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POLICY PAPER

ENERGY TRANSITION, MINERAL RESOURCES AND EUROPEAN STRATEGY TO SECURE INDUSTRIAL SUPPLIES: CONSTRAINTS AND SYNERGIES

YVES JÉGOUREL

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While the very reality of the energy transition is sometimes questioned, even challenged (Fressoz, 2023), the carryover effect it creates on mineral resources, highlighted by numerous forward-looking studies, appears indisputable. More copper, lithium, nickel, graphite or rare earths: these are the non-exhaustive conditions that will enable us to support the development of electromobility and renewable energies, and thus contribute to limiting global warming, in line with the commitments made during the 2015 Paris climate agreements. Beyond the obvious, this new paradigm intrinsically raises the question of how to define and optimize public and private policies that will enable, on the one hand, greater value to be added to the subsoil and industrial development of producing countries and, on the other, reduce supply constraints and the strategic dependence of importing nations. More fundamentally, it also raises questions about the willingness - indeed, the ability - of nations to move beyond bilateral strategies and engage in international negotiations on these resources, in parallel with those on climate change.

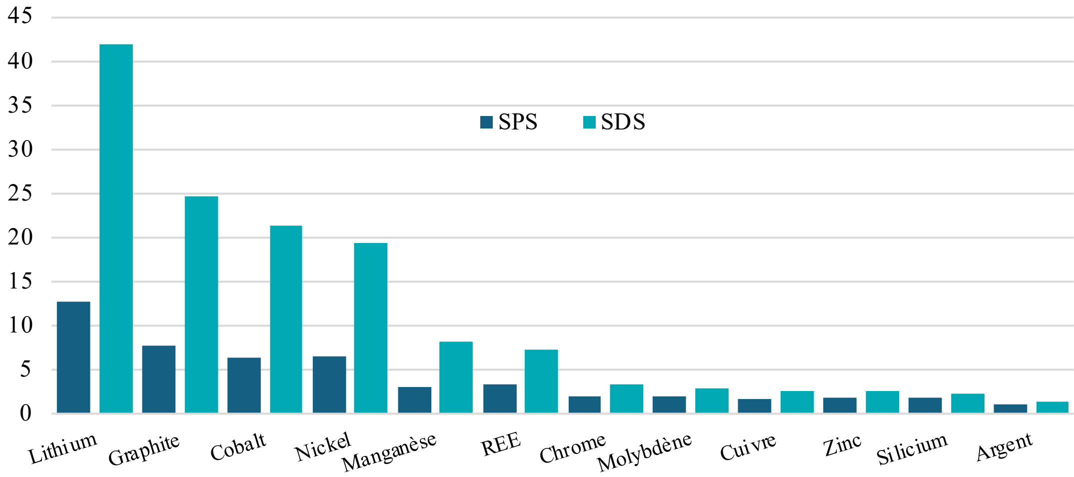
YVES JÉGOUREL

INTRODUCTION

Many scientific studies, including those conducted by the International Energy Agency (IEA, 2021), have reached this conclusion: if we are to meet our ambitions for limiting temperature increases - and therefore for decarbonizing our energies - mineral resource requirements will have to rise sharply over the coming years and decades.

Figure 1

Multiplier factors for demand for mineral resources to meet energy transition needs (2020-2040)



Source: International Energy Agency (2021)

For example, this institution estimated that, for the energy transition "alone", demand for lithium could be multiplied by more than 40 between 2020 and 2040, according to the SDS scenario (sustainable development scenario[1]), for graphite by almost 25, for cobalt or nickel by around 20, while copper demand would increase by "only" 2.6 (graph 1). While the transfer effect on demand for mineral resources is therefore clear, the reading and comparison of these various figures must be accompanied by a contextual approach for two main reasons. The first is the rapid increase in demand for certain resources, such as lithium, which is gradually being met. According to a more recent report (IEA, 2024), the IEA estimated lithium consumption for clean technologies at 92,000 tonnes in 2023, and forecast it at 1.203 million tonnes (Mt) in 2040 - still based on the scenario of carbon neutrality by 2050 - i.e. a multiplication factor of 13, well below the 2020 estimate. The second reason is the large difference in initial demand levels for clean energies: copper demand was already comparatively high, at some 5.71 Mt in 2020 (for global use of around 25 Mt), while lithium demand was in its infancy at that time.

To understand this, we need to remember that the energy transition is based on five main pillars: (1) the development of electromobility, which implies, for the current decade, the massive use of batteries known as "Lithium-ion" (Li-ion), to replace vehicles with internal

1. Footnote 1: According to the Sustainable Development Scenario (SDS), compared with the Stated Policies Scenario (STEPS), which extrapolates to 2030 and 2040 the effects of environmental measures already implemented or decided upon.

combustion engines[2]; (2) the development of renewable and nuclear energies, as the main substitute for coal and natural gas in electricity generation, and the promotion of sustainable heat sources; (3) the development of electricity grids, in particular smarts grids[3], as well as that of transport and storage infrastructures for sustainable energy vectors; (4) promoting eco-design/construction, recycling and reuse, and (5) the affirmation of a need for sobriety that goes beyond the energy dimension to include a global "materials" component. While these last two pillars have a depressive effect on demand for mineral resources, the first three necessarily imply growing consumption of them, thus explaining the previous figures corroborated by numerous studies (Deetman et al., 2018; Liang et al. 2022; Watari et al., 2019). This is all the more true as population growth and urbanization also imply increased dependence on certain mineral resources, whether copper (Schipper, et al., 2018), iron ore, copper, zinc or aluminum, non-exhaustively (Krausmann et al.). According to several studies, including those by Tokimatsu et. al. (2017) or Watari et al. (2021), and excluding lead, demand for most "major metals" (aluminum, copper, iron, zinc) is set to grow steadily over the 21st century. In particular, a study by Seck et al. (2020) suggests that cumulative demand for primary copper between 2010 and 2050 could represent up to 89% of its known resources in 2010.

This growing demand inevitably raises the question of the availability of extractive resources (both energy and mineral), which are by nature non-renewable. This can be estimated in a number of ways, including the so-called "Hubbert peak" model (Hubbert, 1956). This suggests that the rate of growth in production is low in the early stages of a resource's exploitation, before becoming exponential and then declining due to the physical limits associated with it. Although controversial, this approach initially developed to calculate "peak oil" has been applied to many mineral resources (Calvo et al., 2017).

All decarbonation metals are therefore likely to experience significant tensions over their primary supply[4]. These will materialize in the form of increasing scarcity and/or structural price rises (Sverdrup et al., 2019; Valero et al. 2018), justifying both their categorization as strategic or critical mineral resources by importing countries and the implementation of ambitious strategies to secure/diversify supplies by importing countries. However, major differences can be observed within them, as much in terms of constraints and availability issues as in the functioning of the value chains and markets on which they are traded.

II. ENERGY TRANSITION METALS: DIFFERENT SUPPLY ISSUES

Among the various strategic mineral resources, copper certainly occupies a unique place because of its omnipresence in the first three pillars of the energy transition mentioned above, whereas lithium is, for example, only needed for the development of Li-ion batteries.

2. So, for simplicity's sake, we're excluding here the issue of sustainable fuels, whether for heavy or light mobility, even if the latter is fundamental, for example in air or sea transport.

3. Or "smart grid", one of whose functions is to enable real-time control of electricity flows, thereby optimizing the operation of power grids and enhancing their safety. On this subject, see: pedagogy/intelligent-grid-smart-grid.

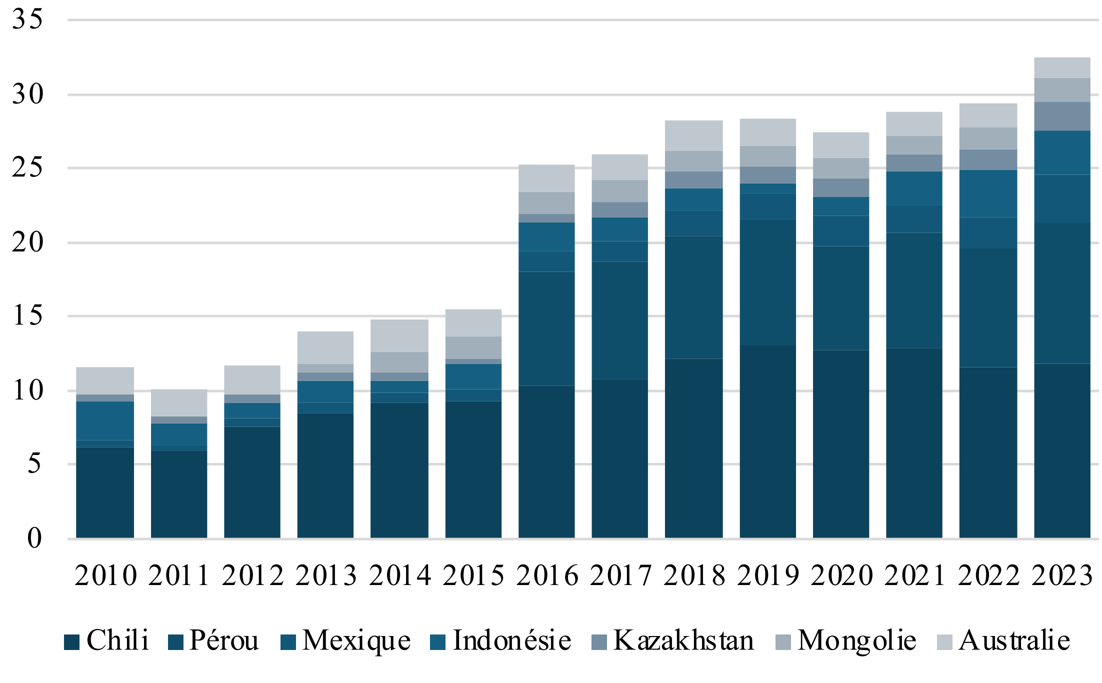
4. Mined sources, as opposed to secondary, recycled sources.

A ubiquitous copper in the face of major geological and political constraints

What's more, copper metallurgy is, like gold, particularly old, which explains not only the gradual decline in major deposit discoveries over time, but also the structural lowering of metal grades in existing mines. In 1800, the copper content of English ores was 9%, whereas in 2015, according to a study by the International Copper Study Group cited by Flores et al. (2020), the global average copper content was just 0.45% in declared reserves and only 0.65% in ores produced, mostly chalcopyrite.[5] Furthermore, a study by S&P Global[6] highlights that of the 239 copper deposits identified over the period 1990 to 2023, only 14 were identified during the previous decade and 3 since 2020. What's more, of the twenty largest deposits, only three were discovered after 2010: Timok (2011), in Serbia, operated by Canadian company Dundee Precious Metals, Onto (2013), in Indonesia, co-owned by Brazilian giant Vale and PT Anta Tambang (Antam) via the joint venture Sumbawa Timur Mining (STM), and Kamoa Kakula, in the Democratic Republic of Congo (DRC), operated by the Canadian Invahoe Mines group (39.6%), the Chinese Zijin Mining Group (39.6%) and the Congolese state (20%) through the Kamoa Copper SA joint venture. Chile and Peru are the two biggest exporters of copper concentrates (graph 2).

Figure 2

Main exporters of copper ores and concentrates (HS Code: 2603, in Mt)
Chile Peru Mexico Indonesia Kazakhstan Mongolia Australia



Source: Trade Data Monitor

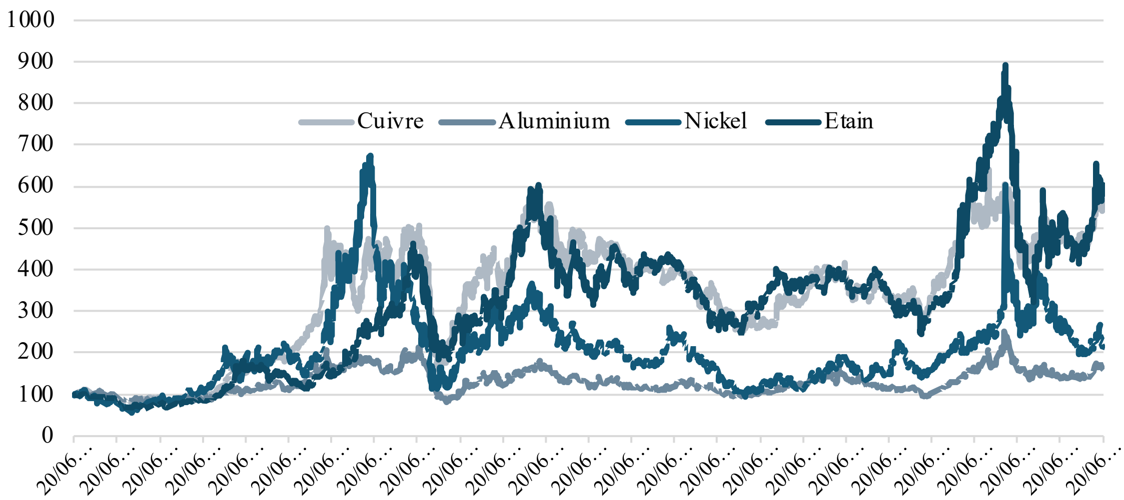
5. Chalcocite and covellite are secondary copper sulfides with a high metal content found mainly in near-surface zones. With the depletion of the most accessible resources, more and more mines are exploiting deeper zones where primary mineralization is more important, i.e. where a greater proportion of copper is contained in chalcopyrite with a lower comparative metal content.

6. See : https://www.spglobal.com/market-intelligence/en/news-insights/research/new-major-copper-discoveries-sparse-amid-shift-away-from-early-stage-exploration

This tight supply of ores and concentrates recently resulted in a record price for the red metal on the London Metal Exchange (LME). According to the London market's cash reference, it reached 10,775 USD/t on May 21, 2024, erasing the previous peak of 10,730 USD/t recorded on March 7, 2022, the day after the outbreak of war in Ukraine, which had seen base metals soar due to the importance of Russian metallurgical supply on world markets. With the exception of tin, whose market is comparatively narrow in relation to those of base metals, and therefore conducive to high amplitude price movements, copper is the only metal to have had this dynamic among the main metals of the energy and digital transition over the recent period: nickel, cobalt, lithium or aluminum, to name but a few (graph 3).

Figure 3

Base metal price trend (base 100 at January 1, 2000)
Copper Aluminium Nickel Tin



Source: London Metal Exchange

It is essential to position mineral resources within their value chain and thus understand, through the bargaining power of the various players in these sectors, precisely where the supply constraints lie. In addition to soaring copper prices, the collapse of treatment charges and refining charges (TC/RC) should be noted for most of 2024. Corresponding to the amount a miner has to pay the smelter to transform a metal concentrate into metal, these TC/RC are representative of the balance of power between upstream mining and its direct downstream. Their decrease therefore signals an increase in market power in favor of the former, illustrating present and future tensions over mining supply.

The lowering of copper ore grades and the resulting constraint on availability have heightened the territorial, and therefore political and social, stakes associated with their extraction. They stem from a legitimate desire on the part of stakeholders (State, local authorities, employees, subcontractors, local populations), on the one hand, to increase the direct and indirect benefits derived from subsoil mining and, on the other, to limit or even prevent the negative environmental externalities and/or nuisances resulting from this industrial activity.[7] This is all the more true as, with lower grades, the energy required to mine the ore increases, as do the impurities, which has a direct impact on the efficiency of the process of transforming the concentrate into a copper anode (Flores et al., 2020).

7. For the sake of brevity, we do not deal here with the fundamental issue of artisanal mining.

Several emblematic examples attest to these issues and the tensions that may have ensued. Between 2019 and 2023, a dispute arose between the Indian multinational mining company Vedanta and the Zambian government over the Konkola mine (KCM). The latter, under the presidency of Egdar Lungu, accused the group of not respecting its investment commitments for the development of the project, and consequently seized KCM's assets until the conflict was resolved at the end of 2023. In the Democratic Republic of Congo (DRC), a similar dispute arose in July 2022 between China's CMOC and state-owned Gécamines over royalties and interest, with Gécamines accusing the operator of downplaying the size of the mining reserves in order to minimize the revenues due to the Congolese state from the Tenke Fungurume mine. After a ten-month stalemate, however, the dispute was settled. More recently, in December 2023, First Quantum Minerals (FQM) was forced to cease operations at the Cobre mine in Panama, following a ruling by the country's Supreme Court declaring the concession contract between the Canadian company and the government unconstitutional. Environmental considerations are at the heart of the problem, and the mine had already been shut down at the end of 2022, but operations resumed in mid-March 2023. The site's copper production was 330,863 tonnes in 2023, i.e. 1.5% of world production, which partly explains the rise in prices and fall in TC/RC mentioned above.[8]

Cobalt and nickel: decisive technological... and economic challenges

Unlike copper, the main market for cobalt and nickel in the energy transition is the Li-ion battery segment, which can use nickel sulfate and cobalt hydroxide in their cathodes, in addition to manganese, lithium and graphite. Several chemistries coexist within the same technology, mainly batteries known as "NCA" (nickel, cobalt, aluminum), "LFP" (lithium, iron, phosphate) and "NMC" (nickel, manganese, cobalt). Among the latter, the share of nickel in cathodes has increased, to the detriment of cobalt. The first NMC 111 batteries, combining these two resources and manganese in equal parts, were followed by NMC 622 and then NMC 811 batteries, increasing the proportion of nickel to 80% for ten percent of cobalt and manganese. This substitution can be explained not only by the high cost of cobalt and the strong localization of its mining supply, but also by the diversity of ethical issues associated with the extraction of this resource in the DRC, foremost among which is child labor, for equal or even greater performance and sustainability. Reducing the amount of cobalt actually tends to improve the cathode material's resistance to mechanical stress, and increases the number of possible charge/discharge cycles for the battery.

The substitution of nickel for cobalt in the cathodes of certain batteries should not, however, obscure the fact that cobalt, which is a by-product of copper and nickel (with the exception of the Bou-Azzer mine in Morocco), is partly linked to the latter two metals by their production processes, notably that of the devil's metal.[9] After the extraction and concentration phases of the ore, which can be either sulfides or laterites (particularly in Indonesia), pyrometallurgy for the former and hydrometallurgy for the latter are used. In this case, high-pressure acid leaching plants (HPAL[10]) are needed to recover the nickel and cobalt contained in the ore and supply intermediate products which are then processed

8. A first international arbitration procedure was requested by FQM in November 2023, with formalization of the Canadian company's request in July 2024.

9. Nickel is sometimes given this nickname for historical reasons. Confused with copper ore by Saxon miners, extraction of the metal was impossible, hence the term "devil's copper", kupfernickel, loosely translated as "devil's metal", that of "old Nick".

10. High Pressure Acid Leaching.

into battery precursor products, such as MHP (Mixed Hydroxide Precipitate), nickel-cobalt hydroxide or MSP (Mixed sulfide pricipitate), although the latter is more likely to be derived from the processing of sulfide clusters.[11] The recent boom in these latter products was partly built on the shortage of high-quality nickel in briquette and powder form, leading the market to favor less expensive intermediate products which, after removal of impurities (MHP contains between 40% and 50% nickel), are relatively easily convertible to sulfate.[12]

Unlike copper, the fundamental challenge associated with nickel is not, strictly speaking, mine availability, but rather its transformation into refined products to meet the demand for electromobility. Given the particularly high construction and operating costs of HPAL plants, as well as the physical constraints associated with this metallurgy, the problem of Class 1 nickel is above all a technical and economic one. This last dimension is expressed from various angles, foremost among which is the profitability of production activities, which is intrinsically dependent on nickel and cobalt prices, but also on those of sulfuric acid or energy. Its influence on the location of production is therefore decisive, and may explain the considerable boom in Indonesian supply... or the impasse in the nickel industry in New Caledonia today.

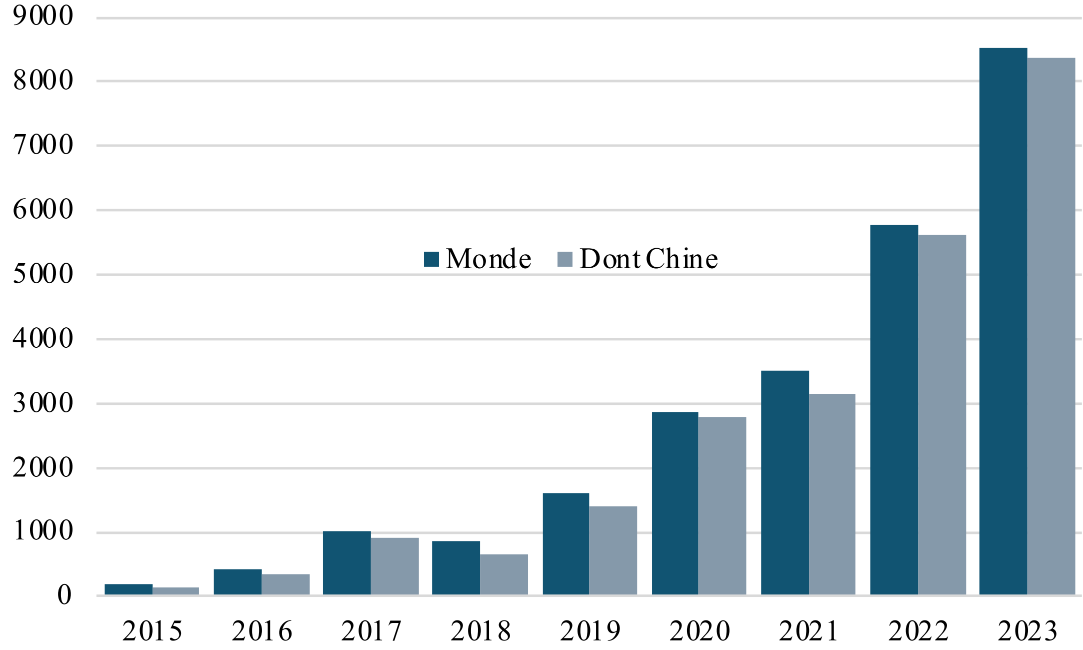
While nickel's role in electromobility has grown, its main market remains the steel industry. Offering ductility and greater resistance to corrosion, it is used, in varying proportions, in the manufacture of certain stainless steels, with chromium in particular. Preferred for the highest grades of steel, refined nickel can face competition from less pure forms, such as ferronickel, containing between 20% and 30% nickel, or nickel pig iron, offering a lower metal content (between 4% and 13%) and a greater quantity of impurities, but benefiting from a significant cost advantage. International supply of these so-called "class 2" nickels - as opposed to the class 1 nickel used for the battery segment - is also dominated by Indonesia, whose exports have soared over the past decade. Exports of ferronickel have risen from just under 1.9 Mt in 2015 to 8.5 Mt in 2023, 5.3 Mt between January and July 2024, and could approach 10 Mt in 2024 (graph 4).

11. For an overview of nickel market issues, see Jégourel (2022b).

12. See: Mixed hydroxide precipitate — the new class one nickel - MINING.COM

Figure 4

Indonesian ferronickel exports (in thousands of tonnes)



Source: Trade Data Monitor

Another major issue associated with the nickel market is the ability to rebalance between its two outlets: stainless steel and batteries. Given the instability of demand for stainless steel, on the one hand, and nickel sulfate, on the other, one of the challenges facing the nickel industry is to create economically and environmentally viable bridges between these two industrial routes. In March 2021, China's Tsingshan Group announced that it would begin production of high-grade (75%) NPI-based nickel mattes by reusing a well-known technology scaled up to industrial scale, with the aim of producing battery-grade nickel. Although more complex than the conversion of MHP due to the necessary desulphurization process, this process fits precisely into these market-balancing challenges, albeit at the cost of a particularly high carbon footprint.

Lithium: a question of time... and place?

As mentioned above, lithium is the mineral resource whose demand was predicted to grow most strongly in 2020 through to 2040, according to the IAE's SDS scenario. Unlike nickel, cobalt or manganese, which are only present in the cathodes of NMC battery sub-categories, this metal is indispensable in all Li-ion batteries, whether NMC, NCA or LFP (Lithium, Iron, Phosphate) types. It is used not only in the cathode, but also in the electrolyte. Lithium can be incorporated in the form of lithium hydroxide (HLM)[13] or lithium carbonate (LCE)[14][15] (Lithium Iron Phosphate).

13. More present in NMC or NCA batteries.

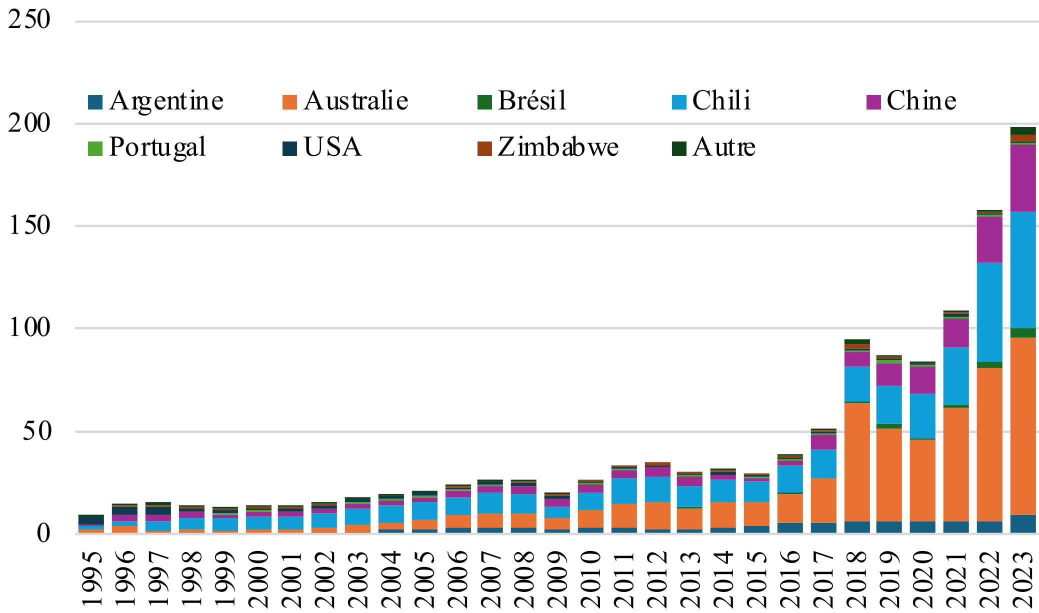
14. More specifically, the electrolyte incorporates lithium in the form of lithium hexafluorophosphate (LiPF), obtained from lithium carbonate.

15. In LFP batteries. This type of battery is considered to incorporate on average between 0.8 and 1.2 kg of LCE per ki- lowatt-hour (kWh), or between 9 and 13 kg of lithium metal in a 60 kWh battery found in a mid-size sedan.

However, lithium is relatively abundant in the earth's crust and, notwithstanding the coming explosion in demand, the issue is not so much geological availability as the level of production capacity over the next decade. There are two main sources of lithium: firstly, pegmatite deposits, such as the Australian spodumene, which will account for 56% of supply in 2023[16], and secondly, salt lakes ("salars"). However, other sources have also been identified, such as geothermal brines - as in the case of the Emili project in eastern France, or that of Vulcan Energy Resources in Germany - or jadarite, as in Serbia (Rio Tinto).

Chart 5

Lithium mine supply (in thousands of tonnes)



Source: Energy Institute - Statistical Review of World Energy (2024)

In line with the anticipated surge in demand, lithium mine supply has risen sharply over the past decade (graph 5). By 2023, it had risen to 198,000 tonnes (measured in lithium content), compared with 30,400 tonnes ten years earlier, an increase of more than 550% over the same period. Reconciling the supply thus measured in 2023 and the prospective analysis carried out by the IEA (IEA, 2024) estimating the demand for lithium at some 1.3 Mt in 2040 to meet the carbon neutrality objective, the increase in production should only be 6.5 Mt between 2023 and that date.

A significant proportion of this increase in mine supply is due to Australia, the world's leading producer with volumes reaching 86,000 tonnes (i.e. 43% of the global total), as well as Chile and China. Given the numerous projects currently under development, these statistics could change significantly over the next few years. Moreover, this geographical breakdown of the upstream extractive sector is only imperfectly representative of the international "balance of power" in lithium, which should be seen primarily in terms of the owners of the mine's capital or the rights to the mining project.

In addition to its supply from underground mining, China is also a shareholder in a number of mines around the world, or in projects currently under development. This is particularly

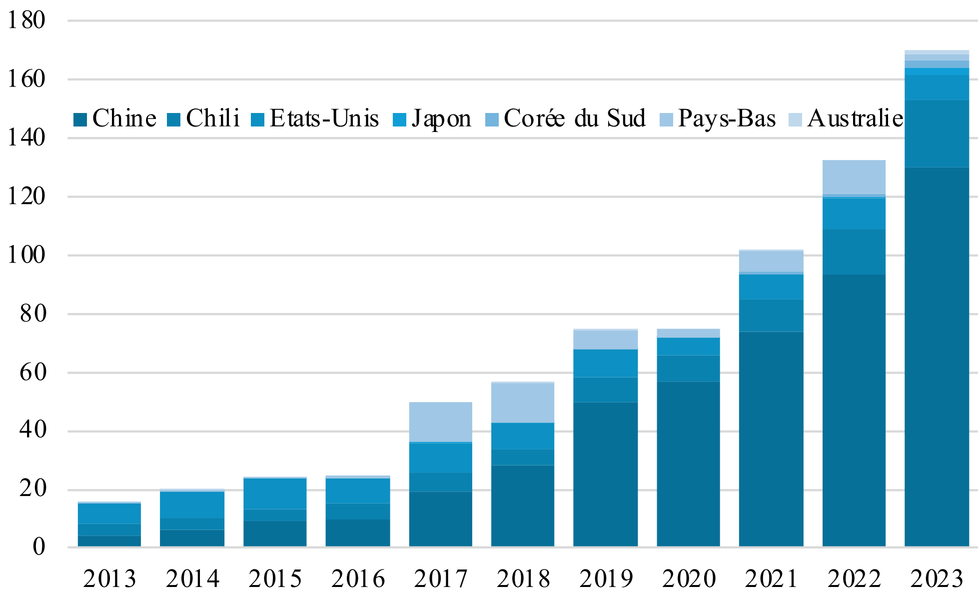
16. Source : https://lelementarium.fr/element-fiche/lithium/.

the case in Australia, where several Chinese groups are present in a traditional joint-venture structure: Tianqi Lithium (in Talison Lithium, 51%; co-shareholder: the American Albermarle), Jiangxi Ganfeng Lithium (in Mount Marion, 50%; co-shareholder: the Australian Mineral Resources), to name but a few. Chinese interests are also present in Argentina, in the mining of the Cauchari-Olaroz salar (Jiangxi Ganfeng Lithium, in partnership with Lithium Argentina) or in the French group Eramet's project to mine the Centenario and Ratones salars (Tsingshan). Last but not least, Tianqi has held a significant minority stake (22.16%) in the Chilean group SQM (Sociedad Química y Minera de Chile) since 2018.

Growth in mine supply has been accompanied by a sharp rise in exports of lithium oxide and hydroxide (graph 6). While these remain relatively stable for most major exporting countries, this is not the case for China, whose volumes have risen from 4,200 tonnes in 2013 to 130,000 tonnes in 2023, an increase of almost 3,000% over a decade.

Chart 6

Main exporters of lithium oxide and hydroxide (HS Code: 282520, in thousands of tons)



Source: Energy Institute- Statistical Review of World Energy (2024)

Despite favorable long-term demand prospects, this dynamic lithium supply has led to a collapse in prices over the past two years. Prices have fallen from a record high of around 590,000 yuan (CNY) per tonne in November 2022 (USD 84,000/t) to CNY 75,500/t, raising questions not only about the short-term profitability of existing mines, but also about the impact of this low valuation on investment decisions for projects currently under development.

III. EUROPEAN PUBLIC POLICIES AND MANAGEMENT FOR SECURING SUPPLIES OF STRATEGIC MINERAL RESOURCES

Faced with China's domination of virtually all the mineral resource value chains involved in the energy transition, most industrial economies have launched strategic plans to limit their dependence and thus secure their supplies, a sine qua non for the long-term survival of their industries, particularly automotive and renewable energies. However, the identification of this strong availability constraint is not new.

European measures: from risk identification to the Critical Raw Materials Act of 2023

Back in 2011, the European Commission drew up an initial list of "critical substances", i.e. those with the dual characteristic of being economically important for EU member states and exposed to a risk of reduced availability. Updated three times a year, the fifth and final edition of 2023 includes 34 resources, with the notable inclusion of copper.[17] In addition, a research consortium dedicated to critical raw materials (EIT Raw Materials) was set up in 2015 and positioned within the European Institute of Technology and Innovation.[18] Pursuing this logic, in 2020 the European Union (EU) launched the European Raw Materials Alliance (ERMA), the aim of which is to "develop resilient value chains for EU industrial ecosystems, reduce dependence on critical primary raw materials through the circular use of resources, strengthen domestic supply of raw materials and diversify supply from third countries".

These various ambitions were reaffirmed in the context of the Critical Raw Materials Act (CRM Act) announced in March 2023[19] in response to the Versailles Declaration of 2022[20], and effective since May 23, 2024. As part of the more global strategy set out in the Green Deal industrial plan, the CRM Act ties in with other flagship European measures, notably the Net Zero Industry Act (NZIA) adopted at the same time. In particular, the intra-European part of the Act sets precise targets for member countries' production capacity by 2030, in order to reduce their dependence on imports, especially from China. For the mineral resources thus identified, the CRM Act aims to ensure that member countries' supply satisfies:

- 10% of Europe's annual mineral consumption ;
- 25% of recycling requirements ;
- 40% of refining needs.

In addition, no more than 65% of the Union's annual consumption of each strategic raw material may come from a single third country, regardless of its degree of processing. Acknowledging the urgent need to promote domestic sources of mineral resources, and the relative inelasticity of supply in the mining and metallurgy sectors to a lesser

17. https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

18. https://eit.europa.eu/

19. https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en

20. https://www.consilium.europa.eu/media/54777/20220311-versailles-declaration-fr.pdf

extent, the CRM Act promotes a number of provisions, including the simplification of administrative procedures and timeframes involved in opening a mine, refinery or recycling plant. Paragraph 32 (preamble) states that "For strategic projects involving processing or recycling only, the duration of the permitting process should not exceed 15 months. For strategic projects involving extraction, given the complexity and importance of the impacts likely to result from such projects, the duration of the authorization procedure should not exceed 27 months".

Going beyond these objectives, the European text acknowledges the importance of an economic and financial environment conducive to the development of European mining and metallurgy. The text focuses on two areas: (i) the triggering of public State aid

(i) "in the form of guarantees, loans or equity or quasi-equity investments" when private investment is insufficient, because the level of risk is too high, and (ii) the development of mechanisms to protect European manufacturers against price risk. Paragraph 41 thus states that

Given that "the volatility of prices for many strategic raw materials, exacerbated by the lack of opportunities to hedge these prices on futures markets, creates an obstacle both for project developers seeking financing for their projects in the strategic raw materials sector, and for downstream consumers seeking stable and predictable prices for their main inputs, the CRM Act suggests developing strategic resource exchange platforms facilitating meetings between European buyers and sellers. Among its many other provisions, the European text also stresses, in paragraphs 45 and 46, the importance of developing increased risk monitoring - including the obligation for certain large companies to carry out stress tests to assess the degree of exposure of their own value chain to the risk of supply disruption. Logically, it also stipulates that the management of strategic stocks of critical metals should be strengthened and coordinated within the Union. Finally, these various recommendations are accompanied by a requirement to apply sustainable development criteria both within the EU and vis-à-vis third countries, whether in terms of labor law, human rights or environmental protection.

On the basis of these various provisions, the CRM Act defines in Chapter 3 (Section 2, Article 6) what constitutes a strategic project according to five criteria: (i) a significant contribution to the security of the Union's supply of strategic raw materials; (ii) technical completion within a reasonable timeframe and with an expected production volume from the project that can be estimated with a sufficient level of confidence; (iii) implementation respecting sustainable development criteria; (iv) cross-border benefits beyond the Member State concerned for projects developed within the Union, and (v) for projects in emerging or developing third countries, mutual benefits for the Union and the third country concerned, which should benefit from significant added value from the project. This strategic recognition is intended to facilitate implementation by speeding up administrative procedures for granting authorizations, raising the funds needed to develop the project, and purchasing the strategic resources that will be produced (section 4, articles 15, 16 and 17).

In addition, under Articles 22 and 23 of the same Chapter 4, it is enacted that Member States must provide the European Commission (EC) with information on the status of their strategic stocks, except where such information may affect their national defense or security and that these must be coordinated. This task is carried out by the EC, which must also set up and manage "*a system intended, on the one hand, to aggregate the demand of interested companies established in the Union which consume strategic raw materials and, on the other hand, to solicit offers from suppliers with a view to meeting this aggregated demand*" (Article 25). Last but not least, the CRM Act includes a governance component, establishing in Chapter 6 a European Committee for Critical Raw Materials (Article 35) made up of representatives from all Member States and the Commission.

Although many of the CRM Act's provisions have a domestic dimension, the international aspect is not forgotten. Clearly, Europe cannot be self-sufficient in a large number of the critical and non-critical raw materials on which it depends, and must therefore develop trade agreements to facilitate their importation. The creation of a critical metals club[21] bringing together countries that produce and use these resources is thus envisaged, while a number of bilateral Memoranda of Understanding (MoUs) have already been signed, with Argentina, Australia, Canada and Chile, among others.[22] Finally, the European Union is one of the fourteen members of the Mineral Strategic Partnership initiative, which aims to encourage signatories to work together to develop diversified, sustainable supply chains.

The need to take into account Europe's energy situation

While the CRM Act's effectiveness will be measured by the facts and by the commitment of member states, it must be remembered that Europe's ability to secure its supplies is, first and foremost, intrinsically dependent on an often-difficult context marked by intense international competition and a marked deterioration in the global geopolitical situation.

As pointed out in the Draghi report on the future of European competitiveness (Draghi, 2024), Europe suffers from a lack of competitiveness vis-à-vis its trading partners when it comes to energy prices, particularly those of natural gas and therefore electricity, due to the specific mechanism used to set these prices. According to the same report, energy prices are around two to three times higher than in the United States or China. As a reminder, Europe has historically been dependent on Russian gas, with the volume of gas imported via pipelines from this country representing 29% of its consumption in 2021, i.e. nearly 168 billion m3 out of a total demand of 572 billion m3[23] (graph 7). This share has since fallen sharply, as has European consumption, to 11% (or 49.8 billion m3) and 463 billion m respectively.3 Europe's dependence on Russian gas remains high, however, and the necessary substitution of Russian gas has been made in favor of liquefied natural gas (LNG), whose import volumes have risen from some 71 billion m3 in 2018 to 169 billion in 2023, an increase of 137% in five years. Yet Europe benefits little from the long-term, indexed-price supply contracts so common in the world of LNG. This means that, until now, most purchases have been made under spot market conditions, with the result that prices are highly variable. The Title Transfer Facility - the gas price reference for continental Europe - reached EUR 227 per megawatt-hour (MWh)[24] on March 7, 2022 (i.e. an almost twenty-fold increase on the price at the beginning of January 2020), then reached the record value of EUR 340/MWh on the following August 29.

21. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661

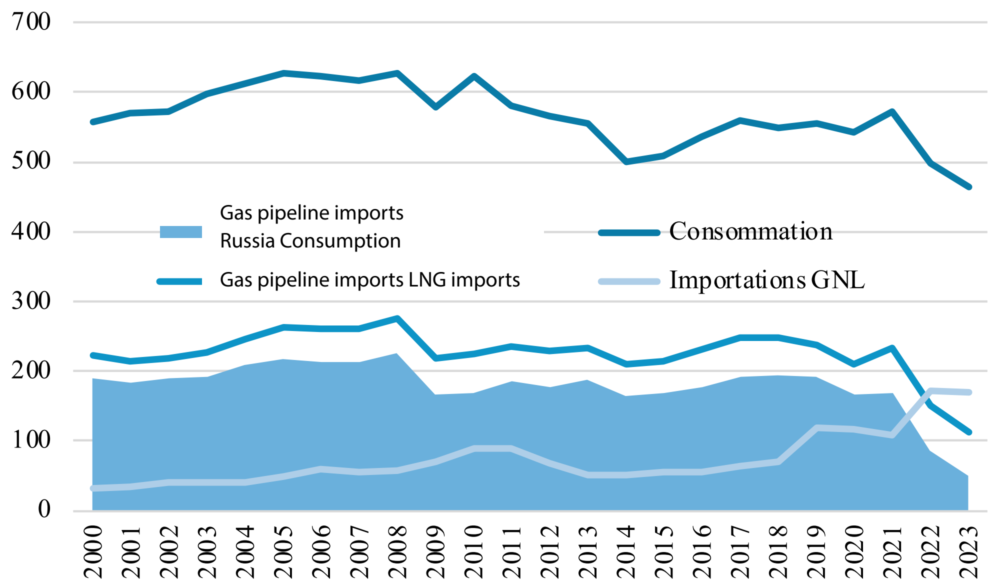
22. https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/raw-materials-diplomacy_en

23. In the broadest sense, i.e. the European members of the Organisation for Economic Co-operation and Development plus Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Georgia, Gibraltar, Latvia, Lithuania, Malta, Montenegro, Northern Macedonia, Romania and Serbia.

24. The price given here corresponds to the closing price of the futures contract on the Intercontinental Exchange (ICE).

Figure 7

European gas supply and demand (in billion m3)



Source: Energy Institute - Statistical Review of World Energy (2024)

European gas prices have since fallen sharply, to around 40 EUR/MWh, but the instability and price differential with the United States remain. This has had a major impact on European industrialization, particularly in the metallurgy sector (Jégourel, 2022a).

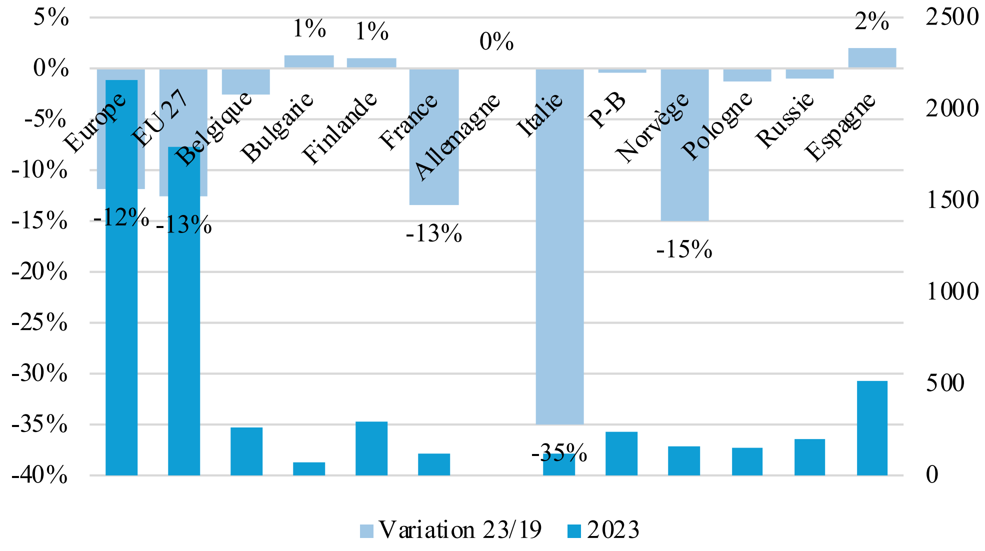
Although not included in the current European list of critical resources, zinc is one of the metals of the energy transition, particularly in offshore wind power, where it is used for galvanizing. However, under the impact of high energy prices and sluggish demand, the EU 27's production level of refined zinc fell sharply between 2019 and 2023 (-13%, from 2.45 Mt to 2.16 Mt), while it rose by 3% in China over the same period to reach 6.85 Mt, i.e. half the world's supply (graph 8). Because of the energy intensity of the electrolysis process used to transform alumina into metal, a similar observation can be made for aluminum - also one of the metals of the energy transition[25] - whose supply has declined significantly over the last decade. According to statistics from the Aluminium Institute[26], primary aluminum production in Western and Central Europe will fall to 2.713 Mt in 2023, compared with 3.45 Mt in 2019 and 3.61 Mt ten years earlier.

25. Bauxite, alumina and aluminum are also on the European list of critical mineral resources for 2024.

26. https://international-aluminium.org

Figure 8

2023 refined zinc production in Europe (in thousands of tonnes & as a percentage)



Source: International Lead and Zinc Study Group (ILZSG)

The issue of electricity prices in Europe raises more general questions about the ability of European industries involved in the energy transition (from upstream extraction to recycling) to strengthen their price competitiveness in the face of international supply, particularly from China.

Secure supplies and competitive pricing

If we look beyond the energy dimension, the issue of competitiveness and profitability for European operators can be interpreted differently, depending on price levels and their position within the industry. Clearly, as stated in the CRM Act, Europe's priority - as for any importing country - can only be to secure the volumes of critical resources required by the various industries that depend on them. However, this is a necessary but not sufficient condition for their long-term survival. It is easy to understand that European users also need to obtain these resources at a price equal to or lower than that enjoyed by foreign competitors, and symmetrically, European miners and recyclers need to produce at price levels in line with global pricing conditions. From this point of view, the predicted imbalance between supply and demand over a period of one to two decades should not blind us to the fact that European measures must take into account the possibility of a major and lasting drop in prices, as is currently the case with lithium. As mentioned above, while the CRM Act (paragraphs 36 and 41) clearly identifies the problem of price volatility, it does not fully spell out how it is to be dealt with at European level. The legitimate ambition to protect the various players in European value chains from its deleterious consequences is announced, but the mechanisms for achieving this are not specified, particularly in a context of falling prices for strategic mineral resources as currently observed.

Faced with the vast European and American plans to secure its supplies, combining the strengthening of mining supply and the development of recycling activities, as well as reinforced mineral resource diplomacy, it seems appropriate for China to create the conditions for a temporary abundance that will undermine the business models of its new "competitors". From this point of view, Europe must implement mechanisms to promote shareholder stability, in order to avoid/limit the flight of private capital when the profitability of its extractive or recycling companies weakens due to falling prices for the materials they produce. In particular, this means strengthening public/private partnerships to help raise funds and deleveraging risks. The inclusion of the mining sector in the European green taxonomy[27][28] is also essential.

Strategic storage: from the obvious to operational constraints

One might also be surprised at the absence of a "doctrine" on the constitution/management of strategic stocks, and the lack of procedures defining their operation. And yet, the optimality of stockpiling strategies is complex to define, once we go beyond the obvious. Having strategic resources (mineral and energy) on hand means that, in the event of supply shocks, there is no interruption in the flow of goods likely to disrupt the smooth running of the companies that depend on them, which is why many countries have them. In 1939, the US Congress enacted the Strategic and Critical Materials Stock Piling Act, a federal law authorizing the stockpiling of certain strategic and critical materials, both military and civilian, for the national defense of the United States (National Defense Stockpile). It was recently reaffirmed by Executive Order (EO) No. 13,817, signed in 2017 by Donald Trump and ordering the Department of the Interior to implement a federal policy reducing the nation's vulnerability to disruptions in the supply of critical minerals. This will be followed by Executive Order No. 14017[29] signed by Joe Biden with the ambition of reactivating US policy in this area. In Japan, the Japan Organization for Metals and Energy Security (JOGMEC) embarked in 1983 on a cooperative strategy involving the state and private interests in the storage of rare earths.

In the face of China's domination and use of coercive strategies in the form of export licenses for gallium, germanium and, more recently, antimony[30] , it is clearly timely for Europe to equip itself with similar tools. Since lithium and rare earths are a sine qua non for the development of electromobility and offshore wind power in Europe, it was therefore logical for the European Commission to announce, in Ursula Von Der Leyen's State of the Union address on September 14, 2022[31], the creation of strategic stocks for these two raw materials.

However, strategic stockpiling is neither free of constraints nor cost, and its proper functioning requires a precise definition of who bears them, in particular between public authorities and private interests. Storing a raw material means anticipating a future purchase for consuming industries or, for producing companies, postponing a sale, which implies not only having storage space at one's disposal, but also mobilizing liquidity, the costs of which must be assumed. At this stage, however, the CRM Act does not provide much

27. Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020, on the establishment of a framework to promote sustainable investment and amending Regulation (EU) 2019/2088.

28. The European Green Taxonomy Regulation proposes an evaluation and classification system enabling companies and investors to determine, using uniform criteria, whether an economic activity is "environmentally sustainable". Its aim is to redirect capital flows towards sustainable investments.

29. https://www.govinfo.gov/content/pkg/DCPD-202100163/pdf/DCPD-202100163.pdf

30. As well as limiting its exports of rare earths to Japan in 2010, due to a long-standing territorial dispute over the Senkaku Islands in the East China Sea.

31. https://ec.europa.eu/commission/presscorner/detail/en/speech_22_5493

information on this subject, and the mode of operation needs to be clarified. It is also important to remember that stockpiling without recourse to forward pricing mechanisms - a situation specific to very many critical mineral resources due to the absence of sufficiently liquid financial markets to do so - ultimately amounts to speculation (Marquet, 1992). Without hedging price risk with derivatives such as futures, buying at t0 to satisfy a need in t+n means setting a purchase price in t0 on the implicit assumption that the price will increase between now and t+n, but without any certainty. If this is not the case, the storage operation becomes financially costly, or even inefficient or counterproductive, operationally, since this drop in prices can only be synonymous with relative abundance on international markets. As Hache and Jeannin (2023) point out, the institution in charge of this strategic storage must therefore "have sufficient financial guarantees to ensure its continuity over a potentially very long period". Furthermore, in addition to the scope to be given on the number of resources to be stored and their quantities, the key to sharing costs between the State and private partners must be defined. While the CRM Act aims above all to coordinate national strategies, this task represents both a major and difficult challenge, since it involves converging - or even homogenizing - practices, and hence cost structures, on a European scale.

Finally, the doctrine defining the use of strategic storage must specify the conditions for its use in situations of European and/or international overcapacity, in line with the argument developed in the previous section. In the probable, but not certain, case of low resource availability, strategic storage plays the legitimate role assigned to it. In the opposite case, where supply exceeds demand for an unpredictable period of time, the institution in charge of stock management, if state-owned, may accumulate the resource in order to assist European producers. While this practice may be considered strategic, since it preserves national capacities potentially threatened by price falls, it amounts de facto to operating as regulatory stocks, the effectiveness of which has often been very limited in recent or earlier history.

To keep costs down, strategic stockholding needs to be combined with an active purchasing and resale policy for the raw materials in question, which implies the use of a physical trading function. This was the approach adopted by the United States when, during the Korean War, the country's tin reserves had to be replenished through a partnership with Philipp Brothers, an international trading house. Under the Agricultural Trade Development and Assistance Act of 1954, this company was given the task of marketing the country's tin reserves.

American agricultural products against this strategic metal within the framework of compensation agreements (Waszkis, 1992). At a time when a number of major international energy traders (Vitol, Mercuria, etc.) are turning their attention to metals, and when IXM, another Geneva-based trading giant owned by the China Molybdenum Corporation (CMOC) mining group, is playing an increasingly decisive role in the Chinese metals universe, it is surprising that the CRM Act does not consider this trading function, both in the management of the European Union's strategic stocks and in its more global policy of securing supplies.

IV. CONCLUSION

The energy transition's dependence on a certain number of mineral resources no longer needs to be demonstrated. Faced with China's domination of both the extraction and refining segments and the downstream sectors (batteries, photovoltaic panels), virtually all industrial economies have legitimately embarked on policies to secure their supplies.

These policies are based, on the one hand, on the development of national capacities and, on the other, on the strengthening of commercial relations with producer countries. In the case of Europe, the Critical Raw Materials Act of March 2023 sets out the guidelines that should enable member countries to limit the risk of supply disruptions, and thus fully commit to their decarbonization policies while preserving their industrial base. Ambitious, but to be compared with other international initiatives, first and foremost those of China and the United States, the European plan aims to ensure that the Union's various economic sectors have sufficient quantities of the strategic mineral resources on which they depend.

This approach, though logical, seems to underestimate a fundamental characteristic of world raw materials markets: price instability. More precisely, it is based on the assumption of rising prices, and does not sufficiently explain the mechanisms to be implemented, in the event of a temporary or lasting drop in prices, in its strategic storage policy or in defense of its mining and recycling industries. Given the continuing uncertainties over future demand and supply levels, and in a context where China may use its dominant position to oversupply the market in order to raise barriers to entry, Brussels should undoubtedly strengthen its mechanisms enabling companies belonging to European value chains to better protect themselves against, or even benefit from, this price variability.

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ABOUT THE AUTHOR

YVES JÉGOUREL

Yves Jégourel is Senior Fellow at Policy Center for the New South as well as Full Professor and head of the Chair in "Economics of Raw Materials and Sustainable Transitions", at the Conservatoire national des arts et métiers. He was previously a professor at the University of Bordeaux, where he directed the Master program in Banking, Finance and Commodity Trading (BFCT) and was vice-dean in charge of relations with companies in the Faculty of Economics, Management and ESA (EGAES). He devotes his teaching and research activities to the economics of commodities, with a particular focus on the common dynamics that characterize the agricultural, energy, and mineral and metal sectors: the internationalization of physical markets, the macroeconomic dependence of exporting countries and the relevance of industrialization strategies, the role of traders, the dynamics of financialization, price risk management, etc. Yves Jégourel is also co-director of the CyclOpe circle and a guest expert at the United Nations Conference on Trade and Development (UNCTAD).

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Policy Center for the New South

Rabat Campus of Mohammed VI Polytechnic University,
Rocade Rabat Salé - 11103
Email : contact@policycenter.ma
Phone : +212 (0) 537 54 04 04
Fax : +212 (0) 537 71 31 54

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