The Hague Centre for Strategic Studies

Cobalt mining in the EU

Securing supplies and ensuring energy justice

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Executive summary

The European Green Deal requires countries to move from a fossil fuel-based energy system to climate neutrality. Yet renewable energy technologies are much more mineral intensive than current ones.[1] Rising global competition over the supply of critical minerals poses serious challenges to the success of the European Union's (EU) energy transition and its goals of strategic autonomy. This report analyses the EU's demand for cobalt in the next decades and the possible contribution of domestic mining to security of supply and energy justice.

Cobalt is essential in manufacturing lithium-ion batteries (LIB) for electric cars and stationary applications, thus bearing significant weight in the energy transition. Ramping up domestic cobalt mining could contribute to European open strategic autonomy, as 70% of global cobalt supply is mined in the Democratic Republic of Congo (DRC) and 70% of global cobalt refining capacity is in China.[2] Next to that, domestic mining could mitigate some of the negative consequences of outsourcing mining and refining activities to countries with less strict environmental, social and governance (ESG) standards.

The future contribution of domestic cobalt mining to European demand in 2035 could amount to 3.1%.[3] This was calculated based on the average annual output of current EU cobalt mines, under the assumption that some of the identified deposits would also be developed. Despite the relatively small contribution of domestic mining, it remains relevant to analyse the obstacles and possibilities for developing EU cobalt mines, especially since some of these findings can be applied to other critical raw materials (CRM) that are more abundantly present throughout EU member states, such as lithium.

Strategic dependencies should be evaluated along the LIB value chain and not solely at one stage, whether mining, refining or battery cell manufacturing. Although Finland is the world's second largest cobalt refiner, increased domestic mining without expanding refining capabilities would not remove the dependency on non-EU cobalt used for LIBs. This report contributes to a holistic understanding of Europe's strategic dependencies by offering an overview of the European mining landscape.

Four prominent obstacles pose a strain on mine development. While the first is specifically applicable to cobalt, the other obstacles concern the European mining industry more broadly. The first issue is cobalt's by-product dependency. Because of its low ore grading in the EU, cobalt can only be mined as a by-product of copper and nickel. In other words, cobalt production cannot be increased separately but has to go hand in hand with the production of copper and nickel. If conditions for mining for either of these two minerals are not favourable, the supply of cobalt cannot be ramped up. For instance, mining company Boliden has recently closed a mine site at Kylylahti in Finland even though it was identified as a commercially viable project for cobalt extraction. The

[1] Benjamin K. Sovacool et al., "The Decarbonisation Divide: Contextualizing Landscapes of Low-Carbon Exploitation and Toxicity in Africa," *Global Environmental Change* 60 (January 1, 2020): 1–19, https://doi.org/10.1016/j.gloenvcha.2019.102028.
[2] "Charting a Path towards Greater Security and Sustainability" (Brussels: European Commission, March 9, 2020), https://ec.europa.eu/docsroom/documents/42849; "Cobalt Market Report 2021" (Cobalt Institute, 2022), 4, https://www.cobaltinstitute.org/wp-content/uploads/2022/05/FINAL_Cobalt-Market-Report-2021_Cobalt-Institute-3.pdf.
[3] Although more cobalt deposits might be discovered over the coming years through increased drillings, it can take 10 to 15 years to develop a cobalt mine, which is why this report has only included geological deposits that are currently well known and could potentially be developed in the relative short term. For details on the method, see section 'EU cobalt ore deposits'.

nickel deposits were no longer economically suitable for mining, leaving the relatively large cobalt deposits untouched.

The second obstacle concerns the high energy prices in the EU. Especially with the war in Ukraine causing extreme volatility in energy markets, energy prices pose severe limitations to high-intensity industries. This has been exemplified by the temporary shut-down of 10% of the aluminium industry and 40% of the Zinc industry in 2022.[4] Access to affordable clean energy could be a game changer in developing mines in the EU. Companies like Anglo American are working on 'mines of the future' that would decrease some of the energy costs. These mines are much more energy efficient than other current high-intensity industries in the EU. For instance, the need for ventilation, which usually constitutes for a large part of energy usage, is eliminated through automated underground fleets.

The development of a 'two-tiered' cobalt market could encourage the mining of cobalt despite the relatively high costs and its by-product dependency. Since the EU's Conflict Minerals Regulation and other responsible mining initiatives only allow sustainably sourced materials to be imported, a 'European premium' for cobalt could arise, which means that prices of responsibly sourced cobalt will be sufficiently high to cover the costs of mining. Moreover, the desire for strategic autonomy could push the EU to promote mine development even though it is not the most cost-effective option. The European boycott on Russian oil in 2022 showed that geopolitical considerations could trump economic aspects in European decision-making.

The third obstacle to mining in Europe concerns the lengthy permitting procedures for mine development, which impact the attractiveness of investing. Prospects of return on investment are uncertain due to the cumbersome and opaque permitting process. In some cases, transparency regarding the development of the permitting procedure of a project is missing for investors.[5] During the process, changes cannot be made to the mine plans. The issue of lengthy permitting procedures should be tackled and transparency throughout the process should be increased.

The fourth and perhaps most prominent obstacle for mine development in the EU is public opposition. Local communities are concerned about the environmental impacts of mines but also about their impact on local aesthetics. The reputation of mining in European culture has suffered since coal mining has dominated most of the mining discourse in recent decades and has given it the image of an impactful and polluting industry. Over the past years, several European mining projects have been delayed or halted due to lack of public support.

The European Union currently has regulations that aim to limit environmental and social impacts throughout its value chain of minerals. The aspiration is only to import ethical and responsibly sourced supplies, as stated in the Conflict Minerals Regulation.[6] Nevertheless, this is difficult to trace, and conflict minerals often still enter the European market through Chinese refineries.[7] Blocking mining activities in the EU under the conception that it impacts the environment is hypocritical, since the EU would simply import materials from elsewhere, where environmental laws are less strict and local communities are harmed. Understanding that the energy transition will go hand in hand with the expansion of mineral extraction worldwide, whether that is desirable or not, is

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[4] Andy Home, "Europe's Aluminium Output Slides as Energy Crunch Bites," *Reuters*, May 25, 2022, sec. Commodities, https://www.reuters.com/markets/commodities/europes-aluminium-output-slides-energy-crunch-bites-2022-05-24/.
[5] Interview conducted by authors with Hampus Dynebrink, Boliden AB, 2022.
[6] European Commission, "Conflict Minerals Regulation," European Commission, 2017, https://policy.trade.ec.europa.eu/development-and-sustainability/conflict-minerals-regulation_en.
[7] Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.

necessary for the EU to make its energy transition just. Responsible sourcing is a justification for increased mining in the EU.

Domestic mine development could become more attractive if communication is improved with local communities about the need for mining activities while acknowledging that mining will always impact the local environment. Strict regulations and high sustainability standards will ensure minimal environmental impact in the EU compared to countries with weaker institution. At the same time, local opposition of European communities can also be attributed to the 'not-in-my-backyard' syndrome. Communication and awareness campaigns of the importance of the EU to secure cobalt for the energy transition through, among others, domestic mining might reduce some of the negative public sentiments.

The EU will still need strategic partnerships with countries like Australia and Canada, as the contribution of domestic mining will remain rather limited. The mining due diligence requirements in these two countries will likely comply with the European premium, allowing the EU to import responsibly sourced cobalt. Next to that, the EU should invest in professionalizing the artisanal mining sector in the DRC, which would decrease the negative consequences on livelihoods and increase the availability of sustainably sourced cobalt.[8]

Ultimately, by ramping up recycling rates and taking action to decrease demand, the EU could become completely self-reliant for cobalt supply by 2050.[9] Until then, however, domestic mine development could contribute to mitigating the potential supply chain disruptions given the extreme pressure on mineral supply chains in the next decades.[10]

[8] "Professionalizing Artisanal Mine Sites," *Fair Cobalt Alliance*, accessed September 27, 2022, https://www.faircobaltalliance.org/approach/professionalizing-artisanal-mine-sites/.
[9] Liesbet Gregoir and Karel Van Acker, "Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge" (KU Leuven, July 13, 2022), https://eurometaux.eu/media/jmxf2qm0/metals-for-clean-energy.pdf.
[10] IEA, "The Role of Critical Minerals in Clean Energy Transitions," 2020, https://iea.blob.core.windows.net/assets/24d5dfbb-a77a-4647-abcc-667867207f74/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

Factsheet

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Cobalt mining in the EU
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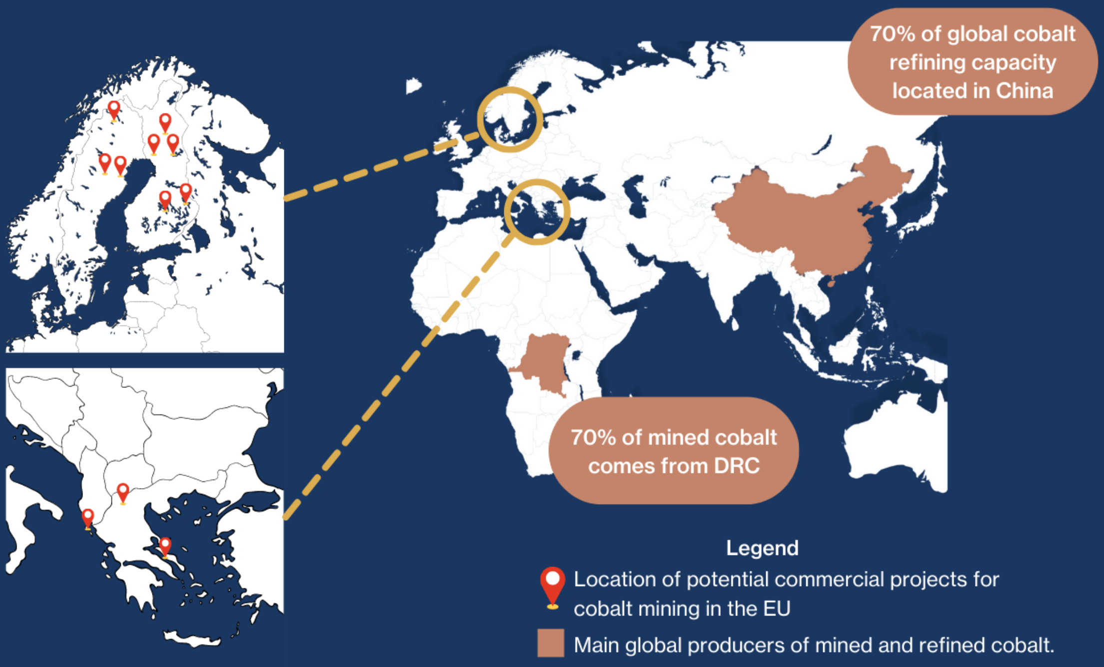
Mining potential in Europe and current supply dependencies



Domestic supply of cobalt

Information about the need to expand mining activities in the energy transition and the impact of mining abroad might decrease public opposition.

To expand mining and refining activities in Europe, a more favourable business environment and policies are needed to attract investments.

Permitting procedures should become more efficient without compromising social and environmental standards.

Demand for consumer products that use cobalt can be reduced through policies like shared mobility.

Domestic recycling can significantly reduce EU's strategic dependencies beyond 2030-2035.

Securing non-EU supply of cobalt

Domestic mining of cobalt could only provide a fraction (3.1%) of EU's demand in 2035.

Cooperating with Australia, Canada or other strategic partners can ensure cobalt supplies that comply with the EU's responsible sourcing requirements.

The global cobalt value chain should be improved. Investing in professionalising the artisinal mining sector can reduce the social and environmental impact of mining abroad.

The findings are also applicable to European mining of other critical minerals to the energy transition.

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Information and transparency ... 43

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List of Abbreviations

Artisanal Mining Sector	ASM
Critical Raw Materials	CRM
Democratic Republic of Congo	DRC
European Battery Alliance	EBA
European Union	EU
Electric Vehicles	EV
Fair Cobalt Alliance	FCA
Just Transition Mechanism	JTC
Lithium Iron Phosphate	LFP
Lithium-ion Battery	LIB
Nickel Cobalt Aluminium Oxide	NCA
Nickel Manganese Cobalt Oxide	NMC
Original Equipment Manufacturers	OEM
Qualitative Document Analysis	QDA
Raw Materials Initiative	RMI
Stratiform Sediment-hosted Copper-Cobalt	SSHC
United Nations Economic Commission for Europe	UNECE
United Nations Classifications Framework	UNFC
Vanadium Redox Flow Batteries	VRB
Worldwide Governance Indicator on Political Stability and Absence of Violence/Terrorism	WGI-PV

1. Introduction

In recent decades, mitigation efforts to limit global warming to 1.5 degrees have received increasing attention.[11] Committed to the Paris Agreement and the European Green Deal, European governments aim to reduce the use of fossil fuels for energy production and reach climate neutrality by 2050. Yet the energy transition comes with its own set of challenges. The expected low-carbon energy system is much more material intensive than our current fossil-fuel based one. The demand for minerals essential to green technologies will dramatically increase, posing geopolitical, economic and environmental challenges to the European Union (EU) and its members. One of these critical minerals is cobalt.

Cobalt plays a vital role in the energy transition. The lithium-ion battery (LIB) industry's demand for the mineral will increase exponentially as a result of production growth for stationary batteries and electric cars.[12] To mitigate potential shortages, the EU and its members are adopting strategies to provide a stable supply of the minerals that are vital in bringing about the energy transition.[13] Although the EU is actively pursuing trade deals and strategic partnerships, less attention is paid to the possibilities for domestic mining of cobalt within its borders.[14]

Driven by the notion of energy justice and security of supply, this research focuses on the possibilities for – as well as the limitations of – expanding cobalt mining activities in the EU. The perspective of energy justice focuses on limiting the emerging decarbonization divide and distributing the burdens of the energy transition fairly.[15] Given that the EU is reliant on countries such as the Democratic Republic of Congo (DRC) and China for its supply, the topic of domestic cobalt mining is also approached from the perspective of security of supply and strategic autonomy. The question guiding this research is 'What are the prospects of increased domestic mining of cobalt in the European Union as a solution for the region's future demand of the mineral and can it contribute to a just energy transition?'

In the next section, the research aims and methodology are laid out. Subsequently, the cobalt and its lithium-ion battery (LIB) value chains are analysed. The fourth chapter provides practical information on EU cobalt deposits and their mining feasibility. Further, the obstacles to and justifications for developing mines within the EU are discussed. This allows for an assessment of whether domestic cobalt mining can be a suitable strategy for achieving energy justice and strategic autonomy, which is found in the last chapter.

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[11] IPCC, *Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-Industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, 1st ed. (Cambridge University Press, 2022), https://doi.org/10.1017/9781009157940.
[12] Patrícia Alves Dias et al., *Cobalt: Demand Supply Balances in the Transition to Electric Mobility* (LU: Publications Office of the European Union, 2018), https://data.europa.eu/doi/10.2760/97710.
[13] Irina Patrahau et al., "Securing Critical Materials for Critical Sectors" (The Hague Centre for Strategic Studies, December 2020), https://hcss.nl/wp-content/uploads/2021/01/Securing-Critical-Materials-for-Critical-Sectors.pdf.
[14] Alves Dias et al., *Cobalt*.
[15] Sovacool et al., "The Decarbonisation Divide."

2. Research approach

The interdisciplinary nature of this research led to several methods being selected to understand and analyse the different aspects of cobalt mining feasibility in the EU. Below, the research goals and main questions are presented, after which the methods are briefly explained. Subsequently, the analytical approach of the energy justice and security of supply frameworks is explained, and relevant EU policies related to mining in the EU are discussed.

2.1 Research goals

The European Commission's Raw Materials Initiative (RMI) presented in 2008 and updated in 2020, sets out a strategy for the EU to secure critical raw materials (CRM).[16] This strategy consists of three main pillars: 1) securing a fair and sustainable supply of materials from global markets; 2) enhancing the sustainable supply of materials within the EU; and 3) reducing CRM demand through technological innovation and increased recycling.

This research aims to determine the extent to which the EU's future cobalt demand can be provided through domestic mining and, thus, to what extent pillar two is a suitable option. It does so by assessing the EU's geological possibilities regarding cobalt mining and uncovering obstacles and possibilities for mine development. Consequently, this report reflects on the RMI's second pillar and gives recommendations to the EU for areas to focus on to make domestic mining more feasible. The following questions will guide the report:

1. How is the European Union's cobalt value chain currently structured?
2. What areas in the European Union have cobalt ore deposits suited for mining?
3. What are the obstacles to increased mining within the European Union?
4. What are the justifications for increased mining within the European Union?
5. What can the European Union do to increase its domestic mining activities, and what alternative strategies exist for the region to meet its future cobalt demand and achieve energy justice and security of supply?

2.2 Methodology

This research relies on literature review, qualitative document analysis, value chain analysis, the United Nations Classifications Framework for resources (UNFC), and semi-structured expert interviews. The literature review, qualitative document analysis, and value chain analysis mostly answer question 1. The UNFC has been selected as a method to answer question 2. For questions 3, 4, and 5, information was mostly gathered through expert interviews, but qualitative document analysis also contributed to this inquiry.

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[16] "Policy and Strategy for Raw Materials," European Commission, accessed September 26, 2022, https://single-market-economy.ec.europa.eu/sectors/raw-materials/policy-and-strategy-raw-materials_en.

Method 1: Literature review

Before gathering primary data, secondary data on this topic was gathered by conducting a literature review. First, the concepts of energy justice and security of supply were described and applied to the European context. Next, analysing the literature on EU policies that aim at securing CRM supply formed a helpful basis for this research.

Method 2: Qualitative document analysis

In addition to the literature review, this research uses qualitative document analysis (QDA). Since the topic of cobalt mining in the EU has not been explored extensively until now, compiling information from different sets of documents gave a good general overview. The structure of the European cobalt value chain could be laid out by looking for information on cobalt mining discourse and on cobalt use in appliances.

Method 3: Value chain analysis

This report aims to outline the current EU cobalt supply chain. Specifically, the potential supply chain vulnerabilities and the social implications of the cobalt value chain on communities are extensively analysed. Value chain analysis offers an overview of the situation as well as an understanding of weaknesses within the system and required actions.[17] Secondly, it can capture the evolution of the supply chain over time and identify potential problems before they materialize. This way, it can be used as an 'early-warning' system by pointing out potential future liabilities.

Method 4: Calculation of ore deposits

Making a resource estimation of cobalt for the entire EU territory is challenging for multiple reasons: available data is sparse, and because cobalt is mostly mined as a by-product, companies often do not report cobalt grades in their statistics.[18] Next to that, available data is often based on different reporting codes and standards throughout the European Union, which is why the European Commission has recently been trying to promote the use of the United Nations Framework Classification (UNFC) for resources.[19] This framework was created by the United Nations Economic Commission for Europe (UNECE) to harmonize existing standards and reporting codes.

In order to estimate the EU's cobalt ore potential, this research has made use of this framework. The UNFC categorizes ore deposits along the lines of three parameters to determine the feasibility of mine development: environmental-socio-economic viability, technical viability, and degree of confidence. Based on the interaction of the results for each parameter, an estimation of how feasible project development of a certain ore deposit is can be made.

Method 5: Expert interviews

Six (online) semi-structured expert interviews were conducted. Expert interviews served the role of uncovering environmental and social impacts of domestic mining, which is difficult to do through quantitative methodological approaches since their nature is

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[17] Erik R. Larsen, Sebastian Osorio, and Ann van Ackere, "A Framework to Evaluate Security of Supply in the Electricity Sector," *Renewable and Sustainable Energy Reviews* 79 (November 1, 2017): 646–55, https://doi.org/10.1016/j.rser.2017.05.085.

[18] "Cobalt Resources in Europe and the Potential for New Discoveries," British Geological Survey, January 26, 2021, https://www.bgs.ac.uk/news/cobalt-resources-in-europe-and-the-potential-for-new-discoveries/.

[19] S. Horn et al., "Cobalt Resources in Europe and the Potential for New Discoveries," *Ore Geology Reviews* 130 (March 1, 2021): 1–25, https://doi.org/10.1016/j.oregeorev.2020.103915.

complex and knows many nuances and sensitivities. Regarding sampling participants, individuals from different sectors were reached out to, such as the mining industry, academia and NGOs. The list of participants is included in the appendix.

2.3 Analytical framework

This research relies on two theoretical frameworks, namely the energy justice framework and the security of supply framework. Whereas the first primarily focuses on the moral implications of the energy transition, the second is concerned with the aspects of strategic autonomy. Both will be explained below, as well as the relevant policies that the EU has established to achieve energy justice and strategic autonomy in the energy transition.

Energy justice framework

As Jenkins et al. point out, energy systems and social justice are interlinked.[20] In other words, achieving energy justice in the energy transition requires the EU to aim for an energy system in which energy is produced in a sustainable, safe, affordable, and especially socially just way. So far, the sociotechnical transitions framework has dominated the narrative in the energy transition. This framework focuses on the adaptation of energy and transportation systems to climate change whilst trying to include societal factors and socio-political dynamics.[21] However, explicit engagement with the concept of justice is often missing from this transitional framework discourse, leading to the false assumption that the energy justice and energy transition frameworks cannot be combined.[22] As the EU's Green Deal strives for a transition where "no person and no place [is] left behind", considerations of justice are essential.[23]

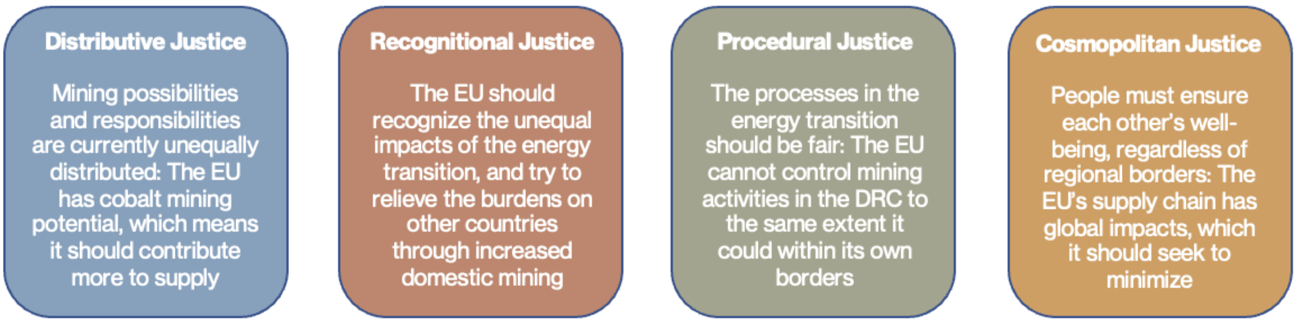

Figure 1. The different aspects of the energy justice framework and their relationship to the EU's role in cobalt supply.

[20] Kirsten Jenkins, Benjamin K. Sovacool, and Darren McCauley, "Humanizing Sociotechnical Transitions through Energy Justice: An Ethical Framework for Global Transformative Change," *Energy Policy* 117 (June 1, 2018): 66–74, https://doi.org/10.1016/j.enpol.2018.02.036.
[21] Francis G. N. Li, Evelina Trutnevyte, and Neil Strachan, "A Review of Socio-Technical Energy Transition (STET) Models," *Technological Forecasting and Social Change* 100 (November 1, 2015): 290–305, https://doi.org/10.1016/j.techfore.2015.07.017.
[22] Jenkins, Sovacool, and McCauley, "Humanizing Sociotechnical Transitions through Energy Justice."
[23] "A European Green Deal," Text, European Commission, 2019, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

The energy justice framework offers four dimensions that should be considered in the EU's energy transition (Figure 1). First, the desirability of green technologies is intrinsically related to issues of specific localities. For instance, the DRC is a popular cobalt mining destination because of the high cobalt grade in the ore. As such, the country is likely to experience an increase in mining, which also impacts its environment. This can be categorised under distributional injustice, which recognizes the unequal distribution of environmental benefits and ills, as well as the allocated responsibilities.[24] In this vein, an increase in European cobalt demand should also bring upon some of the responsibilities associated with increasing supply, such as mining.

Second, the differentiating impacts of the energy transition resulting from the unequal distribution of environmental ills and benefits should be recognized. Essentially, through the lens of recognitional justice, the EU contributes to the negative impacts of supply chains for green technological innovations. In the case of cobalt, its imports are mostly sourced from the DRC, where local communities are negatively impacted by mining activities.[25] Moreover, negative impacts at the end of the material life cycle constituted mainly by e-waste, are also exported by Western countries outside of their territories. Recognizing which communities are impacted the most and acting accordingly should be one of the EU's main considerations in the energy transition.

Third, procedural justice assumes that the processes aiming toward a CO2-neutral energy system should be fair.[26] Within processes such as mining, communities should be able to influence decision-making. Access to legal systems and political rights play an essential role in this. Whilst demanding increased production of green technologies for the energy transition, the EU should ensure that communities are included in the decision-making processes about the distribution of the burdens. As the EU increases its cobalt imports from the DRC, conflicts over mines could be exacerbated.[27] Instead, according to the energy justice perspective, the EU should focus on developing its sourcing potential to be able to exert more influence over the mining activities.

The last of four aspects of the energy justice framework is cosmopolitan justice, which is the moral stance that people must ensure each other's well-being regardless of national borders. Scholars like Sovacool, but also organizations like Amnesty International have pointed out that increased demand for cobalt will lead to an exacerbation of pre-existing human rights abuses in the DRC.[28]

2.4 Just Transition Mechanism

By expanding mining in Europe, not only would the negative impacts on communities in the DRC be mitigated, but the EU would also be able to meaningfully contribute to decreasing impacts within its borders. Different European regions that are negatively affected could be protected by the Just Transition Mechanism (JTM). The JTM aims to

[24] Jenkins, Sovacool, and McCauley, "Humanizing Sociotechnical Transitions through Energy Justice."
[25] Benjamin K. Sovacool, "The Precarious Political Economy of Cobalt: Balancing Prosperity, Poverty, and Brutality in Artisanal and Industrial Mining in the Democratic Republic of the Congo," *The Extractive Industries and Society* 6, no. 3 (July 1, 2019): 915–39, https://doi.org/10.1016/j.exis.2019.05.018
[26] Jenkins, Sovacool, and McCauley, "Humanizing Sociotechnical Transitions through Energy Justice."
[27] Sovacool, "The Precarious Political Economy of Cobalt."
[28] Sovacool; "They Can't Escape the Dust," Amnesty International, May 6, 2020, https://www.amnesty.org/en/latest/news/2020/05/drc-alarming-research-harm-from-cobalt-mine-abuses/.

keep the socio-economic impact of domestic mining activities to a minimum. This would be more difficult to achieve in regions outside of the EU (like the DRC) where European governments have no jurisdiction and communities cannot participate in the EU's decision-making processes like European residents can. The JTM is an instrument that, according to the tenets of procedural justice, would ensure that the regions most affected by the energy transition receive financial support for their adjustment to carbon-free industries. In the period of 2021-2027, 55 billion euros were allocated to regions whose economies largely depend on carbon-intensive industries such as coal mines.[29] This money was spent on providing new job opportunities, offering re-skilling opportunities for people, creating an attractive environment for green investment, and generally supporting regions in their low carbon and resilient climate activities.

However, whether the JTM will offer a solution to energy justice aspects of mining in the EU remains to be seen. The JTM aims to financially support regions where current (carbon-intensive) industries and economies will disappear rather than support regions where new mines will be established. If expanded, the JTM could support the development of cobalt mining activities in the future and provide compensation to affected populations.

Security of supply

In addition to the energy justice aspects of the EU's cobalt supply chain, security of supply and strategic autonomy are strong motivations for looking at domestic mining possibilities. This research deploys the security of supply framework as proposed by Zhang et al., which focuses on pointing out potential technological, environmental, social, and political causes that could threaten energy security.[30]

Analyses of supply security can function as an 'early warning' system that can prevent and mitigate future liabilities.[31] By looking at the different stages of the cobalt supply chain, the EU's most significant vulnerabilities can be uncovered, allowing for the development of detailed strategic roadmaps in the energy transition, including the possibilities of domestic sourcing of materials. Additionally, examining the industries that require the most cobalt, namely battery production and electric vehicle manufacturing, allows for a more holistic overview of the economic opportunities and justifications for increased domestic cobalt mining.

Two important EU initiatives aiming to improve its security of supply are the EU's Raw Materials Initiative and the European Battery Alliance. Their relation to mining in the EU is discussed below.

2.5 EU's Raw Materials Initiative

The Raw Materials Initiative's (RMI) approach is based on the synergy of three main pillars: ensuring future supply from global markets, increasing domestic supply, and

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[29] "The Just Transition Mechanism: Making Sure No One Is Left Behind," Text, European Commission, 2019, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en.

[30] Long Zhang et al., "Measuring and Improving Regional Energy Security: A Methodological Framework Based on Both Quantitative and Qualitative Analysis," *Energy* 227 (July 15, 2021): 1–14, https://doi.org/10.1016/j.energy.2021.120534.

[31] Larsen, Osorio, and van Ackere, "A Framework to Evaluate Security of Supply in the Electricity Sector."

enhancing resource efficiency through recycling and looking for substitutions for CRM.[32] Over the past decade, multiple organizations have been established that aim at supporting increased mining within the EU, such as the 'European Union Raw Materials Knowledge Base' and the 'European Institute of Innovation and Technology's Raw Materials Knowledge and Innovation Community'.

However, diving deeper into these initiatives' activities, it becomes clear that the EU's mineral potential remains largely unexplored, mainly due to limited budgeting for exploration activities. So far, exploration activities were focused on finding non-critical raw materials.[33] Moreover, the organizations established to support the implementation of pillar two have turned their efforts to researching how to improve resource efficiency, which is part of the aims of pillar three. Although this third pillar contributes to limiting the EU's future dependency on cobalt, it seems like the second pillar has remained largely unoperationalized. Therefore, this research will focus on deepening the understanding of the possibilities and obstacles of enhancing domestic sourcing in the EU.

European Battery Alliance

Another major European Union policy initiative that aims to enhance its strategic autonomy in the energy transition is the European Battery Alliance (EBA).[34] The EBA was established in 2017 as part of the EU's new industrial strategy and aimed to domesticize the value chain of LIB. By 2030, 80% of global cobalt production will be used in LIB technology.[35] The LIB industry is therefore the main driver of increased cobalt demand. Currently, the EU is largely dependent on China for LIB cell components. In order to achieve the goals of the EBA, more control over the supply chains of CRM such as cobalt is necessary. In the chapter on the cobalt value chain, the LIB value chain is more extensively discussed.

[32] European Commission, "The Raw Materials Initiative: Meeting Our Critical Needs for Growth and Jobs in Europe," 2008, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A52008DC0699.
[33] Alves Dias et al., *Cobalt*.
[34] "Building a European Battery Industry," European Battery Alliance, accessed September 26, 2022, https://www.eba250.com/.
[35] "Cobalt Value Chain Mapping," *Cobalt Institute* (blog), 2022, https://www.cobaltinstitute.org/responsible-sourcing/cobalt-value-chain-mapping/.

3. European value chains

3.1 Cobalt flows

Cobalt flows are difficult to trace. Throughout most of its life cycle, cobalt is part of various products and technologies.[36] As such, following cobalt flows is most accessible during the stages when it is traded as a separate commodity, which is during the mining, refining, and recycling stage discussed below. To make sure that general trends of cobalt flows in the stages between refining and recycling are covered, this chapter will also investigate the LIB value chain. It should be noted that supply chain analysis is a continuous task rather than a one-time effort and that the findings of this analysis are a snapshot of the contemporary situation. Its conclusions should thus be carefully interpreted and adapted over time.

EU cobalt demand

In 2016, products requiring 24 000 tonnes of cobalt were manufactured in the EU, but goods worth 33 000 tonnes of cobalt that were produced elsewhere were used.[37] Domestic mining currently accounts for about 10% of demand, with approximately 2 100 tonnes mined in 2021.[38]

The EU cobalt demand is predicted to rise significantly in the next years, reaching 53 500 tonnes by 2025 and 288 000 by 2050 (see Figure 2).[39] In order to meet the EU's future needs, global cobalt mining needs to be ramped up.

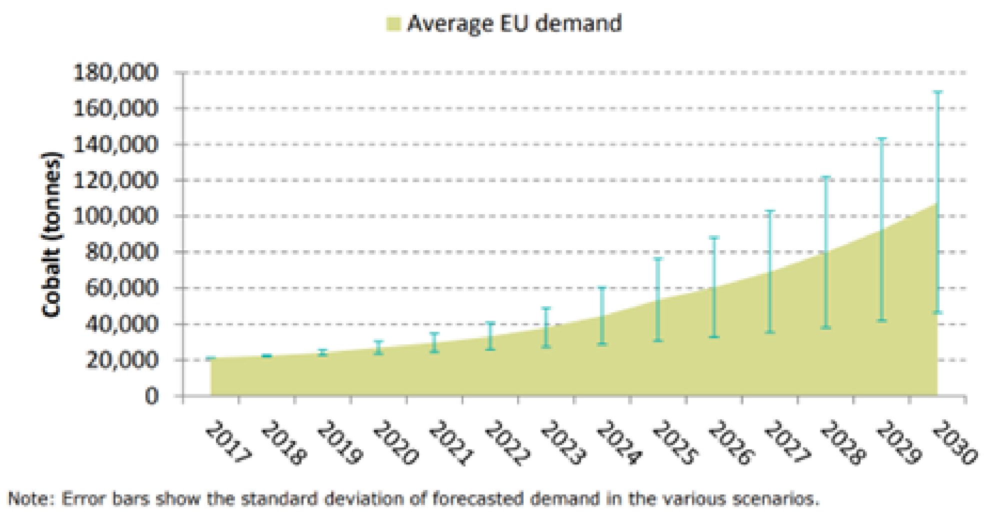

Figure 2 Predicted EU cobalt demand.[40]

[36] Patrahau et al., "Securing Critical Materials for Critical Sectors."
[37] C.T Matos et al., "Material System Analysis of Five Battery-Related Raw Materials: Cobalt, Lithium, Manganese, Natural Graphite, Nickel" (JRC, European Commission, October 29, 2020), https://doi.org/10.2760/519827.
[38] Gregoir and Van Acker, "Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge," 42.
[39] Alves Dias et al., *Cobalt.*
[40] Alves Dias et al.

Cobalt use in appliances

Traditionally, cobalt has mostly been used in applications as a constituent of 'super alloys', which offer strength and durability at high temperatures.[41] However, the most prominent industry currently demanding these super alloys, and thus cobalt, is the lithium-ion battery (LIB) industry. In 2020, it consumed 57% of the global cobalt production, which is predicted to increase up to 80% by 2030, as visualized in Figure 3.[42] Apart from LIBs, cobalt is used in the production of medical applicants, but also in military-related products such as in the airspace industry, where it constitutes a part of jet engines and rockets.[43] This shows how cobalt is not only crucial for the energy transition, but also for defence, something that has gained extra attention throughout the EU after the Russian invasion of Ukraine.[44]

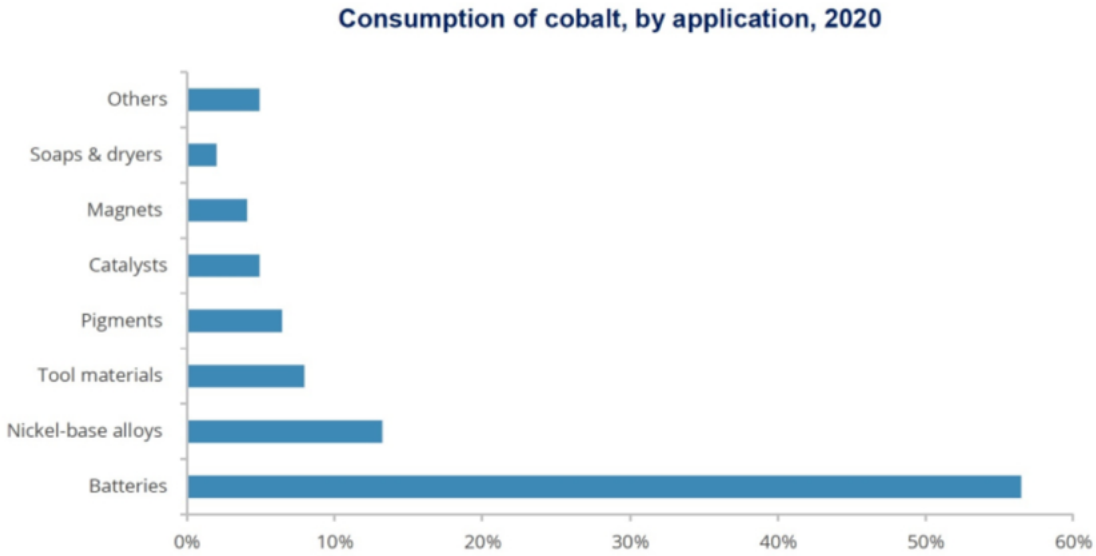

Figure 3 The distribution of cobalt consumption per application.[45]

Figure 4 shows the increase in the percentage of globally produced cobalt that will be used in LIBs up until 2030. Although, the consumer electronics industry was initially driving up the demand for LIBs, it has now become the automotive industry. In 2020, it was predicted that the number of EV models that use LIBs in the EU would increase from 60 to 333 by 2025, which equals approximately 4 million newly manufactured electric cars and vans.[46] This will require 52 000 tonnes of cobalt of the total expected EU demand of 53 500 tonnes in 2025.[47]

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[41] Jeff Amrish Ritoe, "The New Great Game: Securing Critical Minerals Today for a Clean Energy System Tomorrow" (The Hague Centre for Strategic Studies, July 2021), https://hcss.nl/wp-content/uploads/2021/08/The-New-Great-Game-August-2021.pdf.
[42] "Cobalt Value Chain Mapping."
[43] "Industry Overview - Cobalt Industry," Investcom, June 19, 2019, https://www.investcom.com/industry_overview/cobalt/cobalt_industry_19Jun2018.htm; Ritoe, "The New Great Game: Securing Critical Minerals Today for a Clean Energy System Tomorrow."
[44] Max Bergmann, "The Time for Bold EU Action on Defence Is Now," European Leadership Network, October 14, 2021, https://www.europeanleadershipnetwork.org/commentary/the-time-for-bold-eu-action-on-defence-is-now/.
[45] "Cobalt Value Chain Mapping."
[46] Horn et al., "Cobalt Resources in Europe and the Potential for New Discoveries."
[47] Horn et al.

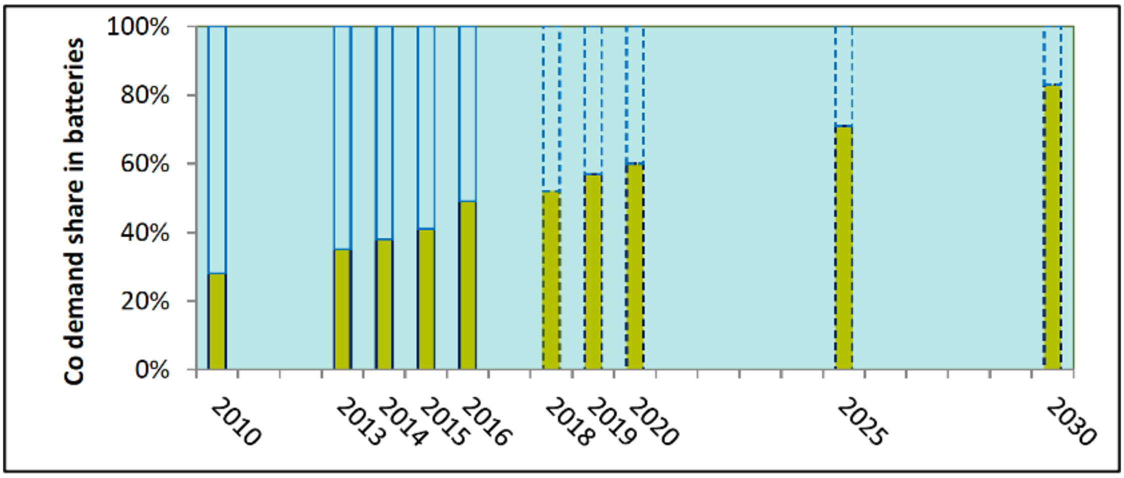

Figure 4 Increase in LIB demand percentage of global cobalt supply.[48]

Cobalt supply

In 2018, global mine production of cobalt reached 168 000 tonnes, 65% of which came from the DRC.[49] The four biggest cobalt mines are located in the DRC and produced 43% of the global supply in 2016.[50] The output of these four biggest mines in the DRC, the Mutanda, Tenke Fungurume, Luiswishi and Lubumbashi mine, is presented in Table 1. In the Mutanda and Tenke Fungurume mines cobalt was mined as a by-product of copper. In contrast, cobalt was mined as a primary material in the Luiswishi and Lubumbashi mines, which is not possible anywhere else in the world. This is because of the exceptionally high cobalt grade in ore deposits in the DRC, making the country very attractive for increased cobalt extraction in the future.[51] Patrahau et al. have pointed out that the geographical concentration of cobalt production in the DRC can be associated with supply risks, especially considering the country's political instability.[52] If the EU remains dependent on cobalt from the DRC, this could cause future supply shortages.

[48] Natalia Lebedeva, Franco DI PERSIO, and Lois BRETT, "Lithium Ion Battery Value Chain and Related Opportunities for Europe," Text, December 19, 2016, https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/lithium-ion-battery-value-chain-and-related-opportunities-europe.

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[50] Alves Dias et al., *Cobalt.*

[51] Horn et al., "Cobalt Resources in Europe and the Potential for New Discoveries."

[52] Patrahau et al., "Securing Critical Materials for Critical Sectors."

Mine name	Country Commodity	Primary Production	Cobalt - production (tonnes)	Global capacity share (%)	Production (tonnes/yr)
Mutanda	DRC	Cu	24 500	20	23 000
Tenke Fungurume	DRC	Cu	16 054	13	16 783
Luiswishi	DRC	Co	7 000	6	3 100
Lubumbashi Slag Hill	DRC	Co	5 000	4	5 500

Table 1 The four biggest cobalt mines in 2016.[53.]

Whereas the DRC is the most prominent player in the mining of cobalt, approximately 70% of cobalt is refined in China.[54] The production of refined cobalt has increased by 400% in the past 20 years, from 27 000 to 119 000 tonnes a year.[55] This growth was mainly driven by the increased production of rechargeable batteries, combined with super-alloys, catalysts and hard metals. In China, cobalt is processed from impure cobalt hydroxide to pure cobalt chemicals, such as cobalt nitrate or cobalt sulphate, through hydrometallurgical and electrometallurgical methods.[56] Approximately 70% of cobalt sulphate, which is mostly used in green technologies such as LIBs, is produced in China.[57] The increase in demand for cobalt sulphate will therefore also most likely increase the EU's dependency on China.

Nevertheless, Finland is the world's second largest refiner of cobalt, having produced 14 000 tonnes in 2021 compared to 104 000 tonnes in China in the same year.[58] Belgium has refining capacity as well. Together, Finland and Belgium provide about 70% of Europe's current demand for refined cobalt.[59] The energy transition will lead to an exponential increase in EU demand. An expansion of domestic mining could also feed into the further development of Europe's refining sector, even though a degree of dependence on China is unavoidable.

Supply risks for cobalt

The DRC and China's cobalt supply concentration could endanger the EU's security of supply. The political instability of the DRC forms a serious supply risk for the EU as most of the cobalt supply in the future will be coming from this country. As the World Bank reported in 2019, the DRC has a WGI-PV (Worldwide Governance Indicator on Political Stability and Absence of Violence/Terrorism) score of -2.23, which is near the lowest possible score of -2.5.[60] In 2020, the DRC scored 7.075% on Political Stability and Absence of Violence/Terrorism.

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53 Alves Dias et al., Cobalt.
54 "Cobalt Market Report 2021," 4.
55 María Fernanda Godoy León, Gian Andrea Blengini, and Jo Dewulf, "Cobalt in End-of-Life Products in the EU, Where Does It End up? - The MaTrace Approach," *Resources, Conservation and Recycling* 158 (July 1, 2020): 1–10, https://doi.org/10.1016/j.resconrec.2020.104842.
56 "Cobalt Value Chain Mapping."
57 Ritoe, "The New Great Game: Securing Critical Minerals Today for a Clean Energy System Tomorrow."
58 "Cobalt Market Report 2021," 29.
59 Gregoir and Van Acker, "Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge," 42.
60 "Worldwide Governance Indicators, 2021, https://info.worldbank.org/governance/wgi/Home/Reports.

Conflicts in the DRC, among other global events, impact the price fluctuation of cobalt on the global CRM market, as seen in Figure 5. Over the past years, conflicts over control of cobalt mines in the DRC have become more prominent.[61] High rates of government corruption in combination with insecurity levels pose severe threats to the stability of cobalt supply for the EU. Because of the high concentration of cobalt mining in the DRC, local disruptions such as natural disasters, market failures, but also political instability can cause supply chain disruptions.[62] The most prominent price peaks were in 1978 and 2008, both because of instability in the DRC (Figure 5). Since conflicts in the DRC are primarily related to the mining industry and are predicted to be exacerbated due to increased cobalt demand, these types of price spikes are likely to occur again.[63]

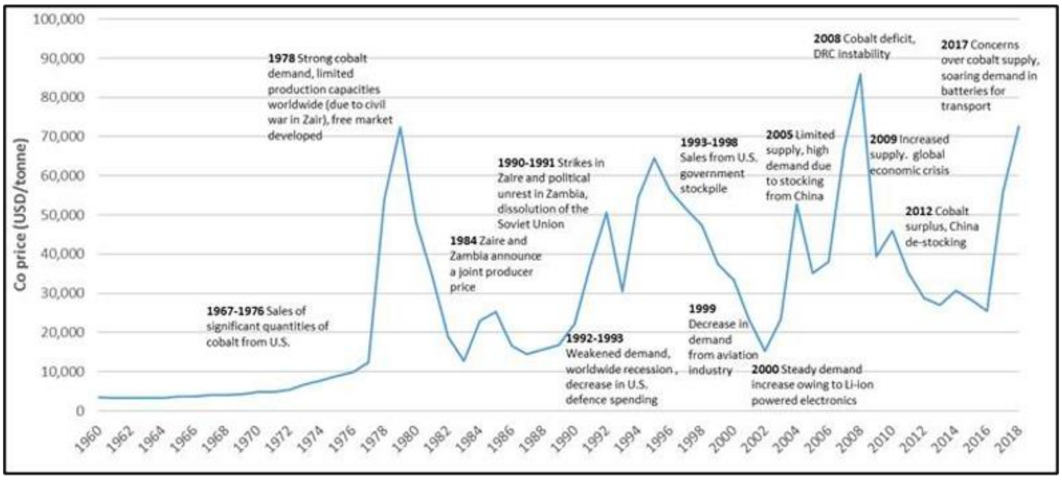

Figure 5 Annual average price of cobalt and significant events affecting it.[64]

Because the supply of cobalt is concentrated, the DRC could use cobalt geopolitical leverage. However, this is not a likely scenario due to the importance of raw material exports for the DRC's economy.[65] Nevertheless, the DRC has imposed export taxes up to 25% on cobalt from 2010 to 2014 in order to stimulate its domestic refining capacity.[66] Export bans and import taxes are examples of uncertainties that the cobalt supply chain is characterized by, which are likely to increase over time with the global demand for cobalt rising.

In the case of China, geopolitical disputes are more likely to pose a threat to supply security. This was exemplified in 2010 when China cut off the material flow to Japan during a diplomatic stand-off, as well as in recent disputes between China and the United

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[61] Twan Huys, *Crimineel Kobalt*, vol. 5, Waarde van de aarde, 2021, https://www.npostart.nl/waarde-van-de-aarde/19-05-2021/KN_1726214.

[62] Amund N. Løvik, Christian Hagelüken, and Patrick Wäger, "Improving Supply Security of Critical Metals: Current Developments and Research in the EU," *Sustainable Materials and Technologies* 15 (April 1, 2018): 9–18, https://doi.org/10.1016/j.susmat.2018.01.003.

[63] Sovacool, "The Precarious Political Economy of Cobalt."

[64] Jaco Huisman et al., Raw Materials in the Battery Value Chain - Final Content for the Raw Materials Information System – Strategic Value Chains – Batteries Section, 2020, https://doi.org/10.2760/239710.

[65] "Cobalt in Democratic Republic of the Congo," OEC - The Observatory of Economic Complexity, accessed September 26, 2022, https://oec.world/en/profile/bilateral-product/cobalt/reporter/cod; Jean Pierre Okenda, "Democratic Republic of the Congo (DRC): Updated Assessment of the Impact of the Coronavirus Pandemic on the Extractive Sector and Resource Governance," Natural Resource Governance Institute, December 2, 2020, https://resourcegovernance.org/analysis-tools/publications/drc-updated-assessment-impact-coronavirus.

[66] OECD, *OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas: Third Edition*, Third (OECD, 2016), https://doi.org/10.1787/9789264252479-en.

States.[67] Exports of refined cobalt could be used by the Chinese government as leverage in case of political conflict.[68] Increasing Chinese investments in cobalt mines in the DRC add another layer of geopolitical leverage against the EU.[69]

Social and environmental impact

Unethical mining practices and weak social and environmental standards are impacting local communities in the DRC.[70] As there are hardly any alternatives for generating income in some regions in the DRC, many people are dependent on the mining sector.[71] This also means that even though child labour, hazardous and perilous working conditions and precarious contracts characterize employment in the mines, people do not have the luxury to reject working in this sector.[72]

Negative social impacts are primarily rooted in the artisanal mining (ASM) sector, which accounts for approximately 20% of DRC cobalt production.[73] The ASM industry is plagued by systemic child labour, difficult working conditions whereby workers often use hand tools and chisels and lack protective gear and other type of equipment.[74] In January 2022, six men died and sixteen were hurt in separate incidents in informal mines at the Kamilombe site in DRC. Heavy rains had caused water flooding in the mines, individual tunnels being blocked off and affecting tunnel walls, leaving people locked inside.[75] Unfortunately such events occur on a regular basis.

Since it is mostly the artisanal mining sector that can respond swiftly to a rise in demand rather than the industrial mining sector, the percentage of ASM's contribution to global production is likely to increase. This means that the issues occurring in artisanal mines will likely be exacerbated as a result of the increased demand by the EU.

Next to its social impacts, cobalt mining contributes to greenhouse gas emissions as it relies on fossil fuels. Land, soil, water and air pollution are further environmental issues associated with cobalt extraction in the DRC, which local communities are confronted with.[76] They are furthermore exposed to hazardous substances such as arsenic, fluoride and cobalt itself, which is impacting human health in the region.[77]

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[67] Ben Blanchard, Michael Martina, and Tom Daly, "China Ready to Hit Back at U.S. with Rare Earths: Newspapers," *Reuters*, May 29, 2019, sec. Technology News, https://www.reuters.com/article/us-usa-trade-china-rareearth-idUSKCN1SZ07V.
[68] Vasileios Theodosopoulos, "The Geopolitics of Supply: Towards a New EU Approach Toæ the Security of Supply of Critical Raw Materials?," *Institute for European Studies*, no. 5 (July 2020): 10.
[69] Luiza Savage, "How America Got Outmaneuvered in a Critical Mining Race," POLITICO, 2020, https://www.politico.com/news/2020/12/02/china-cobalt-mining-441967.
[70] Sovacool, "The Precarious Political Economy of Cobalt."
[71] Sean Goulding Carroll, "Mining Industry Warns against Europe's Drive for Raw Material 'Autonomy,'" www.euractiv.com, October 29, 2021, https://www.euractiv.com/section/batteries/news/mining-industry-warns-against-europes-drive-for-raw-material-autonomy/.
[72] Interview conducted by authors with David Sturmes, Fair Cobalt Alliance (FCA), 2022.
[73] "Cobalt Value Chain Mapping."
[74] "Cobalt Mining in the Democratic Republic of Congo," *Cobalt Institute* (blog), accessed September 26, 2022, https://www.cobaltinstitute.org/cobalt-mining-in-the-democratic-republic-of-congo/.
[75] David Sturmes, "The Fatal Toll of Artisanal Cobalt Mining Continues. Is Responsible ASM Even Possible?," *Fair Cobalt Alliance* (blog), March 1, 2022, https://www.faircobaltalliance.org/blog/the-fatal-toll-of-artisanal-cobalt-mining-continues-is-responsible-asm-even-possible/.
[76] Sovacool, "The Precarious Political Economy of Cobalt."
[77] Shahjadi Hisan Farjana, Nazmul Huda, and M. A. Parvez Mahmud, "Life Cycle Assessment of Cobalt Extraction Process," *Journal of Sustainable Mining* 18, no. 3 (August 1, 2019): 150–61, https://doi.org/10.1016/j.jsm.2019.03.002.

3.2 The lithium-ion battery value chain

The EU is dependent not only on mined and refined cobalt imports, but also on products that contain cobalt, such as lithium-ion batteries (LIBs). This harms the EU's strategic autonomy, which is why the EU is currently working towards developing its battery manufacturing capability through the European Battery Alliance.[78] Increased mining within the EU could be considered vital in the organization's strategic autonomy plan.[79]

As there are countless actors in the LIB value chain, only general trends rather than specific stages can be mapped.[80] Still, geographical concentration of the different segments of the LIB value chain can be identified, which is what this section aims to do. Additionally, exploring how the European Battery Alliance can be supported by domestic cobalt mining, as well as how it would be able to justify, motivate, and stir investment in cobalt mining projects will be discussed.

Cobalt's role in LIBs

LIBs consist of electrochemical cells that are made of three parts: a cathode and an anode connected through an electrolyte. Typically, the anode is based on graphite, and the electrolyte on lithium. The cathode is in many cases made of cobalt and forms an essential part of the battery chemistry.[81] Cobalt acts as a stabilizing material in LIBs with NMC (nickel manganese cobalt oxide) and NCA (nickel cobalt aluminium oxide) compositions. Without cobalt, these are prone to fire hazards and have poor cycling stability, reducing the lifetime of batteries.[82] Because cobalt has a superior resistance to heat compared to other minerals, substituting it with alternatives will lead to worse performance of batteries, making cobalt exceptionally relevant for the LIB industry together with other CRM such as graphite, silicon, titanium, and lithium.[83]

Geographic segmentation and market concentration

The value chain of lithium-ion batteries can be divided into six major segments: mineral extraction and processing, cell component manufacturing, cell manufacturing, battery pack manufacturing, electric vehicle manufacturing, and recycling, as shown in Figure 6.[84]

Currently, the front end of the LIB value chain is dominated by countries such as the DRC and China. The majority of cobalt used in LIBs is extracted in the DRC and refined in China and to a small extent the EU, among other countries. The Chinese battery cell (component) manufacturing industry consumes the major share of global cobalt

[78] European Commission, "The Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe

[79] Anders Hallberg and Helge Reginiussen, "Mapping of Innovation-Critical Metals and Minerals," *Geological Survey of Sweden*, December 2019, 1–81.

[80] Patrahau et al., "Securing Critical Materials for Critical Sectors."

[81] David Coffin and Jeff Horowitz, "The Supply Chain for Electric Vehicle Batteries," *Journal of International Commerce and Economics*, December 2018, 1–21.

[82] "Batteries & Electric Vehicles," *Cobalt Institute*, accessed September 26, 2022, https://www.cobaltinstitute.org/essential-cobalt-2/powering-the-green-economy/batteries-electric-vehicles/.

[83] "Nickel Based Alloys: Everything You Need to Know," *Bortec* (blog), March 15, 2019, https://bortec.de/en/blog/nickel-based-alloy/.

[84] Boon-Brett, Lebedeva, and Di Persio, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*.

production. As of 2020, China controlled around 74% of global battery cell manufacturing, followed by Japan and Korea.[85]

Although the EU is not entirely self-sufficient in any of the presented LIB value chain segments, it is a market leader when it comes to battery pack manufacturing, electric vehicle manufacturing, and recycling, as Lebedeva et al. point out.[86] Due to the long distances that have to be covered, battery cells are often traded between the EU and China as separate components rather than fully assembled battery packs, explaining why the EU is more self-sufficient in the back end of the value chain.

Figure 6 LIB value chain segments.[87]

Domesticizing the LIB value chain

For mining to be competitive, the other segments of the European LIB value chain should to a certain extent be self-sufficient too, making it relevant to look into their domesticizing possibilities.[88] With increased digitalization, European LIB 'factories of the future' could become strong competitors to Asian producers. China has proved that it is possible to catch up with LIB production by closing the production gap with Japan and South Korea in the past decades. With the right strategy, the EU could make similar advancements.[89]

Investment possibilities partly determine whether the LIB manufacturing industry can flourish. With original equipment manufacturers (OEM) of cars facing more stringent emission targets, investment in electric vehicles will be a likely consequence.[90] By expanding the battery cell manufacturing industry within the EU, positive spill over effects such as increased private investment in different segments of the value chain are likely to occur. This means that a properly developed cell manufacturing industry would strengthen both the responsiveness and the competitiveness of the EU's raw materials sector. Additionally, it could stimulate domestic mining and recycling efforts within the EU.[91]

Cobalt substitution

As cobalt is a CRM, policymakers have pushed for the development of batteries with a chemical composition that eliminates the necessity of cobalt. However, cobalt is not easily replaceable in battery chemistries because batteries without cobalt perform worse in terms of cycling stability.[92] Successful findings so far include the vanadium redox flow

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[85] Jakob Fleischmann et al., "Unlocking Growth in Battery Cell Manufacturing for Electric Vehicles," McKinsey, 2021, https://www.mckinsey.com/capabilities/operations/our-insights/unlocking-growth-in-battery-cell-manufacturing-for-electric-vehicles.
[86] Boon-Brett, Lebedeva, and Di Persio, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*.
[87] Lebedeva, DI PERSIO, and BRETT, "Lithium Ion Battery Value Chain and Related Opportunities for Europe."
[88] Boon-Brett, Lebedeva, and Di Persio, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*.
[89] Boon-Brett, Lebedeva, and Di Persio.
[90] Boon-Brett, Lebedeva, and Di Persio.
[91] Alves Dias et al., *Cobalt*.
[92] Boon-Brett, Lebedeva, and Di Persio, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*.

batteries (VRB) and lithium iron phosphate (LFP), which either minimize or remove the need for cobalt altogether.[93] However, these have not yet reached a maturity stage and cost level to overtake the market for the cobalt-intensive battery technologies, which are the most prevalent at this point.[94]

On top of that, the battery factories that are currently under construction within the EU as part of the EBA are geared towards producing batteries with LIB chemical compositions rather than alternative batteries. This means that it could take several years and even decades for the manufacturing industry to respond to new cobalt-free technologies.

Therefore, technology substitution for EVs in the energy transition should not be considered an alternative to mining LIB minerals within the EU. The majority of EV producers have already switched to batteries with cobalt-intensive chemistries because of their advantages in energy density and range, and have additionally spent years on - and invested billions in - perfecting the cobalt cathode chemistries.[95] Therefore, taking away the demand for cobalt in the EV industry is not something that is likely to even start before the mid/late 2030s. If development were to start now, EU cobalt mines would still be able to serve demand for a significant period of time.

Cobalt recycling

By increasing recycling rates and thus decreasing the demand of 'virgin material', i.e., newly mined cobalt, the EU's supply security can be strengthened.[96] Under forecasts based on the EU's current recycling capability, it is assumed that recycling of EV batteries can account for meeting 10% of the EU's cobalt demand in 2030.[97] By ramping up its recycling industry, the EU could become 100% self-sufficient for cobalt supply in 2050. Currently the cobalt recycling industry is still relatively small, partly because battery cells last for around 10 years and recently produced products cannot yet be recycled. Therefore, the stable stream of 'recycled supply' that can be provided by urban mining[98] will be limited until approximately 2030 regardless of the EU's efforts to boost collection rates and recycling efficiency.[99]

After 2030, cobalt recycling from EVs will bring great opportunities, although the EU's current recycling practices are not up to par if it wishes to achieve the goal of complete self-sufficiency by 2050.[100] In 2020, approximately 65% of the recycled cobalt originated from LIBs, which is why focusing on this growing industry as the main source of recyclable material is advisable.[101]

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[93] IEA, 'The Role of Critical Minerals in Clean Energy Transitions', 2020, 88, https://iea.blob.core.windows.net/assets/24d5dfbb-a77a-4647-abcc-667867207f74/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.
[94] IEA, 90.
[95] Ives Dias et al., *Cobalt.*
[96] León, Blengini, and Dewulf, "Cobalt in End-of-Life Products in the EU, Where Does It End Up?"
[97] Alves Dias et al., *Cobalt.*
[98] "Urban mining is the process of recovering and re-using a city's materials." See Merlijn Blok, "Urban Mining and Circular Construction – What, Why and How It Works," *Metabolic* (blog), 2021, https://www.metabolic.nl/news/urban-mining-and-circular-construction/.
[99] Hallberg and Reginiussen, "Mapping of Innovation-Critical Metals and Minerals."
[100] León, Blengini, and Dewulf, "Cobalt in End-of-Life Products in the EU, Where Does It End Up?"
[101] "Cobalt Institute Report: Demand for Cobalt for Batteries Grew at Annual Rate of 10% between 2013 and 2020," Green Car Congress, May 22, 2021, https://www.greencarcongress.com/2021/05/20210522-cobaltinstitute.html.

Recycling can be both functional and non-functional. Functional recycling means that cobalt extracted from end-of-life products is sent back to raw material processing facilities, which can be used again in similar high-end technologies. Non-functional recycling indicates that cobalt will be collected and incorporated in a large-volume material stream with other minerals and end up in lower-end products. Non-functional recycling is also known as ‘downcycling’, which means that the material will end up in products that are uneconomic to recycle, and cobalt will go to waste.[102] Figure 7 shows where cobalt could end up in 2025 under the EU’s current recycling practices, whereas Figure 8 shows its distribution by 2050 under those same standards. As it becomes visible, the ‘downcycling’ of cobalt results in an increased physical loss over the years. Moreover, the e-waste that is exported outside of the EU, which in many cases also has negative humanitarian impacts on the receiving countries, leads to the EU losing part of its potential supply[103] Thus, the EU should focus on the functional recycling of cobalt in order to create more strategic autonomy in the energy transition.

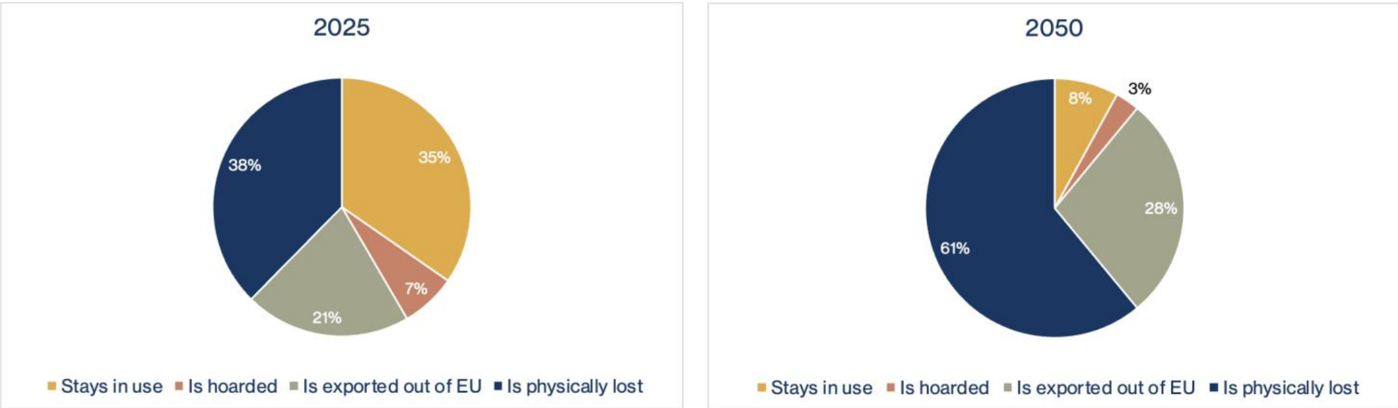

Figure 7 Overview of cobalt destinations in 2025[104] *and Figure 8 Overview of cobalt destinations in 2050.*[105]

[102] León, Blengini, and Dewulf, “Cobalt in End-of-Life Products in the EU, Where Does It End Up?”
[103] Sovacool et al., “The Decarbonisation Divide.”
[104] Data from León, Blengini, and Dewulf, “Cobalt in End-of-Life Products in the EU, Where Does It End Up?”.
[105] Data from León, Blengini, and Dewulf.

4. EU cobalt ore deposits

This chapter focuses on the possibilities of restructuring the cobalt supply chain by looking at the potential of cobalt mining in EU countries. In doing so, the extent to which domestic mining contributes to the EU's future demand, strategic autonomy and energy justice becomes clear.

4.1 Geology of Europe and cobalt resources

Three deposit classes of cobalt production account for 85% of the global supply: magmatic Ni-Co-Cu (Nickel-Cobalt-Copper) deposits; stratiform sediment-hosted Cu-Co (Copper-Cobalt) deposits (SSHC); and Ni-Co (Nickel-Cobalt) laterite deposits.[106] In Europe, black shale hosted deposits and polymetallic veins also account for a large part of cobalt deposits. The deposit types differ in their characteristics, such as the cobalt grade in the ore and deposit size. For instance, not all cobalt can be mined because of the low grade of certain deposits. The map of Europe below shows the location and type of deposits.

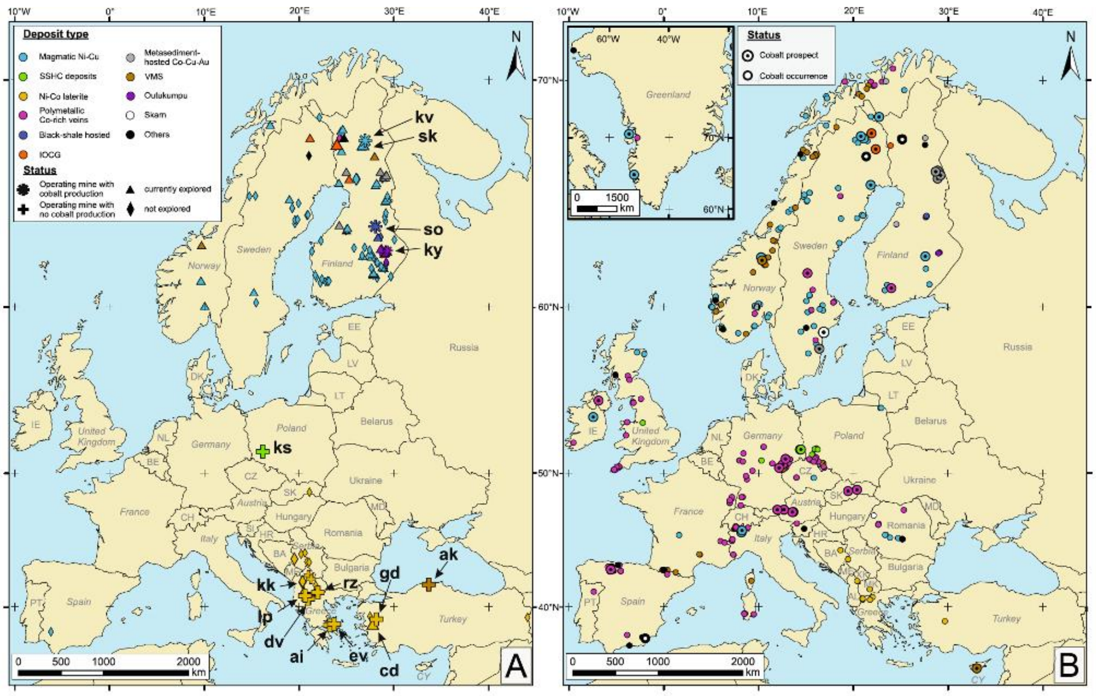

Figure 9A: Cobalt bearing deposits for which quantity estimates can be made, B: Cobalt prospects and occurrences in Europe for which there is not enough information to make resource estimates (Horn et al., 2021).

While it is generally known that cobalt occurs on the seafloor in the shape of so-called 'nodules', there is little knowledge about its present quantities.[107] Because of the uncertainties regarding the technical feasibility and environmental impacts of recovering it, this research does not take seafloor mining of cobalt into account.[108]

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[106] G. M. Mudd et al., "Quantifying the Recoverable Resources of By-Product Metals: The Case of Cobalt," *Ore Geology Reviews* 55 (November 1, 2013): 87–98, https://doi.org/10.1016/j.oregeorev.2013.04.010.
[107] Paul A. J. Lusty and Bramley J. Murton, "Deep-Ocean Mineral Deposits: Metal Resources and Windows into Earth Processes," *Elements* 14, no. 5 (October 1, 2018): 301–6, https://doi.org/10.2138/gselements.14.5.301.
[108] Daniel O. B. Jones, Diva J. Amon, and Abbie S. A. Chapman, "Mining Deep-Ocean Mineral Deposits: What Are the Ecological Risks?," *Elements* 14, no. 5 (October 1, 2018): 325–30, https://doi.org/10.2138/gselements.14.5.325.

Magmatic Ni-Co-Cu (Nickel-Cobalt-Copper) deposits

Magmatic Ni-Co-Cu deposits have cobalt grades in the range of 0.05 to 0.1%. Compared to SSHC deposits that are discussed subsequently, magmatic Ni-Co-Cu deposits are considered to have low cobalt grades. Yet, because their deposit size is relatively large, they still contain significant amounts of cobalt that make mining feasible.[109] Within EU borders, Finland, Sweden, and Greenland have large magmatic Ni-Co-Cu deposits with cobalt grades high enough for mining activities.[110] Figure 10 shows the areas in Fennoscandia where magmatic Ni-Co-Cu deposits (coloured in blue) can be found.

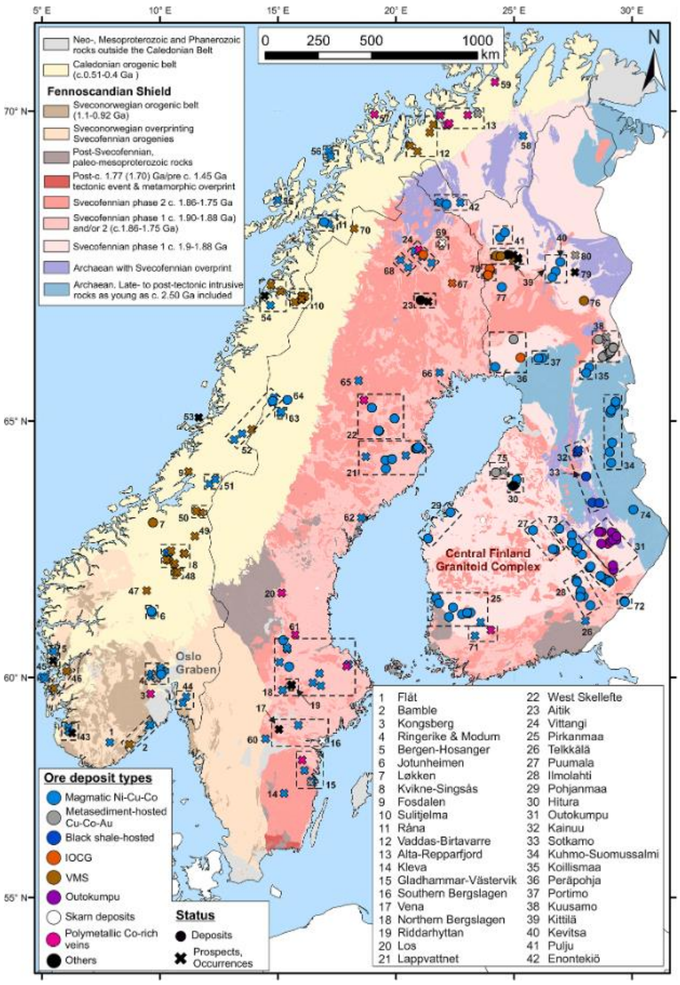

Figure 10 Cobalt bearing deposits in Fennoscandia (Horn et al., 2020).

Stratiform sediment-hosted Copper-Cobalt (SSHC) deposits

The second type of cobalt-containing deposit, SSHC, accounts for 63% of global cobalt supply, and has cobalt grades ranging from 0.001 to 1.08%. The Neoproterozoic Central African Copperbelt, where the DRC is geographically located, is an example of an area where SSHC deposits have been identified and mined. Within the EU, the Mesozoic Kupferschiefer Basin in central Europe, which covers parts of Germany and Poland, also has SSHC deposits that contain up to 122 000 tonnes of cobalt (as can be seen in

[109] Horn et al., "Cobalt Resources in Europe and the Potential for New Discoveries."
[110] Horn et al.

Figure 9, coloured green). However, the cobalt grade in this area is of 0.005 to 0.008%, compared to 0.7 to 1.1% in mines in the DRC, currently making the Kupferschiefer area unfeasible for extraction activities considering the efficiency of mining technologies at hand.[111]

Ni-Co laterite deposits

The third cobalt-bearing deposit type is Ni-Co laterite, which typically occurs in humid and tropical climates since nickel laterite formations containing cobalt are formed under weather conditions marked by high temperatures and large quantities of rainfall. The cobalt concentrations can reach up to 0.22%, the highest of all deposit types, and occur in the South of Europe in countries such as Greece, Albania, Turkey, and Serbia (as presented in Figure 9 in yellow). The total amount of prospective cobalt in these areas is smaller than the magmatic Ni-Cu-Co deposits in Sweden and Finland. Still, some areas in Greece have been identified as potentially commercial for cobalt mine development.

Other deposit types

Besides these three dominant deposit types, there are other geological settings in which cobalt enrichment can be found in Europe, such as the polymetallic cobalt-rich veins in the Kupferschiefer Basin or black shale-hosted deposits in Finland and Sweden. Although the SSHC deposits in the Kupferschiefer Basin contain cobalt grades that are too low to be mined, cobalt has been extracted from polymetallic co-rich veins in Germany and Poland in the past. Nonetheless, in the case of these polymetallic veins, the size of the deposits is unremarkable and estimates of potential cobalt extraction do not exceed 15 000 tonnes.

The deposit at Sotkamo, Finland, is the largest black shale-hosted deposit in the world and is estimated to contain 290 000 tonnes of cobalt.[112] Whereas the cobalt grade of this type of deposit is relatively low (0.02%), the size of the deposits makes it feasible to mine it. This is one of two locations within the EU where cobalt is currently being mined. The other mine is in Kevitsa, also located in Finland.[113]

In Greenland, two cobalt deposits have been identified with a grading of 0.01 to 0.2%. There is insufficient available information to make a resource estimate for Greenland, making it currently unfeasible to develop mining projects. Additional drilling is advised for Greenland in order to make a resource estimate and attract investment.

4.2 European cobalt ore potential

Of 1 342 649 tonnes of identified cobalt in Europe, 483 353 tonnes are commercial or potentially commercial – 107 411 and 375 942 tonnes, respectively (Figure 11). The majority of these are in either Finland or Sweden.[114] Moreover, the Balkans host large viable Ni-Co laterite deposits. However only 90 000 tonnes are located in EU member state Greece. The rest of the deposits in this region are in Albania, Serbia, Kosovo & Herzegovina and Turkey.

[111] Horn et al.
[112] Horn et al.
[113] Horn et al.
[114] Horn et al.

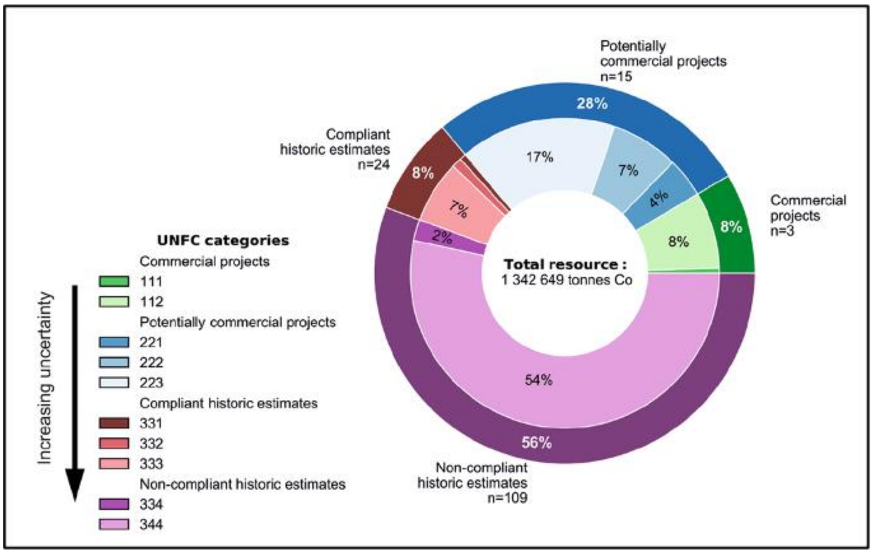

Figure 11 Cobalt resources in Europe classified using the UN Framework Classification (UNFC) categories and classes.[115]

Approximately 752 000 tonnes of cobalt (or 56% of the total) present in Europe cannot be considered as potential supply in the near future. These resources require significant further evaluation in order to prove their viability. Although there are quite some ore deposits in Europe that do contain high-grade percentages of cobalt, their small size makes it relatively unlikely that they will be of economic interest, considering the high costs of developing a new mine that would only operate for a short period of time.[116]

To put into perspective, the largest magmatic deposits in Europe with cobalt grades high enough to make mining feasible are located in Kevitsa and Sakatti in Finland and contain around 30 000 and 20 000 tonnes of cobalt, respectively. Yet, Voisey's Bay in Canada has a deposit size of 123 000 tonnes, and Penchenga in Russia one of 170 000 tonnes.[117]

4.3 European cobalt mining contribution

Although the EU has an estimated total of 483 353 tonnes of cobalt that can potentially be mined in the near future, additional research is necessary to estimate its annual production. Each of the locations that were identified as commercial or potentially commercial is analyzed below. Figure 12A and B show all the locations categorized as (potentially) commercial, together with an indication of the development of the sites.

[115] Horn et al.
[116] Horn et al.
[117] Horn et al.

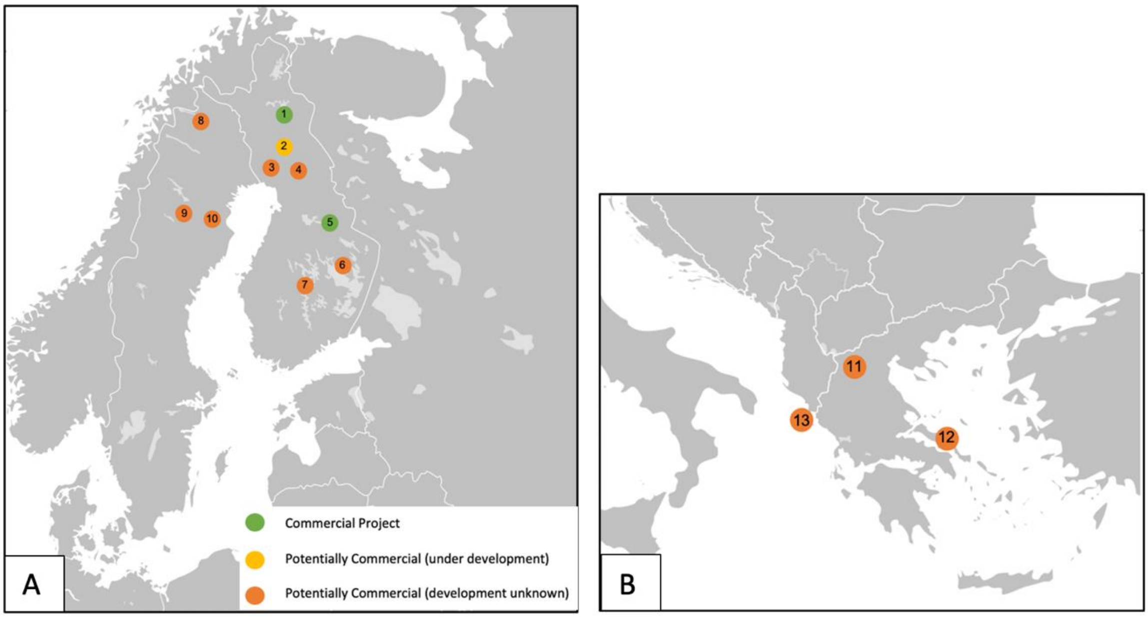

Figure 12 A: commercial and potentially commercial projects for cobalt mining in Finland and Sweden; B: commercial and potentially commercial projects for cobalt mining in Greece.[118]

For each of these locations, the estimated cobalt presence and predicated annual cobalt production capacity are presented in Table 2.

	Location	Estimated cobalt presence (in tonnes)	(Potential) annual cobalt production (in tonnes)
1.	Kevitsa, Finland	31 144	450-600
2.	Sakatti, Finland	20 210	± 600 – 700 (starting per 2030/2032)
3.	Rajapalot, Finland	1 849	± 200 (potentially)
4.	Kaukua, Finland	1 401	unknown
5.	Sotkamo, Finland	289 750	500-600
6.	Kylylahti, Finland	8 436	280-450 (until closure in 2020)
7.	Pappilanmäki, Finland	4 111	unknown
8.	Kiskamavaara, Sweden	3 069	unknown
9.	Lainejaur, Sweden	690	unknown
10.	Lappvattnet, Sweden	208	unknown
11.	Ieropiegi, Greece	5 220	unknown
12.	Evia, Greece	68 500	unknown
13.	Agios Ioannis, Greece	21 800	unknown

Table 2 Commercial and potentially commercial project locations with their estimated cobalt presence and predicted annual production capacity

Based on the information presented in Table 2, a rough estimation of the potential annual contribution that EU mining could have around 2035 can be made. Given that the mines

[118] The information on the development of the mines was gathered through expert interviews with representatives of mining companies Boliden and Anglo American. Boliden is currently mining cobalt at mine sites 1 and 5, Kevitsa and Sotkamo, and Anglo American indicated that they are developing a cobalt mine at location 2, named the 'Sakatti Project'.

at Kevitsa and Sotkamo will stay active and that the Sakatti project will start production around 2030, a total of 1800 tonnes of cobalt per year can be expected to be produced at these locations. Considering the possibility that increased cobalt demand will urge mine production at the locations in Greece, an additional 1200 tonnes could potentially be mined there (400 tonnes for each mine). Rajapalot in Finland has a potential annual production of 200 tonnes a year.[119] Since the remaining locations are smaller in deposit size, their total contribution in an optimistic scenario could be estimated to be around 1000 tonnes. Lastly, the extraction from tailings at Kylylahti could reach similar amounts of mines, adding 600 tonnes a year to the total.[120]

Thus, in a favourable scenario, the EU's mining contribution to cobalt demand could be 4800 tonnes annually. Compared to the predicted EU cobalt demand around 2035, which is approximately 153 000 tonnes based on estimates by Alves et al. (2018), domestic mining accounts for 3.1%.

As it becomes clear from this calculation, the EU's resource potential to contribute to its future demand is limited. However, looking into what the obstacles and possibilities are for developing its resource potential remains relevant, since even 3.1% can still contribute to the EU's strategic autonomy in the energy transition and to energy justice. Additionally, findings from the case of cobalt can be applied to other CRM, which makes looking into these aspects valuable.

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[119] Pekka Tuomela, Tuomo Törmänen, and Simon Michaux, *Strategic Roadmap for the Development of Finnish Battery Mineral Resources*, 2021, https://doi.org/10.13140/RG.2.2.33217.28000.
[120] Interview conducted by authors with Hampus Dynebrink, Boliden AB, 2022.

5. Obstacles to mining in the EU

Geological and technological possibilities are not sufficient to assess the feasibility of cobalt mining in the EU. Social issues such as community rights, governance, and economic conditions must also be considered. This chapter uncovers the obstacles to mining in the EU by touching upon general trends in European mining discourse and specific cobalt-related issues.

5.1 By-product dependency

Cobalt is mined as a by-product of nickel and copper. Most geological deposits in the EU do not allow for extraction of cobalt as a primary material. This is different in the DRC, where the ore grade does allow for this. As cobalt in the DRC can be extracted as a separate commodity, the country will remain an essential player in the future cobalt supply chain. Nevertheless, because ore deposits in Europe are not suited for separate extraction, copper and nickel are always prioritized in mining activities.[121] One of the three operational mines that were producing cobalt in the EU, the Kylylahti mine in Finland, was shut down in 2020 because its copper deposits were not economically attractive to extract anymore.

Despite the 8436 tonnes of cobalt deposit at the Kylylahti site, amounting to almost six times the annual supply provided by the two remaining EU cobalt mines combined, mining activities are unlikely to be picked up again just for cobalt. Unless the revenue of other extracted materials covers the cost of mining, it is not economically feasible. However, nickel exploration activities are currently taking place in the area surrounding the Kylylahti mine. These potential occurrences could also contain cobalt due to the polymetallic nature of nickel deposits.

Another way the by-product dependency of cobalt influences mining possibilities is through the industry's inability to easily respond to price changes of cobalt on the global market.[122] Therefore, cobalt's by-product dependency is also characterized by a form of disconnection between cobalt production and its market price. Whether cobalt is feasible to be mined depends on the nickel market, except in areas where cobalt can be extracted as a separate commodity such as in the DRC. Although cobalt prices might get higher in the short term, nickel and cobalt prices will go hand in hand as long as their production is tied to each other.[123] Still, since the demand for nickel is also predicted to rise, the consequences of the by-product dependency will be limited. As nickel mining is likely to increase, cobalt extraction will increase as well.

Since cobalt is a by-product, its extraction has not always been conducted efficiently. Because cobalt is only a 'bonus' to nickel and copper mining, some of it is lost in the

[121] Interview conducted by authors with Hampus Dynebrink, Boliden AB, 2022.
[122] Interview conducted by authors with Pertti Lamberg, Anglo American PLC, 2022.
[123] Interview conducted by authors with Pertti Lamberg, Anglo American PLC, 2022.

production processes during the repressing and rejecting of iron sulphides.[124] This offers opportunities to extract cobalt from tailing ponds of copper and nickel mines. Tailing ponds are used to store rejected sulphides, which in many cases contain cobalt that was originally disposed of during the extraction. According to Hampus Dynebrink, Boliden estimates that 10 000 tonnes of cobalt can be extracted from the tailing ponds at the closed Kylylahti mine site, which is significant compared to other ore deposits in the EU.[125] Extracting from tailings is not just a single experiment at Kylylahti, but it is being researched globally.[126] Further research could uncover how much the tailing ponds' cobalt potential could contribute to future EU demand.

5.2 European economic context

Another obstacle in developing mining and refining projects is that European economic conditions are not considered attractive. In many cases, the combination of the high energy-intensity of these industries with the energy prices in Europe makes setting up a project economically unfavourable. The impact of the Russian-Ukrainian war on energy prices has contributed even more. In May 2022, energy prices rose to such an extent that 10% of the European aluminium industry and 40% of the Zinc industry had to be temporarily shut down.[127] In light of these events, developing a cobalt mine or refinery seems like a challenging pursuit.

One of the game changers in developing mines or refineries in Europe is getting access to affordable clean energy, which would incentivize more investment in expanding these industries.[128] Investors need to be given some security and guarantees for their investment, which is not possible with high fossil fuel energy prices possibly restraining industrial activities. Yet spot prices of critical raw materials are becoming more and more attractive for project development.

5.3 Permitting procedures

The third major constraining factor of the expansion of the European mining industry is the lengthy permitting procedures that companies have to deal with. Concessions take a very long time to be approved or denied, as well as the reviewing of appeals by mining companies when projects were denied of concession. In an interview conducted for this report, Lamberg explained that the lengthy permitting procedure in Finland is causing the start of the Sakatti Project to be unclear.[129] There is no certainty on whether it will be 2030, 2035 or even 2040 when the mine goes into production. The fact that the Sakatti Project is located in a Natura 2000 area makes permitting even stricter.

Moreover, one of the most prompting issues is that no changes can be made to the original plan during permitting procedures. This means that mining companies cannot adapt to the changes in the global mineral market discourse. This is quite problematic, especially considering the dynamic nature of the energy transition.

[124] Interview conducted by authors with Pertti Lamberg, Anglo American PLC, 2022.
[125] Interview conducted by authors with Hampus Dynebrink, Boliden AB, 2022.
[126] Interview conducted by authors with Susannah McLaren, Cobalt Institute, 2022.
[127] Home, "Europe's Aluminium Output Slides as Energy Crunch Bites."
[128] Interview conducted by authors with Liesbet Gregoir, KU Leuven, 2022.
[129] Interview conducted by authors with Pertti Lamberg, Anglo American PLC, 2022.

Additionally, lengthy permitting procedures impact investment decisions since return prospects become less predictable. Although mining companies, NGOs, national governments, and MPs of the European Union acknowledge the issue of lengthy permitting procedures, there seems to be no consensus on whose responsibility it is to fix it. Norway could be an example of rigorous but fast permitting procedures, showing that it is possible to permit mining activities swiftly but diligently. As long as there is no clarity about who will take the lead in tackling the presented issues, the permitting procedures will remain a severe obstacle to mine development in Europe.

5.4 Lack of public support

The final and arguably the biggest obstacle to increased mining in the EU is the lack of public support. Concerns for environmental impacts of mines and the aversion to the sight of a mine site are the main drivers of this local resistance. Although mining in Europe is not as impactful as in countries outside the European Union, public opposition is much more prominent within the EU than elsewhere. One of the reasons is the reputation of mining in European culture, which differs from areas outside of Europe. Moreover, the democratic nature of EU nation-states allows public opposition to impact the prospects of domestic mining. These two factors will be explained in the following sections. Lastly, the ability of the Sami people (Europe's last remaining indigenous population) to potentially block cobalt mining projects will be discussed.

Reputation of mining in European culture

In Europe, however, mining is seen as an environmentally harmful and undesirable activity. People are no longer accustomed to mining[130] and they increasingly associate it with the suppression of human and social rights, particularly in non-EU countries.[131] Additionally, public aversion towards mine development can be explained by the bad reputation that mining has in European culture. Europe's perception of mining has primarily been shaped by the coal mining activities that have been taking place in the past decades. In other areas in the Western world, such as the US, mining has a certain sense of nostalgia connected to it.[132] There, mining is seen as a respectable profession, held by hard-working people who take pride in what they do and make a good living.

Another reason mining might be more opposed in Europe than in other areas is that local economies are more diverse, and therefore are not dependent on the mining industry. This dependency on mining for income generation plays a much more significant role in areas in the Mid-West of the US or the DRC. Therefore, it should be acknowledged that opposing mining operations can be considered a privilege, something that not all populations worldwide around the world can afford to do.

Impact of public opinion

At the heart of the EU and its member states lie democracy, the rule of law, and human rights. In this participatory system, citizens and communities have a relatively significant influence on public policy. In recent cases, local populations in Europe have successfully blocked or delayed mining projects. In January 2022, the Serbian government overturned licenses for a lithium project of mining group Rio Tinto after massive demonstrations by

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[130] Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.
[131] Masuma Farooki, Chris Hinde, and Anton Lof, "Strategic Dialogue on Sustainable Raw Materials for Europe (STRADE)" (European Commission, October 17, 2018).
[132] Interview conducted by authors with Susannah McLaren, Cobalt Institute, 2022 and David Sturmes, Fair Cobalt Alliance, 2022.

local communities.[133] Even when the environmental concerns of local communities were considered, the project was still opposed to appeal to the public and gain votes in the upcoming elections in Serbia. The cancellation of the project came as a surprise, and considerable investment had gone into the project to get up to that point.[134] For investors, this could be considered a severe reason to refrain from engagement with mining project development.

The particular Serbian context should be understood to evaluate to what extent this case could be considered a precedent for mine development in Europe. Even though Serbia has been struggling to strengthen its democratic system since the Bosnian war of 1992, its participatory system still made it possible for local communities to block mining developments. More robust democracies could undergo even more issues in developing cobalt mining projects when public support is lacking.[135]

Additionally, the electoral cycle in EU states makes long-term planning for the energy transition more difficult.[136] That is because the administration of countries changes so often and politicians do not benefit much from tackling issues that are not considered particularly urgent by the public. The need for urgent increases of mineral extraction within the EU to make the energy transition smoother, is not well-known among the general population.[137] Combined with the seemingly unfavourable economic conditions for mine development, local support is often limited.

Sami population in Sweden and Finland

Unfortunately, an important part of Europe's cobalt ore deposits is located in the living area of the indigenous Sami population, who live in the North of Norway, Sweden, Finland, and Russia.[138] The Sami's main livelihood generator is nomadic reindeer herding, meaning that their populations move around throughout the year. They are estimated to have a population of approximately 28 000 people living in Sweden and Finland.

Figure 13 Living grounds of the Sami people.[139]

Previously, the Sami people successfully opposed other projects that were located on

[133] Brendan McMahon, "Rio Tinto: Outlook for the Jadar Lithium Project," EIN News, May 17, 2022, https://www.einnews.com/pr_news/572774545/rio-tinto-outlook-for-the-jadar-lithium-project.
[134] Interview conducted by authors with Susannah McLaren, Cobalt Institute, 2022.
[135] Interview conducted by authors with Susannah McLaren, Cobalt Institute, 2022.
[136] Interview conducted by authors with Liesbet Gregoir, KU Leuven, 2022.
[137] Interview conducted by authors with Liesbet Gregoir, KU Leuven, 2022.
[138] Mari Lilleslåtten, 'Indigenous Voices Are Marginalised in National Political Communication - Department of Media and Communication', University of Oslo, 12 February 2021, https://www.hf.uio.no/imk/english/research/news-and-events/news/2021/indigenous-voices-are-marginalised-in-national-pol.html.
[139] Lilleslåtten.

their living grounds as well. In the 'Fosen Case', the Saami Council (an indigenous peoples organization established in 1956) took the Norwegian government to court for permitting the construction of a large windmill park. In October 2021, the Supreme Court of Norway ruled that the Norwegian State had violated the rights of the Sami people and therefore restrained plans for the wind farm development.[140] As such, the Sami people can influence on projects planned in their territory, which could make mine development in the northern regions of Sweden and Finland difficult.

To conclude, the feasibility of mining expands beyond the notion of technological and geological aspects. It is also influenced by the European economic context with its high energy prices, by-product dependency on nickel and copper mining and their markets, lengthy permitting procedures with limited governance response, and empowered local opposition due to the EU's democratic system and its coal mining history. Moreover, the recent Foden case has demonstrated that the Sami people have a powerful voice in opposing renewable projects, which could pose significant limitations to the development of cobalt projects in the northern regions of Sweden and Finland, where large ore deposits are located. The predicted local opposition and lengthy permitting procedures weaken investment security in projects, thus making investing less attractive.

[140] Kristoffer Hætta, "SÁMIRÁÐÐI ANNUAL REPORT 2021" (Sámiráddi, 2021), https://www.saamicouncil.net/documentarchive/annual-report-2021.

6. Justifications for mining in the EU

Whereas the previous chapter has uncovered some of the obstacles of increased EU mining, this chapter looks into its justifications. This chapter discusses the lack of substitutes for cobalt in the short term, the rising importance of strategic autonomy in the energy transition, EU mining efficiency standards as well as energy justice and responsible sourcing.

6.1 Rapidly rising demand and lack of alternative prospects in the short-term

To fulfil the EU's growing cobalt demand and reduce the risk of disruption, cobalt mining globally, Europe included, will have to increase. Cobalt substitutability in the appliance in which it is mostly used, LIBs, will not occur on a large scale until around 2040. This is due to the infrastructure of LIB factories currently in operation or under development, which are geared towards producing LIB chemistries that contain cobalt. Next to that, reducing cobalt from LIBs would mean substituting it with - most likely - nickel, adding to the already expected rise in demand for that material.

Moreover, deep-sea mining is as of now not mature enough and it goes hand in hand with environmental risks, of which the magnitude is not clear.[141] Currently, deep-sea mining activities, coordinated and regulated by The International Seabed Authority, are still in the exploration phase (and not in the exploitation phase). Not enough is known about the impacts of deep-sea mining on the largest ecosystem in the world.

6.2 Strategic autonomy in the energy transition

The Former High Representative of the EU for Foreign Affairs and Security Policy, Javier Solana, mentioned that the supranational organization has to "learn the language of power" if it wants to become an independent and relevant geopolitical actor.[142] The EU faces increasingly high risks of both political and economic disruption if it cannot secure reliable access to critical raw materials such as cobalt. In case of failure, it will jeopardize its strategic autonomy, which can lead to limited freedom of choice and action in a future described as "an increasingly hostile geopolitical era".

At the same time, whereas increased mining could contribute to enhanced strategic autonomy, the importance of the refining sector should not be overlooked. The cobalt mined in the EU, near Kevitsa, is exported to refineries in Europe and China.[143] While Finland is an important cobalt refiner, increased domestic mining without expanding refining capabilities would not remove the dependency on non-EU cobalt sulphate used for LIBs. Therefore, the desire of the EU to become more strategically autonomous in the

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[141] Gregoir and Van Acker, "Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge," 35.
[142] Theodosopoulos, "The Geopolitics of Supply: Towards a New EU Approach Toæ the Security of Supply of Critical Raw Materials?"
[143] Interview conducted by authors with Hampus Dynebrink, Boliden AB, 2022.

energy transition justifies not only increased mining, but also the construction of refineries.

Geopolitical considerations form a strong argument for exploring mining activities, even if economic conditions within the EU are not the most favourable. The EU has demonstrated its willingness to prioritize geopolitical aspirations over economic goals with a ban on most of its Russian (maritime) oil imports in response to the Russian invasion of Ukraine, despite its high dependence on Russia and the expected negative impact on the European economy.[144] Whereas the EU's dependencies on imports of minerals are not considered as salient as the Russia-Ukraine war, recent developments indicate that economic justifications are not always the determining factor in EU decision-making.

Still, choosing economic backlash is not a sustainable way forward.[145] This is especially the case in the EU's democratic system, where national elections shift the political discourse every four or five years, making long-term plans of sacrificing economic aspirations difficult – if not impossible – to justify. Additionally, prioritizing geopolitics over economics could disregard community rights.[146] Whereas the EU aspires to achieve security of supply in a just way, the narrative is changing with geopolitical interests rising in priority. This can lead to a discourse where the EU does not consult communities like it used to but focuses on ramping up renewables.[147] Whereas the European mining industry tries to achieve more strategic autonomy, environmental and social concerns should not be sacrificed at the expense of geopolitical power.

6.3 EU mining efficiency

The efficiency and atomization of European mining might offer a solution for the higher labour and energy costs in Europe. Moreover, by developing 'mines of the future', companies like Anglo American aim to provide the materials necessary for the energy transition whilst keeping the environmental and social impacts to an absolute minimum.[148]

Lamberg illustrated EU mining efficiency by explaining how the Sakatti Project was designed.[149] First of all, the high grade of the nickel-cobalt ore body allows to execute mining with a low emission-to-production ratio. The mined metal is relatively 'clean' compared to cobalt mined in the DRC. Secondly, the mine will largely be constructed underground, meaning the footprint of the mine at ground level will be small. Third, emissions will be kept low by using a fully electric and automated underground fleet. The need for ventilation, which usually accounts for the most considerable use of energy, will become unnecessary with the electric fleet since there are no exhaust gasses that need to be disposed of. Lastly, the 'tailings' sulphurs that, in some cases, have the potential to cause acidic mine drainage will not be disposed of above ground. Usually, tailing ponds are situated in the open air next to mines. They are the biggest concern of environmentalists regarding mining activities because of the risk that tailing pond dams would breach. Moreover, Anglo American is considering the possibility of using the tailings containing magnesium silicates, for carbon capture.

[144] Maartje Wijffelaars, Elwin De Groot, and Erik-Jan Van Harn, "Boycott of Russian Oil Will Tip the Eurozone into a Mild Recession," RaboResearch - Economic Research, June 2022, https://economics.rabobank.com/publications/2022/june/boycott-of-russian-oil-will-tip-the-eurozone-into-a-mild-recession/.
[145] Interview conducted by authors with Liesbet Gregoir, KU Leuven, 2022.
[146] Interview conducted by authors with Susannah McLaren, Cobalt Institute, 2022.
[147] Interview conducted by authors with Susannah McLaren, Cobalt Institute, 2022.
[148] Interview conducted by authors with Pertti Lamberg, Anglo American PLC, 2022.
[149] Interview conducted by authors with Pertti Lamberg, Anglo American PLC, 2022.

Regarding the social impacts of the mine, the Sakatti Project claims to have a low interference with local communities. The area where the mine is planned contains two vacation homes, which do not have permanent residents. Therefore, no communities were evicted or convinced to leave. Additionally, there are no villages directly located next to the site, which limits the aesthetic impacts of the mine, which are often a reason for objections.[150]

This example shows that the concept of ‘mines of the future’ could be a feasible option for the EU. By decreasing energy use, labour costs, and environmental as well as social impacts, the Sakatti project illustrates that obstacles to mining in the EU can be effectively overcome.

6.4 Energy justice and responsible sourcing

Considering energy justice aspects is vital in making the energy transition a fair and just process, according to the EU’s Green Deal. However, perspectives of energy justice can be applied on different levels, which in some cases can lead to losing sight of the bigger picture. While mining will always have negative impacts, the impact of European mines on the environment and social communities will be much less compared to other regions in the world. Mining regulation and community rights are much better organized in the EU than in other regions. The health, safety, and environmental management practices at these European mine sites would exceed most mine site practices elsewhere in the world.[151] Blocking mining activities in the EU under the conception that it impacts the environment appears hypocritical, since the EU would simply import materials from elsewhere, where environmental laws are not as strict, as Gregoir, Sturmes, and McLaren all pointed out in interviews. Understanding that the energy transition will go hand in hand with the expansion of mineral extraction, whether that is desirable or not, is necessary for the EU to make its energy transition just.

Although the permitting procedures in Europe have been criticized for their lengthiness in the previous chapter, they have a vital role in preserving natural environments and protecting local populations. By adhering to the minimum EU mining requirements, European mining companies are still ahead of companies operating in the DRC regarding environmental impacts.[152] This should be kept in mind, especially since much of the increased cobalt production will come from the DRC. Its mining discourse, specifically in artisanal mining, is much less mature and not as strict in terms of environmental and social aspects.[153]

The European Union currently has regulations that aim to limit environmental and social impacts throughout its value chain of minerals. The aspiration is only to import ethical and responsibly sourced supplies, as stated in the Conflict Minerals Regulation.[154] Nevertheless, this is difficult to trace, and conflict minerals often still enter the European market through Chinese refineries.[155] Domestic mining could increase responsibly sourced supply, supporting the EU’s progress in the energy transition.

150 Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.
151 Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.
152 Interview conducted by authors with Hampus Dynebrink, Boliden AB, 2022.
153 Interview conducted by authors with Hampus Dynebrink, Boliden AB, 2022.
154 European Commission, “Conflict Minerals Regulation.”
155 Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.

Responsible sourcing would give rise to a 'European premium' for materials such as cobalt. Because the EU has due diligence requirements such as the Conflict Minerals Regulation, a 'two-tiered' market for materials like cobalt will emerge: one for cobalt that is EU compliant and one that is not, which will differentiate in price.[156] Prices for local premiums for some materials are relatively high in Europe because of high energy costs, making domestic mining economically profitable.[157] As this premium market starts to kick in, companies will have extra incentive to invest in domestic mining developments, since a limited supply of material means an increase in prices. Still, businesses and consumers will have to carry the burden of higher prices for electronics, cars and sustainable infrastructure in the short term.[158]

[156] Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.
[157] Interview conducted by authors with Hampus Dynebrink, Boliden AB, 2022.
[158] Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.

7. Conclusion

The EU's cobalt value chain, geological deposits, economic context, and cultural characteristics are critical aspects to analyse in light of expected supply disruptions. The EU's cobalt deposits are not favourable compared to those elsewhere because of their small size and low cobalt grade. A mere 3.1% of the EU's demand in 2035 could be supplied in an optimistic scenario where most of the identified potentially commercial sites would be developed. Although increased cobalt mining in the EU could contribute to more strategic autonomy in the energy transition, its impact will be minimal. Therefore, the EU's Raw Materials Initiative's second pillar on domestic mining in the case of cobalt does not significantly contribute to securing supply.

Since the value chain analysis showed geographical concentrations of cobalt mining in the DRC and refining in China, associated geopolitical challenges, as well as the environmental and social impacts those stages are accompanied by, developing European cobalt mine sites could still contribute to energy justice and a degree of strategic autonomy. Four major restricting factors for developing EU mines came forward: 1) the by-product dependency of cobalt on nickel and copper extraction; 2) the European economic context and high energy prices; 3) the long permitting procedures for mine development; and lastly, 4) the lack of public support for domestic mining.

The EU's due diligence requirements might lead to the development of a two-tiered global market for cobalt: one that is EU-compliant and one that is not. The EU compliant cobalt, also called the European Premium, will be more expensive, making it economically attractive for mining companies to extract the mineral, considering the high energy costs. Moreover, the geopolitical consideration for increased mining could trump this economic obstacle. By limiting its imports of Russian oil, the EU has shown that it is willing to make economically painful decisions based on political considerations.

Even though cobalt would still be mined as a by-product of nickel and copper due to the EU's geological characteristics, the rising demand for those minerals relieves the strain on increased cobalt mining. The lengthy permitting procedures for mine development are putting a hold on project investments due to a lack of investment security. Moreover, it takes away the opportunity for mining companies to actively adapt their mine design to the needs of the global mineral market. Whereas stakeholders from virtually all sectors have acknowledged the issue, consensus on whose responsibility it is to tackle this problem remains absent. By making permitting procedures more efficient without compromising on the level of standards, mining in the EU could become more feasible.

The final and most prominent obstacle to mine development is the lack of public support. Lithium projects throughout Europe have been put on hold or been put off completely as a result of local protests. Because communities fear mines' social and environmental impacts, their development is strongly opposed. This is mostly caused by the negative image of mining has in EU culture. Coal mining has been the main type of mining in the EU in the last decades, leading to its image of an impactful and polluting business. Yet, new designs of 'mines of the future' by companies like Anglo American have shown that mining impacts can be minimized. Although it should be acknowledged that mining will always impact in one way or another, the EU's due diligence requirements will tackle any arising issues as efficiently as possible.

8. Recommendations for securing supplies of cobalt

8.1 Information and transparency

Local opposition has resulted in the cancellation of many mining projects in the past years, even though European mining standards are much higher than those in countries from where the EU will source its materials otherwise. By creating awareness about the necessity of domestic mining for the energy transition and being transparent about the impacts whilst compensating for damages, the EU could gain public support, or at least acceptance, for increased mining. Being transparent and sharing reliable information about green energy supply chains, the negative impacts associated with mining abroad and the challenges of ensuring responsible mining standards across the globe would be beneficial.

8.2 Attract investments

One of the major issues for increased mining, the unattractive European economic context, can become less of an obstacle as a result of the efficiency of European mines, combined with a market for 'European premium' minerals that are sustainably sourced. Still, there is a lack of security for investors when it comes to developing mines. Because of the lengthy permitting process, the time it takes to develop a mine, and the lack of investment security, only bigger companies tend to be able to make serious commitments. EU authorities must find ways to support companies throughout this process.[159] The development of a 'two-tiered market' might be sped up by ensuring that rigorous checks on the origins of minerals like cobalt are conducted. In anticipation of the European premium, investing in primary sourcing and refining could be made more attractive beforehand.

8.3 Permitting procedures

The issue of lengthy permitting procedures can be tackled relatively easily once there is consensus on whose responsibility it is. The EU could take the first step in gathering all parties involved and decide at which level this issue should be regulated. Norwegian cases of permitting procedures should be taken as an example of how the process can be swifter whilst also being rigorous and fair. Boliden indicated that compared to their projects in Finland and Sweden, the Norwegian initiatives could pass the permitting process much quicker. Tackling this urgent issue could attract significantly more investment, since it gives more certainty to developers throughout the process.

The high mineral demand and limited supply might lead companies to receive special treatment in permitting procedures.[160] They should be adapted now to prevent permitting

[159] Interview conducted by authors with Liesbet Gregoir, KU Leuven, 2022.
[160] Interview conducted by authors with Pertti Lamberg, Anglo American PLC, 2022.

procedures from becoming more lenient regarding protecting of local communities and environments. If Europe ends up in a geopolitical crisis due to limited supply, social and environmental aspects should not be discarded.[161] The European Union should therefore take the lead in regulating these permitting procedures for mine developments as soon as possible.

8.4 Reduce demand

Next to focusing on developing technologies that could potentially use less cobalt, the EU should dedicate more attention to reducing demand. Changes in European consumption behaviour such as increasing shared mobility can reduce cobalt demand. Shared mobility has been included in climate commitments of national governments like the Netherlands, mostly to decrease greenhouse gas emissions rather than make the energy transition less material intensive.[162] However, it is also highly beneficial to reducing cobalt demand, as it would decrease the number of cars produced. Next to carsharing, services such as Uber could also be supported in their activities as they have led people to move away from private car ownership.[163] Making sure that shared mobility is seamlessly connected with public transport becomes an attractive alternative for private car ownership. Additionally, national governments and local authorities could be urged to make parking permits for private cars more expensive, thus increasing the economic feasibility of shared mobility. In general, shared mobility should be made more attractive than private ownership to reduce the demand for cobalt.

8.5 Recycling

By keeping cobalt used in LIBs within the European Union and ramping up the recycling industry, the EU can become fully self-sufficient by 2050 regarding LIB production.[164] Although dependencies will characterise the EU's energy transition on foreign countries in the first phase, later years could bring more autonomy due to secondary supplies.

Once there are enough LIBs for electric car production and demand stagnates, the EU could become independent by ensuring that these materials will continue circulating within its borders through recycling. Developing a mature recycling market should therefore be at the top of the EU's priorities when it comes to securing CRM in the long term. Limiting the export of e-waste can ensure that no raw materials are lost from the EU's circular economy discourse. Additionally, it could solve waste pollution issues currently weighing heavily on countries in the Global South and are contributing to the decarbonization divide, thus contributing to energy justice.

8.6 Strategic partnerships

Even though the EU could move past some of the obstacles that currently make mine development in Europe difficult, the contribution of cobalt mining in the EU is marginal compared to predicted future demand (3.1%). Therefore, making strategic partnerships and increasing recycling rates should be priorities in the case of cobalt. The EU should seek cooperation with countries like Canada and Australia, where large mining projects are currently under development. They could reduce the EU's dependence on the DRC while complying with responsible sourcing requirements and the 'European premium'.

[161] Interview conducted by authors with Susannah McLaren, Cobalt Institute, 2022.
[162] Interview conducted by authors with Jochem Beunderman, DOET Association, 2022.
[163] Interview conducted by authors with Jochem Beunderman, DOET Association, 2022.
[164] Gregoir and Van Acker, "Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge."

Next to making partnerships with states, the EU should look into the possibility partnering with companies that are mining CRM within Europe. Part of the materials that are currently being mined within the EU is exported to countries like China, mostly because the EU's refining capacity is not up to par.[165] Therefore, the EU should also focus on ramping up its number of refineries and regulating exports of CRM to keep mined minerals within the EU. It would be difficult to justify increased mining within the European Union if part of that material is nonetheless exported.

8.7 Improve the value chain

The EU will likely have a future deficit of sustainably sourced supply, which is why it should try to improve social and environmental standards throughout the cobalt value chain. This could be done by investing in the professionalization of the artisanal mining (ASM) sector, given that ASM working conditions are the biggest issue associated with cobalt supply, spanning from safety hazards to child labour. Although the EU aims to minimise the import of minerals associated with conflict or poor working conditions, ASM cobalt still enters the EU markets through LIB cell components. Around 15% of DRC's cobalt originates from ASM and ends up in (mostly Chinese) opaque supply chains. This cobalt is, therefore, officially unaccounted for, but it represents a substantial amount of global supply. Additionally, ASM's contribution to EU supply is likely to increase in the future because it can quickly respond to demand and price rises. The EU should urge companies to recognize their contribution in this process and invest in professionalizing the ASM sector. "It is in everybody's supply chain unless you can prove the opposite".[166]

Still, tackling the issues associated with ASM should be done carefully.[167] Previous attempts to improve mineral value chains have had serious negative impacts on the local economy and population. For instance, the US Dodd Frank act of 2010 aimed at improving the ethical supply of tin and did so by shutting down the industry completely, depriving thousands of people from their main income source.[168] When re-opening the sector, companies avoided difficult situations rather than improving them, which caused local crises for artisanal miners.

Currently, between 200 000- and 250 000-people's livelihoods depend on the artisanal cobalt mining sector, which is likely to increase once cobalt prices increase even further. Therefore, EU attempts at professionalizing the ASM sector should be handled with care. In approaching the improvement of ASM conditions, the EU could seek ways to motivate companies to invest in the professionalization of the artisanal mining sector by designing a scheme that allows them to get a discount on purchased material later.[169] However, the increased risk of investment in the front end of the supply chain should be recognized. Moreover, companies should be encouraged to be transparent about issues in sourcing their materials rather than avoiding them, as this would only hurt the local mine workers. Sturmes stated that time and money should not be spent on proving that material is sourced responsibly, but rather it should be acknowledged that around 15% of the EU's cobalt originates from ASM, and funds should be invested in improving the value chain.[170]

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[165] Interview conducted by authors with Hampus Dynebrink, Boliden AB, 2022.
[166] Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.
[167] Interview conducted by authors with Susannah McLaren, Cobalt Institute, 2022 and David Sturmes, Fair Cobalt Alliance, 2022.
[168] Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.
[169] Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.
[170] Interview conducted by authors with David Sturmes, Fair Cobalt Alliance, 2022.