progressively adopting a circular economy strategy. In the meantime, it is hard to believe that recycling will be developed to the point of inverting the rise of mineral prices prompted by the fledging EV mass market.

This context of relative shortage is the source of dependencies of key industries of the new industrial revolution, also called the 'Industrial Revolution 4.0' (Calabrese and Falavigna, 2022): automobile, defence, renewable energies, and the digital economy. They are all highly intensive in the same set of minerals which, because of their strategic importance and their very unequal geographical distribution, are now considered by states and regions as critical minerals and a major geopolitical issue (Lazard, 2021; Careddu et al., 2018). The 'criticality' concept combines the economic importance and the supply risk due to the geographical concentration of supply. The geopolitical stake is rooted in China's overwhelming dominance in critical minerals amid growing USA-China rivalry, placing the EU in the embarrassing position of a helpless guardian of multilateralism. The USA-China conflict is drawing the EU into a geopolitical competition for critical resources that may force car and battery makers and chemical and mining companies to reconfigure their strategies and network.

This article focuses on the new dependencies created by the batteries that equip EVs and the policy responses adopted by the USA and the EU to secure their access to critical minerals. It is organised as follows: Section 2 measures the concentration of minerals and battery components imported by the EU and the USA to better understand their potential vulnerability. The lower the diversity of suppliers, the higher the risk of disruption if one of them is seriously hit by an economic shock or decides to use its position as a political asset. We calculate the Herfindahl-Hirschmann Index (HHI) to estimate the degree of concentration of imports for selected minerals and battery components. We use primary data accessed from the UN COMTRADE database at the six-digit level. Section 3 discusses the geopolitical strategies of the USA and the EU to protect their access to critical minerals. We summarise the evolution of the raw material diplomacies of China, the USA and the EU and their recent protectionist turn: the adoption of the Inflation Reduction Act (IRA) in August 2022 by the USA, and its potential disruptive effect on the 'European Battery Alliance' (EBA), in a context of growing USA/China rivalry and global security tensions. In Section 4, we look at one of the main consequences of this on-shoring or near-shoring policy, which is an attempt to develop mining and refineries of critical materials in the USA and Europe. We rely on secondary sources, particularly academic and selected newspapers, and magazines. We find that it will be difficult to reduce dependencies on foreign supplies by creating local supplies of critical materials due to social and environmental issues.

2 The risky dependence on critical minerals

Governments must ensure the regularity of the supply of critical minerals and intermediate products and avoid any risk of disruption. Since the COVID-19 pandemic, a difference is made in the literature between robustness and resilience (Anukoonwattaka and Mikic, 2020; Miroudot, 2020). Robustness is defined as avoiding any interruption in production or product delivery. Resilience is the capacity to resume delivery when an interruption occurs by switching toward new supply sources. A high level of concentration of supply chains increases the necessity for all the companies involved in a GPN to be very robust, while a diversified GPN minimises the effect of supplier failure thanks to high resilience. In a nutshell, the degree of concentration highlights the potential risk of disruption.

We use the HHI (Babones and Farabee-Siers, 2012), which measures country concentrations.[4]

The HHI on the world import market of product *k*, (HHIk) is the sum of squares of the market shares of all importer countries in total world imports.

$$\text{HHIk} = \sum_j \left(\frac{M_j^k}{M^k} \right)^2$$

where M_j^k is the country *j*'s imports of product *k*, and M^k is the value of total imports of product *k* in the world. World imports are substituted by US imports and EU imports when the HHI is calculated for the EU and the USA. The values range from $\frac{1}{j}$ to 1, with 1 being absolute concentration when all come from one country only, and a value close to $1/j$, in practice, close to 0 when imports come from a large variety of countries. The inverse of HHI can be interpreted as the equivalent number of suppliers in a world where all countries are symmetric.

The US Department of Justice utilises the HHI to identify the concentration level that may be reached in an industry in case of a merger or acquisition of two firms. A market with an HHI between 0.15 and 0.25 is considered moderately concentrated, and a value superior to 0.25 is considered a highly concentrated market (DOJ, 2015). Several publications dedicated to importing dependency take up this level of 0.25, which in practice means that a country is considered dependent when it imports mainly from no more than four countries (Guinea and Espés, 2021; Geissler et al., 2019; Reichl and Schatz, 2019; Chalvatzis and Ioannidis, 2017). On the opposite, Jaravel and Méjean (2020) consider a threshold of 0.5, which implies that a country is dependent if it imports from no more than two countries.

We have chosen a middle way and follow the report from the European Commission report [EU Commission, (2021), p.21], which considers that a country or a region is dependent when the HHI is superior or equal to 0.4, which means that the EU or the USA are considered dependent when their imports originate from mainly 2.5 countries or in practice three countries or less. The EU report acknowledged that this level is conservative.

We calculate, for the year 2021, the HHI for the imports of six critical minerals and materials for battery production: Lithium, graphite, copper, manganese, nickel, and cobalt. Whenever possible, we look at raw minerals, processed chemicals, and refined compounds. We also calculate the index for the imports of lithium-ion batteries.[5]

Table 1 presents the results for each mineral at different processing stages, with values superior or close to 0.4 in bold.

Table 1 HHI import dependency index for selected materials and LIB

Year 2021	*EU Herfindhal index*	*US Herfindhal index*
Unprocessed lithium	0.11	0.15
Lithium carbonates	**0.55**	**0.48**
Lithium oxide and hydroxide	0.31	**0.67**
Refined lithium, chlorides	0.18	0.13
Refined lithium, fluorides	**0.47**	0.28
Refined lithium, alkali	**0.48**	0.35
Natural graphite	0.15	0.27
Copper ore	0.13	**0.90**
Manganese ore	**0.39**	**0.55**
Manganese oxide	0.19	0.16
Nickel ore	0.29	**0.50**
Nickel sulphates	0.19	**0.55**
Cobalt ore	**0.45**	**0.44**
Cobalt oxides and hydroxides	**0.76**	0.25
Refined cobalt	0.11	0.24
Lithium-ion accumulators (LIB)	**0.48**	0.33

Source: Author's calculations with UN COMTRADE database

Table 1 shows that with an HHI equal to 0.48, the EU is highly dependent on two countries for its imports of Lithium-ion batteries (or accumulators in the HS terminology). The USA is not dependent as such but has a rather high index (0.33). Moreover, both the EU and the USA are dependent on at least 6 of the 15 materials, which reveal a high level of risk. Two additional materials have indexes between 0.3 and 0.35 which are relatively high. Both the EU and the USA[6] are not dependent on unprocessed lithium[7] but are dependent on lithium carbonates which are one of the first stages of processed lithium. Moreover, for lithium oxide and hydroxide, a further stage of the refinery, the EU is moderately and the US highly dependent. Both countries are dependent on manganese and cobalt ores, and the USA is very dependent on one country for copper ore. For cobalt oxides and hydroxides, the EU is very dependent on almost one country.

Table 2 Geographical origin of the main material suppliers

2021	*EU main suppliers*	*USA main suppliers*
Unprocessed lithium	*China (18%)*, Australia (18%), USA (12%), *Russia (11%)*, Switzerland (11%), South Africa (8%), Mexico (5%), Norway (3%)	Mexico (24%), Canada (19%), Japan (18.4), Australia (12%), *China (10%)*
Lithium carbonates	Chile (73%), Argentina (9%), UK (8%), USA (5%), *China (2%)*, Korea (2%)	Chile (51%), Argentina (47%), *China (1%)*
Lithium oxide and hydroxide	*Russia (40%), China (12%)*, USA (6%)	Chile (81%), *Russia (16%), China (2%)*
Refined lithium, chlorides	UK (27%), *China (19%)*, USA (18%), India (15%), Argentina (9%), Korea (3%), Switzerland (3%), *Ukraine (2%), Russia (1%)*	India (21%), Germany (18%), Canada (17%), Argentina (10%), *China (9%)*, Korea (7%), UK (6%)
Refined lithium, fluorides	*China (65%)*, Korea (21%), Japan (5%), UK (3%), *Russia (3%)*	*China (44%)*, Japan (21.7), Thailand (18%), Korea (7%)
Refined lithium, alkali	*China (66%), Russia (16%)*, USA (14%)	*Russia (53%), China (24%)*, France (7%), Argentina (5%)
Natural graphite	*China (25%)*, Korea (19%), Japan (15%), Brazil (13%), Madagascar (8%), Mozambique (6%), USA (4%), Norway (3%)	*China (45%)*, Canada (22%), Brazil (10%), Madagascar (8%), Mexico (7%)
Copper ore	Brazil (23%), Chile (18%), Peru (15%), Panama (7%), Canada (7%), Indonesia (6%), Australia (6%), USA (4%)	Canada (95%), Peru (5%)
Manganese ore	Gabon (47%), South Africa (41%), Brazil (6%)	Gabon (72%), South Africa (16%), Mexico (10%)
Manganese oxide	Norway (31%), *China (28%), Georgia (7%)*, Korea (6%), USA (6%), Colombia (6%)	Greece (26%), Japan (20%), India (15%), South Africa (14%), Brazil (7%)
Nickel ore	Canada (47%), Brazil (18%), South Africa (13%), Côte d'Ivoire (9%), *Russia (5%)*, Mozambique (4%), Norway (2%)	*China (52%)*, Germany (48%)
nickel sulphates	Other Asia (25%), Philippines (23%), South Africa (22%), Japan (12%), Korea (8%), USA (7%)	Belgium (93%), Finland (7%)
Cobalt ore	UK (62%), USA (25%), *China (5%)*, Guyana (4%), Morocco (1%)	*China (62%)*, Germany (22%), UK (10)
Cobalt oxides and hydroxides	*China (87%)*, UK (12%), Turkey (1%)	Finland (33%), UK (27%), Belgium (24%), Other Asia (8%)
Refined cobalt	Canada (19%), USA (13%), Morocco (13%), Turkey (10%), Norway (9%), *Russia (7%)*, Japan (7%)	Norway (44%), Japan (13%), Canada (12%), *Russia (10%)*, Finland (7%)
Lithium-ion accumulators (LIB)	*China (67%)*, Korea (18%), Japan (4%), USA (3%),	*China (54%)*, Korea (17%), Japan (10%), Germany (3%)

Source: Author’s calculations with UN COMTRADE Database

Table 2 provides more details on the geographical origin of the dependence. We have highlighted China's and Russia's supplies because of the geopolitical and commercial tensions between them, the EU, and the USA. Firstly, the very high EU dependence on LIB is explained by the very high share of China (67%) and Korea (18%). Together, these two countries account for 85% of European LIB imports. Although China's share is high (54%), the US dependence is weaker because Japan plays a greater role (10%). Secondly, for the EU, we observe that China and Russia appear 12 times with a share at least equal to 10% in European imports and ten times in the US case. These results point to a high potential for disruption for a total of 15 inputs plus LIB. More, the importance of China and Russia is underestimated because some countries import raw minerals from these two countries to process them and later export the refined materials to the EU and USA. Russia produces about 10% of the world's nickel supply and is the second-largest cobalt producer. The invasion of Ukraine drove the nickel price to double its 2021 level, and cobalt has followed (Okinaga, 2022). But what dominates is the dependence of the USA on China for some raw minerals (graphite, nickel, cobalt) and together with Russia for processed materials (refined lithium, fluorides, alkali). The EU is also very dependent on China for refined lithium, fluorides and alkali and on cobalt oxides and hydroxides. It also has a high dependence on Russia for lithium oxide and hydroxide.

3 American and European political strategies in the face of Chinese domination

The dependency on China's critical minerals highlighted above comes from afar and results from an industrial and commercial policy soon after the PRC was established in 1949s.[8] China started investing in innovation in the 1960s and mass-producing rare earths in the 1970s. It established a vertically integrated supply chain in the 1980s and the 1990s attracting foreign investment to upgrade its extractive and refinery technologies. President Deng Xiaoping stated in 1992, "there is oil in the Middle East and rare earth in China" [Barteková and Kemp, (2016), p.155]. Rare earths in China were declared 'protected and strategic materials' as early as 2003. At the same time, China began to deploy economic diplomacy to support its 'going out strategy' adopted in 1999 (Abeliansky and Martínez-Zarzoso, 2019) and to guarantee Chinese companies' access to raw materials in Africa and Latin America (Biedermann, 2018). China has multiplied free trade agreements, loans, donations, and investments in developing countries in exchange for deliveries of raw materials. Chinese companies, particularly state-owned companies, invested abroad in knowledge-intensive-and mining companies. China became, in one decade, the top three largest investors in the world. China adopted in 2009 a Strategic Petroleum Reserve Programme and an EV policy to, among other objectives, reduces oil imports. In 2015, EVs became one of the ten strategic industries selected in the 'Made in China 2025' that received massive support from the state. Meanwhile, China strengthened its economic diplomacy to ensure growing imports of critical materials. It was subsumed in the 'Belt and Road Initiative' in 2013 (Biedermann, 2018), with up to 8 trillion US dollars of loans and investments in infrastructure, energy and telecommunication that will boost its imports of raw materials and exports of manufactured goods and services (Jetin, 2018). The BRI enabled China to extend a 'web of global partnerships' (Kalantzakos, 2020) which includes 146 countries in 2022 that host a large number of Chinese companies. The outcome of this systematic long-term policy is that when the EV market took off, there was overwhelming Chinese domination in rare earths and other critical materials from the early stage of mining to processing and trade (Wang et al., 2022; Bonnet et al., 2022; Sanderson, 2019). According to the IEA, China controls the processing of 35% of the world's nickel, half the lithium, 70% of cobalt and 90% of rare-earth elements [IEA, (2022), p.32].

This domination is all the more worrying for the USA, the EU, Japan and Korea because China applied export restrictions on rare earths and eleven materials (aluminium, cokes, copper, magnesium and nickel) in the past [Biedermann, (2016), p.120]. In 2007, export restrictions were decided because there was a shortage of supplies in China due to the very strong domestic demand. In 2010, the motive was political. When the government of Japan bought the Seikoku islands from its private Japanese owner, China retaliated with an unofficial ban on rare earths exports to Japan because it claims sovereignty over them. In response to the export restrictions, the USA, the EU, and Japan adopted a collective response and filed a complaint at the WTO in 2012. China was condemned in 2014 and eliminated all export restrictions in 2015, five years after the incident. However, in 2021, with the current US/China trade and technology war, President Xi Jing Ping ostensibly visited rare earth plants, and China explored the possibility of banning rare earths exports to the USA to hinder the production of American Lockheed F-35 fighter jets (Yu and Sevastopoulo, 2021). Rare earths and other critical metals are definitely not metals like any other because their production and trade can be disrupted at any time by geopolitical tensions.

The reaction of the European Union and the USA was belated and initially needed to measure up to the challenge.

The European metal industry, particularly since 2005 the German metal industry association, called on the EU to act against export restrictions and tariffs [Biedermann, (2016), p.16]. They feared that these restrictions, plus the fierce competition in resource-rich countries to source raw materials, could lead to limiting their purchases and increasing materials prices. In response, the EU reaffirmed in 2006 with the communication 'Global Europe' the priority given to undistorted access to free markets. The EU is fundamentally a regulatory power with the goals of market creation and regulation [Grabbe, (2021), p.59] 'without preference for radical solutions' (Barteková and Kemp, (2016), p.157]. In practice, it means that no coordinated industrial policy was adopted at the European level (Pardi, 2021). Still, instead, the EU defended the principle of access without discrimination to raw materials at the World Trade Organisation and in the trade and investment agreements negotiated with foreign partners. Although the EU tried to eschew a direct confrontation with China, the latter was perceived as a state that does not hesitate to distort competition rules to defend its strategic interests and those of its companies. However, it was only with adopting a 'raw material initiative' in 2008 that materials came to the fore. The initiative aims at securing external raw materials supplies to the EU (pillar one), developing mining in Europe (pillar two), and reducing internal consumption with better efficiency and recycling (pillar three). This initiative led to the announcement of the first EU list of critical materials in 2011 (EU Commission, 2011), updated every three years. The main concerns were rare earths and magnets, which have dual civil and military applications (Blagoeva et al., 2019) and of which Europe is largely devoid. They were the priority, which was not the case with batteries at the time. The 2011 list did not cover the entire portfolio of critical materials needed to produce batteries (Løvika et al., 2018). Cobalt was registered but not natural graphite, nickel, or lithium.

Graphite was added to the list in 2014 and lithium in 2020 because of the rise of EVs and renewable energy.[9]

During these 12 years (2008–2020), the EU raw material diplomacy was mostly dedicated to achieving the security of raw materials supplies by diversifying the supplier countries thanks to the principle of free trade [Lazard, (2021), p.21], particularly with African countries (Awuah, 2019). It is the only trade policy compatible with the rules of the European single market that stresses the principle of free and undistorted competition. During the 1990s and 2000s, this principle was strictly applied within the EU, and much pressure was put on state members to privatise state-owned companies and reduce state aid to industry to a minimum. These were the decades of implementation of the Single Market, the European Monetary Union, and the Maastricht Treaty. A neoliberal consensus was formed against the state as producer and in favour of the state as regulator [Pianta et al., (2020), p.780]. This resulted in the profound deindustrialisation of Europe, particularly in the wake of the great recession of 2008–2009.[10] It also led to the polarisation of the remaining manufacturing in Germany and Central Eastern Europe at the expense of the rest of the EU.[11] The decline in European mining production is spectacular. At the beginning of the 20th century the European mining industry amounted to 40% of global production while at the start of the 21st century, it had plummeted to 2%–3% [Mateus and Martins, (2021), p.246]. Significant mining production is now confined to only seven countries. The EU is self-sufficient for construction materials (cement, ceramics, glass and lime) but relies too much on imports for a large number of mineral commodities despite a recycling rate of 40 to 60% of the annual inputs the smelting and refining facilities; In construction and automobile industries the recycling rate is very high (90-95%) but only 35% in electronics [Mateus and Martins, (2021), p.246]. On average, the import dependency for minerals is higher than 60%, although it is very mixed for different materials and stages in the value chain [European Commission, (2021), p.47]. It is very high at the mining stage (for instance 86% for cobalt) and much lower at the processing stage (27% for cobalt) [European Commission, (2021), p.49].

Facing the decline of manufacturing and the challenges of the USA, China and new emerging powers, the EU decided to react in the 2010s and to open the debate about a new industrial policy at the European level. The 'European Fund for Strategic Investments (EFSI)', the main tool of the Juncker Plan, was adopted in 2015, followed by a new investment plan, 'InvestEU', over the years 2021–2027. For the first time, there were EU-level programs that went beyond the 'market knows best' dogma. The legitimacy of the state to define and pilot an industrial policy at the EU level was partially restored. One of the positive outcomes is the review of the EU's state aid policies. The general principle of EU legislation is the prohibition of any kind of selective government support, providing any advantage to a firm over its competitors. However, an exception can be made when the aid provided by state members is part of an Important Project of Common European Interest (IPCEI)[12] approved by the EU Commission. This is precisely the case of the EBA[13] formed in 2017 and completed in 2020 by a European Raw Materials Alliance (ERMA).

The EBA was created at the initiative of the French and German Governments, with the support of the European Investment Bank and coordinated by the EU Commission. It is sometimes called in France the 'Airbus of Batteries', which reflects the wish of the French government to reproduce the success of Airbus, thanks to a close relationship with Germany. The EBA launched the first programme at the end of 2019, sponsored by seven state members, which provided together €3.2 billion of state aid to build the first

European Giga factories. A second programme was approved by the European Commission in January 2021, supported by 12 state members with state aid of €2.9 billion to fund a research project on the new generation of batteries. On paper, the EBA looks promising.

There are nonetheless serious flaws that stem from the compliance with EU competition law which is at the core of the project of EU 'open strategic autonomy'. EBA projects are open to any European and foreign company, provided they operate in the EU. It is the private sector's most preferred policy because European companies can make deals with non-European companies, irrespective of geopolitical concerns. European car manufacturers do not care about the nationality of the battery makers as long as the batteries correspond to the quality demanded and are delivered on time at the lowest price. The EU's dependency on China and Chinese companies are not a problem as long as they are the most competitive and are not in a position to impose their conditions on European carmakers. To avoid excessive reliance on external providers, some European carmakers like Volkswagen, Daimler and Stellantis are expanding their own production. Volkswagen plans to build five plants in Europe (Campbell and Dempsey, 2022), and Daimler four (Miller, 2021), one of them being operated by Automotive Cell Company (ACC), a joint venture with Stellantis and SAFT, a company owned by TotalEnergies.

Because there are no European battery makers able to produce large volumes of batteries in the short-term, Chinese, Japanese and Korean battery makers benefit the most from EU funding and member state aid and even regional authorities.

Renault has signed a contract with Chinese battery maker Envision, who in 2019 bought AESC, a former Nissan company. A new Giga factory located in Douai, north of France, near a Renault plant, has received around €200 million subsidy from the French government and local authorities plus €100 million of EU funding. Tesla and Panasonic Giga factory has received around €1.1 billion subsidy from the EU (Poitiers and Weill, 2022; Foo, 2021). Additional state aid can be granted to foreign battery makers when they invest in less-developed European regions, such is the case for the Korean SK company in Hungary (PubAffairs, 2022).

The massive presence of foreign competitors subsidised by European and state members will make it difficult for European newcomers in battery mass production to succeed. The EBA and the ERMA come too late while the EU objective of a total ban on the sale of new diesel and gasoline cars by 2035 to reach net-zero emissions by 2050 comes very soon. This has prompted European carmakers to turn to Asian battery makers in the expectation that their battery production capacities will help them to meet the 2035 EU objective. Moreover, in the short-term, at least, it does not resolve Europe's dependency on raw materials because the battery makers continue to import them mainly from outside Europe. Worse, the whole building was undermined by the adoption in August 2022 by the Biden administration of the IRA.

In the 1950s, the USA had a strong position in rare earths and other minerals now considered critical. Molycorp, founded in 1919, owner of the Mountain Pass mine in southern California, was a leading producer and processor and mastered the related technologies.[14] Because of the growing competition from Chinese companies in the nineties, Molycorp's production and revenues declined, and the company stopped production a first time in 2002 and a second time in 2015. It resumed its activity on a small scale in 2016 (Laplane, 2021). The decline of mining was compounded by the decline of downstream activities in the supply chain. The magnet producer, Magnequench, created by General Motors in 1986 to supply magnets to its automobile plants, was sold in 1995 to a Chinese-American consortium with the approval of President Clinton, who declared that there was no evidence that it could threaten American security [Laplane, (2021), pp.9–10]. In 2003, all the activities of Magnequench were transferred to China. The Clinton (1993–2001) and Bush (2001–2009) administrations did not take the growing US import dependency seriously [He, (2018), p.241]. The Clinton administration closed the US Bureau of Mines, the Defence stockpiles were sold in 1997, and funding for the United State Geological Survey (USGS) stagnated. The Rare Earth Information Centre closed in 2002. There was no critical materials diplomacy. The rare earth security issue came briefly into the spotlight in 2005 when a Chinese conglomerate, CNOOC, tried to buy Unocal, Molycorp's parent company but disappeared when CNOOC withdrew its bid when it sensed that it would not be accepted. The Bush administration tried to cut by half the USGS budget in 2007, which reveals the lack of awareness and interest in critical materials while Japan and the EU had already adopted proactive policies. The wake-up call came in 2010 when US Secretary of State Hillary Clinton discovered that not only China controlled 97% of rare earth world production but was ready to use it for geopolitical purposes against Japan in the Senkoku Island conflict [Kalantzakos, (2020), p.3]. However, the record of the Obama presidency remains modest. Scientific research on reducing supply risks for sectors located downstream of the production chain has been reinforced. This mainly concerns energy and defence. But scientific research and production in the mining industry have received very little support. Diplomacy has been limited to scientific collaboration and information exchange with ally countries like the EU, Japan, Canada, and Australia. But there has been no real commodity diplomacy comparable to that of the EU and Japan [He, (2018), p.246].

The policy change will come with the Trump presidency (2017-2021). A first executive order was signed in December 2017, aimed at establishing a complete inventory of critical minerals on US soil and streamlining the leasing and permitting process in mining. A list of critical minerals was published in 2018. Funding for scientific research in the mining industry and the refinery of metals was granted. Several departments (interior, energy, defence) published reports on the strategy to be followed to develop the production and refining of critical metals in the USA. In September 2020, a second executive order was signed to 'address the threat to the domestic supply chain from reliance on critical materials from foreign adversaries'. This second order introduce for the first time the notion of 'foreign adversaries', which is a clear allusion to China, with whom the Trump presidency has engaged in an escalating trade dispute. The objective is to bring back mining activities in the USA, reduce import dependency and create jobs that cannot be later offshored. Finally, a raw material diplomacy is now explicitly established. Partnerships with resource-rich allied countries are reinforced through bilateral or regional agreements (Canada, Mexico, Australia), and relations with Greenland are strengthened. In June 2019, the 'energy resource governance initiative' was created to establish privileged relations with other countries to diversify and secure a steady supply of minerals.[15] This policy is clearly intended to reduce China's stranglehold on critical minerals.

The Biden presidency, which begins in 2021, is a continuation of the policy inaugurated by Trump, even if the motivations are different. The strengthening of American defence remains a decisive factor, but the development of renewable energies and the EV now play a leading role.

In November 2021, the first bipartisan infrastructure law accorded $2.8 billion in grants to about 20 companies to build lithium refineries to graphite production plants (Dempsey and McCormick, 2022). This is expected to draw $9 billion when combined with private investment.

In August 2022, President Biden approved a second law, the 'IRA', which includes climate and healthcare laws and new standards that EVs must meet to earn their buyer a tax credit worth $7,500. Regarding clean energies, the IRA gives a major boost to solar panels, wind turbines, low-carbon hydrogen, and other low-carbon power generation sources. Regarding the automobile industry, the objective is to get half of the new vehicle sales to be electric by 2030. It is the biggest-ever piece of legislation. It will provide tax incentives until 2031 to companies that develop mines, refineries, battery plants and EVs factories in the USA. It has received the support of the National Mining Association (Werschkul, 2022) which had doubled its lobbying expenditure from 2020 to 2022 (Cama and Northey, 2023).

To get the rebate, EVs must be assembled in Canada, Mexico, or the USA. And from January 2024, they must meet two additional criteria, each worth half of the $7,500. 50% of the value of the battery components must also be manufactured or assembled in North America, where the USMCA (Areous et al., 2022), the new trade agreement, allow an integrated flow of components. And 40% of the critical minerals used in the battery must be sourced either from those countries or from one with which the USA has a free-trade agreement. Both requirements will get stricter over time. Moreover, EVs using any components from a 'foreign entity of concern', such as China or Russia, will be ineligible from 2024. Those using critical minerals from such countries will lose out in 2025.

The IRA serves two purposes. Firstly, a geopolitical purpose. It will significantly reduce the import dependency on China. As stated by Socrates Economou, head of Nickel and cobalt trading at Trafigura, a leading global commodity trading house: "As an initial statement, the IRA underlines what America's target is: It will reward supply of refined product that does not pass through Russia or China" (Dempsey and McCormick, 2022). Secondly, the IRA links a tax break with domestic content, which is a powerful instrument to attract foreign investment in the USA at the expense of Asia and Europe. Several European companies, like Northvolt, the emblematic Swedish battery maker start-up backed by Volkswagen, BMW and Goldman Sachs, are considering whether to build their third factory, after two in Sweden, Germany or the USA (Milne, 2022). "The IRA would subsidise a factory in America by about $600 mn–$800 mn, according to Northvolt. That compares to €155 mn in incentives on the table from Germany" (Financial Times, 2022).

The IRA exposes the limits of the EU. Ursula Van der Leyen, the President of the EU Commission, said that IRA discriminates against European companies. The EU is more a victim of its blind faith in free trade that neither China nor the USA respect with such stubbornness. World Trade Organisation rules forbid subsidies that are only available to domestic producers. The Buy American requirement regarding batteries replicates a similar rule applied by China until recently, which shows that both countries have no problem disregarding it. The EU does not want to engage in a subsidy race with the USA nor adopt a Buy European requirement to match the Buy American requirement. Some European member states are already highly indebted and are committed to reducing their debt-to-GDP ratio to respect the EU fiscal rules. The EU is constrained by the fact that taxation lies with member states, and subsidies are framed by EU state aid rules to maintain a level playing field within the EU. A solution can be a new round of bloc-wide funding for the green transition. Internal market commissioner Thierry Breton has suggested a €350 billion Sovereignty Fund that would be partly funded by common borrowing, which again contradicts the commitment to debt reduction.

To circumvent this difficulty, the EU reacted in 2023 with a set of measures related to environmental regulation and taxation.

The first decision is the adoption of a new European Battery Regulation (European Parliament, 2023). Agreed by the European Commission, the Parliament and the European Council in December 2022 and published in May 2023, it will foster the recycling of batteries and reduce their carbon footprint. The new regulation replaces the previous 2006 Directive and is part of the European Green Deal. It will for the first time cover the entire lithium battery life cycle, from extraction of the raw material to production, design, labelling, traceability, collection, recycling, and reuse. It is expected to boost a European battery circular economy to reduce the imports of batteries and critical materials and therefore push for localisation and improve European autonomy (European Parliament, 2022). However, if successful, this new regulation will take time to provide its benefits.

The second decision is the adoption of a 'carbon border adjustment mechanism' (CBAM) adopted by the European Parliament on 18/04/23. This carbon tax seeks to level the playing field for the domestic companies regulated by the EU's emission trading system (ETS) by imposing a levy on carbon-intensive products to countries that do not have a domestic carbon tax (Financial Times, 2023). The first products to be taxed are iron and steel, cement, fertilisers, aluminium, electricity and hydrogen, the latter being often produced with coal-powered energy. Plastics and chemicals will be taxed in 2026, and all products, including cars and their parts in 2030 (Monkelbaan and Figures, 2023).

The third decision is the adoption of the 'Net Zero Industry Act' which sets out a domestic production target by 2030 for eight industries, including solar and wind energies, batteries, and electrolysers. Companies willing to bid for public tenders or subsidies would have to meet a level of European content of 40% to be eligible, but governments can ignore the provisions if it means prices are 10% higher than imports (Hanckok and Bounds, 2023). An important provision of the 'Net-Zero Act' is that 'public procurement bids using products from a country with more than 65% EU market share would be downgraded' (Bounds and Hanckok, 2023). This provision clearly targets China and the overdependence of the EU on imports of Chinese solar panels, heat pumps and other 'green technologies' and could apply to batteries and their components.

A fourth measure regards critical materials. The EU Commission wants to facilitate domestic mining of lithium and other minerals used in green technology by easing the licensing process. This aims at strengthening the EBA which is weakened by the IRA. One way to overcome the difficulty is to develop mining in Europe, which would alleviate the geopolitical risk and the shortage of materials.

4 Sustainable onshore mining?

The exploration of new mining projects within Europe or the USA is the most direct way to reduce the geopolitical risk of the raw material production network (McKinsey&Company, 2022). In both territories, the public authorities are trying to relaunch mining production to reduce import dependence. In the EU, it is the second pillar of the raw materials initiative adopted in 2008. In the USA, it has been a new policy objective since the Biden administration.

However, mining and refining rare earths and other critical minerals like lithium consume much water and energy and produce huge volumes of toxic waste. These environmental issues have long been neglected and underestimated [Agusdinata et al., (2018), pp.8–11].[16] Since climate change-induced drought is pervasive in Europe and energy cost is skyrocketing because of the new Cold wars (Kennedy-Pipe and Waldman, 2017), boosting mining is not very popular. It meets much social resistance from the local population (Kivinen et al., 2020).

In Europe, some decisive new lithium mining projects supported by national authorities face the hostility of local communities or at least a certain level of mistrust. This is the case in countries where existing mining has led to environmental disasters (Eerola, 2022) or where old closed mines that have left an ambivalent memory could be reopened (Balan, 2021). This is also the case in Serbia, Spain, and Portugal for new lithium projects.

Serbia is rich in gold, silver, copper, bore and lithium that Fiat could use (Economist, 2022c). Chinese and Australian mining companies expect to exploit these huge reserves. Since 2020, Rio Tinto, with the government's support, has purchased land and houses in the Jadar Valley, creating ghost villages and transforming the rural landscape into war-torn areas. Twenty-two villages and around 20,000 inhabitants would see their life completely changed because of the air, land, and water pollution. The local protest, in a region known for its fierce nationalism, turned national-wide, and in the spring of 2021, the whole region was covered with 'no to lithium, yes to life' signs. In the fall, blockades paralysed the traffic on highways, and people marched in the streets of Belgrade, chanting that Serbia was not for sale (Dunai and Hume, 2021). The government, which had planned to pass a law on expropriation, backpedalled quickly, announcing the suspension and then the cessation of Rio Tinto's projects (Dunai and Hume, 2022).

This is an example of what the EU calls the reluctance of the European population towards mining (EU, 2021).

The same reluctance is observed in Spain, where two sites have promising lithium reserves. At three kilometres from the medieval town of Cáceres, foreign investors want to create one of Europe's largest lithium mines with EU financial support (Dombey, 2021). It is strongly opposed by the local population and the town's authorities, which depends on heritage sites, tourism, and sustainable activities for their prosperity. Opponents are winning. Infinity Lithium, the Australian mining company, has lost its research permit and faces a lengthy battle in the courts. However, the surrounding region's government of Extremadura favours lithium mining and supports a €1 billion mine project in the Cañaveral district 40 km to the north. Part of the investment comes from the EU recovery fund. A battery cell factory and a cathode factory would accompany it. The mayor backs the scheme. However, the mine is between two protected bird reserves and ancient woodlands, and environmentalists object to the project. If approved, mining could start in 2023, and cells would feed seat's EVs.

In northeast Portugal, the Barroso mine was expected to produce lithium for cars in 2020 (Wise, 2020). But the mining company has been forced to delay the operation several times as it waits for environmental approval. Part of the environmental regulation comes from the EU Directive, and the processing is longer than in Australia or the USA. The project would be Portugal's first mining license in the last 30 years. Another project in Montalegre ‘was cancelled after intense local controversy and concerns about the quality of the environmental impact assessment commissioned by the developer [Graham et al., (2021), p.12]. Opponents feared that the project would damage farming and tourism.

If these examples are indicative of most European countries, the conclusion is that developing lithium mining in the EU will be a lengthy and uncertain process.

The same can be said about the USA, where critical materials are sparking a mining boom (Hammond and Brady, 2022). According to the US Geological Survey, the USA holds about 8 million tonnes of lithium, putting it in the world’s top five most lithium-rich countries. Yet, mining lithium and other metals face formidable difficulties. 97% of America’s nickel reserves, 89% of copper, 79% of lithium and 68% of cobalt are found within 35 miles of Native American Reservations, (Economist, 2022a). Lithium Americas is planning a mine at Thacker Pass in Northern Nevada. Ioneer USA Corp wants to build a large mine in Southern Nevada, which has the largest lithium resources in the US. Piedmont Lithium in North Carolina plans to exploit the US’s largest deposit of spodumene ore. This mineral can be processed into lithium, which it has already pledged to sell to Tesla (Williams, 2022). All these projects face local opposition, and environmentalists argue that the ‘clean energy transition cannot build on dirty mining’. So far, Piedmont Lithium has delayed deliveries to Tesla indefinitely after falling behind with permitting applications (Dempsey and Campbell, 2022). Ioneer has to delay production after the US Fish and Wildlife Service proposed to protect Tiehm’s Buckwheat, a wildflower, under the Endangered Species Act (Sanderson, 2021).

Not all projects are doomed to fail. Chemicals group Livent completed in November 2022 an expansion of a lithium hydroxide refinery in Bessemer City, North Carolina, that will be the first capacity increase in the USA in more than a decade. Investments are also being made in graphite and cobalt refineries (Dempsey and McCormick, 2022). However, even if progress is made, it is hard to imagine that mining and refinery in the USA will be ready to deliver in 2025 the necessary volumes of all the minerals needed to produce batteries in the USA that excludes materials from China and other ‘foreign entity of concern’. For that reason, carmakers in the USA are trying to water down the IRA (Bushey and Aime, 2022). If no compromise is found, mining companies from countries allied with the USA (Australia, Brazil, Canada, Mexico, and South Africa) will fill the gap and export growing volumes of materials to the USA.

5 Conclusions

This paper has investigated the new economic dependency and the geopolitical risks generated by the rise of the EVs mass market. The energy transition triggered by the Paris Agreement is leading to the fast transition to the EV before the necessary infrastructure, and GPN are in place. This has increased the geopolitical risks to a level that has not been experienced since World War II. The automobile industry was submitted to the vagaries of the oil market that was regularly hit by geopolitical conflicts and war. The transition to EVS will add new uncertainty because, at the world level, ‘critical materials for the ‘clean’ transition are located both in critical ecosystems and conflict-affected and fragile zones’ [Lazard, (2021), pp.22–23]. Our paper shows that both the USA and the EU are dependent on importing many of these critical materials, and they cannot expect to reduce their dependency by a rapid and significant increase of mining and refinery in their respective territories. The EU is particularly vulnerable because it will depend on fossil fuels and critical materials, while the USA only depends on the latter.

Consequently, both the USA and the EU will rely on raw material diplomacy to maintain their access to resource-rich countries. The latter are increasingly part of geopolitical alliances and networks. This implies a politicisation of business affairs and practice. The automobile industry is increasingly caught in the conflict between the USA and China. Russia's invasion of Ukraine adds more political pressure on the GPN. Onshoring and nearshoring will redefine the geography of automobile production according to a new geopolitical divide.

With the IRA, the USA has decided to subsidise decarbonisation with tax incentives. It seems on a fast track to attract many foreign investments and boost domestic investment in the whole EV and green energy supply chain while excluding Chinese companies from the benefits of the policy (Chu and Roeder, 2023). This manufacturing boom gives an edge to South Korean battery producers who have dramatically increased their investments in the USA.

The EU has chosen a different route. It has lessened its exclusive reliance on free trade agreements to source the critical raw materials it needs and has made significant steps in its new quest for strategic autonomy. It is pricing carbon while staying open to Chinese companies. The CBAM has raised concerns from China who asked the EU to send a report to the World Trade Organisation to check if the new EU legislation complies with the WTO rules and is not a disguised 'green protectionism'. Chinese battery producers in China do not face the same environmental restrictions as in the EU in particular in terms of carbon emissions. Their imports in the EU may be taxed in 2030 if they cannot provide evidence of a low-carbon emission record. Their production in the EU will have to comply with the new rules. This may give a window of opportunities to EU companies that are starting their operations to catch up with their Chinese competitors provided that they invest massively in green energy to reach a low-carbon footprint. By using less bellicose rhetoric towards China and thanks to a different policy, the EU is aiming for the same objectives of reducing excessive dependence on foreign supplies and relaunching the European industry. It remains to be seen how long it will take for this gradual and more open policy to be successful.

Acknowledgements

This research was funded by a UBD Research Grant UBD/RSCH/1.12/FICBF(b)/2023/023.

References

Abeliansky, A.L. and Martínez-Zarzoso, I. (2019) 'The relationship between the Chinese 'going out' strategy and international trade', *Economics*, Vol. 13, No. 1, https://doi.org/doi:10.5018/economics-ejournal.ja.2019-21.

Agusdinata, D.B., Liu, W., Eakin, H. and Romero, H. (2018) 'Socio-environmental impacts of lithium mineral extraction: towards a research agenda', *Environmental Research Letters*, Vol. 13, No. 12, 123001.

Alochet, M. and Midler, C. (2019) 'Reorienting electric mobility research focus on industrialisation issues', *International Journal of Automotive Technology and Management*, Vol. 19, Nos. 3–4, pp.229–256, https://doi.org/10.1504/IJATM.2019.100915.

Anukoonwattaka, W. and Mikic, M. (2020) 'Beyond the COVID-19 pandemic: Coping with the 'new normal' in supply chains', *ESCAP Policy Brief*.

Areous, G.I.B., Covarrubias Valdenebro, A. and González, N.I. (2022) The USMCA and the Mexican automobile industry: towards a new labor model?', *International Journal of Automotive Technology and Management*, Vol. 22, No. 4, pp.128–144 [online] https://www.inderscience.com/info/inarticle.php?artid=122140.

Awuah, M.A. (2019) 'Raw materials diplomacy and extractives governance: the influence of the EU on the African extractive industry space', *South African Journal of International Affairs*, Vol. 26, No. 2, pp.251–275. https://doi.org/10.1080/10220461.2019.1608852.

Baars, J., Domenech, T., Bleischwitz, R., Melin, H.E. and Heidrich, O. (2021) 'Circular economy strategies for electric vehicle batteries reduce reliance on raw materials', *Nature Sustainability*, Vol. 4, No. 1, pp.71–79, https://doi.org/10.1038/s41893-020-00607-0.

Babones, S. and Farabee-Siers, R.M. (2012) 'Indices of trade partner concentration for 183 countries', *Journal of World-Systems Research*, Vol. 18, No. 2, pp.266–277.

Balan, H. (2021) 'Exploitation, post-mining, re-exploration? New projects for former French metal mines', *The Extractive Industries and Society*, Vol. 8, No. 1, pp.104–110, https://doi.org/ https://doi.org/10.1016/j.exis.2020.07.009.

Barteková, E. and Kemp, R. (2016) 'National strategies for securing a stable supply of rare earths in different world regions', *Resources Policy*, Vol. 49, pp.153–164.

Biedermann, R. (2016) 'The European union's raw materials diplomacy: market access and development?', *European Foreign Affairs Review*, Vol. 21, No. 1, pp.115–134 [online] https://www.kluwerlawonline.com/document.php?id=EERR2016008.

Biedermann, R. (2018) 'China's raw materials diplomacy and governance cycle: toward sustainable mining and resource extraction?', *Issues & Studies*, Vol. 54, No. 4, 1840009, https://doi.org/10.1142/s101325111840009x.

Blagoeva, D.C.P., Wittmer, D., Huisman, J. and Pasimeni, F. (2019) *Materials Dependencies for Dual-Use Technologies Relevant to Europe's Defence Sector (Science for Policy Report, Issue. P.O.o.t.E. Union* [online] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/materials-dependencies-dual-use-technologies-relevant-europes-defence-sector (accessed 5 July 2023).

Bloomberg (2021) 'Battery pack prices fall to an average of $132/kWh, but rising commodity prices start to bite', *Bloomberg NEF*, 30 November [online] https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite (accessed 5 July 2023).

Bonnet, T., Grekou, C., Hache, E. and Mignon, V. (2022) 'Métaux stratégiques: la clairvoyance chinoise', *La Lettre du CEPI* (428).

Bounds, A. and Hanckok, A. (2023) 'Brussels to curb imports of Chinese green tech', *Financial Times*, 15 March [online] https://www.ft.com/content/4ba01b96-a117-4811-98c0-61d1439e3559 (accessed 5 July 2023).

Bushey, C. and Aime, W. (2022) 'Carmakers try to frustrate US push to cut China from EV supply chain', *Financial Times*, 22 November [online] https://www.ft.com/content/2bcb1c6b-61aa-4ec7-80ac-2c455fbc8099 (accessed 5 July 2023).

Calabrese, G.G. and Falavigna, G. (2022) 'Does Industry 4.0 improve productivity? Evidence from the Italian automotive supply chain', *International Journal of Automotive Technology and Management*, Vol. 22, No. 4, pp.506–526 [online] https://www.inderscience.com/info/inarticle.php?artid=126843.

Cama, T. and Northey, H. (2023) 'Lobbying 'frenzy' follows Biden's electric car push', *Politico*, 17 April [online] https://www.politico.com/news/2023/04/17/biden-electric-car-lobbying-companies-00091779 (accessed 5 July 2023).

Campbell, P. and Dempsey, H. (2022) 'Chinese battery makers set to dominate Europe's car industry', *Financial Times*, 6 December [online] https://www.ft.com/content/d407772c-4a76-4e59-9bb0-998b3f22383b. (accessed 5 July 2023)

Careddu, N., Dino, G.A., Danielsen, S.W. and Přikryl, R. (2018) 'Raw materials associated with extractive industry: an overview', *Resources Policy*, Vol. 59, pp.1–6, https://doi.org/ https://doi.org/10.1016/j.resourpol.2018.09.014.

Chalvatzis, K.J. and Ioannidis, A. (2017) 'Energy supply security in the EU: benchmarking diversity and dependence of primary energy', *Applied Energy*, Vol. 207, pp.465–476, https://doi.org/https://doi.org/10.1016/j.apenergy.2017.07.010.

Chu, A. and Roeder, O. (2023) 'Transformational change': Biden's industrial policy begins to bear fruit', *Financial Times*, 17 April [online] https://www.ft.com/content/b6cd46de-52d6-4641-860b-5f2c1b0c5622 (accessed 5 July 2023).

Dempsey, H. and Campbell, P. (2022) 'Carmakers switch to direct deals with miners to power electric vehicles', *Financial Times* [online] https://www.ft.com/content/a8e0f1bb-f69a-4a77-b762-02f957e47f5c (accessed 5 July 2023).

Dempsey, H. and McCormick, M. (2022) 'Billions flow to nascent US battery sector with push from climate law', *Financial Times*, 16 November [online] https://www.ft.com/content/ 05e7a6ba-bdde-4c3b-b7d1-657523204021 (accessed 5 July 2023).

DOJ (2015) *Horizontal Merger Guidelines (08/19/2010)*, The US Department of Justice, 25 June [online] https://www.justice.gov/atr/horizontal-merger-guidelines-08192010#5c (accessed 9 December 2022).

Dombey, D. (2021) 'Spain's rush for lithium falls foul of local opposition', *Financial Times*, October 20 [online] https://www.ft.com/content/459191d9-774d-4a2b-8ec6-ba472017b05e (accessed 5 July 2023).

Duffner, F., Mauler, L., Wentker, M., Leker, J. and Winter, M. (2021) 'Large-scale automotive battery cell manufacturing: analyzing strategic and operational effects on manufacturing costs', *International Journal of Production Economics*, Vol. 232, 107982, https://doi.org/ https://doi.org/10.1016/j.ijpe.2020.107982.

Dunai, M. and Hume, N. (2021) 'Rio Tinto's lithium mine plan electrifies Serbia', *Financial Times*, 12-27 [online] https://www.ft.com/content/707e7a39-f357-484a-8efc-b0b7dc475600 (accessed 5 July 2023).

Dunai, M. and Hume, N. (2022) 'Rio Tinto warns of delay to Serbia lithium project', *Financial Times* [online] https://www.ft.com/content/a930ec31-be67-46fb-841b-b337a78cce90 (accessed 5 July 2023).

Economist (2022a) 'The energy transition is sparking America's next mining boom', *The Economist*, 19 February [online] https://www.economist.com/united-states/the-energy-transition-is-sparking-americas-next-mining-boom/21807704 (accessed 5 July 2023).

Economist (2022c) 'An unexpected tech boom in Serbia', *The Economist*, 27 February [online] https://www.economist.com/europe/2020/02/27/an-unexpected-tech-boom-in-serbia (accessed 5 July 2023).

Economist (2022b) 'How supply-chain turmoil is remaking the car industry', *The Economist*, 6 December [online] https://www.economist.com/business/2022/06/12/how-supply-chain-turmoil-is-remaking-the-car-industry (accessed 5 July 2023).

Eerola, T. (2022) 'Corporate conduct, commodity and place: ongoing mining and mineral exploration disputes in Finland and their implications for the social license to operate', *Resources Policy*, Vol. 76, 102568, https://doi.org/https://doi.org/10.1016/ j.resourpol.2022.102568.

EU Commission (2011) *Tackling the Challenges in Commodity Markets and on Raw Materials*, EU Commission, Brussels.

EU Commission (2021) *Strategic Dependencies and Capacities*., European Commission [online] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1124 (accessed 5 July 2023).

European Commission (2021) *3rd Raw Material Scoreboard*, E. Union.

European Parliament (2022) *Batteries: Deal on New EU Rules for Design, Production and Waste Treatment*, | News | European Parliament, 12 September [online] https://www.europarl.europa.eu/news/en/press-room/20221205IPR60614/batteries-deal-on-new-eu-rules-for-design-production-and-waste-treatment (accessed 5 July 2023).

European Parliament (2023) *New EU Rules for More Sustainable and Ethical Batteries*, European Parliament, 3 March [online] https://www.europarl.europa.eu/news/en/headlines/economy/20220228STO24218/new-eu-rules-for-more-sustainable-and-ethical-batteries (accessed 29 April 2023).

Fernyhough, J. (2022) 'Electric vehicle targets 'impossible' without changes to lithium pipeline', *Financial Times*, 4 November [online] https://www.ft.com/content/7beef24f-29a2-4683-8b30-b076528416c1 (accessed 5 July 2023).

Financial Times (2022) 'European industry pivots to US as Biden subsidy sends 'dangerous signal'. *Financial Times*, 2022-11-20 [online] https://www.ft.com/content/59a8d135-3477-4d0a-8d12-20c7ef94be07 (accessed 5 July 2023).

Financial Times (2023) 'The EU's pioneering carbon border tax', *Financial Times*, 11 January [online] https://www.ft.com/content/b1c2055c-15ec-4f29-9227-1a4bfa21bcea (accessed 5 July 2023).

Foo, N., Bloch, H. and Salim, R. (2018) 'The optimisation rule for investment in mining projects', *Resources Policy*, Vol. 55, pp.123–132, https://doi.org/https://doi.org/10.1016/j.resourpol.2017.11.005.

Foo, Y.C. (2021) 'EU looks to Tesla, BMW and others to charge $3.5 billion battery project. *@Reuters*, 26 January [online] https://www.reuters.com/article/us-eu-stateaid-batteries-idUSKBN29V1LS (accessed 16 December 2021).

Geissler, B., Mew, M.C. and Steiner, G. (2019) 'Phosphate supply security for importing countries: Developments and the current situation', *Science of The Total Environment*, Vol. 677, pp.511–523, https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.04.356.

Grabbe, H. (2021) 'Conclusion', in Lazard, O. and Youngs, R. (Eds.): *The EU and Climate Security: Toward Ecological Diplomacy*, pp.57–60, Carnegie Endowment for International Peace.

Graham, J.D., Rupp, J.A. and Brungard, E. (2021) 'Lithium in the green energy transition: the quest for both sustainability and security', *Sustainability*, Vol. 13, No. 20, p.11274.

Griffiths, R.T. (2022) 'Greening the ungreenable: the prospects for deep-sea mining', *IIAS Newsletter*, No. 93.

Guinea, O. and Espés, A. (2021) *International EU27 Pharmaceutical Production, Trade, Dependencies and Vulnerabilities: a Factual Analysis*, European Centre for International Political Economy (ECIPE) [online]https://www.efpia.eu/media/602699/production-import-dependencies-and-export-vulnerabilities-of-pharmaceuticals-for-the-eu27-final.pdf (accessed 5 July 2023).

Hammond, D.R. and Brady, T.F. (2022) 'Critical minerals for green energy transition: a United States perspective', *International Journal of Mining, Reclamation and Environment*, Vol. 36, No. 9, pp.624–641, https://doi.org/10.1080/17480930.2022.2124788.

Hanckok, A. and Bounds, A. (2023) 'EU's net zero plans will fail without more money, warn industry chiefs', *Financial Times*, March 16 [online] https://www.ft.com/content/c4cf9462-1a42-46de-8ebe-0f586d524694 (accessed 5 July 2023).

Hao, H., Geng, Y., Tate, J.E., Liu, F., Chen, K., Sun, X., Liu, Z. and Zhao, F. (2019) 'Impact of transport electrification on critical metal sustainability with a focus on the heavy-duty segment', *Nature Communications*, Vol. 10, No. 1, p.5398, https://doi.org/10.1038/s41467-019-13400-1.

He, Y. (2018) 'The trade-security nexus and U.S. policy making in critical minerals', *Resources Policy*, Vol. 59, pp.238–249, https://doi.org/https://doi.org/10.1016/j.resourpol.2018.07.010.

Henderson, J., Dicken, P., Hess, M., Coe, N. and Yeung, H.W-C. (2002) 'Global production networks and the analysis of economic development', *Review of International Political Economy*, Vol. 9, No. 3, pp.436–464 [online] https://www.jstor.org/stable/417743.

IEA (2022) *The Role of Critical Minerals in Clean Energy Transitions (World Energy Outlook Special Report, Issue* [online] https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (accessed 5 July 2023).

Jaravel, X. and Méjean, I. (2020) 'Quelle stratégie de résilience dans la mondialisation?', *Notes du conseil d'analyse economique*, No. 10, pp.1–12.

Jetin, B. (2018) 'One Belt-One Road Initiative' and ASEAN connectivity: synergy issues and potentialities', in *China's Global Rebalancing and the New Silk Road*, pp.139–150, Springer, Singapore.

Jetin, B. (2020) 'Who will control the electric vehicle market?', *International Journal of Automotive Technology and Management*, Vol. 20, No. 2, pp.156–177.

Jiskani, I.M., Moreno-Cabezali, B.M., Ur Rehman, A., Fernandez-Crehuet, J.M. and Uddin, S. (2022) 'Implications to secure mineral supply for clean energy technologies for developing countries: a fuzzy based risk analysis for mining projects', *Journal of Cleaner Production*, Vol. 358, 132055, https://doi.org/https://doi.org/10.1016/j.jclepro.2022.132055.

Kalantzakos, S. (2020) 'The race for critical minerals in an era of geopolitical realignments', *The International Spectator*, Vol. 55, No. 3, pp.1–16, https://doi.org/10.1080/03932729.2020.1786926.

Kawakami, T. (2022) 'EV price hikes fueled by battery costs send jolts across China', *Nikkei Asia*, 18 April [online] https://asia.nikkei.com/Spotlight/Electric-cars-in-China/EV-price-hikes-fueled-by-battery-costs-send-jolts-across-China (accessed 5 July 2023).

Kennedy-Pipe, C. and Waldman, T. (2017) 'Ways of war in the twenty-first century', in Beeson, M. and Bisley, N. (Eds.): *Issues in 21st Century World Politics*, pp.23–37, Macmillan Education, UK.

Kivinen, S., Kotilainen, J. and Kumpula, T. (2020) 'Mining conflicts in the European Union: environmental and political perspectives', *Fennia*, 198.

Laplane, E. (2021) *The US Mineral Independence Strategy: An All-Out Mobilization*, Institut francais des relations internationales 2021 Paris, France, DOI: https://www.ifri.org/en/publications/notes-de-lifri/us-mineral-independance-strategy-all-out-mobilization.

Lazard, O. (2021) 'The need for an EU ecological diplomacy', in Lazard, O. and. Youngs, (Eds.): *The EU and Climate Security: Toward Ecological Diplomacy*, Vol. 12, pp.13–24, Carnegie Endowment for International Peace.

Liu, D., Gao, X., An, H., Qi, Y., Sun, X., Wang, Z., Chen, Z., An, F. and Jia, N. (2019) 'Supply and demand response trends of lithium resources driven by the demand of emerging renewable energy technologies in China', *Resources, Conservation and Recycling*, June, Vol. 145, pp.311–321.

Løvika, A.N., Hagelüken, C. and Wägera, P. (2018) 'Improving supply security of critical metals: current developments and research in the EU', *Sustainable Materials and Technologies*, April, Vol. 15, pp.9–18 [online] https://www.sciencedirect.com/science/article/pii/S2214993717300908?via%3Dihub.

Mateus, A. and Martins, L. (2021) 'Building a mineral-based value chain in Europe: the balance between social acceptance and secure supply', *Mineral Economics*, Vol. 34, No. 2, pp.239–261.

Mauler, L., Duffner, F., Zeier, W.G. and Leker, J. (2021) 'Battery cost forecasting: a review of methods and results with an outlook to 2050', *Energy & Environmental Science*, Vol. 14, pp.4712–4739.

Mayyas, A., Steward, D. and Mann, M. (2019) 'The case for recycling: overview and challenges in the material supply chain for automotive li-ion batteries', *Sustainable Materials and Technologies*, April, Vol. 19, p.e00087, https://doi.org/https://doi.org/10.1016/j.susmat.2018.e00087.

McKinsey&Company (2022) *Lithium Mining: How New Production Technologies could Fuel the Global EV Revolution* [online] https://www.mckinsey.com/industries/metals-and-mining/our-insights/lithium-mining-how-new-production-technologies-could-fuel-the-global-ev-revolution (accessed 5 July 2023).

Miller, J. (2021) 'Daimler teams up with Stellantis to build European gigafactories', *Financial Times*, 24 September [online] https://www.ft.com/content/e7063567-0a6a-4059-bd63-8cd2bd678190 (accessed 5 July 2023).

Miller, J., Campbell, P. and McGee, P. (2022) 'Car bosses warn of supply chain threat to electric vehicle rollout', *Financial Times*, 13 May [online] https://www.ft.com/content/fbe8843e-1d2e-4a25-bce8-dcf77304fc37 (accessed 5 July 2023).

Milne, R. (2022) 'Northvolt's new chair urges Europe to follow US lead on battery subsidies', *Financial Times*, December 15 [online] https://www.ft.com/content/4e39bb68-58bb-465d-b11c-4b426640409c (accessed 5 July 2023).

Miroudot, S. (2020) 'Resilience versus robustness in global value chains: some policy implications', in Baldwin, R. and Evenett, S.J. (Eds.): *COVID-19 and Trade Policy: Why Turning Inward Won't Work*, Vol. 2020, pp.117–130, CEPR Press.

Monkelbaan, J. and Figures, T. (2023) 'What you should know about carbon-reduction incentive CBAM', *World Economic Forum* [online] https://www.weforum.org/agenda/2022/12/cbam-the-new-eu-decarbonization-incentive-and-what-you-need-to-know (accessed 5 July 2023).

Okinaga, S. (2022) 'Japan battery material producers lose spark as China races ahead', *Nikkei Asia*, 4 April [online] https://asia.nikkei.com/Business/Materials/Japan-battery-material-producers-lose-spark-as-China-races-ahead2 (accessed 5 July 2023).

Opinion Lex (2022) 'Lithium/EVs: fears of a battery shortage will power up prices', *Financial Times,* 30 March.

Pardi, T. (2021) 'Prospects and contradictions of the electrification of the European automotive industry: the role of European Union policy', *International Journal of Automotive Technology and Management*, Vol. 21, No. 3, pp.162–179 [online] https://www.inderscienceonline.com/doi/abs/10.1504/IJATM.2021.116620.

Paulikas, D., Katona, S., Ilves, E. and Ali, S.H. (2022) 'Deep-sea nodules versus land ores: a comparative systems analysis of mining and processing wastes for battery-metal supply chains', *Journal of Industrial Ecology*, Vol. 26, No. 6, https://doi.org/10.1111/jiec.13225.

Pianta, M., Lucchese, M. and Nascia, L. (2020) 'The policy space for a novel industrial policy in Europe', *Industrial and Corporate Change*, Vol. 29, No. 3, pp.779–795, https://doi.org/10.1093/icc/dtz075.

Poitiers, N. and Weill, P. (2022) *Opaque and Ill-Defined: The Problems with Europe's IPCEI Subsidy Framework*, 26 January [online] https://www.bruegel.org/blog-post/opaque-and-ill-defined-problems-europes-ipcei-subsidy-framework (accessed 5 July 2023).

PubAffairs (2022) 'State aid: Commission approves €90 million Hungarian investment aid to SKBM's electric vehicle battery plant', *@PubAffairsEU* [online] https://www.pubaffairsbruxelles.eu/eu-institution-news/state-aid-commission-approves-e90-million-hungarian-investment-aid-to-skbms-electric-vehicle-battery-plant (accessed 5 July 2023).

Punshi, M. (2022) *Battery Pack Costs Rise for Battery Electric Vehicles (S&P Global Mobility, Issue*.

Reichl, C. and Schatz, M. (2019) *World Mining Data 2019 (Minerals Production, Issue)*.

Sanderson, H. (2019) 'Electric battery cars: China powers the battery supply chain', *Financial Times*, 22 May [online] https://www.ft.com/content/455fe41c-7185-11e9-bf5c-6eeb837566c5 (accessed 5 July 2023).

Sanderson, H. (2020) 'Tesla's move into mining aimed at energising battery supply chain', *Financial Times*, October 22 [online] https://www.ft.com/content/b13f316f-ed85-4c5f-b1cf-61b45814b4ee (accessed 5 July 2023).

Sanderson, H. (2021) 'US lithium mining faces new hurdle in form of rare flower', *Financial Times*, 4 June [online] https://www.ft.com/content/eb24a0d0-2df6-4d51-9600-426182f33d30 (accessed 5 July 2023).

Spears, B.M., Brownlie, W.J., Cordell, D., Hermann, L. and Mogollón, J.M. (2022) 'Concerns about global phosphorus demand for lithium-iron-phosphate batteries in the light electric vehicle sector', *Communications Materials*, Vol. 3, No. 1, p.14, https://doi.org/10.1038/s43246-022-00236-4.

Wang, X., Wei, Z. and Ruet, J. (2022) 'Specialised vertical integration: the value-chain strategy of EV lithium-ion battery firms in China', *International Journal of Automotive Technology and Management*, Vol. 22, No. 2 [online] https://www.inderscience.com/offer.php?id=124377 (accessed 5 July 2023).

Werschkul, B. (2022) 'Why miners are cheering Biden's move to help EV makers', *@YahooFinance*, 1 April [online] https://finance.yahoo.com/news/why-miners-are-cheering-bidens-move-to-help-ev-makers-142532414.html (accessed 5 July 2023).

Williams, A. (2022) 'Powering electric cars: the race to mine lithium in America's backyard', *Financial Times*, 10 May [online] https://www.ft.com/content/dd6f2dd0-1dad-4747-8ca4-cb63b026a757 (accessed 5 July 2023).

Wise, P. (2020) 'Lithium fever' grips Portugal as mining project raises hackles', *Financial Times*, 6 January [online] https://www.ft.com/content/efa997fc-1b7a-11ea-97df-cc63de1d73f4 (accessed 5 July 2023).

Xu, C., Dai, Q., Gaines, L., Hu, M., Tukker, A. and Steubing, B. (2020) 'Future material demand for automotive lithium-based batteries', *Communications Materials*, Vol. 1, No. 1, p.99, https://doi.org/10.1038/s43246-020-00095-x.

Yoon, J. (2022) 'Tesla's reverse on battery cells signals shift for electric vehicles', *Financial Times*, 22 February [online] https://www.ft.com/content/accde2e1-08a2-4bc3-bbb1-1a1e72eb4508 (accessed 5 July 2023).

Yu, S. and Sevastopoulo, D. (2021) 'China targets rare earth export curbs to hobble US defence industry', *Financial Times*, 16 February [online] https://www.ft.com/content/d3ed83f4-19bc-4d16-b510-415749c032c1 (accessed 5 July 2023).

Zeng, A., Chen, W., Rasmussen, K.D., Zhu, X., Lundhaug, M., Müller, D.B., Tan, J., Keiding, J.K., Liu, L., Dai, T., Wang, A. and Liu, G. (2022) 'Battery technology and recycling alone will not save the electric mobility transition from future cobalt shortages', *Nature Communications*, Vol. 13, No. 1, p.1341, https://doi.org/10.1038/s41467-022-29022-z.

Notes

1 Punshi (2022) gives an estimate of 65%.

2 Dry lands cover only 30% of the planet and attention is now turning to the oceans. Deep sea mining plans to exploit critical minerals, particularly nickel, cobalt, manganese, copper that are abundant in polymetallic nodules, at a depth of over 200 metres. The environmental damage would be irreparable (see Griffith, 2022).

3 GPN are 'the nexus of interconnected functions and operations through which goods and services are produced, distributed and consumed' at the global, regional, and national level [see Henderson et al., (2002), p.445].

4 Albert Hirschman was the first to propose an index of trade concentration 'as an indicator of national economic and political vulnerability, with specific reference to the expansion of German economic imperialism in the run-up to World War II' [Babones and Farabee-Siers, (2012), p.267]. Clemens Orris Herfindahl built a similar indicator to analyse the concentration of the US steel industry.

5 Lithium-ion batteries are rechargeable and are called 'Lithium-ion accumulators' in the Harmonised System Code of international trade of the United Nations.

6 For the ease of language, we will consider hereafter the EU as a country.

7 Lithium is not found in nature as an independent ore but has to be extracted from a combination of different materials.

8 This brief historical summary of Chinese critical material policy rests mainly on Bartekova and Kemp, 2016.

9 The Commission published a Communication on 'critical materials and the circular economy' in 2018 and another on 'raw materials for strategic technologies and sectors' based on EU's 2050 climate neutrality scenarios' in 2020.

10 Manufacturing accounted for 14.73% of GDP in the EU in 2021 down from 19.74% in 1991. For industry, the respective data are 22.79% and 28.80%. These data show that the EU lost 5% in both sectors. Source: World Bank.

11 In 2021, manufacturing accounts for 18.9% of GDP in Germany and 8.88% in France. Source World Bank.

12 https://www.ipcei-batteries.eu/about-ipcei Both IPCEIs have in common that their participants represent the complete value chain, from material through the cells to the battery system and the final step of recycling. At the same time, there is a high degree of networking between the companies themselves and the two IPCEIs.

13 https://www.eba250.com EBA aims at building a pan-European battery industry. It brings together 750 members throughout the value chains from the EU national authorities, regions, industry research institutes, companies, and investors, from mining to recycling.

14 The following rests mainly on He (2018) and Laplane (2021).

15 Australia, Canada, Botswana, Peru, Argentina, Brazil, Congo, Namibia, Philippines, and Zambia.

16 At the world level, the locations of critical metals "overlap with critical ecosystems that house various types of biodiversity and that cycle carbon and water globally" [Lazard, (2021), p.22].

Appendix

HS codes

Unprocessed lithium, 253,090

Lithium carbonate, 283,691

Lithium oxide and hydroxide, 282,520

Refined Lithium Chlorides, 282,739

Refined Lithium fluoride, 282,690

Refined Lithium alkali, 280,519

Natural Graphite, 250,410

Copper ores and concentrates, 260,300

Manganese ores and concentrates, 260,200

Manganese oxides, 2,820

Nickel ores and concentrates, 260,400

Nickel sulphates, 283,324

Cobalt ores and concentrates, 260,500

Cobalt oxides and hydroxides, 282,200

Refined Cobalt, 810,520

Lithium-ion accumulators, 850,760