CHARLES UNIVERSITY

FACULTY OF SOCIAL SCIENCES

Institute of Political Studies Department of Security Studies

Master's Thesis

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CHARLES UNIVERSITY

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Institute of Political Studies Department of Security Studies

Europe's Strategy for Tech Security in the Era of Raw Critical Materials

Master's Thesis

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Study program: Security Studies

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Declaration

1. I hereby declare that I have compiled this thesis using the listed literature and resources only.
2. I hereby declare that my thesis has not been used to gain any other academic title.
3. I fully agree to my work being used for study and scientific purposes.

In Prague on April 30, 2024. Bc. Vojtěch Štěpánek

References

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Abstract

This diploma thesis is a single case study focusing on the European Union's approach to the issue of critical materials as a security concern. Critical raw materials will play an increasingly important role in Europe due to the ambitious Green Deal policy. The technologies necessary to address environmental challenges require a significant share of materials identified as critical in Europe. However, the problem is that most of these materials are concentrated in unstable and undemocratic regimes, which may pose strategic rivals. This creates a threat that supplier states may use critical materials as a tool of power and thus jeopardize the economic security of European Union countries. This thesis examines critical materials as a phenomenon, analyzes their criticality and relationship to technologies. It further conducts an analysis of selected critical materials and their risks, particularly about the nature of supplier states. The final chapter addresses the European strategy in this area and describes how critical materials affect strategic technologies.

Abstrakt

Tato diplomová práce je single case study, která se zaměřuje na přístup Evropské unie k problematice kritických materiálů jako bezpečnostního problému. Kritické surové materiály budou hrát v Evropě čím dál významnější roli v kontextu ambiciózní politiky Green Deal. Technologie nezbytné k řešení environmentálních výzev vyžadují značný podíl materiálů, které jsou v Evropě označovány jako kritické. Avšak problémem je, že většina těchto materiálů je koncentrována v nestabilních a nedemokratických režimech, které mohou představovat riziko. Tím vzniká hrozba, že dodavatelské státy mohou využít kritické materiály jako nástroj moci a ohrozit tak ekonomickou bezpečnost zemí Evropské unie. Tato práce zkoumá kritické materiály jako fenomén, analyzuje jejich kritičnost a vztah k technologiím. Dále provádí analýzu vybraných kritických materiálů a jejich rizik, zejména s ohledem na povahu dodavatelských států. Poslední kapitola se věnuje evropské strategii a popisuje, jak kritické materiály ovlivňují oblasti jenž Evropská unie považuje za strategické.

Keywords

Critical Raw Materials, dependence, strategic autonomy, supply chains, China, European Union, strategic partnership, green technologies

Klíčová slova

Kritické surové materiály, závislost, strategická autonomie, dodavatelské řetězce, Čína, Evropská Unie, strategické partnerství, zelené technologie

Title

Europe's strategy for Tech Security in the Era of Raw Critical Materials

Název práce

Strategie Evropy pro bezpečnost technologií v éře kritických surových materiálů.

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Introduction

Europe has long enjoyed a period of prosperity, marked by the benefits of globalization that have significantly enriched the states within the European Union. This era of economic interconnection between large states fostered a tendency towards cooperation over conflict and enabled European businesses to expand into foreign markets, generating wealth and enhancing international connectivity. This linkage facilitated an exchange of ideas and opportunities across borders, reinforcing the European commitment to a globalized economy.

However, recent years have seen a marked shift towards what many politicians and leading newspapers have termed "deglobalization."[1] This reversal is attributed mainly to the COVID-19 health crisis, which severely disrupted the flow of goods and people globally and within the European Union—a region previously characterized by its open borders. The crisis highlighted vulnerabilities starting with shortages of medical supplies, such as masks, and extending to critical components like semiconductors. These shortages underscored the dangers of excessive reliance on global supply chains, particularly in times of global unrest.

The challenges posed by the pandemic were further compounded in 2022 by the largest conflict in Europe since World War II—Russia's invasion of Ukraine.[2] This conflict disrupted the supply of critical energy resources, such as oil and gas, essential to the functioning of both the European economy and society. The dependence on Russian energy sources led to significant political instability in affected states, with some analysts predicting catastrophic social upheaval exacerbated by skyrocketing gas prices. Despite these challenges, Europe has managed to navigate through these crises and emerge resilient, though not unscathed. The experiences have underscored the need to critically assess Europe’s dependencies on strategic supplies from potentially unreliable sources. Moving forward, Europe must devise strategies that mitigate the risks associated with geopolitical and other external disruptions, ensuring a more secure and stable future.

These crises have compelled Europe to thoroughly analyze its strategic supply imports, leading to a robust initiative to address dependencies on additional raw materials. In addition to diversifying its sources of fossil fuels, Europe is actively working to reduce its reliance on "critical raw

[1] Alden, Edward. "The Dangerous New Anti-Globalization Consensus." *Foreign Policy,* May 3, 2022,
[2] European Investment Bank. "How Bad Is the Ukraine War for the European Recovery?" European Investment Bank, 2022, p. 26.

materials," which are essential for developing new technologies. These technologies are crucial for Europe's goal to become a climate-neutral bloc by 2050.[3] Critical raw materials like lithium, cobalt, and copper are not only fundamental to green energy technologies such as wind turbines, solar panels, and batteries but are also integral to economically strategic sectors like information and digital technologies, which underpin the development of areas such as artificial intelligence. The demand for these materials also extends into the military domain, where they are used to develop advanced military systems and weaponry.[4]

In this context, the European Union faces more significant dependencies on individual states for these materials than it does for Russian fossil fuels. The most challenging dependency is on China, which holds a dominant position in the global supply chain of these critical materials. China's control extends from the initial mining and processing stages to the production of components and final products.[5] The issue is compounded by China's economic influence in resource-rich countries, particularly in Africa and Latin America, where it has established sophisticated processing capacities. This economic dominance makes it challenging to address these dependencies, as Chinese companies control significant portions of strategic resources that are concentrated in only a few countries. For instance, approximately 70% of the world's discovered cobalt reserves are located in the Democratic Republic of Congo, where Chinese firms dominate about 80% of local production. However, Europe's dependencies extend beyond China to include other countries characterized by political instability or those that are allies of strategic rivals to the Western world. This complex geopolitical landscape necessitates a strategic reevaluation and diversification of Europe's raw material sources to ensure resilience and security in its supply chains.

In response to heightened concerns over resource security and sovereignty, the European Union took decisive action in 2023 by introducing the "Critical Raw Materials Act." This legislation is designed to capitalize on domestic resources and establish new global partnerships, enabling the EU to diversify its supplies and enhance its resilience. This move is particularly crucial as the EU

[3] International Energy Agency. "Clean Energy Technologies Need a Major Boost to Keep Net Zero by 2050 Within Reach." News, November 4, 2021. https://www.iea.org/news/clean-energy-technologies-need-a-major-boost-to-keep-net-zero-by-2050-within-reach.

[4] European Commission. "Critical Raw Materials." Accessed April 8, 2024. https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en.

[5] European Commission. "Critical Raw Materials Act: Securing the New Gas & Oil at the Heart of Our Economy." Blog of Commissioner Thierry Breton, September 14, 2022. https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_22_5523.

has also ratified the Climate Law, committing legally to achieving climate neutrality by 2050.[6] It is imperative for the European Union to intensify its efforts in this domain to maintain its prosperity, security, and competitiveness on the global stage.

The urgency of this initiative is underscored by the existential threat posed by resource insecurity, recently highlighted by the conflict in Ukraine. The risk is particularly acute in the realm of critical materials, where the EU faces significant challenges from China. As China engages in an economic confrontation with the USA, and tensions over Taiwan's sovereignty loom, any major disruptions from China could plunge the EU into a deeper crisis, similar to or worse than the current situation with Russia.[7] This issue, primarily viewed through an economic lens, is only beginning to be recognized as a security concern, necessitating greater attention from political science and other relevant disciplines.

This thesis is structured into three main chapters, supported by a theoretical framework and a clear methodology that guides the analysis in the empirical parts. The first chapter outlines the historical evolution of critical materials within the EU and globally, assessing the risks associated with critical materials and their technological affiliations. The second chapter delves into the legislative landscape concerning critical materials, focusing on those identified by the EU as strategic, and analyzes the dependencies on certain countries, incorporating multiple perspectives. This chapter also evaluates the geopolitical implications of Europe's reliance on risk-laden countries. The final chapter discusses the EU's strategic response, highlighting efforts to forge new partnerships and initiatives. It also examines the impact of critical materials on strategic sectors, including defense and economically vital industries. The thesis concludes by summarizing the findings and answering the research questions posed.

[6] European Commission. "Critical Raw Materials." Accessed April 8, 2024.
[7] Wischer, Gregory. "The U.S. Military and NATO Face Serious Risks of Mineral Shortages." Carnegie Endowment for International Peace, February 12, 2024. https://carnegieendowment.org/2024/02/12/u.s.-military-and-nato-face-serious-risks-of-mineral-shortages-pub-91602.

Conceptual Framework

Strategic Autonomy

Strategic autonomy is a concept that can be traced back to the first founding treaty of the European Coal and Steel Community when six European states decided to gain greater autonomy in certain areas through cooperation. This effort to act as an actor capable of autonomously making strategic decisions gradually expanded through European integration. However, it is a concept primarily rooted in security policy. Its beginnings can be dated back to 1991 when the Common Foreign and Security Policy (CFSP) was established in Maastricht as the second pillar of the Maastricht Treaty, one of the first initiatives towards building a political union.[8] Another important milestone was in 2003 when the EU created the European Security Strategy, aiming for the EU to be more active in pursuing its strategic goals. At that time, the focus was mainly on policies in the Middle East, where the EU, for example, led negotiations with Iran on its nuclear program as part of the EU3 format.[9] The first explicit mention of strategic autonomy appears in a European Council report from 2013, which calls for a more integrated, sustainable, and innovative policy in the security, technological, and industrial domains.[10]

In 2016, the High Representative of the European Union for Foreign Affairs, Federica Mogherini, presented the EU Global Strategy on Foreign and Security Policy. This document responds to a turbulent period marked by phenomena such as Brexit and the migration crisis. It also responds to geopolitical shifts associated with globalization, acknowledging both the economic opportunities and the destabilization of the EU's immediate neighborhood and the growing role of other powers.[11] Regarding China, the document takes a relatively lenient approach, calling for cooperation.[12] It also maintains the tradition of cooperation and multilateralism globally.[13] This document, replacing the 2003 strategy, places strategic autonomy in a broader context beyond purely military considerations.

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[8] European Council. "Timeline: EU Cooperation on Security and Defence." Accessed April 15, 2024. https://www.consilium.europa.eu/en/policies/defence-security/defence-security-timeline/.
[9] Fiott, Daniel. "Strategic Autonomy: Towards 'European Sovereignty' in Defence?" European Union Institute for Security Studies (EUISS), 2018, 2.
[10] Damen, Mario. "EU Strategic Autonomy 2013-2023: From Concept to Capacity." EU Strategic Autonomy Monitor, PE 733.589, Briefing, July 2022, 1.
[11] European External Action Service. "Shared Vision, Common Action: A Stronger Europe. A Global Strategy for the European Union's Foreign and Security Policy." 9.
[12] Ibid, 38.
[13] Ibid, 4.

In his 2017 Sorbonne speech, French President Emmanuel Macron presented a vision for Europe that emphasizes strategic autonomy, urging the continent to achieve greater sovereignty and robustness in global affairs. Macron argued for a Europe capable of defending its interests and values by deepening integration across multiple dimensions, including security, economy, and environmental policies. He proposed the development of a European intervention force, a common defense budget, and a unified foreign policy stance, aiming to reduce dependence on external powers and enhance Europe's capacity to act independently. Macron highlighted the necessity of bolstering Europe's economic independence by reducing reliance on non-European sources for critical technologies and energy. Moreover, he stressed the role of shared cultural values and identity in solidifying a cohesive and resilient European Union. According to Macron, this comprehensive approach is essential for Europe to navigate the complexities of global politics and maintain its influence on the world stage.[14]

The main impetus for firmly grasping strategic autonomy was the COVID-19 crisis, which revealed Europe's vulnerability to critical health materials, chips, and critical minerals, with all lines leading to extreme dependence on China. In 2020, the European Commission, in its strategic foresight report "Resilience as a New Compass," directly referring to strategic autonomy, describes it as a concept mainly associated with the strategic goals of the European Union, such as being a leader in promoting policies to combat climate change. It also vividly describes the situation with critical materials, stating that the EU cannot afford dependence on individual states if it wants to meet its strategic goals. Strategic autonomy is described here as a path through which the EU will operate within democratic values, promoting human rights and the rule of law, particularly through cooperation with like-minded states. Since then, the concept of strategic autonomy has been used in various aspects of European policy.[15]

Its significance was further emphasized by the conflict in Ukraine and the realization of the immediate danger posed by lack of sovereignty, particularly in security and strategic resource areas. In his briefing, Marian Damen of the European Parliament's research center compares strategic autonomy to Maslow's hierarchy of needs. The lower level, self-actualization, represents Europe as an autonomous democratic federation, a global example. "Esteem" emphasizes the EU

[14] Ouest France. "Sorbonne Speech of Emmanuel Macron - Full Text." September 26, 2017. Accessed at: https://international.blogs.ouest-france.fr/archive/2017/09/29/macron-sorbonne-verbatim-europe-18583.html.
[15] European Commission. "2022 Strategic Foresight Report: Twinning the Green and Digital Transitions in the New Geopolitical Context." Press Release, June 29, 2022. Brussels. Accessed April 16, 2024. https://ec.europa.eu/commission/presscorner/detail/en/IP_22_4004.

as a normative actor with a strong emphasis on European values. Love and belonging illustrate European promotion of multilateralism and the forging of new friendships (agreements) with other states. Safety needs are equated with European economic independence, which must be achieved through stable supply chains. At the top of the pyramid of physical needs are the basic key security domains, such as energy or water security.[16]

Guntram Wolff, Nathalie Tocci, Charles Powell describe strategic autonomy as a situation where the EU must live sovereignly according to its laws and must be able to defend its interests without foreign influence. Although it mentions the EU as strongly interconnected with the world, an organization based on consensus must strike a good balance in foreign actions. Multilateral negotiations are conducted, when possible, but the EU must also be capable of unilateral action when the situation is dire.[17] Niklas Helwig characterizes strategic autonomy as a concept that evolves over time in response to geopolitical changes. The first two waves from the 1990s to 2016 mainly focus on military-diplomatic efforts. The third wave, in response to the election of Donald Trump and a shift in reliance on the United States, addresses not only security but also economic aspects. The fourth wave represents the period after COVID-19, bringing threats associated with the breakdown and riskiness of global supply chains.[18]

Nathalie Tocci outlines strategic autonomy from both internal and international perspectives. According to the authors, from an internal perspective, it is understood as the EU being able to live according to its laws and norms, protecting itself both internally and internationally by joining an international community characterized by values it helps shape.[19] Therefore, strategic autonomy is not about detachment from the world since the EU fundamentally lacks the ability to do so, given its rootedness in international organizations and close alliance with the United States. Thus, Strategic autonomy is a way for the EU to be capable of action based on its capacity. This policy can be pursued in various ways, but the goal should be to continue actively cooperating in foreign policy and shaping the international order to reflect European values as much as possible.

[16] Damen, Mario. "EU Strategic Autonomy 2013-2023: From Concept to Capacity.", 5.
[17] Wolff, Guntram, Nathalie Tocci, and Charles Powell. "Making European Strategic Autonomy Work." German Council on Foreign Relations, November 24, 2023. Accessed April 16, 2024. https://dgap.org/en/research/publications/making-european-strategic-autonomy-work.
[18] Helwig, Niklas (ed.). Strategic Autonomy and the Transformation of the EU: New Agendas for Security, Diplomacy, Trade and Technology. Finnish Institute of International Affairs, 2021, p. 111. Accessed April 20, 2024.
[19] Tocci, Nathalie. European Strategic Autonomy: What It Is, Why We Need It, How to Achieve It. Rome: Istituto Affari Internazionali (IAI), 2021. ISBN 978-88-9368-178-0, 3.

The European Union, therefore wants to remain an important multilateral player, but one with the ability to act sovereignly in various strategic areas.

Economic Security

Economic security is a concept that is not clearly defined, and its dynamics change over time. In the field of social sciences, it can be perceived especially in economic disciplines, which address, for example, the vulnerability of individuals to the consequences of economic impacts, or financial science, which views economic security as a behavior where people save or invest for their future comfort and security. In the field of security studies, we have several definitions that point out that this concept lacks clear anchoring and, therefore also becomes a subject of criticism due to its vagueness. [20]

The concept of economic security within international relations and security studies is deeply rooted in the significant theory of economic interdependence, which emerged in the post-1945 era. This theory, eloquently formulated by Joseph Nye and Robert Keohane during the Cold War, has substantially shaped our understanding of global dynamics. It accounts for the widespread cooperation observed in periods marked by extensive multilateral alliances and seamlessly integrates international economics with politics, creating a comprehensive analytical framework.[21]

Liberal theorists argue that economic interdependence among states reduces the likelihood of conflict by increasing the economic costs associated with war and promoting cooperative, mutually beneficial relationships. According to this view, the integration of national economies through trade and investment fosters a collective interest in maintaining stability and prosperity, which serves as a deterrent against conflict.[22] In contrast, realists offer a more critical stance on the pacifying effects of economic interdependence. They assert that states consistently prioritize military security and strategic interests over economic relationships. Realists point out that economic ties can potentially lead to conflicts, particularly in situations where these relationships are asymmetrical. They argue that when economic benefits are distributed unevenly, more

[20] Joris van Esch, Sijbren de Jong, and Marjolein de Ridder, "The Evolution of the Concept of Economic Security in the Dutch Security Policy Context," in No Blood for Oil? Economic Security, Energy Security and the Military (The Hague: Hague Centre for Strategic Studies, 2014), 26.
[21] Doran, Charles F. "Living with Asymmetry." *Mershon International Studies Review* 38, no. 2 (1994): 260.
[22] King, Amy. "Economics and Security." In New Directions in Strategic Thinking 2.0: ANU *Strategic & Defence Studies Centre's Golden Anniversary Conference P*roceedings, edited by Russell W. Glenn, 26. Canberra: ANU Press, 2018.

powerful states may exploit these imbalances to enhance their own power at the expense of weaker states, thereby increasing the likelihood of conflict.[23]

Vincent Cable described possible concepts from the perspective of security studies/international relations in his article "What is international economic security?" in which he builds on the concept of "geo-economics," which began to be used during the Cold War.[24] As a first perspective, he describes economic security as a condition where investments or trade relationships influence a state's ability to acquire weapons, new technologies, and the reliability of weapon suppliers, affecting whether the state can build sufficient infrastructure to be defense capable. The second perspective is the ability of a state to use economic instruments as weapons in the form of sanctions, economic restrictions, or boycotts of energy supplies. The third term is particularly linked to the mentioned term Geo-Economics, which indicates that states in modern times often replaced conventional warfare with economic warfare, using methods such as export restrictions, sanctions, strong state support for domestic producers to undermine foreign competitors. From this perspective, the threat to security can manifest in a way that weak economic development in a country can endanger the state's military capacity or even the overall significance and strength of the state in the international arena.[25]

The G7 summit in March 2023 in Hiroshima brought greater clarity to the definition of economic security, where G7 states outlined 7 areas falling within this domain in their communiqué. These include building resilient supply chains, resilient critical infrastructure, responding to non-financial policies and practices, economic coercion, harmful practices in the digital sphere, cooperation on setting international standards, and preventing leakage of critical and new technologies. G7 leaders are thus responding to today's geopolitical challenges, particularly associated with China's assertive policies, as well as the disruptions caused by the COVID-19 pandemic and the increasing role of the cyber domain in security. It is also a document mentioning that G7 states aim to build economic security within the framework of improving international systems, confirming a shift from the concept of decoupling, which simplistically means isolating

[23] Ibid., 27.
[24] Vincent Cable, "What is International Economic Security?" International Affairs 71, no. 2 (April 1995): 305-324, 308.
[25] Joris van Esch, Sijbren de Jong, and Marjolein de Ridder, "The Evolution of the Concept of Economic Security, 27.

oneself economically from a certain state to a less radical de-risking approach focused more on threat prevention.[26]

At the European level, this concept is clarified by a joint statement of the European Council, Commission, and Parliament regarding the "European Economic Security Strategy." Here, the EU identifies its own 4 areas of risks concerning economic security. These include risks to the resilience of supply chains and energy security, risks associated with physical and cyber-attacks on critical infrastructure, technology security and technological leakage, and risks associated with economic dependence and economic coercion. To fulfil this strategy, the EU has chosen the 3Ps: promoting, protecting, and partnering, which are aimed at strengthening the domestic economy, identifying and preventing risks, and establishing new partnerships with states with whom it aims to build a more secure and resilient economic environment.[27]

Methodology

This thesis is a single case study analyzing the European Union's strategic approach to critical materials, framed as a key security concern. It employs both qualitative and quantitative research methods to address the multifaceted nature of critical materials. The study involves a detailed individual analysis of the most important materials, providing numerical data for clearer understanding and effective contextualization.

Critical materials are now receiving closer attention, intersecting various scientific fields. This thesis, however, narrows its focus to the dimensions relevant to political science and security studies. It is important to note that the insights derived from this work are specific to these fields and do not extend to other disciplines. The core of the research examines the influence of critical materials on the EU's economic security, strategic positioning, and technological advancements, primarily from the viewpoint of EU institutions. It intentionally avoids detailed discussions on individual EU member states, which have unique needs and strategic considerations.

[26] Matthew P. Goodman, "G7 Gives First Definition to 'Economic Security'," commentary, Center for Strategic and International Studies (CSIS), published May 31, 2023. https://www.csis.org/analysis/g7-gives-first-definition-economic-security

[27] European Commission, "European Economic Security Strategy," joint communication to the European Parliament, the European Council, and the Council, JOIN(2023) 20 final (Brussels: European Commission, June 20, 2023), 4-5.

Structured into three empirical chapters, this thesis first defines critical materials, outlining their security implications and the legislative responses from the EU. While existing data on these materials is typically evaluated through an economic lens, this work reinterprets them within a security framework, assessing risks associated with the dominant supplier states.

Moreover, the thesis analyzes the geopolitical behaviors of these states, examining their political stability and democratic values, crucial for understanding the EU's strategic dependencies. It critically reviews the EU's strategies for managing these dependencies, especially through strategic partnerships that may entail significant risks despite often being portrayed as unproblematic. Additionally, this work explores the intersection of critical materials with strategic sectors and technological innovations, clarifying how dependencies on risky countries could impact Europe's economic security and strategic objectives.

The study acknowledges several limitations. First, the exploration of critical materials as a security issue is relatively underdeveloped, especially within European academia. The topic is more frequently addressed by economists, and there's a noticeable lack of political science analysis from European scholars compared to their American counterparts. Another limitation concerns the complexity of the supply chains; the data may not fully reveal the risks associated with suppliers, particularly when these suppliers are controlled by entities from countries considered high-risk, such as China. Lastly, the thesis does not predict technological advancements like recycling or new material substitutions, which could eventually mitigate some of the current risks associated with critical materials, making some concerns potentially obsolete in the future.

Research Design & Data Collection

This thesis sets out three research questions.

How does European legislation influence dependence on critical materials and how does it attempt to address this issue? This question aims to demonstrate how the development of climate change and newly adopted green strategies by the European Union increase the demand for critical materials and thereby enhance the strategic importance of sectors requiring these materials for their functioning. In this regard, the thesis relies on the analysis of primary sources from the European Union focusing on the most important strategies issued by the EU, such as the Net Zero Industry Act, Critical Raw Materials Act, and others, contextualizing the individual materials used for strategic technologies in Europe.

Which critical materials are most important for Europe from a strategic perspective and what are the risks associated with supplier countries? In this second research question, the aim is to identify the most important materials from the total list of 34 critical materials and highlight the risks associated with supplier countries, emphasizing the geopolitical vulnerabilities that may pose a dangerous character in this area for the future.

Is the European Union primarily value-oriented in its strategies for seeking new strategic partners? The European Union is a value-oriented entity that often emphasizes its goal of reorienting its policies toward "like-minded countries," through which it can mitigate risks in the field of critical materials. The primary task in this question is to determine to what extent the EU has formed new initiatives in this issue with value-aligned states and to what extent they can help it.

The results of these three questions should address two hypotheses posed:

The dependence of the European Union on undemocratic and unstable countries increases the risk of disruptions in the supply of strategic raw materials. Major players may exploit their dominant position as leverage in resolving economic/political issues, while developing countries threaten supplies due to their instability and unclear political orientations.

This hypothesis stems from the fact that the world is shifting towards new technologies aligned with addressing climate change sustainability. The EU faces the greatest challenge in this regard, as it has set the most ambitious green goals among all major global players and will therefore need to address the issue of critical materials most intensively. These materials are largely imported by the EU from states that are strategic rivals or characterized by ambiguous political orientations and instability, posing risks of supply disruption due to current geopolitical tensions worldwide or competition for dominance in new technologies.

The European Union's strategy to reduce its reliance on critical materials from undemocratic and unstable regions by partnering with like-minded states is unlikely to significantly decrease its dependency in the short to medium term, due to geopolitical and practical constraints.

The EU has presented a plan to reduce dependence on critical materials through its legislation, the "Critical Raw Materials Act," indicating that Europe is fully aware of this issue, which undermines the broader goal of achieving greater strategic autonomy. Although the EU plans to increase mining and processing within its territory, it will not be able to solve this problem in this way due

to the limited capacity of these resources on the European continent, while their demand will steeply rise. Similarly, it is not feasible to primarily focus on ideologically aligned countries, as they are unable to compete with states like China, which has a years-long lead and necessary know-how. Therefore, Europe will need to engage with partners who will continue to be risky and ideologically unrelated.

The thesis relies on primary sources in the form of officially issued documents from European Union institutions. The most significant role in this regard is played by sources from the European Commission, as the executive body responsible for preparing and coordinating procedures in the field of critical materials. This primarily includes reports, communications, legislative proposals, analyses, and summarizing information on official websites. It is important to highlight sources from analytical and scientific teams of the European Commission, such as the Joint Research Center, which have issued important documents that European authorities have relied on when building their strategies and policies. The thesis adopts from these analytical reports the list of critical materials as compiled and determined by the JRC. Similarly important are the analyses from the perspective of identifying technologies and sectors affected by this issue.

Furthermore, the thesis utilizes data from relevant expert institutions such as the International Renewable Energy Agency (IREA), the Organization for Economic Cooperation and Development (OECD), and the International Energy Agency (IEA). Regarding individual critical materials, the thesis also utilizes data from the US Geological Survey (USGS), especially for information regarding the distribution of critical materials worldwide. To describe political indicators for identifying risks of supplier countries, the thesis utilizes data from the World Bank, Freedom House, and Transparency International.

From the perspective of secondary sources, the thesis relies on academic articles, reports, and analyses found in various academic databases such as JSTOR, Tandforline, Directscience, EBSCO, and others. Another important role is played by articles and analyses from prestigious international think tanks, which have been able to contextualize other sources correctly, such as Bruegel, The Council on Foreign Relations, the Center for Strategic and International Studies, the Carnegie Endowment for International Peace, the Atlantic Council, Foreign Policy, the German Council on Foreign Relations. Lastly, the thesis also uses newspaper articles from prestigious news media focusing on European politics, such as Politico, EUobserver, or EUractiv. Similarly,

the thesis also utilizes globally influential media outlets such as The New York Times, the Financial Times, or The Economist.

Literature Review

This thesis primarily relies on primary sources, especially direct sources from the European Union. In its press release "Critical Raw Materials: ensuring secure and sustainable supply chains for EU's green and digital future,"[28] the European Union views critical raw materials as strategic commodities for which strong demand is anticipated in the coming years. The EU perceives this issue as a security problem, as it touches on strategic sectors crucial for economic security and achieving climate goals within the Green Deal strategy. The EU acknowledges its dependency on monopolistic suppliers from third countries, which could pose a security risk. It particularly emphasizes the need to build economic resilience in connection with two crises that have exposed vulnerabilities: the Covid-19 pandemic and the war in Ukraine. The Raw Critical Materials legislation distinguishes two areas. Internally, where Europe can improve the situation by maximizing its own capacities, and internationally, which is focused on creating more resilient supply chains through partnerships with new states outside the EU.

Grohol, Milan and Veeh, Constanze from Joint Research Center[29] emphasize that critical materials are at the start of every value chain. JRC highlights that although CRMs are produced in relatively small quantities, their special properties make them indispensable in many areas we consider strategic. JRC specifically mentions renewable energy, digital technologies, and the defense industry. This study categorizes critical materials into critical and strategic according to its methodology—supply risk and economic importance. While critical materials are generally important, strategic ones are those that relate to the most crucial technologies and face the highest risk of supply disruption.

"Critical Raw Materials for Strategic Technologies and Sectors in the EU"[30] delves into more detail, where it breaks down the dependency on individual materials for various technologies. This study then places the information within a broader geopolitical framework, highlighting the risks

[28] European Commission. "Critical Raw Materials: Ensuring Secure and Sustainable Supply Chains for EU's Green and Digital Future." Press release, March 16, 2023. Brussels.
[29] European Commission. "Study on the Critical Raw Materials for the EU 2023 - Final Report." 2023. European Union.
[30] European Commission, Joint Research Centre. "Critical Raw Materials for Strategic Technologies.

associated with certain countries. It sees the greatest risk particularly in technologies related to renewable energy, where it identifies a strong dependency on certain countries with rare earth elements or battery materials, looking ahead to the coming years. The International Renewable Energy Agency in its report - Geopolitics of the Energy Transition: Critical Materials[31] describes the main geopolitical risks associated with critical materials, such as external shocks that illustrate the situation in the world regarding natural disasters or wars. It also describes trends such as increasing "material nationalism," where more and more, especially developing states, impose various restrictions on the export of materials considered critical.

Secondary sources are equally important in the work. "Critical Raw Materials: A Perspective from the Materials Science Community"[32] Margarethe Hofmann discusses critical materials and their criticality from a technical perspective, particularly from the perspective of the United States and the European Union, highlighting the basic approach oriented on the axis of supply risk and economic importance, while pointing out other approaches such as geographical conditions or importance from the perspective of strategic sectors. In the publication "Raw Material Criticality in the Context of Classical Risk Assessment,"[33] the authors emphasize using a different methodology, the "criticality matrix," which shows that the traditional risk methodology has a static form and does not consider the dynamics and long-term framework of demand for critical materials.

In "Securing Europe's Supply of Critical Raw Materials: The Material Nature of the EU's Strategic Goals" Guillaume Ragonnaud[34] from European Parliaments research service describes the importance of critical materials for green technologies, which are necessary for achieving the climate goals of the European Union, emphasizing that this area is also of interest for achieving broader European objectives, such as strategic autonomy. The author highlights that critical materials are one of the 10 strategic themes that are key to European capability for the coming decades. However, there is a question of whether climate goals can be geopolitically secured

[31] International Renewable Energy Agency. 2023. "Geopolitics of the Energy Transition: Critical Materials." Abu Dhabi: International Renewable Energy Agency.
[32] Hofmann, Margarethe, et al. "Critical Raw Materials: A Perspective from the Materials Science Community." Received July 25, 2017; Revised August 7, 2018; Accepted August 7, 2018
[33] Glöser, Simon, et al. "Raw Material Criticality in the Context of Classical Risk Assessment." Fraunhofer Institute for Systems and Innovation Research ISI and Clausthal University of Technology.
[34] Ragonnaud, Guillaume. "Securing Europe's Supply of Critical Raw Materials: The Material Nature of the EU's Strategic Goals." Members' Research Service, European Parliament, PE 739.394, March 2023.

safely. Rodrigo Castillo and Caitlin Purdy from The Brookings Institute[35] points out the global dominance of the supply chain for critical materials in China, which particularly has strength in processing materials necessary for green energy technologies. The authors note that the EU has realized that China is its biggest threat in terms of potential disruption of supply chains. Disconnecting from dependence on China, according to the authors, will be costly and complex, but warns that a scenario in which dependence remains unchanged or increases is the worst, as it significantly deepens geopolitical, social, and environmental risks.

Anne Rehill in The article "Ensuring Rare Earth Elements for National Security"[36] in the Yale Review highlights a case where China banned the export of rare earths to Japan due to the detention of a Chinese fishing vessel in disputed waters. Additionally, analysts Simon Evenett and Johannes Fritz from the University of St. Gallen[37] found that China had significantly restricted supplies to Australia and the United Kingdom by up to 75%, demonstrating the exploitation of these materials, which represent a major weapon in China's material portfolio. Alexander Holderness, Nicholas Velazquez, Henry H. Carroll, and Cynthia Cook[38] point out that more recently, in 2023, China demonstrated its ability to use these materials in disputes, particularly in the technological arena. China imposed restrictions on the export of Germanium and Gallium, which authors suggest is clearly a retaliation for the ban on exporting technology machines for processing modern technologies, although China argues it is a matter of national security related to the dual use of these materials.

However, China is not the only problematic country on which the EU is dependent for critical materials. Another prominently highlighted issue generally concerns the Democratic Republic of Congo (DRC), which is identified by relevant metrics as a country with very low stability. Authors Christian-Géraud Neema Byamungu[39] points out that the DRC does not control the majority of its cobalt reserves, as the largest part is controlled by investors from China. The author describes how

[35] Purdy, Caitlin, and Rodrigo Castillo. "China's Role in Supplying Critical Minerals for the Global Energy Transition: What Could the Future Hold?" Brookings Institution, July 2022. https://www.brookings.edu/articles/chinas-role-in-supplying-critical-minerals-for-the-global-energy-transition-what-could-the-future-hold/

[36] Rehill, Anne. "Ensuring Rare Earth Elements for National Security." The Yale Review of International Studies, 28 Nov 2023. https://yris.yira.org/column/ensuring-rare-earth-elements-for-national-security/

[37] Evenett, Simon, and Johannes Fritz. "Revisiting the China–Japan Rare Earths Dispute of 2010." VoxEU CEPR, 19 Jul 2023.

[38] Holderness, Alexander, Nicholas Velazquez, Henry H. Carroll, and Cynthia Cook. 2023. "Understanding China's Gallium Sanctions." Critical Questions. Published July 7. Washington, DC: Center for Strategic and International Studies (CSIS). https://www.csis.org/analysis/understanding-chinas-gallium-sanctions.

[39] Byamungu, Christian-Géraud Neema. 2022. "Blue Metal Blues: Cobalt, the Democratic Republic of Congo, and China." May 1. https://www.jstor.org/stable/resrep41904.

countries like the DRC easily sign various agreements with undemocratic states for infrastructure projects in exchange for investments in mineral resources. This way, the consumer states can be indirectly threatened because they cannot fully rely on the given country, but must consider the risk that, for example, Chinese companies are under the strong influence of the Chinese state. This influence of indirect control of critical materials is not only a subject in poor and developing countries but also in wealthy ones that are part of the OECD. Alti parmak, Selim Özkan[40] note that chinese state companies have been able to gain substantial control, although not as much as in African states, even in Latin America, where Chinese firms hold stakes in the largest lithium companies, for example, in Argentina or Chile. This situation does not spare even the wealthiest states, such as Australia, where China has a stake in the largest hard rock lithium mine.

For this reason, there is an inclination that the EU should form broad international alliances to diversify sources. Marie le Mouel, Niclas Poitiers[41] argues that this problem can be partially solved through cooperation, especially with "like-minded states," and according to the authors, it should involve serious investments not only from the EU but also from member states. The European Union responds to this problem primarily in two ways. Ursula von der Leyen[42] in speech to address the state of the union presents two approaches to tackle this issue from the perspective of international cooperation. These include the creation of a "critical raw materials club" and the establishment of strategic partnerships.

Nicole Lawler and Francis Shin[43] from Atlantic Council highlights the strong cooperation between the EU and the United States. Although the aforementioned club has not yet taken form, the Atlantic Council describes it as a sort of buyers' cartel that, through investment, will form respective policies within these countries. In this area, the authors argue that a balanced policy is necessary so as not to place the main burden on supplier states, which may not be able to meet all criteria, such as environmental standards. The greatest emphasis on creating multilateral alliances is on "like-minded states" in this regard. Vlado Vivoda[44] describes an existing agreement, the

[40] Altiparmak, Selim Özkan. "China and Lithium Geopolitics in a Changing Global Market." Chinese Political Science Review, August 25, 2022, pp. 5-8. doi: 10.1007/s41111-022-00227-3.
[41] Marie le Mouel, Niclas Poitiers, Why Europe's Critical Raw Materials Strategy Has to Be International, Bruegel, June 2023, 5,k
[42] European Commission. "2023 State of the Union Address by President von der Leyen." Speech presented in Strasbourg, September 13, 2023. European Commission.
[43] Lawler, Nicole, and Francis Shin. 2023. "The EU Needs a Buyers' Club for Critical Minerals. Here's Why." New Atlanticist, December 15. Atlantic Council.
[44] Vivoda, Vlado. "Friend-shoring and Critical Minerals: Exploring the Role of the Minerals Security Partnership." Energy Research & Social Science (June 2023).

"strategic mineral partnership." He expands on the concept of like-minded states, which in his view can be understood from a European perspective as a set of states that are trustworthy and interested in economic prosperity and climate protection. In this regard, these partnerships are set up as a counterbalance against strategic rivals, in this case, against Russia, but mainly against China.

Many states that the EU is trying to bring to its side have complex political orientations, and strategic rivals of the EU exert influence over them. Arynov, Zhanibek[45] argues that Kazakhstan, in its multi-vector policy, tries to appear as an independent player; however, the author argues for the strong influence of Russia under the CSTO organization, which had to assist Kazakhstan during the protests in the country in 2022. Similarly, the authors argue for dependence on Russia in terms of fossil fuel transport routes. Evan Hsiang[46] points to China's influence in Zambia and DRC, where, despite economically disadvantageous agreements, particularly in loans, China is increasing its influence in the country to set an example that it is willing to help, whereas Western countries are not. The author argues that China's interests in this regard cannot be seen only on a pragmatic level but also as an expansion of ideological influence.

Benedetta Girardi, Irina Patrahau, Giovanni Cisco, and Michel Rademaker[47] analyze critical materials in relation to the defense industry. Their assessment is based on impact/risk probability. In this regard, the study identifies Aluminum and natural graphite as the riskiest due to supply chains reliant on Russia and China. Unlike EU analyses, this study considers the material needs for different types of military products. The authors particularly emphasize the importance of strong transatlantic cooperation and collaboration between the civilian and military sectors.

In economic security, the European Comission[48] highlights the roles of the COVID-19 crisis and the war in Ukraine as two major issues for reorientation in strategic matters. In this respect, Europe sets priorities for strengthening supply chains and the economy overall. The main strategy involves identifying priorities and risks of economic security, with critical materials being an integral part. To achieve economic security, according to the authors, it is necessary to add new

[45] Arynov, Zhanibek. "Is Kazakhstan's Multi-Vector Foreign Policy Threatened?" Horizons: Journal of International Relations and Sustainable Development, no. 21 (Summer 2022):
[46] Hsiang, Evan. "Chinese Investment in Africa: A Reexamination of the Zambian Debt Crisis." Harvard International Review, January 25, 2023.
[47] Defence: Mapping European Industry Needs. The Hague: The Hague Center for Strategic Studies, January 2023. ISBN: 9789083254180,
[48] European Commission. "Joint Communication to the European Parliament, the European Council and the Council on 'European Economic Security Strategy'." Brussels, June 20, 2023. JOIN(2023) 20 final.

methods to traditional national security procedures that can achieve prosperity, sovereignty, and security in the current era. The Critical Raw Materials Act is cited as a practical example of policy to achieve these goals. Joint Research center[49] categorizes economic strategic sectors, describing the highest risk dependencies in the renewable energy sector (including batteries), due to some dependencies being up to 100% and significant use of so-called battery metals, over which China has substantial control. The study determines how many critical materials are needed for the most important types of products in a given sector. This information is then placed within the broader geopolitical context.

[49] European Commission, Joint Research Centre. 'Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study 2023.' JRC Science for Policy Report, 2023.

1. Significance of Critical Materials

1.1 Historical Development of Approaches to Managing Critical Materials

Most of the materials considered critical today began to be mined in the 19th century. First, however, we must ask what led to some materials being designated as critical throughout history.[50] This was led as in many other cases, particularly by war. During World War I, the United States created the first list of critical materials. This list consisted of five first-rank minerals – tin, nickel, platinum, nitrates, and potash. Reserves of these minerals were not clearly known. At the beginning of World War I, the prevailing view among Americans was that it would be a short conflict. However, as the war developed, it became apparent that it was necessary to determine the material reserves needed for the conduct of the war.[51]

European allies also urgently needed steel, copper, and explosives from the Americans. For this reason, Americans initiated geological mapping, which initially focused mainly on oil fields, and only later did the expeditions start to monitor materials (metals, minerals.). By the time the United States entered the war, it found that domestic supplies were inadequate in many cases, both in quantity and quality. As a result, the search for minerals was expanded to Central America and the West Indies. In 1917, the American Congress passed the Lever Act, which allowed the president to stimulate the protection and control of the distribution of fuels that were necessary for war operations. A similar law concerning mineral commodities was passed at the end of the war but was never put in place.[52]

During World War II, Americans had a much more sophisticated strategy regarding strategic materials. These materials were divided into two main categories: strategic materials, which were essential for defense, and critical materials, which were less difficult to obtain but still crucial for the nation. Strategic materials included aluminum for aircraft production, copper for ammunition, carbon steel and alloy for weapons. Critical materials encompassed steel in (various forms such as shapes, plates, tubing, rails, and shells), tinplate, zinc, aluminum (excluding aircraft purposes), magnesium, copper (excluding ammunition purposes), brass, bronze, tin, nickel, and rubber. During the conflict, the United States devised a strategy for

[50] "Periodic Table: Lithium." Royal Society of Chemistry. Accessed [date]. https://www.rsc.org/periodic-table/element/3/lithium.
[51] Nicholls, Jane. "A brief history of critical minerals." Resourceful: Mining and Resources, Issue 27. CSIRO, last updated August 9, 2022.
[52] "World War I Centennial: U.S. Entry and U.S. Geology." U.S. Geological Survey.

conserving critical materials (especially high-grade ores). This strategy primarily included substitution, simplification, and standardization in production, and later recycling (especially for iron). Additionally, the USA significantly expanded the import of critical materials from South America. The overall policy involved strict controls and distribution of materials (particularly due to overreliance on Canadian supplies). The expansion of domestic mining with support for foreign producers was also implemented. (Which even lead to surpluses in certain sectors towards the end of the war.)[53]

At the opposing side of WWII, Germany faced acute shortages of critical materials, which were essential for its military campaigns. Prior to the war, the scarcity of resources led to drastic measures such as melting down coins to extract nickel for ammunition production. By 1940, Germany's situation became dire, with only a six-month supply of essential materials remaining.[54] Germany's occupation of Western Europe enabled them to secure crucial resources, including significant iron mines in northern France and aluminum resources in the south. Although the primary reasons for the occupation were strategic and political, controlling these resources became a substantial benefit. The Benelux region, while lacking in substantial mineral deposits, contained industries vital for processing ores imported from the colonies of Western European countries, essential for the Nazi war effort. These supply lines were eventually disrupted as anti-Nazi forces rerouted shipments to the United States.

Additionally, Germany secured vital resources through the occupation of Norway and through collaboration with Sweden and Finland, which were rich in iron ore deposits.[55] This influx of materials was crucial, enabling the German military to engage on multiple fronts. It is important to note that Germany, similar to the USA, also benefited from engineering innovations that allowed for the substitution of some critical materials. This strategic shift from reliance on resource plundering, a tactic heavily utilized during World War I, marked a significant advancement in resource management.[56]

Post-World War II, the importance of maintaining reserves of critical materials was recognized, especially in the uncertain early years of the Cold War. During the Korean War, the U.S.

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[53] Technical Options for Conservation of Metals: Case Studies of Selected Metals and Products. September 1979. Princeton University. NTIS Order Number PB80-102619.

[54] Critical Minerals of World War 2." Arizona Geological Survey Blog, March 2022. http://blog.azgs.arizona.edu/blog/2022-03/critical-minerals-world-war-2

[55] UArizona Mining & Mineral Resources. "Critical Minerals in World War 2: Part 2. The War Years (1939-1945)." YouTube. https://www.youtube.com/watch?v=RaVHJyCiPDA&t=1074s

[56] Scherner, Jonas. "Preparing for the Next Blockade: Non-ferrous Metals and the Strategic Economic Policy of the Third Reich." English Historical Review 137, no. 585 (April 2022): 508-509

dramatically increased its budget for stockpiled materials from $2.9 billion to $10.9 billion within six months in 1950.[57] In 1951, following a presidential directive, the Paley Commission was established to assess critical minerals and their reserves, deemed vital for national defense and sustaining the rising standard of living. The findings from this commission influenced the U.S. to adopt a policy of acquiring minerals at the lowest cost, whether the sources were domestic or foreign. This policy shift led to the repeal of the protectionist "Buy American Act."[58] In 1983, further steps were taken with enacting the National Critical Materials Act, which established an advisory body to the president. This body coordinated research and addressed supply issues of critical materials, leading to policy formulations as the U.S. faced growing dependencies in certain areas concerning critical raw materials (CRM).[59]

During the Cold War, it can be said that centrally planned economies were more self-sufficient, whereas Western countries were dependent on imports. For Europe, critical materials became a unifying concern as the European Commission in the 1970s acknowledged that addressing the shortages of these materials exceeded the national framework of member states, necessitating a collective solution at the European level. Concerns of Western Europe centered particularly around aluminum, chromium, copper, tin, iron ore, manganese, platinum, tungsten, zinc, and phosphates.[60] The reason was not the risk of geological scarcity, but rather the realization of heavy dependence on imports, concentration of production in unstable countries, nationalization of mining companies, and the trend of processing raw materials in producer countries. The Commission proposed the creation of an agency within the European Community to gather information on critical materials. The strategy to help address this issue was relatively uniform across the Western world, focusing particularly on recycling, substitution, and material efficiency.

After the end of the Cold War, the situation rapidly improved especially in western countries through increase in interregional trade exchanges, which were previously hindered by political disagreements. This situation was also facilitated by globalization, which eliminated the need for an active resource policy. The sense of security was further enhanced by the privatization of mining companies from the hands of states. Geological exploration activities, which had long

[57] Peck, David. Critical Materials: Underlying Causes and Sustainable Mitigation Strategies. World Scientific Series in Current Energy Issues. Sec. "A Historical Perspective of Critical Materials, 1939 to 2006." 90
[58] Document 16," Foreign Relations of the United States, 1952-1954, Volume I, Part 2. Office of the Historian, U.S. Department of State.
[59] United States. Congress. House. "National Critical Materials Act of 1983." H.R. 4186, 98th Cong. (Introduced October 20, 1983).
[60] European Communities Commission. 1975. "The Community's Supplies of Raw Materials, Communication from the Commission to the Council. COM (75) 50 final."

been focused only on Australia, Canada, and the USA, also greatly expanded to other regions, such as South America. These aspects led to a shift in focus from supply security to emphasizing climate security, where social and environmental concerns dominated.[61]

In the new millennium, China started to be a major player around CRMs. Initially China started to massively build infrastructure projects, and in 2001, also joined the WTO, which particularly gave Western companies an impulse to strengthen the relocation of production to China, which was considered as a place with unlimited supply of cheap labor.[62] Thanks to its dynamic economic growth, China has not only built infrastructure in the area of industrial products, where critical materials are needed, but it has also started to work on dominating the entire supply chain. In 1999, Chinese Premier Zhu Rongji announced the "zou chuqu" (go out) strategy, with the Chinese government creating financial conditions to successfully carry out investments in natural resources, both in the developed but mainly in the undeveloped parts of the world. This has gradually led to situation where China now controls the entire supply chain in significant number of critical materials.[63]

This situation is a critical security issue because China represents not only an economic rival for Western democracies but also, as a communist dictatorship, a political adversary by nature. Critical materials, in which China holds dominance, are essential for fulfilling one of the highest priorities of Western states, namely combating climate change. The fight against climate change requires a range of technological products that contain critical materials which are subjects of supply chain controlled dominantly by China. For Western states, this issue threatens their prosperity and security. The situation is particularly serious due to recent crises, such as the COVID-19 pandemic, which led to the breakdown of global supply chains, and the Russian invasion of Ukraine, which caused a sharp increase in commodity and energy prices.[64]

[61] Sievers, Henrike, Bram Buijs, and Luis Tercero. 2012. "Critical Minerals for the EU." POLINARES Working Paper No. 31, March.
[62] Humphreys, David. "The Great Metals Boom: A Retrospective." Resources Policy. 2009.
[63] Economy, Elizabeth, and Michael Levi. By All Means Necessary: How China's Resource Quest is Changing the World. Oxford University Press, USA, 2014. ISBN 9780199921782.
[64] Nivelle, Christophe. "China and Critical Raw Materials: A Strategy of Domination." Modern Diplomacy, August 3, 2023. https://moderndiplomacy.eu/2023/08/03/china-and-critical-raw-materials-a-strategy-of-domination/

1.2 How Materials Become Critical: Contemporary Perspectives

As critical, we consider materials for which there is no long-term certainty of secure supplies, which are of high importance for the functioning of society. Nowadays, the term "Critical Raw Materials" is used in connection with metals and minerals that are vital for todays and future economy. CRMs are particularly associated with the so-called fourth industrial revolution, which is linked to new technologies such as electromobility, green energy, batteries, and digitalization. These technologies are on a rapid rise and are shaping the future trends of societies and economies. These materials are supplied based on several supply chains that are subject to economic and security-political risks, making them a vulnerable commodity.[65]

The criticality of a material as such is not easily determined. There are several reasons for this. One of them is that the criticality of a material depends on the specific time in relation to the economy that needs the materials to achieve certain technological goals. Therefore, it is more about short or medium-term outlooks in which certain materials play an important role with respect to global competition. It is necessary to understand that a material is not designated as critical for its properties, but rather due to the externalities surrounding it.[66]

According to a recent study published in the journal Joule, the current global stocks of CRMs are sufficient for the energy transition, except for a few rare metals that could still be subject to substitution.[67] Thus, the criticality of a material is mainly influenced by trade or legislative restrictions. Most studies conducted in the field of material criticality follow the system developed by the US National Research Council. According to the research matrix, the main criticality revolves around four areas: local (enterprise), nationwide, economic area (e.g., impact on a certain continent), global. Then, according to the matrix, subcategories of risks are assessed. For example, supply risk, where risks include: the importance of the raw material for specific areas, the impact on reducing the economy, slowing down, or completely halting technological progress. According to the pioneer of examining the criticality and risk of material, Angerer et al. in Europe, criticality is understood along the axis of economic importance - supply risk. Supply risks are then characterized by the socio-economic stability of the producing country, the concentration of producers by one country, current possibilities for

[65] "Critical Raw Materials." British Geological Survey. Last modified 2021.
[66]Hofmann, Margarethe, et al. "Critical Raw Materials: A Perspective from the Materials Science Community." Received July 25, 2017; Revised August 7, 2018; Accepted August 7, 2018.
[67] Wang, Seaver, et al. "Future Demand for Electricity Generation Materials Under Different Climate Mitigation Scenarios." *Joule,* February 2023.

substitution and recycling.[68] As mentioned, risk parameters are constantly evolving, both due to trends and methodology. Therefore, it cannot be said that there are universal rules that would provide a clear framework for the criticality of materials. It is always subject to the given time and the entity setting the criticality.[69]

A key milestone for understanding the criticality is the period around 2009 when urgency of the climate crisis was amplified during UN climate summit in Copenhagen in 2009. At this summit, nations agreed on the necessity to heed scientific findings that global warming must not exceed a 2°C threshold. The summit's conclusion acknowledges the increasing urgency of climate change issues and the essential steps needed for decarbonization, for which critical materials are an essential part.[70] That also confirms the statement from the accords report: „*We underline that climate change is one of the greatest challenges of our time. We emphasize our strong political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities.* "[71]

In response to the financial crisis, which was ongoing during that time, western countries introduced green stimulus programs mixed with policy and financial tools. These programs targeted areas such as technological efficiency, low-carbon vehicles, green transport infrastructure, and overall research into green energy.[72] These activities correspond with the initial contemporary steps taken by the EU in the field of critical materials. In 2010, the European Commission created a memorandum analyzing the criticality of 41 materials.

Risk assessment consists of two pillars: supply risk, considering the political-economic stability of producing countries, potential for substitution, and recycling; the second pillar is "environmental country risk," meaning the risk arising from supplier states improving their environmental standards, potentially limiting mining and exports of raw materials, thus disrupting supplies to the EU.[73] In 2010, from the mentioned 41 materials, the European Commission identified 14 as "high risk supply." These materials were antimony, beryllium, cobalt, fluorspar, gallium, germanium, graphite, indium, magnesium, niobium, platinum group metals (PGMs), rare earths elements (REE), tantalum, and tungsten. At the same time, these

[68] Hofmann, Margarethe, et al. "Critical Raw Materials: A Perspective from the Materials Science Community."
[69] Glöser, Simon, et al. "Raw Material Criticality in the Context of Classical Risk Assessment." Fraunhofer Institute for Systems and Innovation Research ISI and Clausthal University of Technology, n.d. 43.
[70] IEA. "Green Stimulus After the 2008 Crisis: Learning from Successes and Failures." Report, 29 June 2020. Authors and contributors. License: CC BY 4.0.
[71] United Nations. "Copenhagen Accord." Conference of the Parties, Fifteenth Session, Copenhagen, 7-18 December 2009,2.
[72] IEA. "Green Stimulus After the 2008 Crisis: Learning from Successes and Failures
[73] European Commission. "Report Lists 14 Critical Mineral Raw Materials." MEMO/10/263, 17 June 2010.

materials lacked good substitutability and had low recycling options. The risk was also inherent in the nature of the supplying states, as many of them could not be considered like-minded states in terms of close political friendship. Significant portion of platinum metals originated from Russia, while cobalt and tantalum were primarily sourced from the Democratic Republic of Congo, and Brazil as a key provider of niobium and tantalum.[74]

In the same year, the USA also introduced its first comprehensive strategy. Like the EU, the US divides criticality into two categories. The first, "clean energy demand," represents the need for critical materials in products like magnets, batteries, or photovoltaics, accounting for 75% of the assessment. The remaining 25% evaluates the substitutability of the material with another that meets green energy standards. The second category, like the EU, is "supply risk," further divided into subcategories, with "basic availability" in short-term supplies being the most significant at 40%. Political, regulatory, and social factors and "producer diversity" each contribute 20%. "Competing technology demand" and "co-dependence on other markets" each accounted for 10%.

Since 2010, both the USA and the EU have issued new and revised strategies regarding critical materials multiple times. In the USA, new revised versions of material criticality are released every year, with several agencies involved, including the Department of the Interior, the Department of Energy, and the U.S. Geological Survey. It's challenging to determine the pace of criticality over time, as American agencies use various methodologies. According to the DOE's 2010 report, there were 11 materials identified as being at risk in both the short and medium term.[75] By 2023, this number had increased to 18 materials. The European Commission presents the total number of critical materials via communications that release the Critical Raw Materials (CRM) lists. While the first communication in 2011 listed 14 critical materials, by the fifth communication in 2023, the number had increased to 34 materials.[76]

Looking at the top 6 importers of critical materials (USA, EU, Japan, Korea, United Kingdom, India), all these countries are increasingly developing strategies in the area of critical materials, which are then often incorporated into legislation.[77] The fact that competition in this area will be even more significant is also shown by the involvement of developing countries in the

[74] Ibid., 2.
[75] U.S. Department of Energy. 2023. Critical Materials Assessment. July. Washington, D.C
[76] European Commission. "Critical Raw Materials." Accessed February 11, 2024. https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en.

[77] OECD trade. 2023. Raw Materials Critical for the Green Transition: Production, International Trade and Export Restrictions. Trade Policy Paper No. 269. April 2023, 28.

struggle for critical materials, such as India, which in 2023 expanded its list of critical materials from the previous 12 to 30 materials.[78] Similar tendencies can be observed, for example, in Vietnam, Indonesia, and other countries, which as producers may start to behave much more restrictively in terms of exports. These trends clearly illustrate that additional players besides Western countries want to engage in the race within green economy, which has potential to further intensify the supply issue in the future.[79]

1.3 How Critical Raw Materials Influence Technology and Security

Critical raw minerals are particularly linked to the theme of transitioning to green energy. The International Renewable Energy Agency (IRENA) has developed a scenario in which, to maintain global warming at 1.5 degrees, it would be necessary to construct 91% of the energy mix from green sources by 2050. This would lead to an increase in installed capacity from 3,000 GW in 2022 to 33,000 GW in 2050, a 1000% increase.[80] Another estimate, by the IEA (International Energy Agency), states that if we want to adhere to the 2°C Celsius global warming limit set by the 2015 Paris Agreement, it will mean a 400% increase in critical materials by 2040. To achieve global carbon neutrality by 2050, an increase of up to 600% by 2040 would be necessary.[81] Whether such progress is feasible is highly debatable, but this vision clearly illustrates the tremendous rise in critical materials needed for the green transition. There are dozens of key materials that serve in various types of technologies. Subsequently, we will describe only the most crucial ones that illustrate the technological needs associated with decarbonization.

Lithium is considered the most important material for the energy transition, known for its use in batteries, such as those in mobile phones and laptops.[82] Lithium will play a key role in the future, especially in electricity storage and electric vehicle batteries. The main lithium products are lithium carbonate, from which lithium iron phosphate cathodes are made, and lithium hydroxide, used for nickel-manganese-cobalt cathodes and other types of batteries that require lithium. Electric cars will be the main driver of lithium consumption, which is expected to

[78] Ministry of Mines. 2023. Report of the Committee on Identification of Critical Minerals for India. June. Page 3.
[79] Findeisen, Dr. Francesco, and Dr. Yann Wernert. 2023. "Meeting the Costs of Resilience: The EU‘s Critical Raw Materials Strategy Must Go the Extra Kilometer." 30 June.
[80] International Renewable Energy Agency. "Critical Materials." Accessed February 11, 2024
[81] International Energy Agency. "The Role of Critical Minerals in Clean Energy Transitions: Executive Summary." Accessed February 11, 2024
[82] Doe, Jane. "The Top Ten Critical Minerals Powerhouses of the Energy Transition." Energy Monitor. January 1, 2023

increase tenfold between 2020 and 2030. Similarly, the share of consumption in automotive batteries is expected to rise from about 30% to 70% by the end of 2030.[83]

Cobalt is key in green technologies due to its properties that allow it to maintain a constant temperature in both high heat and freezing conditions. Its use can be found in many sectors, including aerospace or nuclear energy. However, its most important use, as with lithium, is in the field of batteries. Cobalt, in combination with nickel (also important CRM with similar proprieties), increases the energy density of lithium-ion batteries, which improves the performance and capacity of electric vehicles. Cathodes that are cobalt-based extend the stability and longevity of the battery, which contributes especially to less battery degradation over time. Furthermore, cobalt in batteries contributes to stable voltage and faster charging.[84]

Copper is used in nearly all types of renewable power plants (hydro, thermal, wind, etc.). This metal is primarily important due to its high conductivity, which can reach up to 100%. The importance of copper is illustrated by the fact that it is used about 6 times more in the renewable energy sector than elsewhere.[85] Thanks to its efficient properties, it helps reduce the amount of energy needed to produce electricity. Other great properties include resistance to corrosion, high temperatures, and UV degradation. Moreover, an important aspect is that copper is 100% recyclable, regardless of cycles and degradation of properties.[86]

Silicon is a crucial material used in chips, also known as semiconductors. Its key property is that as a semiconductor metal, it can be combined with other materials, such as phosphorus or boron, which allows for the regulation of electrical current – turning it on and off. As is well known, semiconductors are required in most electronic devices, such as appliances, phones, computers, and more. Their role in clean technologies is especially significant in electromobility, where twice the number of semiconductors is needed compared to fossil-fueled cars. Semiconductors are also crucial in charging stations, wind turbines, or smart power grids to efficiently regulate energy demand and supply.[87] Special mention should also be made of solar panels, where silicon is used as an appropriate semiconductor for effective light absorption, thereby facilitating the conversion of light into energy.[88]

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[83] ielen, D., and M. Lyons. 2022. Critical Materials for the Energy Transition: Lithium. Abu Dhabi: International Renewable Energy Agency, 6.
[84] Stanford Advanced Materials. "Cobalt in EV Batteries: Advantages, Challenges, Alternatives." Accessed February 11, 2024. https://www.samaterials.com/cobalt-in-ev-batteries-advantages-challenges-alternatives.html
[85] International Copper Association. "Renewable Energy." Accessed February 11, 2024.
[86] Copper Development Association Inc. "Selecting Copper Tube." Accessed February 11, 2024.
[87] "Semiconductors in the Renewable Energy Transition." Earth.org. Accessed February 11, 2024.
[88] U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. "Solar Photovoltaic Cell Basics." Accessed February 11, 2024.

Lastly, it is necessary to mention rare earth elements (REEs) such as neodymium and praseodymium, which are used in magnets to improve hardening. Two other REEs, dysprosium and terbium, are added to magnets due to their resistance to demagnetization and to improve thermal stability. These magnets are primarily used in clean technologies for electric vehicle motors or wind turbine generators (especially those offshore).[89] It should be added that there are many rare REEs, and their prices can vary significantly. Their consumption is expected to grow in the tens of percent (mainly because less material is needed), unlike previous critical materials, which are expected to grow by hundreds of percent.[90]

Due to the Green Deal plan to achieve climate neutrality and strategic autonomy, CRMs have become an essential commodity, increasingly representing an element of security. A shortage of CRMs can significantly slow down, or even halt, the green industrial transformation, thereby undermining European values in the form of climate protection. The supply of critical materials could mimic a similar dependency that Europe faces/faced in the past, especially with fossil fuels, when the EU was in a position of being vulnerable to supply blackmail, as the sources of fossil fuels were not sufficiently diversified.[91] This was evident during the Russian invasion of Ukraine, when the EU was drawing 25% of its oil and 40% of its gas from Russia, with the gas dependency being 100% in some of the EU's countries. Replacing these sources led to a sharp increase in the cost of these commodities, which had the potential to cause significant destabilization.[92] Similarly, it's worth recalling the shortage of sophisticated semiconductors during the Covid-19 crisis period.

In the case of CRMs, some markets are even more concentrated than those for oil and natural gas. In many countries where concentration is high, there is a correspondingly low level of political and economic stability. Moreover, with CRMs, the issue of concentration is not so much a matter of natural reserves but of production itself, which makes the problem even more complex.[93]

[89] Columbia Climate School. "The Energy Transition Will Need More Rare Earth Elements. Can We Secure Them Sustainably?" April 5, 2023.
[90] Gielen, D., & Lyons, M. (2022). Critical materials for the energy transition: Rare earth elements. International Renewable Energy Agency, Abu Dhabi, p. 6.
[91] Ragonnaud, Guillaume. "Securing Europe's Supply of Critical Raw Materials: The Material Nature of the EU's Strategic Goals." Members' Research Service, European Parliament, PE 739.394, March 2023.
[92] "Institute of Energy of South East Europe. 'Russian Oil: EU Agrees Compromise Deal On Banning Imports.' Energy News. Accessed February 15, 2024.
[93] Guillaume. "Securing Europe's Supply of Critical Raw Materials, 3-4.

In 2023, there were particularly three crucial sources of CO2 emissions in Europe: energy supply (26%), domestic transport (22%), and industry (22%). Especially for the first two sources, which together account for nearly half (48 %) of CO2 emissions, critical materials are essential for their decarbonization/energy transition.[94] For this reason, CRMs are also one of the essential means to achieve climate security in Europe, which is defined at the EU legislative level. This primarily involves the wide ranged Green Deal legislation, aimed at achieving carbon neutrality by 2050. Additionally, the accompanying legislative package Fit for 55 sets the goal of achieving a 55% reduction in emissions by 2030 compared to 1990 levels. These two fundamental goals are further legally anchored in the so-called Climate Law, making these targets legally binding. Furthermore, there is the RepowerEU plan, which aims to increase the share of renewable sources in the mix to 42.5 percent by 2030 from 22% in 2023.[95]

Another important aspect is economic consequence. According to the European Commission, the energy transition could affect up to 40% of all jobs in the European Union. The biggest impact of the energy transition will be on the industry, which creates 20% of the European economy and 35 million jobs.[96] There are no data showing how many jobs could be affected by the availability of critical materials. However, considering that one of the most affected sectors will be the automotive sector, which employs directly and indirectly 13.8 million people[97], it can be assumed that, together with other sectors, tens of millions of jobs could be affected to some extent by the availability of CRMs. For this reason, the EU places emphasis on economic security within the Green Deal plan. The main stimulus is the Green Deal Industrial Plan, which stimulates support for sectors in green technologies through different incentives.[98]

2. Strategical Approach for CRM

2.1 Legislative Playbook

The EU's strategy on critical materials from 2010-2020 was primarily characterized by the creation of lists of critical materials and conducting impact analyses on the circular economy, or regarding bilateral cooperation. The situation clearly changed in 2019 when the European Council adopted a plan for a green transformation known as the "Green Deal," aimed at

[94] European Environment Agency. "What Are the Sources of Greenhouse Gas Emissions in the EU?"
[95] Council of the European Union. "Timeline: European Green Deal and Fit for 55." Accessed February 15, 2024.
[96] European Commission. "The Green Deal Industrial Plan: Putting Europe's Net-Zero Industry in the Lead." Press Release, February 1, 2023, Brussels.
[97] European Commission. "Automotive Industry." Accessed February 15, 2024.
[98] European Commission. "The Green Deal Industrial Plan.

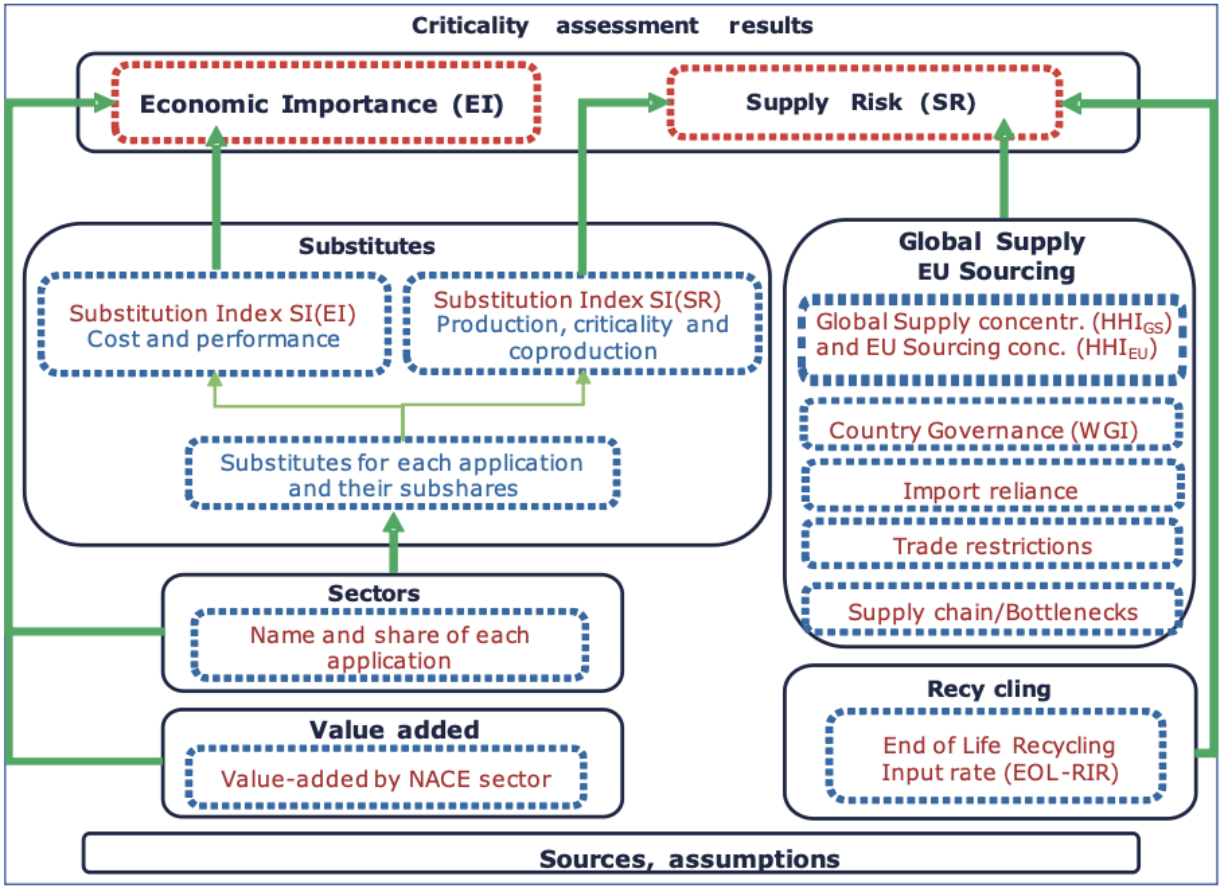
achieving carbon neutrality across the European continent by 2050. Thus, the policy of greater resilience and strategic autonomy in critical materials comes at a time when the transition to clean technologies will also have a legislative framework.[99] In 2020, the European Commission developed the strategy "Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability," which describes the situation in terms of value chains and associated risks. This analysis led to a 10-point action plan, primarily aimed at addressing the situation through the internal European market. Three points in this 10-point plan are particularly crucial: 1) the creation of a European CRM alliance that brings together stakeholders and regulators for better communication and cooperation, 2) the creation of favorable financial conditions to support the production, refinement, and manufacturing of critical materials, 3) expanding general know-how with a strong emphasis on exploring mining, refining, and manufacturing possibilities within the EU.[100]

Critical Raw Materials Act is a legislation presented by the European Commission in 2023, with a preliminary agreement reached within the trialogue with the European Parliament and the European Council in November of the same year. This legislative proposal follows the 2022 Versailles Declaration, which called on the EU to ensure strategic autonomy and sovereignty in this area. This legislative proposal is a component that aims to help achieve the vision of the Green Deal and the fulfilment of the principles of the Climate Law.[101] It is also one of three initiatives within the "Green Deal Industrial Plan" aimed at supporting industry in the transition to a carbon-neutral economy. Alongside the Critical Raw Materials Act, there are also the Net-Zero Industry Act, which is intended to help with bureaucratic barriers to strategic investments, and the "reform of the electricity market design," which aims to reduce the weight of fossil fuels on electricity pricing. These initiatives are designed to significantly support the production of green technologies.[102]

The criticality of selected materials was chosen according to the European Commission's methodology, which follows methodologies used in other three-year cycles (2011, 2014, 2017, 2020). The methodology employs the most common method, monitoring two already

[99] European Commission. "Critical Raw Materials." Single Market, Industry, Entrepreneurship and SMEs.
[100] European Commission. "Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability." Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2020) 474 final. Brussels, September 3, 2020.
[101] European Commission. "Proposal for a Regulation on Critical Raw Materials." COM(2023) 160 final, 3. March 17, 2023.
[102] "Commission Proposes Rules to Ensure Access to and Sustainable Use of Critical Raw Materials for the EU." European Commission - Press Corner. September 14, 2023.

mentioned parameters. Economic Importance is calculated based on the potential for substitution and the strategic importance of the sector. Supply Risk is calculated based on global supply and recycling. In the figure below, we can see an illustration of the entire criticality methodology.

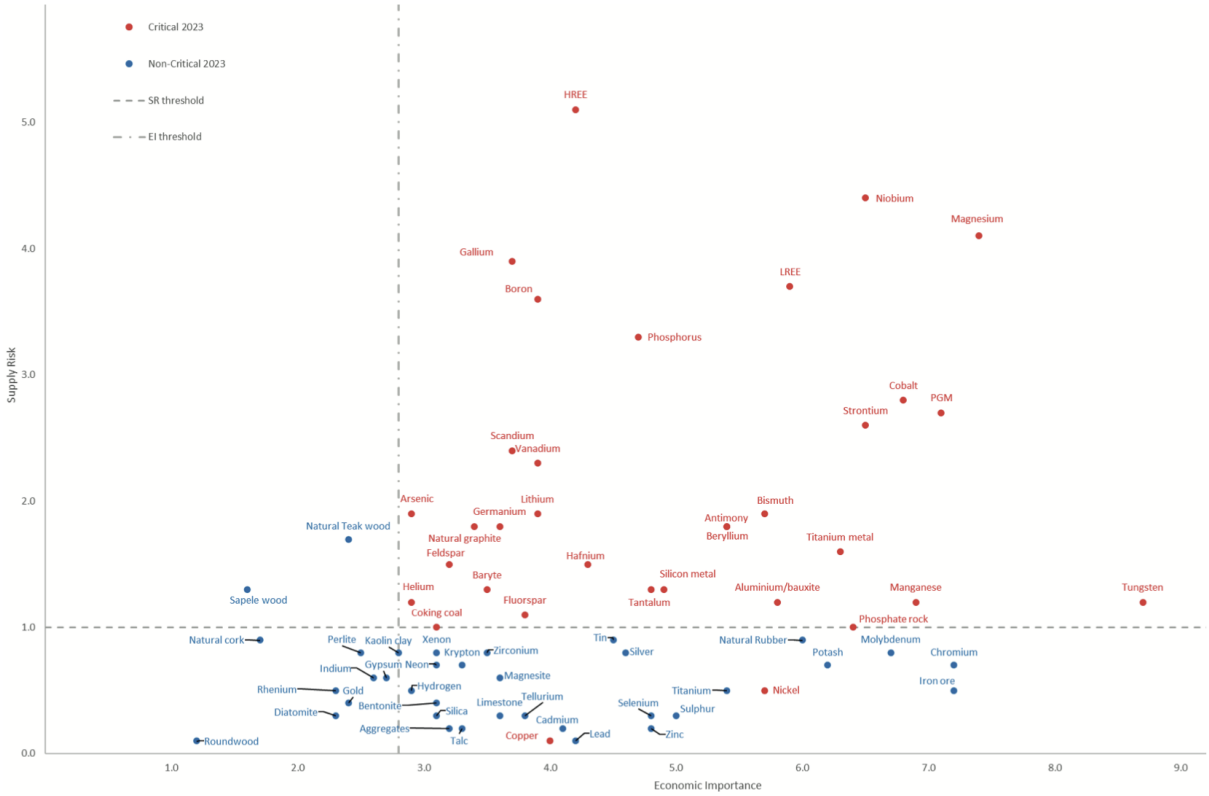


Note: Methodological approach by Joint Research Center

Source: JRC Study, European Commission

Economic Importance (EI) and Supply Risk (SR). The 2023 study determined the threshold values to be SR ≥ 1.0 and EI ≥ 2.8. In the following graph, we can see how the individual materials were ranked according to the mentioned values. [103]

[103] European Commission. "Study on the Critical Raw Materials for the EU 2023 - Final Report." 2023. European Union, 17-21.



Note: Graphic assessment of criticality for raw materials

Source: JRC Study, European Commission

On the graph, as can be seen, 70 materials were examined for their criticality. The ones in blue did not surpass the mentioned threshold values for Economic Importance (EI) and Supply Risk (SR) and are thus not classified as critical materials. Conversely, the materials in red are within the threshold for being categorized as "critical," which includes: aluminum/bauxite/alumina, coking coal, lithium, phosphorus, antimony, feldspar, light rare earth elements, scandium, arsenic, fluorspar, magnesium, silicon metal, baryte, gallium, manganese, strontium, beryllium, germanium, natural graphite, tantalum, bismuth, hafnium, niobium, titanium metal, boron, helium, platinum group metals, tungsten, cobalt, heavy rare earth elements, phosphate rock, vanadium, copper, nickel.[104]

It can be noted that Nickel and Copper are not within the boundary for CRMs. The reason why they are included as CRMs is that their role in the future green transition is so crucial that these materials need to be treated as strategic already now. For copper as well as nickel, the supplies are well-diversified. The problem with copper, however, is that it has very low substitutability due to its unique properties in electrical engineering. Nickel, on the other hand, is equally well-diversified, but the assessment did not consider the concentration of production and private

[104] Ibid.,8.

contracts, which can be unpredictable for this material.[105] Out of these critical materials, the European Commission has selected 16 that it considers to be "strategically critical raw materials" due to their complex production processes and the expected high global demand for them. Simply put, these 16 materials are currently the most critical in following areas: "industrial value chains, strategic sectors (space, security), and climate (energy, environment)."[106]

The regulation "Critical Raw Materials Act" is specifically tailored for these 16 strategic materials, aiming at the following changes related to the internal market to enhance resilience and strategic autonomy.[107] Firstly, the Union plans to increase its extraction capacity of SRMs to at least 10 %. Secondly, the EU intends to create capacities to produce at least 40 % of SRMs (including preceding processes). Thirdly, the Union aims to obtain at least 15 % of strategic materials through recycling processes. In addition to these clear targets in the processing phases, the European Union aims to: a) diversify sources so that European Union countries ideally have several possible suppliers of critical materials, with total supplies to the union not exceeding 65 % for any one strategic material from a single country; b) improve the monitoring of critical materials and thus avoid various risks associated with supply risk; c) strengthen environmental protection so that products with critical materials are sustainable and at the same time able to circulate on the internal EU market for a long time.[108]

2.1 Assessment of the riskiness of strategic materials

To understand the dependence on strategic materials, it's important to recognize that various materials go through different phases in their chain before they can be used for manufacturing different components, especially in the case of Critical Raw Materials (CRMs) for new technological products. The processing of critical materials is a highly complex matter. The process usually includes crushing and roasting of the materials, followed by a chemical treatment to ensure the materials can be used in final products, such as electric batteries.[109] The

[105] European Commission. "Study on the Critical Raw Materials for the EU 2023 - Final Report," 4.
[106] Villa, Annalisa. "European Council Adds Bauxite, Alumina, Aluminum to Strategic Materials." Edited by James Leech. S&P Global Commodity Insights. Last modified July 3, 2023. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/metals/070323-european-council-adds-bauxite-alumina-aluminum-to-strategic-materials.https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/metals/070323-european-council-adds-bauxite-alumina-aluminum-to-strategic-materials
[107] Council of the European Union. "Infographic: Critical Raw Materials."
[108] European Commission. "Proposal for a Regulation on Critical Raw Materials." COM(2023) 160 final, 3. March 17, 2023.
[109] Cohen, Jared. "Resource realism: The geopolitics of critical mineral supply chains." Goldman Sachs, September 13, 2023. https://www.goldmansachs.com/intelligence/pages/resource-realism-the-geopolitics-of-critical-mineral-supply-chains.html.

European Union particularly speaks of two phases: extraction and processing. In the case of extraction, it refers to obtaining the primary material from the Earth. Critical materials are thus associated with various areas and countries, according to geological deposits of reserves. Different materials are extracted in different ways, especially by extracting material below the surface of the earth or even at the surface.

The second step is processing the material so that its properties can be used for the intended purposes.[110] This requires concentration, refining, and smelting, depending on the type of material. Only after this process can the materials be sent to companies that manufacture a certain type of products. In some cases, this process takes place in one location. It can be a single complex with a mine and a facility that processes the metal according to specifics and requirements. However, for critical materials, this is not a very common variant. The problem is particularly in processing, which requires considerable know-how, huge investments, and a skilled workforce. For this reason, a large part of the material is mined in one place and processed elsewhere, even on different continents.[111]

European Union countries face the fundamental problem that they cannot extract most critical materials within their territory, as the reserves are not sufficiently abundant to meet market demand. The second issue is that the processing of critical materials also takes place outside European states because other countries can process the materials more efficiently thanks to long-term strategic investments, lower ecological requirements and cheaper labor.[112]

In the following table, we can see 16 strategic critical materials that this text will focus on in terms of supply security. The listed materials are most important for key industries such as clean technology or defense industry. The table shows a distribution by material, stage, country, and the percentage from the largest supplier (country). The indicator "E" suggests that EU countries rely on too few states for the extraction of certain materials, meaning EU member states either lack sufficient domestic mining capacity or have little diversification among trade partners for sourcing these materials. Similarly, "P" for processing indicates that Europe does not process enough certain materials within its territory to avoid risks.[113]

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[110] Geological Survey of Sweden. "An Introduction to Minerals, Ore and Exploration." Last modified 2022. https://www.sgu.se/en/itp308/knowledge-platform/1-introduction-minerals-ore-exporation/.

[111] Purdy, Caitlin, and Rodrigo Castillo. "China's Role in Supplying Critical Minerals for the Global Energy Transition: What Could the Future Hold?" Brookings Institution, July 2022.

[112] Georg Zachmann et al., Why Europe's Critical Raw Materials Strategy Has to Be International, Bruegel, June 2023, 5, https://www.bruegel.org/sites/default/files/2023-06/why-europe's-critical-raw-materials-strategy-has-to-be-international-%288941%29_1.pdf.

[113] European Commission. "Study on the Critical Raw Materials for the EU 2023 - Final Report." 2023. European Union, 9.

Material	Stage	Country	Share (%)
Aluminum	E	Guinea	63
Lithium	P	Chile	79
Silicon metal	E	Norway	35
Gallium	P	China	71
Manganese	E	South Africa	41
Germanium	P	China	45
Natural Graphite	E	China	40
Bismuth	P	China	65
Titanium	P	Kazakhstan	36
Boron	E	Turkey	99
Tungsten	P	China	32
Cobalt	E	N/A*	N/A*
Copper	E	Poland	19
Nickel	E	Finland	38
HREEs	P	China	100
LREEs	P	China	85
PGMs	P	USA	38

Note: List of critical strategic raw materials

Source: JRC study (European Commission)

In the table, we can observe that the issue of the EU's dependency on Strategic Raw Materials (SRMs) is roughly balanced in terms of phases. There are 9 materials associated with extraction and 8 with processing. According to a study by the European Commission, a problem in the supply chain was identified either at the extraction or processing stage, with the specified country and the percentage of their supplies. This categorization does not mean that some materials could not have issues at the other stage of the supply chain; in this case, the data show us which stage was deemed more problematic according to the 2023 JRC study.

The most significant dependency can be observed with rare earth elements (HREEs and LREEs), with China controlling 100% and 85% respectively of their processing. These elements are crucial due to their conductive and magnetic properties and are essential in most advanced technologies such as LED displays, smartphones, hard drives, and other technologies

in defense, energy, and telecommunications.[114] In 2023, China produced 240,000 tones of rare earths, making it the world's largest producer, with the United States as the second largest at 43,000 tones. While countries like Brazil, Vietnam, and Myanmar also have considerable reserves, their production is marginal compared to China's. According to the International Energy Agency, China controls 87% of the rare earth processing capacity.[115] The other total dependency can be observed with Boron (99%). Turkey is home to approximately 948,712 tones of boron, accounting for 73% of the known global reserves. Other significant reserves are found mainly in Russia and the USA. [116] Boron has a wide range of applications, including in wind turbines, heat-resistant glass, and agricultural products. While the EU is extremely dependent on Turkey for boron extraction, it is less dependent on Turkey for processing, relying on it for 46%. The EU can process 25% of its boron needs in Germany, and it imports another 20% from the USA. [117]

It should be noted that the perspective of total consumption must also be considered when addressing critical materials (table below).[118] Aluminum, due to its use in construction and vehicle manufacturing such as cars, ships, and aircraft, is at the forefront, with the EU pinpointing extraction as the issue, predominantly importing from Guinea at 63%. For processed aluminum, the largest import comes from Russia at 19%.[119] Copper, crucial for electrification, particularly in electrical cables and future renewable energy, is deemed well-managed. Extraction is the risk phase, with Poland being the EU's largest supplier at 19%, followed by Peru and Chile.[120] Germany and Poland lead production, collectively around 31%, contributing to copper's lower risk profile and its initial exclusion from the CRM list.[121]

Silicon metal, now third in total volume, is an essential metal used in chips, transistors, solar cells, and batteries, as well as providing unique properties to aluminum and chemical products. Its production requires silica and a natural carbon source like wood or coal. EU deems the

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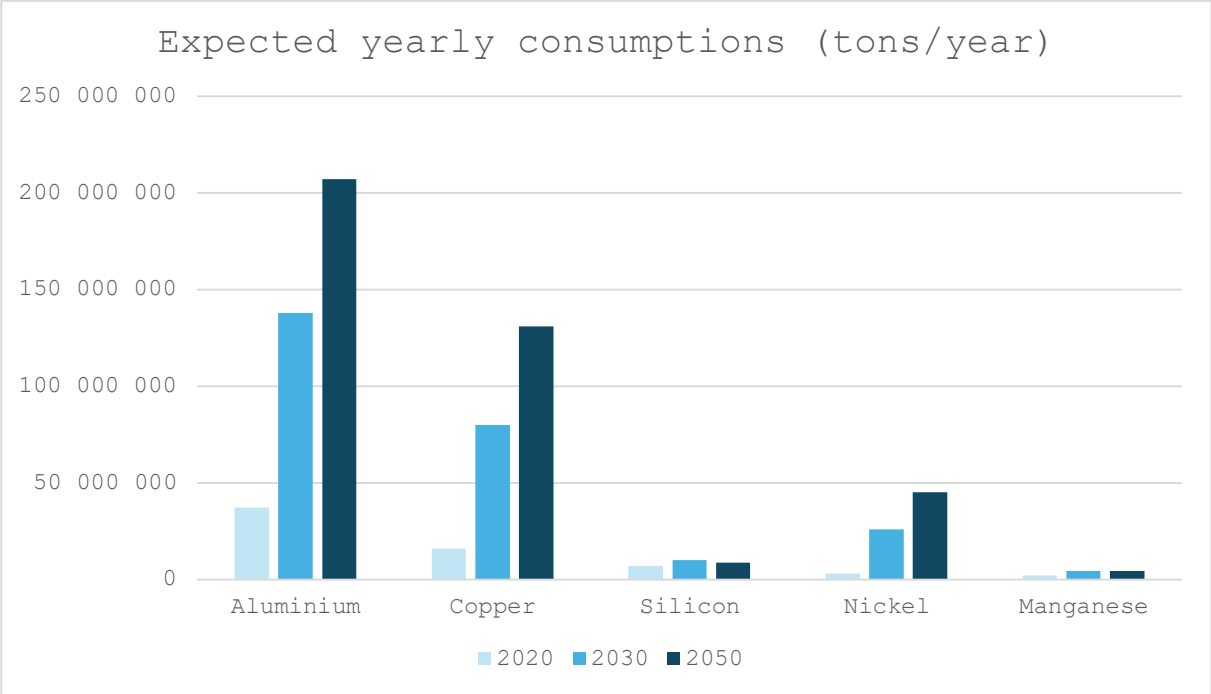
[114] Kamasa, Julian. "Securing Europe's Supply of Rare Earths." Policy Perspectives 11, no. 2 (April 2023): 2-4. Center for Security Studies, ETH Zurich.
[115] Scheyder, Ernest. "Western Start-Ups Seek to Break China's Grip on Rare Earths Refining." Reuters, December 4, 2023. https://www.reuters.com/sustainability/climate-energy/western-start-ups-seek-break-chinas-grip-rare-earths-refining-2023-12-04/.
[116] Eti Maden. "Boron in the World." Accessed March 24, 2024. https://www.etimaden.gov.tr/en/boron-in-the-world.
[117] European Commission, Joint Research Centre. "Boron." European Raw Materials Information System.
[118] "European Council. 'An EU Critical Raw Materials Act for the Future of EU Supply Chains.' Last reviewed March 23, 2024. https://www.consilium.europa.eu/en/infographics/critical-raw-materials/."
[119] "European Commission, Joint Research Centre. 'Aluminium.' Raw Materials Information System. Accessed March 22, 2024. https://rmis.jrc.ec.europa.eu/rmp/Aluminium."
[120] European Commission, Joint Research Centre. 'Copper.' Raw Materials Information System.
[121] Lia, Baihua, Huajiao Li, Zhiliang Dong, Yu Lu, Nairong Liu, and Xiaoqing Hao. "The Global Copper Material Trade Network and Risk Evaluation: A Industry Chain Perspective." *Resources Policy*. 2021: 7.

extraction phase risky, though it doesn't specify origins due to diverse production methods. Refinement is led by Norway (34%) and France (29%), with China dominating global production at 79%. Nickel, expected to surpass Silicon metal consumption, is crucial for stainless steel alloys and modern technologies like batteries and mobile phones, marked risky in the extraction phase. Currently, unprocessed Nickel mainly comes from Finland (38%) and Canada (24%), with Russia (29%) and Finland (17%) leading in refining according to a 2023 CRM study. Indonesia holds about half of the world reserves. Lastly, Manganese, essential in iron production and future LMD batteries, sees the EU heavily reliant on imports from South Africa (41%) and Gabon (39%) for extraction, with Norway (21%) and Ukraine (19%) leading in refining. The largest reserves are in the USA and Australia, with the USA utilizing its potential comparably to Gabon's production.[122]



Note: The numbers provided are only approximate

Source: European Commission

The final criteria within SRM analysis concern the perspective of the greatest percentage increase in demand. Here, it's apparent that materials needed for battery construction are dominant as they will be particularly crucial for energy and transportation vehicles. A sharp

[122] European Commission, Joint Research Centre. 'Raw Materials Information System (RMIS).' Accessed March 25, 2023. https://rmis.jrc.ec.europa.eu/rmp/.

increase in the demand for rare earth elements is also anticipated, but this is only under the high demand scenario. In a potential low demand scenario, the demand could remain constant or even decrease.[123]

Lithium is perhaps the most well-known metal in the critical materials debate due to its properties that allow it to store energy, making it vital for batteries. Currently, the EU does not produce or refine any lithium, thus relying heavily on imports of refined lithium, predominantly from Chile, which accounts for 80% of EU imports. Globally, the largest producers are Australia and Chile, with China, often associated with lithium, only accounting for 13% of extraction.[124] China however leads the world in terms of imports and the production of final or semi-final products, like EV batteries representing around 60% of the global market.[125]

graphite is expected to see the largest percentage increase in EU demand. Natural graphite is used as a refractory material in heavy industry, and synthetic graphite is primarily used in battery production for its electrical conductivity.[126] The risk lies in extraction, with approximately 40% being imported in its primary form from China, and around 25% from Mozambique and Brazil. China dominates globally with 65% of the production and has the largest reserves, representing 45%. Cobalt, a metal crucial in batteries for its resilience and density, is arguably the most controversial on the list of critical strategic materials. This is because approximately 70% of all world reserves are in the Democratic Republic of Congo, known for poor working conditions and child labor.[127] The EU lacks clear data regarding the import of raw cobalt. Regarding refined cobalt, Finland is the largest supplier within the EU (62%) and the only EU country with a cobalt mine. Belgium is second with 29%. [128]Nickel and Dysprosium (rare earth elements), which are expected to see significant demand growth in the future, have been described in previous statistics.

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[123] European Commission, Joint Research Centre. 'Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study 2023.' JRC Science for Policy Report, 2023, 10.
[124] European Commission, Joint Research Centre. 'Raw Materials Information System (RMIS).' Accessed March 25, 2023.
[125] Wald, Ellen. "The US Wants to End Its Reliance on Chinese Lithium. Its Policies Are Doing the Opposite." New Atlanticist. Atlantic Council, January 23, 2024. https://www.atlanticcouncil.org/blogs/new-atlanticist/the-us-wants-to-end-its-reliance-on-chinese-lithium-its-policies-are-doing-the-opposite/.
[126] Ritoe, Amrish, Irina Patrahau, and Michel Rademaker (PL). Graphite: Supply Chain Challenges & Recommendations for a Critical Mineral. March 2022. The Hague Centre for Strategic Studies.
[127] Norton, Kara. "Cobalt Mining Congo Batteries Electric Vehicles." National Geographic, December 21, 2023. https://www.nationalgeographic.com/environment/article/cobalt-mining-congo-batteries-electric-vehicles.
[128] European Commission, Joint Research Centre. 'Raw Materials Information System (RMIS).' Accessed March 25, 2023.

Material	2020 Consumption (t)	2030 Consumption (t)	2020 to 2030 Increase (%)	2050 Consumption (t)	2020 to 2050 Increase (%)
Lithium	4 891	42 313	765%	101 873	1 983%
Graphite	33 726	478 740	1 305%	886 573	2 527%
Cobalt	8 620	54 101	527%	40 202	366%
Nickel	28 346	285 806	908%	455 269	1 506%
Dysprosium	126	713	466%	916	627%

Note: Materials with highest demand in the future

The entire table assumes a high demand scenario.

Source: JRC Study, European Commission

2.3 Political-security context of supplier countries

Many countries upon which the EU relies for supplies of critical materials are nations facing with multiple challenges, such as armed conflicts, corruption, lack of freedom etc. In numerous EU studies on critical materials, several risk assessments are identified that are based on political-security indicators, with the most used rating being the World Bank's World Governance Index (WGI). World bank divides the index into six categories: Voice and Accountability, Political Stability and Absence of Violence and Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. The World Bank measures each indicator on a percentile scale from 0 to 100.[129] There is only one country classified as having "very low" governance levels, which is the Democratic Republic of Congo. Furthermore, suppliers with "low" governance levels include China, Russia, Kazakhstan, Turkey, Morocco, Guinea, Brazil, and Mexico. Subsequent are countries with medium or high levels of governance. For the purposes of this section, the text focuses on very low and low WGI countries emerging from the JRC 2023 study on strategic raw materials, specifically China, Guinea, Kazakhstan, Turkey, and the Democratic Republic of Congo.[130]

[129] Kaufmann, Daniel, and Aart Kraay. 2023. "Worldwide Governance Indicators, 2023 Update." Accessed March 28, 2024. www.govindicators.org.

[130] "European Commission. 'EU Critical Raw Materials.' Accessed March 28. https://rmis.jrc.ec.europa.eu/eu-critical-raw-materials."

Country	World Governance Index Percentile (%)
DRC	6,59
Guinea	16,65
Russia	16,88
Turkey	32,64
Kazakhstan	41,3
China	41,29
South Africa	46,6

Source: World Governance Index (World Bank)

Two countries with similar results regarding the World Governance Index (WGI) are Russia (16.88%) and Guinea (16.55%).[131] In both cases, the EU is dependent on these countries for aluminum. For EU countries purposes aluminum is mined in Guinea and processed in Russia. Guinea has experienced a series of political unrests, with a coup in 2021 where President Alpha Condé was ousted by a military junta, which significantly alarmed the aluminum trading community.[132] The political turmoil in Guinea presents a particularly acute geopolitical risk for Europe, which relies heavily on Guinea for bauxite—the primary ore for aluminum production. Europe imports approximately 63% of its bauxite from Guinea, making any disruption in supply potentially disastrous for the continent's aluminum industry. This dependency places Europe in a vulnerable position, where political instability in Guinea could lead to significant shortages and drive-up aluminum prices dramatically.[133] The uncertainty about the new military regime's policies towards international trade and export could exacerbate these risks, affecting not only the availability and price of aluminum but also broader economic stability and manufacturing across Europe.

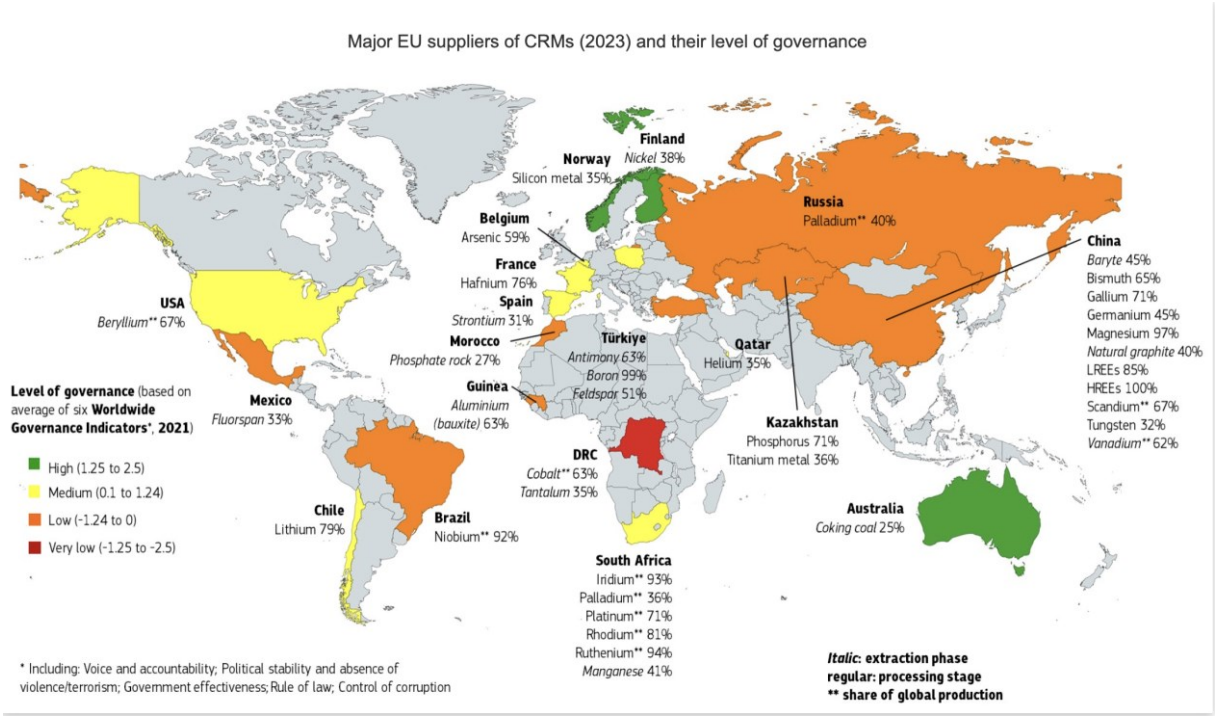
When it comes to Russia, aluminum is one of the commodities from which the EU has struggled to disengage during the Russian invasion in Ukraine. This material is not on the sanctions list, precisely because of its strategic importance. There is no consensus within the EU states on banning imports, as some European countries are heavily dependent on Russian aluminum in terms of price. A group representing the aluminum industry mentioned in an

[131] Kaufmann, Daniel, and Aart Kraay. 2023. "Worldwide Governance Indicators, 2023 Update.
[132] Munshi, Neil, and Neil Hume. "The Coup in Guinea That Shook the Aluminium Market." Financial Times, September 10, 2021. https://www.ft.com/content/a2f4f6a7-b8f6-42a8-a065-061d372282f8.
[133] Home, Andy. "Column: Guinea Coup Adds Bauxite to Aluminium's Supply Concerns." *Reuters.* September 7, 2021. https://www.reuters.com/article/idUSKBN2G317X/.

interview with Politico that a ban would be an *"economic tactical nuclear bomb"* for them.[134] Similarly, the EU has so far failed to eliminate the need to import palladium. Currently, as with other critical raw materials like Russian natural gas and oil, these are used to help finance Russian aggression. Despite this fact, disconnecting from these strategic materials is, similarly to gas or oil, unacceptable for some EU countries.[135]

Countries with somewhat higher credibility from the World Governance Index (WGI) perspective include South Africa (46.6%), on which the EU is dependent for platinum supplies. Then there's Kazakhstan (41.3%), where the dependency is primarily on phosphorus, and Turkey (32.64%), where the EU has almost a 100% dependency on boron. All these countries present a dangerously high dependency on certain strategic materials, while also having reduced stability from the WGI perspective. However, EU aims to strengthen relationships with these countries for better diversification and protection against vulnerability of material dependence especially in case of China and Russia.[136] This also applies to other countries with lower World Governance Index (WGI) scores, such as Mexico and Brazil. With most of these countries, the EU is trying to establish some form of strategic cooperation. An example could be the deepening relationship with Kazakhstan, with whom the European Commission signed a strategic partnership in 2023.[137]

[134] Verhelst, Koen, and Camille Gijs. "EU Faces Pressure to Sanction Russian Aluminum." Politico, February 5, 2024. https://www.politico.eu/article/russia-aluminum-sanctions-europe-ukraine-war/.
[135] Jozwiak, Rikard. "Wider Europe Briefing: Will The EU Ban Russian Aluminum?" Radio Free Europe/Radio Liberty, February 26, 2024. https://www.rferl.org/a/wider-europe-russia-aluminum-eu-ban-estonia-russian-assets-jozwiak/32835598.html.
[136] De Decker, Victor. "The CRM Act in a Global Perspective." Egmont Institute, April 2023.
[137] "EurActiv. 'Strengthening EU-Kazakhstan Relations: What Role for Trade and the Supply of Critical Raw Materials.' Accessed March 29, 2024. https://events.euractiv.com/event/info/strengthening-eu-kazakhstan-relations-what-role-for-trade-and-the-supply-of-critical-raw-materials.



Note: Differentiation of countries based on the criterion of political stability (WGI).

Source: European Commission

Among the most problematic countries from the EU perspective, we find the Democratic Republic of Congo, which is primarily known for its cobalt mining, essential for batteries in electric cars, phones, and computers. The Democratic Republic of Congo holds about 70% of the world's cobalt reserves and contributes to 50% of its production. Looking at the World Governance Indicators, we find it to be one of the least developed countries globally. The summary percentile for WGI is 6.59%. For political stability, it stands at 6.13%, whereas in 2018, it was only at the 2.86% percentile.[138] The most visible problem is the ethical issue associated with cobalt mining. Approximately 15-30% is mined through artisanal mining (i.e. with miners not employed by a company) or small-scale mining (employed by a company). These people operate informally and mine the material by hands, even though such a method is officially prohibited by the government. Besides the dangerous conditions for the workers, there are also conflicts with the security personnel of the mines or criminal groups, leading to numerous deaths.[139]

For millions of people in Congo, poverty often offers no other choice than to engage in artisanal mining, which also involves children. Child labor is thus one of the biggest ethical problems.

[138] Kaufmann, Daniel, and Aart Kraay. 2023. "Worldwide Governance Indicators, 2023 Update." Accessed March 28, 2024. www.govindicators.org.

[139] The Council on Foreign Relations. "Why Cobalt Mining in the DRC Needs Urgent Attention." Blog post. Accessed March 29, 2024. https://www.cfr.org/blog/why-cobalt-mining-drc-needs-urgent-attention.

According to sources in the U.S. Congress, at least 25,000 children work in cobalt mines in the DRC.[140] Children are also often abducted by local militias, for whom they must then work; unlike adults, they have minimal chance to defend themselves in this regard.[141] Another issue is corruption. According to Transparency International, the DRC ranks 162nd out of 180 countries.[142] Additionally, the country has fought numerous wars since its independence and today struggles with various rebel groups, significantly undermining the possibility of greater stability.[143]

Europe's increasing environmental and ethical standards present a significant risk to the EU's reliance on cobalt sourced from the Democratic Republic of Congo (DRC). About 15-20% of DRC's cobalt, essential for lithium-ion batteries and the EU's green energy initiatives, comes from sources that often involve poor working conditions, safety hazards, and child labor. These practices starkly conflict with the EU's commitment to ethical and sustainable sourcing, making the reliance on DRC cobalt increasingly problematic as the EU strives to uphold higher environmental and ethical standards in its supply chains.[144]

The issue with cobalt is inextricably linked to China's raw material expansion. China owns 70-80% of the cobalt mines in the DRC.[145] In 2007, China signed a $9 billion deal with the country resulting in the agreement based on the premise that while the DRC allows China to mine cobalt, in return, China would build infrastructure projects, hence this deal is also referred to as the "resource for infrastructure". Chinese investors are notably dominant in the DRC's copper and cobalt rich Haut Katanga and Lualaba areas of the former Katanga province, with investors including China Molybdenum, and Minerals and Metals Group (MMG). The biggest Chinese-owned mine in the DRC is Tenke Fungurume (80% ownership) which is estimated to have the world's largest cobalt reserves. It is essential to note that the Chinese purchased the stake from the American company Freeport McMoran. This serves as one example of how Western companies have contributed to increasing Chinese dominance in the realm of critical materials,

[140] United States Senate. "From Cobalt to Cars: How China Exploits Child and Forced Labor in the Congo." November 14, 2023.
[141] Center for Preventive Action. "Conflict in the Democratic Republic of Congo." Council on Foreign Relations. Updated February 21, 2024. https://www.cfr.org/global-conflict-tracker/conflict/violence-democratic-republic-congo.
[142] Transparency International. "Democratic Republic of the Congo." Accessed on March 28, 3024. https://www.transparency.org/en/countries/democratic-republic-of-the-congo.
[143] Center for Preventive Action. "Conflict in the Democratic Republic of Congo.
[144] Roelfsema, Arnoud, Irina Patrahau, and Michel Rademaker. "Cobalt Mining in the EU: Securing Supplies and Ensuring Energy Justice." *Hague Center for Strategic Studies*, September 2022, 45.
[145] United States Senate. "From Cobalt to Cars: How China Exploits Child and Forced Labor in the Congo."

illustrating that the issue is more complex than merely the economic relations between China and developing countries.[146]

The refined cobalt is then sent to China to produce components or products. Here, the most important product is batteries, which are manufactured by Chinese companies, accounting for 40% of the global production.[147] Customers include large global companies such as Tesla or BMW. Cobalt serves as a prime example of how China has established dominance over a metal not naturally found within its borders, achieving over global dominance.

Just as with cobalt, lithium is the other most visible example where China has dominated the market for this commodity, despite being only the fifth largest producer in the world. Chinese companies have aggressively entered ownership positions in the largest companies in countries with the largest lithium reserves. This is particularly the case in South America, where the Chinese company Tianqi Lithium became the second-largest shareholder in Chile's largest lithium mining company, Sociedad Química y Minera (SQM). In 2020, the Chinese company Ganfeng Lithium Co. acquired a majority stake in Lithium Americas Corp's project in northern Argentina. Tianqi Lithium also owns a majority stake in the largest hard-rock lithium mine in Greenbushes, Australia.[148] Through these acquisitions and the development of the best and cheapest refining technologies, China has dominated the lithium battery supply chain, which is now the most important lithium product, accounting for around 60% of the global market.[149]

China is known to be the largest player in the field of critical materials, yet its governance index level is also relatively low. Across the six indicators, the average World Governance Indicator (WGI) for China is 41.29%. The worst score for China is in "Voice and Accountability," which simply means the freedom of speech and participation in public matters. In that case, China reached only a 6.28% percentile. Similarly, China does not fare well in terms of political stability, with a score of 28.30%.[150] Political stability is particularly threatened by confrontational relations with the United States, who are vying for economic and political dominance in the world. Currently, we can see that these relationships are particularly reflected in economic issues, especially in key sectors where strategic materials are used. There is,

[146] Lipton, Eric, and Dionne Searcey. "How the U.S. Lost Ground to China in the Contest for Clean Energy." The New York Times, November 21, 2021. https://www.nytimes.com/2021/11/21/world/us-china-energy.html.
[147] Byamungu, Christian-Géraud Neema. "Blue Metal Blues: Cobalt, the Democratic Republic of Congo,
[148] Altiparmak, Selim Özkan. "China and Lithium Geopolitics in a Changing Global Market." *Chinese Political Science Review*, August 25, 2022, pp. 5-8. doi: 10.1007/s41111-022-00227-3.
[149] Shepardson, David. "Senators urge US to take steps to boost battery production, citing China." Reuters, November 7, 2023. https://www.reuters.com/technology/senators-urge-us-take-steps-boost-battery-production-citing-china-2023-11-06/
[150] Kaufmann, Daniel, and Aart Kraay. 2023. "Worldwide Governance Indicators, 2023 Update."

however, a great concern regarding a possible military conflict between the USA and China over the sovereignty of Taiwan. In such a case, China could significantly profit from its dominance over the supply chain of critical materials, which could not only greatly benefit its war production but also serve as a deterrent to other parties that would face socio-economic turmoil in the event of a material outage from China.[151]

The fact that China is not afraid to use certain materials as a weapon has already been confirmed in the past. China has shown its capability to use rare earths as an economic weapon, such as when it halted exports of rare earths to Japan in 2010 over the detention of a Chinese fishing boat in disputed area.[152] Similar tactics have been used against Australia and the UK, where economists from the University of St. Gallen discovered that China had reduced supplies by more than 75% during certain times in the past.[153] China demonstrated that it could use this strategic commodity, particularly in trade wars. During the dispute in 2019 under the administration of Donald Trump, there was a serious threat that China would ban the export of rare earths to the United States, which at that time depended on China for 90% of their supply. The potential retaliation was a reaction on the increasement in tariffs from 10% to 25% on Chinese goods exceeding 200 billion dollars.

The situation has escalated recently. In December 2023, China introduced a requirement for Chinese companies to obtain state permission before exporting two types of materials. These are "high-purity, high-hardness and high-intensity synthetic graphite material and natural flake graphite and its products."[154] Similarly, earlier that same year, China imposed similar controls on the export of germanium and gallium, materials over which China has considerable dominance. Such barriers are often presented as preventive, as many critical materials have dual uses, meaning they are used in the military industry. However, this primarily represents a fierce competition over the latest technologies that have the potential to change geopolitical forces around the world. In the case of graphite, it is about cementing China's position in the battery sector, while with germanium and gallium, China is responding to the ban on chip manufacturing technology exports introduced by other chip powers such as Japan and the

[151] Wischer, Gregory. "The U.S. Military and NATO Face Serious Risks of Mineral Shortages." Carnegie Endowment for International Peace, February 12, 2024. https://carnegieendowment.org/2024/02/12/u.s.-military-and-nato-face-serious-risks-of-mineral-shortages-pub-91602

[152] Rehill, Anne. "Ensuring Rare Earth Elements for National Security." *The Yale Review of International Studies*, 28 Nov 2023. https://yris.yira.org/column/ensuring-rare-earth-elements-for-national-security/

[153] Evenett, Simon, and Johannes Fritz. "Revisiting the China–Japan Rare Earths Dispute of 2010." VoxEU CEPR, 19 Jul 2023.

[154] Benson, Emily, and Thibault Denamiel. "China's New Graphite Restrictions." Commentary, Center for Strategic and International Studies, 23 Oct 2023. https://www.csis.org/analysis/chinas-new-graphite-restrictions

Netherlands, in addition to the United States.[155] At the end of 2023, China also moved to restrict the export of rare earth processing technologies, It's unsurprising at the moment, considering that the major European powers of the EU and the USA are almost entirely dependent on China for rare earth elements. From the perspective of Strategic Rare Earth Materials (SRMs), it's evident that rare earths are one of China's most formidable tools. In the event of a supply disruption, Western countries would struggle to find alternatives, which is why this issue is often highlighted as one of the greatest security concerns regarding raw materials strategic autonomy and sovereignty.[156]

[155] Liang, Annabelle, and Nick Marsh. "Gallium and Germanium: What China's New Move in Microchip War Means for World." BBC News, 2 Aug 2023. https://www.bbc.com/news/business-66118831

[156] Baskaran, Gracelin. "What China's Ban on Rare Earths Processing Technology Exports Means." Commentary. Center of International and Strategic Studies. January 8, 2024. https://www.csis.org/analysis/what-chinas-ban-rare-earths-processing-technology-exports-means

3. Rethinking dependencies and strategic sectors

3.1 Challenges in Executing the European Strategy

As we know, in its Raw Materials Act the EU counts on a minimum of 65% dependency by 2030 according to its goal, which, even in the case of potential success of the CRM strategy, will not solve the problem of dependency on certain undemocratic states. Next to it achieving the goals set forth in the EU's strategy for utilizing its raw material capacities will be challenging, particularly in the short to medium term. The extraction capacity is contingent upon locating sufficient concentrations of critical raw materials within European soil that make mining commercially viable. Moreover, the initiation of CRM mining and processing is not assured for political reasons.[157]

With no active proposals for extraction yet, the tension between the demand for critical raw materials and the commitment to environmental preservation is evident. This is reflective of a broader issue across Europe, where the drive for resource extraction to support technological advancements is clashing with ecological conservation efforts. As European authorities consider new legislation to expedite mining operations, these conflicts are expected to intensify, highlighting the ongoing struggle to balance economic development with environmental integrity. Gaining all necessary approvals alone can take many years. Additionally, the complete process of opening a mine, from exploration to actual operation, can span 15 to 20 years.[158] Despite Europe's efforts to boost local production, it will take a significant amount of time before newly mined critical materials in Europe are ready for use.[159]

Regarding the processing of critical materials, Australia serves as a notable example, facing significant challenges, particularly with lithium. The projects in Australia are experiencing considerable delays due to labor shortages and budget overruns. Additionally, the cost of establishing lithium processing facilities in Australia is approximately two and a half times higher than in China. This high financial burden can hinder rapid capacity expansion and requires long-term planning and substantial financial investment. This reality suggests that

[157] Guinea, Oscar, and Vanika Sharma. "European Economic Security and Access to Critical Raw Materials: Trade, Diversification, and the Role of Mercosur." *European Center for International Political Economy*, July 2023, 5-6. https://ecipe.org/publications/trade-diversification-the-role-of-mercosur/.

[158] Zimmermann, Antonia. "Europe's Green Dilemma: Mining Key Minerals Without Destroying Nature." *Politico,* March 15, 2023. https://www.politico.eu/article/europes-green-dilemma-mining-key-minerals-without-destroying-nature/.

[159] Guinea, Oscar, and Vanika Sharma. "European Economic Security and Access to Critical Raw Materials.

similar challenges could await European projects aimed at increasing domestic production of critical materials.[160]

For this reason, it seems that at least for now, placing a greater emphasis on international cooperation will be much more important for addressing the situation. The European Union has developed a two-pronged strategy aimed at achieving safer supply chains: creating the Critical Raw Materials club and signing new strategic partnerships. The first element winvolves the creation of the so-called "Critical Raw Materials Club",[161] similarly to the Indo-Pacific strategy, emphasizing strong cooperation with like-minded states advocating for the support of multilateralism, free trade, democracy, and a rules-based order. Although this mode of cooperation is ideologically driven, it also contains an important pragmatic component, which is to counterbalance China. [162]

Ursula von der Leyen, the President of the European Commission, announced the formation of the Critical Raw Materials Club in June 2023 during the State of the Union address, stating it would convene by the end of 2023. As of April 2024, this meeting has not yet occurred, and the members of this club remain unidentified, indicating the EU's role in multilateral diplomacy is not as successful as anticipated.[163] The focus so far has been mainly on the United States, with whom the EU has signed the "Critical Minerals Agreement" to support ecological and social standards relating to critical materials. The EU is also part of the American "Minerals Security Partnership" initiative, which includes 14 states including the EU, USA, Japan, South Korea, and India. This initiative emphasizes responsible environmental approaches, community consultation, and the promotion of ethical business operations, marking it more as a value-oriented platform than a pragmatic initiative aimed at ensuring diversification of critical materials. It's a matter of question who will be a member of the "European club" and whether it will have a more pragmatic character.[164]

The member states would collaborate to finance resource extraction in third countries while concurrently committing to mutual support in the event of supply disruptions. This initiative is supported in the Communication accompanying the Critical Raw Materials Act and further

[160] Frost, Natasha. "Australia Tries to Break Its Dependence on China for Lithium Mining." The New York Times. May 23, 2023. https://www.nytimes.com/2023/05/23/business/australia-lithium-refining.html.
[161] European Commission. "Critical Raw Materials."
[162] Forsby, Andreas Bøje. "Like-Mindedness: How the West Shapes the Geostrategic Landscape in the Indo-Pacific." Danish Institute for International Studies, February 8, 2023. 5.
[163] European Commission. "2023 State of the Union Address by President von der Leyen." Speech presented in Strasbourg, September 13, 2023. European Commission.
[164] European Commission. "EU Moves Forward with Critical Minerals Agreement Negotiations with the US." Press Release, June 21, 2023. European Commission.

emphasized in the recently published Communication for the European Economic Security Strategy. However, while these documents advocate for the establishment of such a club, they do not provide a detailed roadmap or clear guidelines on how to effectively implement this strategy. The absence of a specific action plan raises questions about the operationalization of the club and the steps required to achieve these strategic objectives.[165]

These partnerships, such as the critical raw materials club or the American led critical mineral partnership, are closely linked to the previously mentioned term "like-minded states," now also used in the context of supply security as "friend shoring." This term re-emerged in the context of changing global supply chains due to the COVID-19 pandemic and the invasion of Ukraine, when Western countries realized their risks of dependency on strategic rivals. Friend shoring attempts to implement a certain strategy that is shared with states that have similar values, thereby eliminating risks, especially from a geopolitical perspective.[166]

In the EU, we can see a reference to this term from 2022 in the communication of the European Commission to the European Parliament in its Strategic Foresight Report of 2022. Here, the report mentions that current geopolitical shifts have accelerated the need to increase European resilience and strategic autonomy. It discusses a range of risks that are reasons for low resilience and strong dependencies, such as cyber risk, the need to use fossil fuels for longer, higher inflation rates, and limited access to critical raw materials and technologies. *"It will add pressure to move to less vulnerable, more diversified, and more reliable supply chains and, possibly, 'friend- shoring."*[167]

Although the strategy advocates for the creation of alliances such as the Critical Raw Materials Club, aimed at fostering mutual support among member states during supply crises, it notably lacks a clear framework for establishing these partnerships. This oversight complicates the process of forming effective collaborations with like-minded states through "friend-shoring," which involves partnering with countries that share similar values and strategic interests. However, not all like-minded states possess the necessary raw materials, making it impossible to completely circumvent key players such as DRC or China. The absence of a detailed strategy for these alliances, combined with the limited availability of critical raw materials among

[165] Findeisen, Francesco, and Yann Wernert. "Meeting the Costs of Resilience: The EU's Critical Raw Materials Strategy Must Go the Extra Kilometer." Jacques Delors Centre, March 30, 2023. https://www.delorscentre.eu/en/publications/eu-critical-raw-materials.

[166] Vivoda, Vlado. "Friend-shoring and Critical Minerals: Exploring the Role of the Minerals Security Partnership." Energy Research & Social Science (June 2023): 3.

[167] European Commission. "2022 Strategic Foresight Report: Twinning the Green and Digital Transitions in the New Geopolitical Context." Brussels, June 29, 2022. COM(2022) 289 final, p. 8.

aligned nations, could significantly hinder Europe's ability to effectively respond to and manage international supply chain vulnerabilities.[168]

3.2. Forging New Partnerships

To achieve the goal of better diversification of resources and risk mitigation, the EU is also developing more pragmatic steps as part of a second strategy that focuses on entering strategic partnerships on critical materials. The first such agreement was concluded with Kazakhstan at COP 27 in Egypt. According to the statement, the agreement aims to develop a secure and sustainable supply of raw materials and refined products.[169] This treaty is very important for Europe, as Kazakhstan possesses a large portion of the critical materials listed on the European list on its territory. Minister of Industry and Development Marat Karabayev even stated: "*currently Kazakhstan was able to provide 16 out of 30 critical materials, stressing that "in future, in cooperation with the European Commission, I believe we can reach all 30 elements".*[170]

Kazakhstan pursues what is called a multi-vector policy. This means it orients in various directions, particularly towards Russia, China, and Europe. However, in January 2022, the Kazakh regime experienced one of the largest demonstrations in history, during which Prime Minister Tokayev had to call for help from the Russia led organization CSTO, which sent troops to Kazakhstan to calm the situation during the demonstrations and thus protect the Kazakh regime. Similarly, Russia exerts significant pressure in terms of control over the Caspian Consortium group's transmission systems, through which 80% of Kazakhstan's oil and gas supplies to Europe flow, comprising most of its exports related to these resources.[171] This demonstrates that although Kazakh foreign policy strives to be independent, in critical situations, it relies on Russia so far. The increasing influence can also be seen from China, which is Kazakhstan's largest trading partner. It can be assumed that both powers have significant influence in the country, which could manifest in future geopolitical crises.[172]

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[168] Findeisen, Francesco, and Yann Wernert. "Meeting the Costs of Resilience: The EU's Critical Raw Materials Strategy Must Go the Extra Kilometer."
[169] European Commission. "EU-Kazakhstan Strategic Partnership Becomes Operational." Press Release, May 19, 2023. Brussels: European Commission.
[170] Szumski, Charles. "EU, Kazakhstan Vow to 'Go Beyond' Raw Materials-Based Relationship." Euractiv.com, November 24, 2023, updated November 28, 2023. https://www.euractiv.com/section/central-asia/news/eu-kazakhstan-vow-to-go-beyond-raw-materials-based-relationship/.
[171] Arynov, Zhanibek. "Is Kazakhstan's Multi-Vector Foreign Policy Threatened?" Horizons: Journal of International Relations and Sustainable Development, no. 21 (Summer 2022): 193-195.
[172] Dukeyev, Berikbol. "Kazakhstan Cautiously Intensifies Ties with China." Eurasia Daily Monitor 20, no. 152 (October 3, 2023).

Another Central Asian country with which the EU has signed a strategic partnership is Uzbekistan. Unlike Kazakhstan, it is not a member of the CSTO military pact, which partly reduces the possibility of Russian involvement in the country's political problems.[173] But who is becoming an increasingly influential player in Uzbekistan is China, which is the largest trading partner and is expanding its influence here through investments. In 2023 alone, China invested 6 billion dollars in energy projects in Uzbekistan. Likewise, China expects to increase mutual trade by 42% in 2024 compared to 2023. China also supports Uzbekistan in its strategic sectors, such as the automobile manufacturing of UzAuto brand. In addition, Chinese companies Chinese CITIC Group and COSTAR Group have built "safe cities monitoring" systems in northern Uzbekistan, known from China for monitoring using face recognition.[174] Therefore, Uzbekistan also represents a country under the influence of strategic rivals, here primarily China, but also Russia due to historical reasons.

Africa is another focus for the EU in terms of strategic agreements. It's a continent that has remained somewhat overlooked in terms of geopolitical priorities. Meanwhile, across the continent, China has managed to establish several economic strategic connections, as well as Russia in terms of security influence.[175] In terms of institutional cooperation, the relationship between the continents operates based on the Joint Africa-EU Strategy from 2007, which addresses political, economic, and humanitarian collaborations. Nowadays, a sign of progress in European strategy is the so-called Global Gateway partnership, which aims to strengthen partnerships around the world in key future areas such as digitalization, energy, transportation, and research. The first investments are headed to Africa, where up to 150 billion EUR is to be directed through this platform.[176] In contrast, Asia and the Pacific, or Latin America and the Caribbean, will have investments of only around 45 billion dollars compared to Africa.[177] Regarding more specific cooperation on critical materials, the EU has so far signed four

[173] Rakhimov, Alisher, Ulugbek Khasanov, and Akram Umarov. "The New Foreign Policy of Uzbekistan: Central Asia, the EAEU and the BRI." University of Kent, November 18, 2020, p. 5.
[174] "Eurasianet." "Uzbekistan, China Pledge to Boost Trade to $20Bln in 'Near Future'." January 24, 2024. https://eurasianet.org/node/91527.
[175] Tadesse Shiferaw, Lidet, and Mariella Di Ciommo. "Trouble in Paradise: The EU-Africa Partnership in a Geopolitical Context." ECDPM, November 13, 2023.
[176] European Commission. "Africa-EU Partnership." Last modified 2023. European Commission. https://international-partnerships.ec.europa.eu/policies/africa-eu-partnership_en.
[177] European Commission. "Global Gateway." European Commission. Last modified 2023. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/stronger-europe-world/global-gateway_en.

strategic agreements with African countries. This includes Namibia, where cooperation within CRM is planned, but cooperation on hydrogen is expected to be more important.[178]

The more interesting players will be especially two countries, the Democratic Republic of Congo, Zambia which are important especially for battery materials such as lithium, cobalt, and copper. China's influence on cobalt in the country has been described in the previous chapter. As for Zambia, a similarly strong economic imperialism is evident, with Chinese mining companies buying large stakes, especially in copper mines. China already has a majority stake in Luanshya and Chambishi mines.[179] However, now there is also the sale of the largest copper mine, Sentinel, which is 80% owned by Canadian miners First Quantum Minerals, which may sell this mine to the Chinese firm Jiangxi Copper Corp. Just like in the case of the Congo, there is a risk of selling these strategic assets from Western companies to Chinese ones, which are inherently under strong influence of the Chinese regime, potentially affecting the future security of supplies to Europe.[180]

The last African country with which the EU has entered a strategic partnership is Rwanda, which has rich reserves of Tantalum, Tungsten and Niobium.[181] With Niobium, in particular, the EU has the opportunity, through Rwanda, to diversify its dependence on Brazil, which is over 80%. For Tungsten, this may reduce dependence on China, although it is one of the smaller dependencies at 30%. However, Rwanda has a long-standing regional problem with the Democratic Republic of Congo, which accuses it of supporting M23 terrorists. DRC President Felix Tshishekedi has even described the EU-Rwanda agreement as: *'a provocation in very bad taste'*. There is therefore a risk that, after this step, Europe will have less access to the DRC, which is crucial for raw material security, particularly in terms of cobalt.[182]

In addition to the mentioned countries, the EU has managed to sign other strategic agreements regarding critical materials with states that are much more closely aligned and interconnected with the EU and much safer due to being relatively stable democratic states. An exception may

[178] European Commission. "Global Gateway: EU and Namibia Agree on Next Steps of Strategic Partnership on Sustainable Raw Materials and Green Hydrogen." Press Release, October 24, 2023. Brussels: European Commission.
[179] Hsiang, Evan. "Chinese Investment in Africa: A Reexamination of the Zambian Debt Crisis." Harvard International Review, January 25, 2023. https://hir.harvard.edu/chinese-investment-in-africa-a-reexamination-of-the-zambian-debt-crisis/
[180] Rajagopal, Divya. "First Quantum in Talks with Jiangxi Copper on Sale of Stake in Zambian Mines—Source." Reuters, January 5, 2024. https://www.reuters.com/markets/commodities/first-quantum-talks-with-jiangxi-copper-sale-stake-zambian-mines-source-2024-01-04/
[181] European Commission. "EU and Rwanda Sign a Memorandum of Understanding on Sustainable Raw Materials Value Chains." Press Release, February 19, 2024. Brussels: European Commission.
[182] Onyango, Gilbert. "Commission Plays Down Row over Rwanda Minerals Pact." EUobserver, March 1, 2024. https://euobserver.com/africa/158166

be Ukraine, which has a specific status due to the ongoing war. Other countries include Chile, Argentina, Canada, and the autonomous territory of Greenland. These are states that could be categorized as "like-minded" since they share similar values with EU member states.[183]

Also, in this context, it's important to mention Free Trade Agreements (FTAs), which, although not directly focused on critical materials, are one of the most important topics within these treaties. Particularly significant is the EU-Chile FTA, due to the largest reserves of lithium and copper. In Southeast Asia, agreements are being negotiated with Indonesia, which is the largest producer of nickel, and with the Philippines, which have strong copper reserves. [184]

Perhaps the most discussed FTA in the negotiation process is with the Mercosur countries, which could potentially represent reliable partners due to their close cultural and historical connections to Europe. Brazil is the main leader of this bloc and the country with the broadest range of critical material reserves within the group. This cooperation could, for example, significantly mitigate risks related to manganese and nickel, as well as other materials on which the EU depends on China and Russia.[185] However, this potential deal reveals the incompatibility between European and other policies. One of the fundamental conflicts arises from European demands for environmental standards. Additionally, under President Lula da Silva, there is a rapprochement with Moscow and Beijing, along with the president's different stance towards the conflict in Ukraine. Brazil is an example of how the EU encounters various problems in achieving strategic agreements with partners who might initially seem like obvious like-minded states.[186]

Free trade agreements would eliminate many tariffs and barriers, which on one hand will make it cheaper to import materials, and on the other, thanks to the legislative framework, will make it much safer. This is one of the key principles that could significantly strengthen the EU's resilience and competitiveness in this area.[187]

3.3 Critical Materials and Defense

[183] European Commission. "Raw Materials Diplomacy." Last modified 2023.
[184] European Commission. "Negotiations and Agreements." Accessed April 15, 2024. https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/negotiations-and-agreements_en.
[185] Guinea, Oscar, and Vanika Sharma. "European Economic Security and Access to Critical Raw Materials: Trade, Diversification, and the Role of Mercosur." ECIPE Policy Brief, no. 09/2023, 13-14.
[186] Foy, Henry. "Why Brazil's Lula is a Bellwether for EU-Latin American Relations." Financial Times, July 17, 2023. https://www.ft.com/content/e0b7b9a7-753e-420c-a728-ec1fed5ca2a1.
[187] European Commission. "Negotiations and Agreements.

The war in Ukraine has exposed Europe's unpreparedness in security matters. Member states are unable to sufficiently supply Ukraine for its fight against Russia, while also finding, upon reviewing their own armed forces, that they would not be very prepared for a similar military conflict as the one being experienced today. This situation has uncovered a long-overlooked issue: Europe's strong security dependence on the United States.[188] Looking at military budgets, we find that collectively, states contribute $1.3 trillion to defense, with the United States' budget accounting for $860 billion, approximately 68% of the total NATO budget.[189] This is also one of the reasons why some EU member states are now strongly calling for a policy of strategic autonomy, aimed at ensuring the EU can rely on itself in key areas. The fact that increased attention to defense in Europe is not only a response to Ukraine but also a broader strategy which was described by Camille Grand from the European Council on Foreign Relations: *"[The strategy] is not an answer to the war in Ukraine, but rather a broader response to a strategic paradigm shift. It's a recognition that [defense] is a subject that's not going to go away for a while."*[190]

Concepts that were often dismissed in the past, such as a European joint army or a commissioner for security, are seriously being discussed.[191] The work on strategic autonomy is also evidenced by the fact that the European Commission introduced a "defence industrial strategy" in March 2024. This EU program will initially be supported with an incentive of 1.5 billion euros. Commissioner Thierry Breton, however, acknowledges that the EU will eventually need an investment of up to $100 billion. Like the Critical Raw Materials Act, this program sets targets: Procure at least 40% of defense equipment in a collaborative manner by 2030; Ensure that, by 2030, the value of intra-EU defense trade represents at least 35% of the value of the EU defense market; Make steady progress towards procuring at least 50% of their defense procurement budget within the EU by 2030 and 60% by 2035. The third point is crucial for the topic of

[188] Karnitschnig, Matthew. "America's European Burden: How the Continent Still Leans on the US for Security." POLITICO, June 14, 2023. https://www.politico.eu/article/america-europe-burden-continent-leans-security-defense-military-industry/.
[189] Lu, Marcus. "Breaking Down $1.3T in NATO Defense Spending." Visual Capitalist, February 23, 2024. https://www.visualcapitalist.com/breaking-down-1-3t-in-nato-defense-spending/.
[190] Karnitschnig, Matthew. "America's European Burden: How the Continent Still Leans on the US for Security.
[191] Kayali, Laura, Joshua Posaner, and Jacopo Barigazzi. "Peace Dividend Dead: Brussels' Plan for War in Ukraine and Eurobonds." POLITICO, March 4, 2024. https://www.politico.eu/article/peace-dividend-dead-brussels-plan-war-ukraine-eurobonds-thierry-breton/.

critical materials, as it aims to significantly increase the consumption of the defense budget within EU countries.[192]

This plan will significantly intersect with the objectives of the Critical Raw Materials Act as it clearly points to the fact that Europe plans to produce many more weapons on its territory in the years to come, for which it will need several critical materials. While the demand for critical materials in the defence industry is low in terms of volume, some critical materials are irreplaceable for the overall functioning of certain types of military products. The EU has identified that the defence industry uses 39 raw materials, about half of these materials are subject to import, of which 22 are considered critical materials.[193] The dependency on the identified 39 materials is 58% on China,[194] which is particularly sensitive at a time when the possibility of a future military conflict with China, such as the mentioned dispute over Taiwan, is taken into real consideration. The JRC study from the EC evaluates rare earth elements as the most critical, with the most alarming state in this order: Dysprosium, Samarium, Neodymium, Other REEs, Praseodymium.

However, the Hague Center for Security Studies looks at the materials from a different metric, evaluating materials according to their usage in terms of volume.[195] They identify that aluminum and natural graphite are the greatest risk in terms of volume of demand and the potential for supply disruption. This is not surprising as both materials are used in various types of constructions. The use of these materials can be seen almost everywhere, examples include fighters, transporters, helicopters, landing ships, frigates, but also in onboard electronics.[196] Looking back at the analysis of these materials, we find that natural graphite is imported 40% from China, this material is also subject to export controls by Chinese authorities from the end of 2023. For aluminum, EU imports 62% from Guinea, which according to the WGI is a very unstable country, likewise, there is the problem of mentioned imports of refined aluminum from Russia, which is with 20% significant importer.[197]

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[192] European Commission. "First Ever Defence Industrial Strategy and a New Defence Industry Programme to Enhance Europe's Readiness and Security." Press Release, March 5, 2024. Brussels: European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_24_1321.

[193] European Commission, Joint Research Centre. "Critical Raw Materials for Strategic Technologies and Sectors in the EU: A Foresight Study." European Commission, 2022, p. 59.

[194] Ibid, 58.

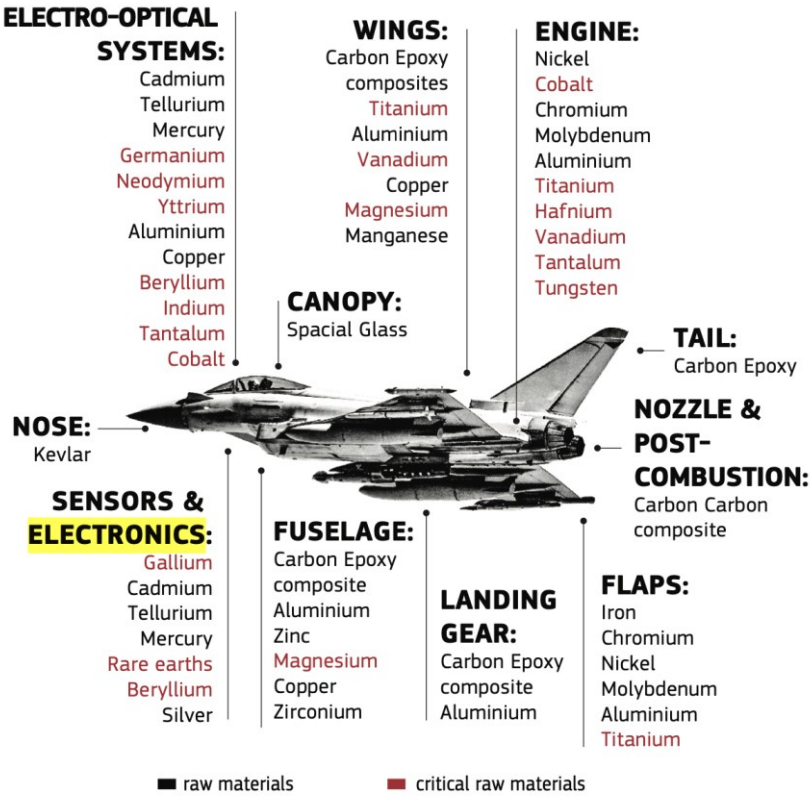
[195] Girardi, Benedetta, Irina Patrahau, Giovanni Cisco, and Michel Rademaker. Strategic Raw Materials for Defence: Mapping European Industry Needs. The Hague: The Hague Center for Strategic Studies, January 2023. ISBN: 9789083254180, p. 5.

[196] Ibid, 7.

[197] European Commission, Joint Research Centre. 'Raw Materials Information System (RMIS).' Accessed March 25, 2023.

The aerospace industry undeniably faces the greatest challenge, as studies by the JRC indicate it utilizes 19 of the 22 critical materials used, excluding praseodymium, yttrium, and germanium. The aerospace sector requires a vast number of high-tech materials that can be continually innovated, such as alloys with titanium, graphite, or fiberglass. This allows for materials to be lighter or have higher resistance to high temperatures. Similarly, a large quantity of titanium is needed for sensors, avionics, electro-optical cables, and copper for electrical and optical control systems. Military electronics is the second sector that needs the most critical materials, as it involves high-end technology, which, like unconventional products, needs a lot of CRMs. An example can be Gallium – used for chips that are essential for guiding missiles and complex computer systems, germanium - necessary for various night vision technologies.[198]

Figure 60. Materials used in different parts of the combat aircraft Rafale



Source: JRC Study, European Commission

The space technology is also an increasingly growing sector, with various military uses, such as various satellite devices. The space industry is increasingly being democratized and

[198] European Commission, Joint Research Centre. "Critical Raw Materials for Strategic Technologies, 71.

industrialized, with more and more private actors entering it, leading to a significant growth of startups, or the number of satellite devices. Since research in this field is dynamic, it is not precisely established which materials are needed. It is important to have light and durable materials, such as in aerospace, for example, Graphite, Aluminum. For advanced materials, it involves carbon fibers, precursors, or special alloys.[199]

According to data from the JRC study, we can see that the risks in the military and space industry sectors are particularly related to China, on which these sectors are dependent for supplies of critical materials by 58%. For comparison, it's worth mentioning that second and third places are jointly occupied by Chile and South Africa, countries with much lower risk, but each representing only 8%. The United States accounts for 2% of supplies, and for 24%, it is not specified.[200]

This issue was also directly addressed in the recent European Parliament resolution titled: "REPORT on the security and defense implications of China's influence on critical infrastructure in the European Union." In this resolution, the European Parliament supports the EU plan to establish strategic partnerships mentioned above and thereby reduce dependence on China in strategic sectors: *critical materials are essential for the security and defense sector, as well as for the success of the EU's digital and green transitions; calls on the Commission and the Member States, in coordination with industry stakeholders, to implement the decision to gradually reduce the dependence on China by diversifying the sources of critical raw minerals and rare earth elements, establishing strategic partnerships with reliable third countries with the aim of ensuring secure and reliable supplies of critical raw materials; urgently calls on the EU to assist Member States in developing projects that will aim for greater independence from Chinese production.*[201]

One of the most emphasized issues are the aforementioned rare earths. In Europe, promising deposits exist, such as in Greenland and Sweden, but due to low prices and China's monopoly, these resources remain underutilized. For instance, one of the potential deposits in Greenland is being developed by non-European companies, predominantly from Australia, like Energy Transition Minerals Ltd (formerly Greenland Minerals Limited), which has been negotiating the development of the Kvanefjeld project. Importantly, Shenghe Resources, a Shanghai-listed

[199] Ibid, 72.
[200] Ibid, 75.
[201] European Parliament. "Report on the Security and Defence Implications of China's Influence on Critical Infrastructure in the European Union." (2023/2072(INI)). Committee on Foreign Affairs, Rapporteur: Klemen Grošelj, December 11, 2023.

company that operates across the entire rare earth supply chain, purchased over 10% of this company, becoming its largest shareholder.[202] This situation complicates the EU's efforts to diversify sources and reduce dependency. China, controlling approximately 40% of the world's reserves and 80% of production of rare earths, dominates the market, crucial for military technologies, particularly in the production of high-performance magnets. China's two-decade lead and its monopolistic position make it exceedingly challenging for Europe to shift away from Chinese supplies and secure alternative sources, significantly impacting Europe's military security and strategic autonomy.[203]

3.3 CRMs for Green and Digital Technologies

The connection between the economy and security has several obvious parameters. The first is that a state with good economic health could allocate more resources to its defence capabilities, which in turn determine the military power of a country. For this area, certain economic factors, such as critical materials and technologies that are interconnected, are particularly important. On the other hand, a growing economy also brings the side effect that wealthier states, due to higher production, have an increasing need for energy resources, which are available in limited quantities in various forms around the world, creating global competition.[204]

The European Parliament, Council, and Commission drafted a joint document in 2023 titled "European Economic Strategy," in which they mention how certain economic linkages may become dangerous amidst increasing geopolitical tensions. "Risks to the resilience of supply chains" appear at the forefront in the identification of risks, particularly in connection with the green transition. In this document, the EU acknowledges that economic dependencies, once considered safe in past decades, are no longer perceived as such, and significant changes are needed in their configuration. In addition to securing supply chains, with the Critical Raw Materials Act being its flagship, the document also addresses the protection of technologies, both in terms of physical and intellectual property. These and other documents clearly indicate the direction that critical technologies, important for the economy and requiring critical

[202] San Martín, Blanca Marabini. "De-risking Rare Earths: The Greenland Stalemate and the Critical Raw Materials Act." China Observer, May 30, 2023. https://chinaobservers.eu/de-risking-rare-earths-the-greenland-stalemate-and-the-critical-raw-materials-act/.

[203] Kullik, Jakob. "Unter dem Radar: Die strategische Bedeutung Seltener Erden für die wirtschaftliche und militärische Sicherheit des Westens." *Bundesakademie für Sicherheitspolitik*, 2019. https://www.baks.bund.de/de/arbeitspapiere/2019/unter-dem-radar-die-strategische-bedeutung-seltener-erden-fuer-die.

[204] Banna, Hasanul, Ashraful Alam, Xihui Haviour Chen, and Ahmed W. Alam. "Energy Security and Economic Stability: The Role of Inflation and War." Energy Economics. *Department of Finance and Economics, Business School, Manchester Metropolitan University,* p. 4.

materials, will become increasingly sought after from secure countries.[205] Concerns have previously arisen with Huawei's 5G network, flagged by intelligence services for potential data misuse. Similar worries extend to emerging technologies, such as electric cars and solar panels. For instance, the Estonian secret service has warned that electric cars might employ systems that collect environmental data, and solar panels could gather data through software updates. There's a prevailing concern that this data could ultimately be accessed by the Chinese government, given the close ties between large Chinese technology firms and state authorities. This situation underscores the need to produce certain technology components within the EU rather than in China to mitigate security risks. Additionally, this shift would increase the demand for critical materials necessary for manufacturing these components locally, highlighting the importance of securing a stable and secure supply of these essential resources within Europe.[206]

The fact that certain areas related to critical materials are designated as critical, meaning they have a significant impact on security, can also be inferred from broader European legislation. A prime general example is the Internal Affairs Commission's directive, which mandates EU member states to ensure critical services essential for maintaining societal functions and economic activities integral to the EU internal market. This directive serves as a superior legislative framework intended to strengthen the resilience of these critical areas against various types of risks, including human, natural, accidental, and intentional. These critical areas must be reviewed every four years to update new risks brought by societal developments or external events. Naturally, some key sectors of the economy have their own legislative adjustments, for instance, the energy and transport sector. The Critical Entities Resilience Directive is divided into 10 sectors.[207] The JRC Science Report, which tracked key sectors in relation to strategic materials, identified 5 sectors, with 4 of them falling under areas described by the mentioned directive, including: energy (explicitly renewable energy in JRC), transport (E-mobility in JRC), digital infrastructure (ICT sector in JRC), and Space sector (defense and aerospace, as described in the previous chapter). The sector JRC identified as key in the CRM area is also energy-intensive industry, which, however, the directive does not consider.[208]

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[205] European Commission. "Joint Communication to the European Parliament, the European Council and the Council on 'European Economic Security Strategy'." Brussels, June 20, 2023. JOIN(2023) 20 final.
[206] Estonian Foreign Intelligence Service. The Advance of Chinese Technology. Accessed April 10, 2024. https://raport.valisluureamet.ee/2024/assets/VLA_ENG-raport_2024_240122_Web_6-3.pdf.
[207] European Commission. "Enhancing EU Resilience: A Step Forward to Identify Critical Entities for Key Sectors." Press Release, July 25, 2023. Brussels: European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3992.
[208] European Commission, Joint Research Centre.

Analyzing the mentioned economic sectors, we find that the greatest weakness exists in relation to clean energy technologies. Here, there is a significant dependence on China, especially in wind energy technologies, which require rare earth elements (dependence on China 85-100%) and Boron (100% dependence on Turkey). Solar panels are also problematic, where besides silicon metal, Gallium and Germanium are needed, with the largest dependence on China in the processing part. An alarming fact is also that the EU countries import finished solar panels largely from China, accounting for 72%, while only 2% are produced in Europe.[209] This is one of many examples showing that dependence is largely also on final products. A major future challenge will also be electrolysis, which is used to produce the often-emphasized hydrogen technologies. Here, the most critical materials are needed, 22 out of the 27 listed in the JRC study.[210]

Batteries are linked both to clean energy and clean mobility. A large portion of primary sources comes directly or indirectly from Chinese sources, especially Lithium, natural Graphite, Cobalt, and others.[211] The question of how European industry will manage the competitive fight for electromobility remains. However, its dependence on China in terms of critical materials and final products necessary for electromobility is alarming, confirmed by the fact that China controls 75% of the world's battery capacities.[212]

In this case, we can already see specific threats within the EU territory. Swedish battery manufacturing companies, which are among the leaders in this field on the European continent, have been facing supply disruptions of graphite from their Chinese suppliers since 2020. According to available sources, these supplies completely disappeared in 2021-2022. Behind this issue, several signals are evident. China and Sweden have had several minor diplomatic disputes, with the most visible being the awarding of the PEN club prize to Gui Minhai for the defense of free speech. However, perhaps the most important aspect is the attempt to limit competition. Chinese companies are now expanding into Europe. For example, they have established firms in Poland and Hungary, where CATL, the world's largest battery company from China, has started production. In countries like Poland and Hungary, the influx of graphite has sharply increased. This is an example of how China can significantly damage European

[209] Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study." JRC Science Policy Report. European Commission, Joint Research Centre, p. 149.
[210] Ibid.,144.
[211] Joint Research Centre. "Raw Materials Information System." Accessed April 10, 2024. https://rmis.jrc.ec.europa.eu/bvc#.
[212] Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study.", p. 157.

strategic companies while strongly supporting its own during expansions into foreign markets and therefore threaten economic security.[213]

Finally, we have information and communication technologies (ICT). These technologies are used by almost everyone nowadays and are also part of all important economic sectors. ICT technologies are also very important in the transition to a zero-emission society.[214] They can ideally optimize the performance of energy sources and the grid. Materials that are needed to produce semiconductor wafers, such as germanium, borate and rare earths, may be at risk in the future. This is a similar scenario to that of wind technologies, as these are materials on which there is almost 100% dependence on China (Germanium, rare earths) and Turkey (Borate).[215]

The JRC study again mentions permanent magnets, on which China has majority control, as the biggest weakness. In semiconductor chip production, there is an increased risk of dependence on gallium nitride and photoresist chemicals, which are concentrated in large numbers in Japan, but which represent a relatively low risk from a political point of view. In terms of components, by far the largest demand is for chips, which account for up to 71% of total demand.[216]

These chips can be found in all types of electronics, such as computers, telephones, data servers and, of course, critical infrastructure systems. From this point of view, the concentration of logic chips in Taiwan, which accounts for up to 40% of global capacity, represents quite a big risk. The risk of dependence on Asian chip manufacturers was demonstrated during the covid-19 pandemic when there was a major supply shortage of these components. This is also the reason why in August 2023 the EU approved the so-called Chips Act, which is to massively support the development of this industry on European territory.[217] ICT technologies are nowadays playing an increasingly key role in geopolitics. Through these means, key communication takes place for the transmission of internal and external communications. Especially then, data networks are now part of all critical infrastructure such as energy, transport, finance or healthcare.[218] In the event of a failure of these systems, major paralysis occurs and often puts society in an untenable situation. Attacks on these critical networks are

[213] The Economist. "Why Is China Blocking Graphite Exports to Sweden?" The Economist, June 22, 2023. https://www.economist.com/business/2023/06/22/why-is-china-blocking-graphite-exports-to-sweden.
[214] OECD. Security of Supply for Critical Raw Materials: Vulnerabilities and Areas for G7 Coordination. p. 3.
[215] Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study.", p. 167.
[216] Ibid, 167.
[217] European Parliament. "Chips Act – the EU's Plan to Overcome Semiconductor Shortage." Published February 15, 2023. Last updated July 11, 2023.
[218] European Commission. "The Role of ICT in Critical Infrastructure Protection." April 12, 2024. https://cordis.europa.eu/programme/id/H2020_DS-03-2015/it.

increasingly occurring through various types of hybrid warfare. A prominent example is the attack on the Nord Stream pipeline, which has alarmed the security community regarding possible other attacks on the seabed, such as data cables.[219]

[219] Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU – A Foresight Study.", p. 171.

Conclusion

This master's thesis examines the security implications of critical materials from a comprehensive perspective. It underscores how climate change, central to European legislative efforts such as the Green Deal and climate legislation targeting carbon neutrality by 2050, heightens the importance of these materials. Critical materials are not only vital for decarbonization through green technologies—expected to see demand surges of hundreds to thousands of percent in the coming decades—but are also crucial for military technologies, directly impacting the security of European military capabilities. The EU's reliance on critical materials from a limited number of states introduces risks similar to previous dependencies on Russian fossil fuels, which significantly compromised European sovereignty during the Ukraine crisis.

The thesis highlights two interlinked strategic concepts: economic security and strategic autonomy. Economic security is essential for maintaining the continent's prosperity and requires a reliable supply of critical materials for producing key technologies that ensure global competitiveness. Strategic autonomy, a cornerstone of recent EU legislation, is driven by past crises such as NATO's instability under President Trump, the COVID crisis, and the Ukraine war. These events have shown the EU's need for self-reliance, leading to the enactment of the Critical Raw Materials Act, which seeks to mitigate risks from excessive dependencies that could disrupt the supply chain and threaten Europe's economic and social stability.

However, the EU's strategy faces challenges in actionability. Domestic capabilities to mitigate dependency are hampered in the short to medium term by extensive permitting processes, stringent environmental standards, and labor cost issues that impact competitiveness. In multilateral efforts, the EU often collaborates with like-minded states through initiatives like the Raw Materials Club. Yet, these partnerships sometimes lack the capacity to secure safe material supplies to Europe, hindered by competitive disadvantages against countries with lower costs and standards.

Strategic partnerships have seen positive developments with agreements on critical materials, but there remains uncertainty about the reliability of these partners due to their foreign policy orientations. High-risk factors also include political instability in supplier countries, particularly in Africa. The EU's ideologically driven approach, focusing on environmental and social standards, can sometimes conflict with pragmatic needs. Unlike the EU, countries like China,

which prioritize pragmatic over ideological considerations, have effectively secured influential positions in mineral-rich states.

The risk of dependence on China is starkly illustrated as Chinese companies are present in almost every aspect of the supply chain for critical materials. The greatest vulnerabilities lie in raw materials for rare earths and battery metals, where China's control is near total and extends even to reserves in foreign territories. China's ability to leverage these materials as geopolitical tools is growing, posing risks that could impact Europe's ability to conduct an assertive foreign policy.

How does European legislation influence dependence on critical materials and how does it attempt to address this issue?

European legislation plays a significant role in managing critical materials, which are extremely important for addressing climate change as they are used to produce the green technologies essential for decarbonization. Driven by the EU's ambitious climate goals, the Green Deal aims for climate neutrality by 2050, a target firmly established by the Climate Law, demonstrating a strong commitment to environmental sustainability. Key policies such as the Fit for 55 legislation and the Net-Zero Industry Act set clear short-term goals that emphasize the importance of these issues. The Fit for 55 sets strict climate targets for 2030, and the Net-Zero Industry Act offers financial aid to sectors working towards a zero-emission economy.

To mitigate potential supply disruptions—such as the semiconductor shortage during the COVID pandemic or the gas crises due to the conflict in Ukraine—the European Union has enacted the Critical Raw Materials Act. Although the primary strategy of this legislation focuses on enhancing domestic production, this thesis has found that, from a short to medium-term perspective, it will be more crucial to seek new reliable partners, especially for the most strategic metals, due to Europe's relatively modest internal production capabilities. The EU acknowledges that depending up to 65% on imports from a single country by 2030 is acceptable, indicating that, despite efforts to increase local sourcing, maintaining a focus on importing from reliable partners remains essential. This strategy is an important part of the EU’s strategic autonomy and economic security, aiming to secure the sustainability of its environmental goals by establishing a stable and reliable supply chain for critical materials.

Which critical materials are most important for Europe from a strategic perspective and what are the risks associated with supplier countries?

The most significant risk is associated with rare earth elements, where the European Union's dependency is nearly total. This makes reducing reliance on these essential materials, used in everything from military to energy and digital technologies, extremely challenging. Another significant concern is the future high demand for battery materials like lithium, cobalt, or graphite. Although dependency on China for these resources is considerable, it is somewhat more manageable due to their broader global distribution. For instance, lithium, primarily sourced from Australia and Chile—both viewed as friendly nations—presents a viable alternative. However, the substantial Chinese investments in the lithium sectors of these countries complicate efforts to reduce this influence. Addressing the concentration of materials like cobalt, which is heavily controlled by China through companies that manage up to 80% of its supply primarily from countries like the Democratic Republic of Congo (DRC) or Zambia, is even more complex. The political instability and corruption in these countries could allow authoritarian states to solidify their influence further, potentially disrupting European Union plans and collaborations in these regions.

The risks are compounded by China's potential to restrict exports of certain critical materials, a tactic previously used against Japan in 2010 and threatened against the United States in 2018. For instance, last year, China required state approval for the export of germanium and gallium, complicating logistics and giving Chinese authorities significant control over these supplies. Moreover, China has also banned the export of refining technologies for rare materials, reflecting the ongoing technological rivalry between the West and China. These actions introduce substantial risks and tensions, undermining the economic resilience of European states, which rely heavily on China for these critical materials. Additionally, the potential escalation of conflict in Taiwan, which China claims as its territory, poses further risks. The United States has expressed its commitment to defend Taiwan, and in the event of a conflict, the European Union would likely support the United States as a strategic ally. This alignment could prompt retaliatory measures from China, potentially leveraging its control over critical materials as a form of economic retaliation.

Is the European Union primarily value-oriented in its strategies for seeking new strategic partners?

A The European Union, as an entity that values democracy, human rights, and the rule of law, usually prefers to work with countries that share similar ideals, especially in the framework of its strategic autonomy. However, because critical materials are so important, the EU sometimes has to work with countries that don't necessarily align perfectly with its ideals. This includes

countries like Kazakhstan and Uzbekistan, or nations in Africa such as Rwanda or the Democratic Republic of the Congo, which have significant issues with human rights.

The EU is trying to broaden its collaborations as much as possible. It's setting up new groups and signing deals with developed countries and important global players who are open to cooperation but aren't directly competing against the EU, like Mercosur countries or India. It also maintains strategic relationships about critical materials with countries like Japan, Canada, and the USA, which are more aligned with the EU.

Even though the EU must be practical sometimes, it still promotes strategic partnerships that support its ideals, such as initiatives for climate action and civil society support. But this strategy can make it harder for the EU to be as influential as countries like China, which are more flexible and pragmatic in how they handle their international cooperation around critical materials.

Now let's look at the results of the two hypotheses.

The dependence of the European Union on undemocratic and unstable states increases the risk of disruptions in the supply of strategic raw materials. Major players may exploit their dominant position as leverage in resolving international political issues, while developing countries threaten supplies due to their instability and unclear political orientations.

This hypothesis was confirmed in the thesis, partly through the description of the behavior of certain states in this issue, particularly China, which used critical materials as a weapon against European allies such as Japan. It also currently demonstrates its restrictive behavior in imposing conditions on the export of certain materials. Instability was confirmed mainly through the WGI index from the World Bank, as well as by a general description of the situation in individual countries. However, it's crucial to note that many of these threats are primarily theoretical at the current time.

The European Union's strategy to reduce its reliance on critical materials from undemocratic and unstable regions by partnering with like-minded states is unlikely to significantly decrease its dependency in the short to medium term, due to geopolitical and practical constraints.

This hypothesis has been largely confirmed. The thesis suggests that the new collaboration with like-minded states is primarily at a theoretical level of values. The European Union faces a significant challenge in that many strategic materials cannot be sourced solely from friendly countries, and not all friendly countries process and extract these materials on their territory for economic and other reasons. Even if the process could be accelerated and states started

extracting these materials regardless of economic reality, it would not be very significant for the aforementioned short-to-medium-term outlook, as preparing such projects can take up to 15 years. Therefore, the EU focuses on forging new partnerships with states that are not like-minded at least in terms of values but have important strategic materials. We can see this in strategic agreements with Kazakhstan and Uzbekistan, which have a political orientation more towards Russia and China, as well as in African countries like the DRC and Zambia, where there are human rights issues. However, what may pose a black swan event is the fact that technology can significantly change the trend of dependence on certain strategic materials due to development. Thus, some materials that we consider endangered today may not be so in the future thanks to progress. Similarly, better recycling or further advances in maintaining materials in circulation may also contribute to this situation.

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