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Increasing Lithium Supply Security for Europe's Growing Battery Industry:

Recommendations for a Resilient Supply Chain

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The analysis presented in the paper, including the conclusions and recommendations are based on independent research conducted by the author during his International Political Economy Master program at King's College London. The responsibility for the content of this paper lies with the authors and the authors alone.

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Executive Summary

Lithium is key for global decarbonisation and is expected to face the biggest growth in demand for all critical raw materials (CRM) due to the rapid development of lithium-ion batteries used in electric vehicles (EVs). Booming demand and the high geographic concentration of lithium mining and processing result in supply vulnerabilities and geopolitical competition for this raw material. China dominates lithium processing and the midstream and downstream stages of the lithium-ion battery supply chain.

While the lithium-ion battery supply chain will likely remain Chinese-dominated until 2030, a European CRM supply security policy and other global supply diversification policies are picking up. Re-shoring activities create opportunities for Europe to strengthen the resilience of its lithium supply chain and to become more self-sufficient. Various lithium mining and processing projects in Europe are being developed and planned to come online before 2030, resulting in varying lithium production projections. However, lithium projects in Europe, especially lithium mines, take time to materialise and are subject to barriers and uncertainties, like untested production processes and local protests, leading to production delays.

Scaling up lithium processing capacity in Europe looks more feasible than lithium mining, as the project development lead times are shorter, even if lithium processing projects face environmental concerns. Securing enough lithium ore as feed for processing facilities in Europe in a growing competitive geopolitical environment remains crucial. Moreover, employing more environmentally friendly processes allows the EU to move away from coal-based lithium processing in China. Ramping up lithium mining and processing activities in Europe can best be done by geographically integrating lithium mining and processing into one project. With this approach, the raw lithium supply is more safeguarded, and there is less need to purchase lithium ore as feedstock for lithium processing in a tight global lithium market. Moreover, with emerging and less pollutant mining technologies, like direct lithium extraction (DLE) from geothermal brines and underground extraction, lithium producers in Europe can source more responsibly.

Considering the lengthy project development lead times and environmental and social concerns, investing in capital-intensive lithium projects in Europe is risky, and lithium mining projects especially face difficulties with access to adequate funding. There is a risk that some lithium projects in Europe will fail to be realised because of a lack of EU-level targeted and additional funding. Establishing a sovereign public-private EU-level CRM Fund directly involving private companies can help de-risk European lithium projects. An EU-level fund would also help maintain a level playing field in the EU. Setting up a specific Important Project of Common European Interest (IPCEI) on CRM is also worth exploring.

Regardless of Europe's increasing lithium mining and processing capacities, responsibly importing battery-grade lithium will still be required to meet Europe's growing mid- and downstream lithium-ion battery production. Therefore, the EU needs to continue to employ its Global Gateway Investment Agenda and conclude more CRM strategic partnerships with Australia and other lithium-rich countries in Africa (Mali, Ghana, Zimbabwe, etc.) and Latin America (Brazil and Mexico) to diversify lithium supply, support local battery industrialisation and counter China's deep involvement in the global lithium industry. In doing so, ESG standards need to be met. CRM strategic partnerships provide a flexible framework for friend-shoring, cooperation between governments and private companies, and the integration of lithium-ion battery supply chains.

Furthermore, European governments and companies should move quickly to invest in overseas lithium projects and secure lithium offtake agreements, given the intense competition from Chinese companies controlling lithium offtake agreements in resource-rich regions like Africa. The EU and EU member states need to involve European companies and use Japan's and Germany's resource diplomatic tools, including equity investments, loans and untied loan guarantees to de-risk overseas lithium projects in Western Australia, Africa and Latin America and support European companies with securing lithium offtake agreements.

Developing lithium-free cathode battery chemistries, like sodium-ion batteries, can reduce demand for mined lithium and help alleviate Europe's lithium supply vulnerabilities. Although China is leading the race for this next generation of batteries and progressing in battery performance, Europe should foster international cooperation with other Mineral Security Partnership (MSP) members, like the US, Japan and South Korea, besides supporting local R&D in new battery technologies. EIT RawMaterials can play a key facilitating role in this.

Finally, increasing recycling rates of lithium-ion batteries will help alleviate Europe's lithium supply vulnerabilities. Still, this will take time and may only result in a decline in primary lithium demand after 2040, as lithium recovery rates are still very low, mainly due to the limited commercial viability of lithium recycling. Recycling companies in Europe could face a lack of recycling feedstock due to battery waste leakage and exports of black mass to Asia, including South Korea and China. EU member states need to effectively implement the EU Battery Regulation, with its mandatory lithium recovery and minimum levels of recycled lithium use in battery production, to increase lithium recovery rates. If needed, these targets can be enhanced through delegated acts. Prioritising EU funding to recycling projects in Europe that aim to integrate the recycling supply chain's pre-processing, processing and material recovery stages is also essential to close the loop, secure enough recycling feedstock and ultimately increase lithium supply security. In addition, black mass exports need to be limited through the regulatory classification of black mass as hazardous waste at the EU level to address the current battery waste leakage to Asia.

1. Introduction

Decarbonisation requires many metals and minerals, like lithium, with global demand expected to grow significantly in the coming decades.[1] A group of metals and minerals deemed important for the economy and with a high supply risk is called critical raw materials (CRM) by the European Union (EU).[2] The lack of viable substitutes given current technologies and the high geographic concentration are other factors determining their critical nature.[3] Lithium is expected to face the biggest growth in demand of all CRM due to the rapid development of lithium-ion batteries used in electric vehicles (EVs).[4]

Despite lithium reserves being widely geographically distributed, one of the main concerns for lithium supply is that mining and processing activities are geographically concentrated among a few countries and companies.[5] Australia and Chile were the biggest lithium-producing countries in 2022, while China dominated the processing stage.[6] China holds a dominant position in raw material and clean tech supply chains, including lithium-ion batteries.[7]

Booming demand and the high geographic concentration of lithium mining and processing result in supply vulnerabilities and geopolitical competition for this raw material.[8] The 2010 rare earth crisis, sparked by China's restrictions on exports of rare earths to Japan, triggered concerns about being overly dependent on CRM supply and was a wake-up call for the international community.[9] As a result, CRM supply security policies emerged globally over the last few years, including in the EU. With its goal of achieving carbon neutrality by 2050 amid an increasingly tense geopolitical context, the EU is taking steps to address its strategic supply vulnerabilities and dependencies on China.[10] To increase its open strategic autonomy and the security of lithium supply, the EU has developed a CRM supply security policy aimed at creating a local European lithium supply chain, boosting supply diversification through international cooperation with lithium-rich third countries and fostering a European circular economy through lithium-ion battery recycling.

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[1] Dolf Gielen, 'Critical Materials for the Energy Transition' (International Renewable Energy Agency (IRENA), 2021), https://www.irena.org/-/media/Irena/Files/Technical-papers/IRENA_Critical_Materials_2021.pdf?rev=e4a9bdcb93614c6c8087024270a2871d; International Energy Agency (IEA), 'The Role of Critical Minerals in Clean Energy Transitions', 2021, https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

[2] Elmer Rietveld et al., 'Strengthening the Security of Supply of Products Containing Critical Raw Materials for the Green Transition and Decarbonisation', 2022, https://www.europarl.europa.eu/thinktank/en/document/IPOL_ATA(2022)740059; Ewa Lewicka, Katarzyna Guzik, and Krzysztof Galos, 'On the Possibilities of Critical Raw Materials Production from the EU's Primary Sources', *Resources* 10, no. 5 (17 May 2021): 50, https://doi.org/10.3390/resources10050050.

[3] International Renewable Energy Agency (IRENA), 'Geopolitics of the Energy Transition: Critical Materials', 2023, https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials.;

[4] International Energy Agency (IEA), 'The Role of Critical Minerals in Clean Energy Transitions'; Karla Cervantes Barron, Shobhan Dhir, and Jonathan M Cullen, 'The Geopolitics of Critical Materials and Minerals and Implications for the Low-Carbon Transition' (Apollo - University of Cambridge Repository, 18 January 2023), https://doi.org/10.17863/CAM.93361.

[5] International Renewable Energy Agency (IRENA), 'Geopolitics of the Energy Transition: Critical Materials'.

[6] International Energy Agency (IEA), 'Critical Minerals Market Review 2023', 2023, https://iea.blob.core.windows.net/assets/c7716240-ab4f-4f5d-b138-291e76c6a7c7/CriticalMineralsMarketReview2023.pdf; US Geological Survey (USGS), 'Mineral Commodity Summaries 2023', 2023, https://doi.org/10.3133/mcs2023.

[7] Cervantes Barron, Dhir, and Cullen, 'The Geopolitics of Critical Materials and Minerals and Implications for the Low-Carbon Transition'; Guillame Pitron, 'The Geopolitics of the Rare-Metals Race', *The Washington Quarterly* 45, no. 1 (2 January 2022): 135–50, https://doi.org/10.1080/0163660X.2022.2059146.

[8] Sophia Kalantzakos, 'The Race for Critical Minerals in an Era of Geopolitical Realignments', *The International Spectator* 55, no. 3 (2 July 2020): 1–16, https://doi.org/10.1080/03932729.2020.1786926; Roman Vakulchuk, Indra Overland, and Daniel Scholten, 'Renewable Energy and Geopolitics: A Review', *Renewable and Sustainable Energy Reviews* 122 (April 2020): 109547, https://doi.org/10.1016/j.rser.2019.109547; International Renewable Energy Agency (IRENA), 'Geopolitics of the Energy Transition: Critical Materials'.

[9] Kalantzakos, 'The Race for Critical Minerals in an Era of Geopolitical Realignments'.

[10] Elmer Rietveld et al., 'Strengthening the Security of Supply of Products Containing Critical Raw Materials for the Green Transition and Decarbonisation'; Sophia Kalantzakos, Indra Overland, and Roman Vakulchuk, 'Decarbonisation and Critical Materials in the Context of Fraught Geopolitics: Europe's Distinctive Approach to a Net Zero Future', *The International Spectator* 58, no. 1 (2 January 2023): 3–22, https://doi.org/10.1080/03932729.2022.2157090.

In this geopolitical context, this report assesses Europe's lithium supply vulnerabilities and the key barriers the continent faces to increasing its lithium supply security up to 2030. At the same time, this paper examines opportunities and provides recommendations to make Europe's lithium supply chain more resilient and diversified in view of its growing battery industry.

This report is structured as follows. Chapter 2 provides background on lithium as a CRM and outlines Europe's vulnerabilities along the lithium-ion battery supply chain. Chapter 3 discusses the EU's CRM supply security policy, including the European Critical Raw Materials Act (CRMA) and Europe's upcoming lithium projects. Chapter 4 then explores the key barriers to making Europe's lithium supply chain more resilient and provides recommendations to address these. Chapter 5 concludes and summarises the main findings.

2. European vulnerabilities along the lithium-ion battery supply chain

2.1. Lithium-ion battery supply chain

Lithium is primarily sourced from hard rock, like spodumene, or brine (concentrated salt water), which involves pumping the brine from underground into large evaporation ponds, where it is exposed to the sun and wind until the water evaporates and a lithium concentrate is formed.[11] Lithium from hard rock is mainly sourced in Australia, while lithium brines are primarily found in the Lithium Triangle, which consists of Chile, Argentina, and Bolivia. Australia was the world's biggest lithium mine producer in 2022, followed by Chile, China and Argentina.[12] Bolivia has the world's largest known lithium resources, but they remain largely untapped, partly due to mismanagement and years of political turmoil.[13]

Sourcing lithium from brines is relatively cheap and environmentally less damaging in terms of carbon emissions than hard rock because it relies primarily on solar energy.[14] The major downsides of the evaporation process are the lengthy nature and the use of large quantities of water, causing water stress in desert regions, as is the case in the Lithium Triangle.[15] Lithium can also be sourced unconventionally from clay sources, like in the US and Mexico, as well as from geothermal brines, such as in Germany, using geothermal energy to extract lithium from beneath the ground.[16] Lithium has been designated a CRM by the EU and is included in the 2023 EU CRM list, together with 33 other materials.[17] Lithium is also included in the EU's list of strategic raw materials (SRMs), which are crucial to developing green and digital technologies.[18] Despite this recently introduced concept of SRM, this research paper will consistently use the concept of CRM to refer to both CRM and SRM.

[11] Ana Elizabeth Bastida et al., 'Latin America's Lithium_Critical Minerals and the Global Energy Transition' (Wilson Center, 2023), https://www.wilsoncenter.org/sites/default/files/media/uploads/documents/Latin%20America%E2%80%99s%20Lithium_Critical%20Minerals%20and%20the%20Global%20Energy%20Transition.pdf; Thomas Graham, 'Chinese and Russian Companies Dominate in Race to Tap Bolivia's Lithium', *Financial Times*, 17 October 2022, https://www.ft.com/content/7c12bb7e-26fe-49b3-939f-376cc1ee76e2.
[12] US Geological Survey (USGS), 'Mineral Commodity Summaries 2023'.
[13] Graham, 'Chinese and Russian Companies Dominate in Race to Tap Bolivia's Lithium'.
[14] Ana Elizabeth Bastida et al., 'Latin America's Lithium_Critical Minerals and the Global Energy Transition'.
[15] Ana Elizabeth Bastida et al.
[16] J. Holzman and Susan Dlin, '$22.6B Mexican Lithium Mine Bogs down in Drug Cartel, Tech Risks', n.d., https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/22-6b-mexican-lithium-mine-bogs-down-in-drug-cartel-tech-risks-66512627; Harry Dempsey and Patricia Nilsson, 'Lithium Shortages Threaten Europe's Electric Car Transition', *Financial Times*, 2 April 2023, https://www.ft.com/content/154c53aa-5a9a-4004-abf9-2e6e5396dca4; Kira Taylor, 'Lithium from German Geothermal Plants Could Supply a Million Electric Vehicles a Year from 2025', Euractiv.com, 1 December 2021, https://www.euractiv.com/section/energy/news/lithium-from-german-geothermal-plants-could-supply-a-million-electric-vehicles-a-year-from-2025/.
[17] European Commission, 'Critical Raw Materials', n.d., https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en.
[18] European Commission; Victor De Decker, 'The CRM Act in a Global Perspective' (Egmont Institute, 2023), https://www.egmontinstitute.be/app/uploads/2023/04/Victor-De-Decker_Paper_121_vFinal.pdf?type=pdf.

Although demand projections vary considerably as they are subject to technological innovations and climate policy uncertainties, it is estimated that reaching the 2015 Paris Climate Agreement's goals would require 42 times more lithium globally in 2040, relative to 2020.[19] Europe would need up to 60 times more lithium in 2050, compared to 2020, to reach carbon neutrality by 2050.[20] Despite the emergence of new battery technologies, including sodium-ion batteries (see section 4.1.3), demand for lithium for manufacturing lithium-ion batteries is expected to remain high.[21] Based on known and planned lithium mining development projects, demand is expected to exceed supply after 2029-2030 unless sufficient investments are made to bridge this gap. This raises concerns about lithium's availability between 2030 and 2040.

As shown below in Figure 1, after extracting the lithium from brines and hard rocks (spodumene and lepidolites), the lithium ores and concentrates are chemically processed and refined into battery-grade lithium (lithium carbonate[22], hydroxide[23] and chloride), used to make precursors and cathode active materials to manufacture battery cells and packs of lithium-ion batteries for EVs and energy storage systems (ESS).

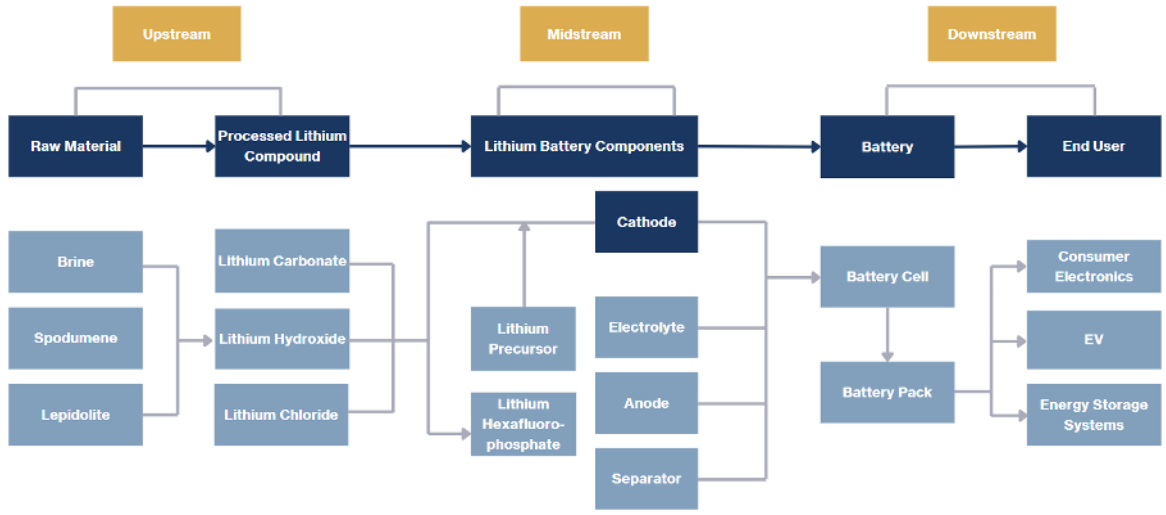

Figure 1: Lithium-ion battery supply chain. Sources: Deutsche Bank and Acclime.[24]

Finally, batteries can be recycled. The battery recycling process consists of three stages: (1) pre-treatment or pre-processing, (2) material processing and recovery and (3) battery reproduction.[25] The pre-treatment stage involves collecting, discharging and disassembling batteries, as well as the mechanical shredding of battery cells and modules into so-called black mass, a power containing crushed battery materials, like lithium.[26]

[19] International Energy Agency (IEA), 'The Role of Critical Minerals in Clean Energy Transitions'.
[20] Guillaume Ragonnaud, 'Critical Raw Materials Act' (European Parliamentary Research Service (EPRS), 2023), https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/747898/EPRS_BRI(2023)747898_EN.pdf.
[21] Samuel Carrara et al., 'Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU ? A Foresight Study', (European Commission, 2023), https://publications.jrc.ec.europa.eu/repository/handle/JRC132889.
[22] This is typically produced from lithium brine.
[23] This is typically produced from spodumene.
[24] Acclime, 'Lithium Industry In China: Overview', 3 November 2022, https://china.acclime.com/news-insights/lithium-industry-china/.
[25] Solvay, 'Battery Recycling', n.d., https://www.syensqo.com/en/solutions-market/batteries/recycling.
[26] Thomas Schmaltz and Anne-Catherine Jung, 'Recycling of Lithium-Ion Batteries Will Increase Strongly in Europe', Fraunhofer Institute for Systems and Innovation Research ISI, 19 January 2023, https://www.isi.fraunhofer.de/en/blog/themen/batterie-update/recycling-lithium-ionen-batterien-europa-starke-zunahme-2030-2040.html.

The second stage consists of processing the black mass and recovering the battery materials (nickel, cobalt, and lithium) using pyrometallurgy (pyro) or hydrometallurgy (hydro), which are currently the two main processes.[27] With pyro, the cheapest, most energy-intensive and most frequently used process, mainly cobalt and nickel are recovered at high temperatures, while lithium is lost in this process.[28] The pyro process can also be performed directly with battery cells. On the other hand, hydro involves a chemical leaching process through which the black mass is treated, and higher material recovery levels - lithium included - can be achieved. Direct recycling is a promising technology, but this is still at a nascent stage.

2.2. European import dependency

While Europe imports only small volumes of battery-grade lithium, mainly from Chile, an increased demand may lead to vulnerabilities along the lithium-ion battery supply chain, primarily from supply concentration.[29] More than 90% of Australian raw lithium production goes to China, where nearly 60% of global lithium processing occurs.[30] It should be noted that Chinese companies control substantial financial stakes in foreign companies with mining rights in Australia, Chile and Argentina.[31] Moreover, Chinese battery giant CATL announced an investment to help develop Bolivia's lithium reserves.[32] Acquiring mining stakes and gaining a strategic foothold in lithium-rich countries in Africa, Latin America, and the Asia-Pacific has been part of China's foreign supply security strategy.[33]

As illustrated by Figure 2, Chinese companies currently dominate the mid- and downstream stages of the lithium-ion battery supply chain, with Japanese and Korean companies taking much smaller shares. China is home to around 70% of the global production of cathode materials and even 85% of anode materials, both critical components of lithium-ion batteries.[34] Battery cell production is highly concentrated among East-Asian producers, like CATL (China), LG Energy Solution (South Korea) and Panasonic (Japan), for example accounting for around 65% of global production in 2021. Companies located in Europe have very low shares in the worldwide supply of battery components, particularly cathode materials, whereas capacities are more developed for battery cell and EV production, with approximately 25% of global EV assembly.

[27] Thomas Schmaltz and Anne-Catherine Jung; International Energy Agency (IEA), 'Global Supply Chains of EV Batteries', 2022, https://iea.blob.core.windows.net/assets/4eb8c252-76b1-4710-8f5e-867e751c8dda/GlobalSupplyChainsofEVBatteries.pdf; Chengetai Portia Makwarimba et al., 'Assessment of Recycling Methods and Processes for Lithium-Ion Batteries', *IScience* 25, no. 5 (May 2022): 104321, https://doi.org/10.1016/j.isci.2022.104321.
[28] Transport and Environment (T&E), 'Lithium Recycling in the Battery Regulation. Higher Recovery Targets Are Beneficial and Feasible', 2022, https://www.transportenvironment.org/wp-content/uploads/2022/10/2022_10_Lithium_recycling_factsheet.pdf.
[29] Liesbet Gregoir and Karel van Acker, 'Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge' (KU Leuven and Eurometaux, 2022), https://www.eurometaux.eu/media/jmxf2qm0/metals-for-clean-energy.pdf.
[30] Marie Le Mouel and Niclas Poitiers, 'Why Europe's Critical Raw Materials Strategy Has to Be International', *Bruegel* (blog), 2023, https://www.bruegel.org/analysis/why-europes-critical-raw-materials-strategy-has-be-international; International Energy Agency (IEA), 'Critical Minerals Market Review 2023'.
[31] International Energy Agency (IEA), 'The Role of Critical Minerals in Clean Energy Transitions'; Kalantzakos, 'The Race for Critical Minerals in an Era of Geopolitical Realignments'; Daniel Macmillen Voskoboynik and Diego Andreucci, 'Greening Extractivism: Environmental Discourses and Resource Governance in the "Lithium Triangle"', *Environment and Planning E: Nature and Space* 5, no. 2 (June 2022): 787–809, https://doi.org/10.1177/25148486211006345.
[32] Reuters, 'Chinese Battery Giant CATL Seals $1.4 Billion Deal to Develop Bolivia Lithium', *Reuters*, 19 June 2023, sec. Commodities, https://www.reuters.com/markets/commodities/chinese-battery-giant-catl-seals-14-billion-deal-develop-bolivia-lithium-2023-06-19/.
[33] Kalantzakos, 'The Race for Critical Minerals in an Era of Geopolitical Realignments'; Voskoboynik and Andreucci, 'Greening Extractivism'.
[34] International Energy Agency (IEA), 'Global Supply Chains of EV Batteries'.

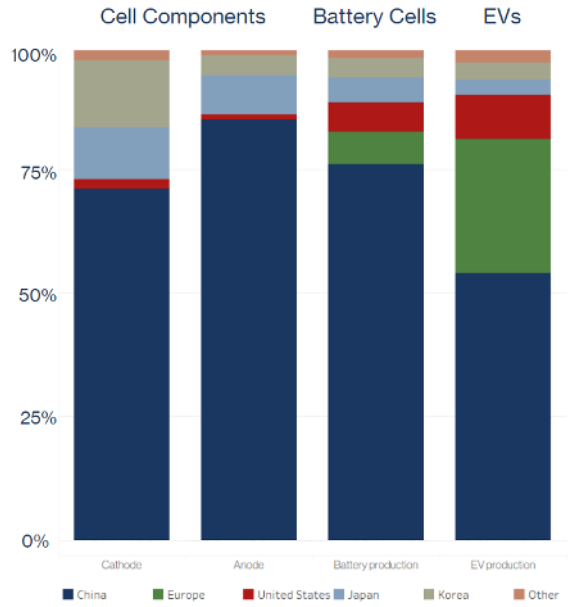

Figure 2: Geographical overview of mid- and downstream lithium-ion battery production shares. Data from IEA, 2022.

Furthermore, increasing recycling rates of end-of-life (EOL) batteries and battery production waste are an effective way to decrease the need for primary lithium supply and, in turn, address Europe's import dependency.[35] Battery production waste refers to by-products from cathode materials and battery cells which do not pass quality controls.[36] It will likely represent the primary feedstock of lithium-ion battery recycling until 2030-2035, when more EOL batteries in EVs will become widely available, becoming the primary battery recycling feedstock.[37] However, lithium recovery through lithium-ion battery recycling today is still minimal due to several barriers (see section 4.2). Its contribution to alleviating supply vulnerabilities will likely become critical after 2030 and may even result in a decline in primary lithium demand after 2040.[38]

In 2022, China accounted for about half of the global capacity for battery recycling.[39] The significant presence of the Chinese battery industry can explain China's strong position in the recycling industry. The Chinese government developed an advanced battery recycling industry, among others through non-binding recovery targets (85% for lithium) linked to government support.[40] Nevertheless, some European and North American companies, like Li-Cycle (Canada) and Hydrovolt – a joint venture between Northvolt (Sweden) and Hydro (Norway) - claim to be able to recover up to 95% of battery materials, including lithium, from lithium-ion batteries.[41]

[35] Arnoud Roelfsema, Irina Patrahau, Michel Rademaker, 'Cobalt Mining in the EU Securing Supplies and Ensuring Energy Justice' (The Hague Centre for Strategic Studies (HCSS), 2022), https://hcss.nl/wp-content/uploads/2022/09/Cobalt-mining-in-the-EU-Securing-supplies-and-ensuring-energy-justice-PDF.pdf; André Månberger and Bengt Johansson, 'The Geopolitics of Metals and Metalloids Used for the Renewable Energy Transition', *Energy Strategy Reviews* 26 (November 2019): 100394, https://doi.org/10.1016/j.esr.2019.100394; Saleem H. Ali et al., 'Closing the Infrastructure Gap for Decarbonisation: The Case for an Integrated Mineral Supply Agreement', *Environmental Science & Technology* 56, no. 22 (15 November 2022): 15280–89, https://doi.org/10.1021/acs.est.2c05413.

[36] Northvolt, 'Revolt: Closing the Loop on Batteries', 18 May 2022, https://northvolt.com/articles/revolt/.

[37] Andreas Breiter et al., 'Battery Recycling Takes the Driver's Seat', McKinsey & Company, 2023, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-recycling-takes-the-drivers-seat; Edoardo Righetti and Vasileios Rizos, 'The EU's Quest for Strategic Raw Materials: What Role for Mining and Recycling?', *Intereconomics* 58, no. 2 (1 March 2023): 69–73, https://doi.org/10.2478/ie-2023-0015.

[38] Thomas Schmaltz and Anne-Catherine Jung, 'Recycling of Lithium-Ion Batteries Will Increase Strongly in Europe'; International Energy Agency (IEA), 'Global Supply Chains of EV Batteries'; Liesbet Gregoir and Karel van Acker, 'Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge'.

[39] International Energy Agency (IEA), 'Global Supply Chains of EV Batteries'.

[40] Transport and Environment (T&E), 'Lithium Recycling in the Battery Regulation. Higher Recovery Targets Are Beneficial and Feasible'.

[41] Anna Cheung, 'How Li-Cycle Is Recovering Critical Materials From Lithium-Ion Batteries - Regional President, EMEA, Richard Storrie', Li-Cycle, 2 August 2023, https://globalnews.ca/news/9405696/electric-vehicle-battery-recycling/; Northvolt, 'Revolt: Closing the Loop on Batteries'.

3. The EU's CRM supply security policy and new lithium projects

3.1. A local European lithium supply chain and supply diversification

Following the EU Raw Materials Initiative in 2008[42], the EU New Industrial Strategy[43] and the EU CRM Action Plan[44] in 2020, the EU unveiled its proposal for a European Critical Raw Materials Act (CRMA[45]) in 2023, which is aimed at ensuring the EU's access to a secure and sustainable supply of CRM. This legal framework is based on three pillars: developing local CRM supply chains in the EU, covering mining, processing and recycling; boosting CRM supply diversification through international cooperation with third countries; and fostering a circular economy through recycling. Contrary to the US Inflation Reduction Act (IRA), which is heavily focused on reshoring/onshoring, the CRMA is more balanced between reshoring/onshoring and friend-shoring. At the time of writing this paper, the CRMA still awaits formal adoption and is expected to enter into force in early 2024.

To spur the development of local CRM supply chains and to ensure that no more than 65% of the EU's annual consumption of each strategic raw material comes from a single third country, the EU has put forward the following aggregate benchmarks that it aims to meet by 2030: European mining capacity covering at least 10% of the EU's annual consumption of strategic raw materials; European processing capacity covering at least 40% of EU annual consumption of strategic raw materials and European recycling capacity covering at least 25% of EU annual consumption of strategic raw materials.[46] While these aggregate targets will likely be met, it should be noted that there is significant heterogeneity among CRM.[47] As a result, meeting some of these benchmarks will be more challenging for certain CRM, in particular the recycling benchmark for lithium (see section 4.2.). Furthermore, with the CRMA, the EU aims to implement so-called strategic projects covering the entire CRM supply chain.[48] European strategic projects are designed to attract investments by accelerating national permitting procedures and improving access to finance through existing EU programs, like InvestEU.[49]

As the EU cannot become self-sufficient, it is simultaneously taking steps to diversify its lithium supply. Supply diversification aims to reduce the power that a supplying country can employ to exercise geo-economic coercion by

[42] 'COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL The Raw Materials Initiative — Meeting Our Critical Needs for Growth and Jobs in Europe' (Commission of the European Communities, 2008), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008DC0699.
[43] European Commission, 'Communication "Updating the 2020 New Industrial Strategy: Building a Stronger Single Market for Europe's Recovery"', 2021, https://commission.europa.eu/system/files/2021-05/communication-industrial-strategy-update-2020_en.pdf.
[44] 'COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability' (European Commission, 2020), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474.
[45] European Commission, 'COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A Secure and Sustainable Supply of Critical Raw Materials in Support of the Twin Transition' (European Commission, 2023), https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661.
[46] Marie Le Mouel and Niclas Poitiers, 'Why Europe's Critical Raw Materials Strategy Has to Be International'; Guillaume Ragonnaud, 'Critical Raw Materials Act'.
[47] Righetti and Rizos, 'The EU's Quest for Strategic Raw Materials'.
[48] Guillaume Ragonnaud, 'Critical Raw Materials Act'.
[49] Victor De Decker, 'The CRM Act in a Global Perspective'; Francesco Findeisen and Yann Wernert, 'Meeting the Costs of Resilience: The EU's Critical Raw Materials Strategy Must Go the Extra Kilometer', Hertie School Jacques Delors Centre, 2023, https://www.delorscentre.eu/en/publications/eu-critical-raw-materials.

increasing the number of suppliers.[50] Recently concluded EU free trade agreements (FTA) with lithium-rich countries like Chile contain an energy and raw materials chapter, ensuring non-discriminatory access to lithium.[51] At the time of writing this paper, FTA negotiations with Australia are still ongoing. However, with the world's largest network of FTAs concluded with 72 countries, EU trade policy offers limited incentives to diversify supply, because the EU already applies low tariffs on CRM imports.[52] For instance, the applied tariffs on lithium ore, lithium hydroxide and lithium carbonate are 2,6%, 5,3% and 5,5%. So, the scope for diversification through country-specific tariff reduction through FTAs is limited.[53]

Consequently, European foreign policy tools, such as strategic CRM partnerships, development assistance and investments in lithium-rich economies, may be more appropriate to increase the security of lithium supply.[54] The EU has already signed Memoranda of Understanding (MOUs), establishing CRM strategic partnerships with lithium-rich third countries like Canada (2021),[55] Namibia (2022),[56] Argentina (2023), [57] Chile (2023)[58] and the DRC (2023). [59] MOUs are non-binding and soft-power tools serving as political frameworks for potential cooperation between governments and companies.[60] These strategic partnerships aim to integrate the EU's CRM supply chains with those of third countries, from exploration activities to recycling.

These strategic partnerships are linked to investments and development assistance through the Global Gateway initiative, the EU's most recent global infrastructure development scheme, launched in 2021 in response to China's Belt and Road Initiative (BRI).[61] Lithium-related projects in Argentina, Chile and Mexico are illustrative cases of recently announced Global Gateway investments.[62] With the Global Gateway, the EU also aims to mobilise and leverage public and private investments in infrastructure in mineral-rich emerging and developing economies to develop so-called strategic mineral corridors.[63] Strategic mineral corridors can be understood as transport networks (port, rail and roads), which are supposed to facilitate trade, attract investments and support the development of CRM supply chains in mineral-rich regions, like Sub-Saharan Africa, ensuring European access to CRM. 11 strategic

[50] Elmer Rietveld et al., 'Strengthening the Security of Supply of Products Containing Critical Raw Materials for the Green Transition and Decarbonisation'.
[51] Marie Le Mouel and Niclas Poitiers, 'Why Europe's Critical Raw Materials Strategy Has to Be International'; European Commission, 'The EU-Chile Agreement Explained', n.d., https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/chile/eu-chile-agreement/agreement-explained_en; Elmer Rietveld et al., 'Strengthening the Security of Supply of Products Containing Critical Raw Materials for the Green Transition and Decarbonisation'.
[52] Ibid.
[53] Ibid; Transport and Environment (T&E), 'A European Response to US IRA How Europe Can Use Its Soft and Financial Powers to Build a Successful Electric Vehicle Value Chain', 2023, https://www.transportenvironment.org/wp-content/uploads/2023/01/2023_01_TE_Raw_materials_IRA_report-1.pdf.
[54] Elmer Rietveld et al., 'Strengthening the Security of Supply of Products Containing Critical Raw Materials for the Green Transition and Decarbonisation'.
[55] European Commission, 'EU-Canada Strategic Partnership on Raw Materials', n.d., https://single-market-economy.ec.europa.eu/news/eu-and-canada-set-strategic-partnership-raw-materials-2021-06-21_en.
[56] European Commission, 'EU-Namibia Strategic Partnership on Raw Materials and Hydrogen', n.d., https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6683.
[57] European Commission, 'Global Gateway: EU and Argentina Step up Cooperation on Raw Materials', n.d., https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3217.
[58] European Commission, 'Global Gateway: EU and Chile Strengthen Cooperation on Raw Materials', n.d., https://ec.europa.eu/commission/presscorner/detail/en/IP_23_3897.
[59] European Commission, 'EU Signs Strategic Partnerships on Raw Materials with DRC and Zambia', n.d., https://ec.europa.eu/commission/presscorner/detail/en/IP_23_5303.
[60] Folashadé Soulé, 'What a U.S.-DRC-Zambia Electric Vehicle Batteries Deal Reveals About the New U.S. Approach Toward Africa', Carnegie Endowment for International Peace, n.d., https://carnegieendowment.org/2023/08/21/what-u.s.-drc-zambia-electric-vehicle-batteries-deal-reveals-about-new-u.s.-approach-toward-africa-pub-90383.
[61] Michele Barbero, 'Europe Is Trying (and Failing) to Beat China at the Development Game', *Foreign Policy* (blog), 27 December 2023, https://foreignpolicy.com/2023/01/10/europe-china-eu-global-gateway-bri-economic-development/.
[62] Claudia Baranzelli et al., 'EU–Africa Strategic Corridors and Critical Raw Materials: Two-Way Approach to Regional Development and Security of Supply', *International Journal of Mining, Reclamation and Environment* 36, no. 9 (21 October 2022): 607–23, https://doi.org/10.1080/17480930.2022.2124786.; 'Global Gateway. EU-Chile: Country Project Examples', European Commission, June 2023, https://international-partnerships.ec.europa.eu/system/files/2023-06/EU-Chile-partnership_0.pdf; 'Global Gateway in Latin America and the Caribbean', European Commission, n.d., https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/stronger-europe-world/global-gateway/global-gateway-latin-america-and-caribbean_en.
[63] Claudia Baranzelli et al., 'EU–Africa Strategic Corridors and Critical Raw Materials: Two-Way Approach to Regional Development and Security of Supply', *International Journal of Mining, Reclamation and Environment* 36, no. 9 (21 October 2022): 607–23, https://doi.org/10.1080/17480930.2022.2124786.

mineral corridors have been identified, including the Maputo-Gaborone-Walvis Bay corridor running through Namibia.[64] These are displayed in Figure 3.

The EU is also involved in various multilateral initiatives, like the US-led Mineral Security Partnership (MSP), which aims to develop global resilient and sustainable CRM supply chains and support CRM projects, from mining to recycling, focusing, among others, on lithium.[65] The MSP is the first institutionalised application of the US policy focused on friend-shoring, and intends to address China's dominance in the CRM space.[66]

Next to developing local CRM supply chains and supply diversification, fostering CRM recycling is another vital part of the EU's supply security policy.[67] Both the mandatory targets for lithium recovery from batteries - 50% by the end of 2027 and 80% by the end of 2031 – and the minimum use of recycled lithium in lithium-ion battery production - 6% by 2031 and 16% by 2036 – in the recently adopted EU Battery Regulation[68] will help spur lithium recycling, rather than the non-mandatory 25% recycling benchmark in the CRMA.[69] Notably, the mandatory lithium recovery target will be vital to increasing lithium recovery rates through recycling, as lithium has not been a value driver for recycling (see more in section 4.2).

Figure 3: Strategic mineral corridors for Global Gateway in Africa. Data from European Commission, 2023.

[64] 'Global Gateway. EU-Africa: Global Gateway Investment Package – Strategic Corridors', Publications Office of the European Union, November 2022, https://ec.europa.eu/commission/presscorner/detail/en/fs_22_1119.
[65] United States Department of State, 'Minerals Security Partnership', n.d., https://www.state.gov/minerals-security-partnership/.
[66] Vlado Vivoda, 'Friend-Shoring and Critical Minerals: Exploring the Role of the Minerals Security Partnership', *Energy Research & Social Science* 100 (June 2023): 103085, https://doi.org/10.1016/j.erss.2023.103085.
[67] Righetti and Rizos, 'The EU's Quest for Strategic Raw Materials'.
[68] Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC [2023] OJ L 191/1.
[69] Council of the EU, 'Council Adopts New Regulation on Batteries and Waste Batteries', n.d., https://www.consilium.europa.eu/en/press/press-releases/2023/07/10/council-adopts-new-regulation-on-batteries-and-waste-batteries/.

In parallel with the CRMA, the EU unveiled a proposal for a Net Zero Industry Act (NZIA)[70] which contains measures to strengthen Europe's cleantech manufacturing capacity with a target of meeting at least 40% of the EU's annual deployment needs by 2030.[71] The NZIA and the CRMA are part of the EU's Green Industrial Plan, the EU's response to the US IRA.[72] As argued before, it is important to remember that the EU's primary exposure is through imports of manufactured cleantech components and goods in which CRM are embedded rather than through direct imports of raw materials.[73] As with the CRMA, a key aim of the NZIA is to strengthen supply diversification and reduce Europe's reliance on China. Considering this, Europe's green industrial policy can only succeed if the CRM Act and the NZIA run in tandem.

3.2. Upcoming lithium projects in Europe and Europe's growing battery industry

While lithium deposits can be found across Europe, including Finland, France, Germany, the Czech Republic, Austria, Serbia, Portugal, and Spain, as of 2023, no lithium mine is supplying battery-grade lithium within Europe.[74] Even if lithium production in Portugal was ranked 7th globally in terms of mining output, mined lithium in Portugal today is exclusively used for the ceramics industry. Similarly, at the time of writing this report, there are currently no lithium processing plants operational in Europe.[75]

Nevertheless, this situation will change in the coming years, with various lithium mining and processing projects under development in Europe and plans to start commercial production of battery-grade lithium before 2030. For instance, the Barroso mine in Portugal is supposed to commence production in 2026 and is set to become one of Europe's biggest lithium mines and a cornerstone of Europe's lithium supply chain.[76] In fact, geographically integrated lithium projects, in which lithium processing plants are directly supplied by closely located mining sites, are ideal for safeguarding basic lithium supply and avoiding the need to purchase lithium ore in a tight global lithium market.[77] European lithium integrated (mining and processing) and non-integrated (processing) projects under development include AMG Lithium (non-integrated project in Germany and likely the first processing plant coming online in Europe); RockTech Lithium (non-integrated project in Germany and Romania), Vulcan Energy Resources (integrated project in Germany); Northvolt and Galp (non-integrated project in Portugal), Lithium de France (integrated project in France) and Imerys (integrated project in France). Looking outside of the EU, the non-integrated Green Lithium project in the UK is also significant. By 2030, the UK, France and Germany will have the largest lithium refining capacities in Europe. According to some estimations, planned lithium mine projects could cover 25-35% of European

[70] 'Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on Establishing a Framework of Measures for Strengthening Europe's Net-Zero Technology Products Manufacturing Ecosystem (Net Zero Industry Act)' (European Commission, 2023), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0161.

[71] European Commission, 'The Net-Zero Industry Act', 2023, https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en.

[72] Simone Tagliapietra, Reinhilde Veugelers, and Jeromin Zettelmeyer, 'Rebooting the European Union's Net Zero Industry Act' (Bruegel, 2023), https://www.bruegel.org/sites/default/files/2023-07/PB%2015%202023.pdf.

[73] Marie Le Mouel, 'What Should Europe Do to Secure Its Supply of Critical Raw Materials?', 5 April 2023, https://www.bruegel.org/newsletter/what-should-europe-do-secure-its-supply-critical-raw-materials.

[74] Aiko Bünting et al., 'Resilient Supply Chains in the Battery Industry' (VDI/VDE Innovation + Technik GmbH, 2023), https://www.ipcei-batteries.eu/fileadmin/Images/accompanying-research/publications/2023-03-BZF_Studie_Lieferketten-ENG.pdf; Righetti and Rizos, 'The EU's Quest for Strategic Raw Materials'; US Geological Survey (USGS), 'Mineral Commodity Summaries 2023'.

[75] Transport and Environment (T&E), 'A European Response to US IRA How Europe Can Use Its Soft and Financial Powers to Build a Successful Electric Vehicle Value Chain'.

[76] Savannah Resources, 'Barroso Lithium Project - COMMUNITY INFORMATION SHEET', 2023, https://www.savannahresources.com/media/vizl3f4s/barroso-lithium-project-community-information-sheet-march-2023.pdf; Catarina Demony, 'Portugal Gives Environmental Green Light for Savannah's Lithium Mine', *Reuters*, 31 May 2023, https://www.reuters.com/markets/commodities/savannah-says-portugal-gives-environmental-green-light-lithium-mine-2023-05-31/; Sam Fleming, Alice Hancock, and Peter Wise, 'EU Digs for More Lithium, Cobalt and Graphite in Green Energy Push', 16 August 2023, https://www.ft.com/content/363c1643-75ae-4539-897d-ab16adfc1416.

[77] Transport and Environment (T&E), 'A European Response to US IRA How Europe Can Use Its Soft and Financial Powers to Build a Successful Electric Vehicle Value Chain'; Aiko Bünting et al., 'Resilient Supply Chains in the Battery Industry'.

demand by 2030 and around 50% of European demand could be met by local supply of processed lithium by 2030.[78] However, these 2030 projections need to be nuanced, as lithium projects in Europe, especially lithium mines, take time to materialise and are subject to uncertainties, like untested production processes and local protests (see section 4.1.1.), which can lead to delays.[79] As a result, it remains to be seen which projects will ultimately be able to start with battery-grade lithium production by the end of this decade.

Given that lithium enters the European market already embedded in lithium-ion batteries[80], the EU is investing in the development of local mid- and downstream capabilities across the lithium-ion battery supply chain, with the help of the recently adopted European Battery Regulation and programmes like the European Battery Alliance and the Important Projects of Common European Interest (IPCEI) on batteries, with some European companies, like Northvolt (Sweden), Freyr (Norway), Verkor (France) and Automotive Cells Co (ACC)[81] (France) developing battery gigafactories across Europe.[82]

Despite these industrial policy efforts, the lithium-ion supply chain will remain China-dominated in 2030, but to a lesser extent due to various global supply diversification strategies.[83] Regardless of Europe's increasing lithium mining and processing capacities, importing battery-grade lithium will still be required to meet Europe's increase in mid and downstream lithium-ion battery production.[84]

Finally, despite the current global capacity for battery recycling being mainly located in Asia, many battery recycling facilities are operational and being developed across Europe.[85] European companies, including Northvolt and Umicore, are entering into competition for recycling against their Asian competitors.

[78] Transport and Environment (T&E), 'A European Response to US IRA How Europe Can Use Its Soft and Financial Powers to Build a Successful Electric Vehicle Value Chain'; Euractiv, 'Europe's Mining Quest Faces a Hurdle: Angry Locals', 14 September 2023, https://www.euractiv.com/section/energy-environment/news/europes-mining-quest-faces-a-hurdle-angry-locals/; Antonia Zimmermann, 'Europe's Green Dilemma: Mining Key Minerals without Destroying Nature', *POLITICO*, 15 March 2023, https://www.politico.eu/article/europes-green-dilemma-mining-key-minerals-without-destroying-nature/.

[79] Aiko Bünting et al., 'Resilient Supply Chains in the Battery Industry'; Liesbet Gregoir and Karel van Acker, 'Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge'.

[80] Marie Le Mouel and Niclas Poitiers, 'Why Europe's Critical Raw Materials Strategy Has to Be International'.

[81] A joint venture between Stellantis, Mercedes-Benz and TotalEnergies, through its affiliate Saft.

[82] 'Inauguration of ACC's First Gigafactory: A European Mega-Project for Battery Production', TotalEnergies.com, 6 May 2023, https://totalenergies.com/news/inauguration-accs-first-gigafactory-european-mega-project-battery-production; Transport and Environment (T&E), 'How Not to Lose It All. Two-Thirds of Europe's Battery Gigafactories at Risk without Further Action.', 2023, https://www.transportenvironment.org/wp-content/uploads/2023/03/2023_03_Battery_risk_How_not_to_lose_it_all_report.pdf.

[83] International Energy Agency (IEA), 'Global Supply Chains of EV Batteries'; European Commission, 'RMIS - Battery Supply Chain Challenges', RMIS - Raw Materials Information System, n.d., https://rmis.jrc.ec.europa.eu/analysis-of-supply-chain-challenges-49b749.

[84] Aiko Bünting et al., 'Resilient Supply Chains in the Battery Industry'.

[85] Transport and Environment (T&E), 'A European Response to US IRA How Europe Can Use Its Soft and Financial Powers to Build a Successful Electric Vehicle Value Chain'; Thomas Schmaltz and Anne-Catherine Jung, 'Recycling of Lithium-Ion Batteries Will Increase Strongly in Europe'.

4. Making Europe's lithium supply chain more resilient: barriers and recommendations

4.1. Lithium mining and processing

4.1.1. Barriers to lithium mining

Box 1: Summary of barriers to lithium mining

- Lack of a comprehensive and reliable geological picture of Europe's CRM deposits.
- Long mining project development lead times because of complex geological exploration, feasibility studies, long and complex environmental permitting procedures, consultation with local stakeholders, etc.
- Low public acceptance of mining due to social and environmental concerns.
- Difficult access to funding and lack of EU-level targeted and additional funding.

The first barrier to ramping up lithium mining in Europe is the lack of a comprehensive and reliable geological assessment of Europe's mineral deposits due to the historically low investment rate in mining, the insufficient monitoring over the past years in Europe and technical and geological constraints preventing accurate measurements.[86] As a result, many of Europe's CRM remain untapped and unexplored. Therefore, Geological Survey Organisations in Europe, like in the Netherlands, Germany, France, and the UK, deepened their expertise and cooperation.[87]

Second, even if Europe has numerous lithium mining projects in the pipeline, lithium mines take time to materialise and become fully operational. While the average lead time for the development of a raw material mining project is between 15 and 16 years, it can take around 10 years before a lithium mine starts to be fully commercially operational because of complex geological exploration, feasibility studies, long and complex environmental permitting procedures, consultation with local stakeholders, such as indigenous communities, etc.[88] Mining facilities must be

[86] Righetti and Rizos, 'The EU's Quest for Strategic Raw Materials'; Sam Fleming, Alice Hancock, and Peter Wise, 'EU Digs for More Lithium, Cobalt and Graphite in Green Energy Push'; Irmgard Anglmayer, 'EU Critical Raw Materials Act' (European Parliamentary Research Service (EPRS), 2023), https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2023)747419.

[87] TNO, 'Geologische Dienst Nederland Maakt Ondergrond Nederland Zichtbaar',2022, https://www.tno.nl/nl/newsroom/2022/01/ondergrond-nederland-zichtbaar-gemaakt/; Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), 'BGR and BRGM Sign an Agreement to Cooperate More Closely', 2023, https://www.bgr.bund.de/DE/Gemeinsames/Oeffentlichkeitsarbeit/Pressemitteilungen/BGR/bgr-2023-03-24_bgr-and-brgm-sign-an-agreement-to-cooperate-more-closely.html?nn=1557798; British Geological Survey (BGS), 'BGS Strategy 2023 to 2028', *British Geological Survey* (blog), n.d., https://www.bgs.ac.uk/about-bgs/strategy-2023-to-2028/.

[88] Jeff Amrish Ritoe and Michel Rademaker, 'The New Great Game: Securing Critical Minerals Today for a Clean Energy System Tomorrow' (The Hague Centre for Strategic Studies (HCSS), n.d.), https://hcss.nl/report/the-new-great-gamesecuring-critical-minerals-todayfor-a-clean-energy-system-tomorrow/; Marcelo Azevedo et al., 'The Raw-Materials Challenge: How the Metals and Mining Sector Will Be at the Core of Enabling the

connected to transport networks and water and electricity systems when located in remote areas.[89] Especially in Europe, raw material projects face long and complex permitting procedures. Hence, the CRMA aims to streamline permitting procedures, with a timeline of a maximum of 27 months for national approval of strategic European mining projects.[90] In addition, a mine will initially produce far below its predetermined production, taking years to reach the nameplate production capacity.[91] Consequently, the long lead times for developing new commercial, fully operational lithium projects create supply vulnerabilities, making it challenging for Europe to ramp up its lithium production up to 2030.

Third, there are social and environmental concerns involved in lithium mining, like water stress, environmental degradation, pollution, land dispossession and a resulting need to engage with local and indigenous communities.[92] This has led to public NIMBY – Not In My Back Yard - opposition against opening new lithium mines in Europe, causing delays in European lithium production. For instance, Rio Tinto's Jadar project in Serbia, which would have become one of the largest lithium mines in the world, was put on hold, and the mining licence was retracted because of local opposition.[93] The Barroso mine in Portugal also faced public opposition, though it eventually received environmental approval and is supposed to start commercial production in 2026.[94]

Thanks to improved mining technologies in Europe, cleaner ways to extract lithium emerged, with direct lithium extraction (DLE) from geothermal brines in Germany and underground extraction in Spain, reducing land pollution and resulting in a smaller carbon footprint.[95] In any case, raising awareness of the need to develop local lithium projects involving concerned local communities at an early stage, inclusively and transparently, through community development agreements remains critical.[96]

Finally, due to the barriers described above, capital-intensive mining projects are perceived as highly risky and need help with access to funding.[97] European mining projects must thus be financially de-risked through public interventions.[98] Because of a lack of EU-level targeted and additional funding for CRM projects, there is a risk that European lithium mining projects will fail to be realised.

Energy Transition', McKinsey & Company, 10 January 2022, https://www.mckinsey.com/industries/metals-and-mining/our-insights/the-raw-materials-challenge-how-the-metals-and-mining-sector-will-be-at-the-core-of-enabling-the-energy-transition; Righetti and Rizos, 'The EU's Quest for Strategic Raw Materials'.

[89] Francesco Findeisen and Yann Wernert, 'Meeting the Costs of Resilience'.

[90] Council of the EU, 'Council and Parliament Strike Provisional Deal to Reinforce the Supply of Critical Raw Materials', 2023, https://www.consilium.europa.eu/en/press/press-releases/2023/11/13/council-and-parliament-strike-provisional-deal-to-reinforce-the-supply-of-critical-raw-materials/.

[91] Jeff Amrish Ritoe and Michel Rademaker, 'The New Great Game'.

[92] Righetti and Rizos, 'The EU's Quest for Strategic Raw Materials'; Ryan C. Berg and Henry Ziemer, 'The Indispensable Industry: Mining's Role in the Energy Transition and the Americas', Centre for Strategic and International Studies, 24 January 2023, https://www.csis.org/analysis/indispensable-industry-minings-role-energy-transition-and-americas.

[93] Dempsey and Nilsson, 'Lithium Shortages Threaten Europe's Electric Car Transition'; Aiko Bünting et al., 'Resilient Supply Chains in the Battery Industry'.

[94] Savannah Resources, 'Barroso Lithium Project - COMMUNITY INFORMATION SHEET'; Catarina Demony, 'Portugal Gives Environmental Green Light for Savannah's Lithium Mine'; Sam Fleming, Alice Hancock, and Peter Wise, 'EU Digs for More Lithium, Cobalt and Graphite in Green Energy Push'.

[95] Julia Poliscanova, 'The Critical Raw Materials Act: EU's Attempt to Have Quality and Speed', 24 July 2023, https://www.transportenvironment.org/discover/the-critical-raw-materials-act-eus-attempt-to-have-quality-and-speed/; Kira Taylor, 'Lithium from German Geothermal Plants Could Supply a Million Electric Vehicles a Year from 2025', Euractiv.com, n.d., https://www.euractiv.com/section/energy/news/lithium-from-german-geothermal-plants-could-supply-a-million-electric-vehicles-a-year-from-2025/.

[96] International Energy Agency (IEA), 'The Role of Critical Minerals in Clean Energy Transitions'.

[97] Righetti and Rizos, 'The EU's Quest for Strategic Raw Materials'; International Energy Agency (IEA), 'The Role of Critical Minerals in Clean Energy Transitions'; Marcelo Azevedo et al., 'The Raw-Materials Challenge: How the Metals and Mining Sector Will Be at the Core of Enabling the Energy Transition'.

[98] Francesco Findeisen and Yann Wernert, 'Meeting the Costs of Resilience'.

4.1.2. Barriers to lithium processing

Box 2: Summary of barriers to lithium processing

- Lithium processing projects face lengthy permitting procedures.
- Low public acceptance of chemical processing activities due to environmental concerns.
- Significant capital investment requirements and lack of EU-level targeted and additional funding.

Like mining projects, capital-intensive lithium processing projects in Europe face lengthy permitting procedures, various environmental issues and significant capital investment requirements.

While lithium mines take around 10 years to be commercially operational, lithium processing facilities can be operational in 3 to 5 years.[99] Putting this in perspective, lithium processing plants in China can be built in less than two years.[100] Considering this, ramping up lithium refining and processing capacity in Europe looks more feasible than lithium mining. To address the lengthy permitting procedures, the EU has included a timeline of a maximum of 15 months for national approval of strategic lithium processing projects in the CRMA.[101]

As for the environmental concerns, large lithium processing operations can lead to landscape change, increased water stress, hazardous waste, water and soil contamination resulting from hazardous materials spills, etc.[102] Most of the lithium processing and refining occurs in China, where coal-powered installations are used.[103] Similar to the development of lithium mines, awareness raising and the involvement of local communities remain essential, along with stringent environmental policies, such as waste management and preventing ecological degradation. As argued before, geographically integrated lithium projects with newer and more efficient technologies, including DLE from geothermal brines, will result in a smaller carbon footprint.

Finally, capital-intensive lithium processing projects risk not being realised due to a lack of EU-level targeted and additional funding. Therefore, lithium processing projects, facing significant capital requirements, need to be financially de-risked through public interventions.

[99] Jeff Amrish Ritoe and Michel Rademaker, 'The New Great Game'.
[100] Sergey Alyabyev et al., 'Australia's Potential in the Lithium Mining Market', 2023, McKinsey & Company, https://www.mckinsey.com/industries/metals-and-mining/our-insights/australias-potential-in-the-lithium-market.
[101] Council of the EU, 'Council and Parliament Strike Provisional Deal to Reinforce the Supply of Critical Raw Materials'.
[102] International Energy Agency (IEA), 'The Role of Critical Minerals in Clean Energy Transitions', 20; Joris Teer et al., 'The Semiconductor and Critical Raw Material Ecosystem at a Time of Great Power Rivalry Full Version' (The Hague Centre for Strategic Studies (HCSS), 2023), https://hcss.nl/wp-content/uploads/2022/10/Reaching-Breaking-Point-Full-Version-HCSS-2022.pdf.
[103] International Renewable Energy Agency (IRENA), 'Geopolitics of the Energy Transition: Critical Materials'.

4.1.3. Recommendations for lithium mining and processing

Box 3: Summary of recommendations for lithium mining and processing

- Create a sovereign European public-private CRM fund to de-risk lithium projects in Europe. Setting up a specific Important Project of Common European Interest (IPCEI) on CRM is also worth exploring.
- Invest more in infrastructure and lithium projects through the EU Global Gateway and conclude more CRM strategic partnerships with Australia and other lithium-rich countries in Africa (Mali, Ghana, Zimbabwe, etc.) and Latin America (Brazil and Mexico) to diversify lithium supply, support local battery industrialisation and counter China's deep involvement in the global lithium industry, provided that ESG standards are met.
- Use Japan's and Germany's resource diplomatic tools (equity investments, loans and untied loan guarantees to de-risk overseas lithium mining and processing investments and involve European companies in view of securing lithium offtake agreements.
- International R&D cooperation with the US, Japan, South Korea and other MSP members with strong R&D capabilities to develop sodium-ion batteries and similar battery technologies.

Establishing a sovereign public-private European CRM fund directly involving private companies could help de-risk and secure private investments in lithium mining and processing projects in Europe.[104] Another idea would be replicating the European Hydrogen Bank to support CRM projects. EU-level support could encourage the involvement of European downstream players, like battery and car manufacturers, in lithium projects. An EU-level sovereign fund would also help maintain a level playing field in the EU. Additionally, an important project of common European interest (IPCEI) on CRM, supporting European member states with their CRM projects, is worth exploring, as proposed by the EU Parliament in 2021.[105]

As seen before, even with various local lithium mining and processing projects, Europe will need to import battery-grade lithium responsibly, ensuring that ESG standards are met. Therefore, the EU should continue to employ its Global Gateway Investment Agenda and conclude more CRM strategic partnerships with Australia and other lithium-rich countries in Africa and Latin America to diversify lithium supply, support local battery industrialisation and counter China's deep involvement in the lithium industry. For instance, a strategic CRM partnership with Australia can provide the necessary framework for friend-shoring and cooperation between governments and private investors, given its lithium mining expertise, high ESG standards and its aim to develop domestic lithium hydroxide processing plants to decrease its reliance on China.[106] Most of Australia's mined lithium (spodumene) is currently shipped to China. According to the Australian government, approximately 20% of global lithium processing could occur in Australia by 2027.[107] As Western Australia, which accounts for about half of the worldwide lithium production, is looking to attract investments, Europe could seize this opportunity to diversify its lithium supply,

[104] Transport & Environment (T&E), 'Expansion of the EU Innovation Fund Needed for Battery Supply Chain', 2023, https://www.transportenvironment.org/discover/expansion-of-the-eu-innovation-fund-needed-for-battery-supply-chain/.
[105] European Parliament, 'A European Strategy for Critical Raw Materials European Parliament Resolution of 24 November 2021 on a European Strategy for Critical Raw Materials (2021/2011(INI))', 2021, https://www.europarl.europa.eu/doceo/document/TA-9-2021-0468_EN.pdf.
[106] Natasha Frost, 'Australia Tries to Break Its Dependence on China for Lithium Mining', *The New York Times*, 23 May 2023, https://www.nytimes.com/2023/05/23/business/australia-lithium-refining.html; Dutch Ministry of Foreign Affairs, 'Critical Minerals Opportunities in Australia', 2023, https://www.rvo.nl/sites/default/files/2023-03/Critical%20Minerals%20Opportunities%20in%20Australia%202023.pdf; Elmer Rietveld et al., 'Strengthening the Security of Supply of Products Containing Critical Raw Materials for the Green Transition and Decarbonisation'; Sergey Alyabyev et al., 'Australia's Potential in the Lithium Mining Market'.
[107] Colin Clark, 'Resources and Energy Quarterly' (Department of Industry, Science and Resources, Commonwealth of Australia, 2022), https://www.industry.gov.au/sites/default/files/minisite/static/ba3c15bd-3747-4346-a328-6b5a43672abf/resources-and-energy-quarterly-september-2022/documents/Resources-and-Energy-Quarterly-September-2022.pdf.

decreasing its reliance on Chinese coal-based lithium processing operations.[108] Contrary to Chile and Argentina, which continue to attract Chinese investors, Chinese investments in Canadian and Australian lithium industries face greater scrutiny.[109]

Given the growing lithium industries in Mexico and Brazil, the EU could strengthen the relationship with both countries through new CRM strategic partnerships and continue to deploy the Global Gateway Investment Agenda to support local infrastructure and lithium projects.[110]

Similarly in Africa, the EU could support African battery industrialisation and, at the same time, diversify lithium supply through new strategic partnerships and the Global Gateway, provided that ESG issues are addressed. Thanks to lithium deposits in Zimbabwe, Ghana, Mali and the DRC, Africa is forecasted to be one of the largest growth areas for lithium supply.[111] The recently concluded EU-DRC strategic partnership can be used to support the development of the DRC's nascent lithium industry.[112] Furthermore, like the US, the EU can support the development of an integrated EV battery supply chain through its strategic partnerships with the DRC and Zambia. In 2022, the US signed a trilateral MOU with the DRC and Zambia to develop an integrated EV battery supply chain from the extraction to the manufacturing stage.[113] This agreement strengthens the cooperation agreement between the DRC and Zambia in 2022 to develop a cross-border EV battery supply chain with special economic zones, starting with producing battery precursors.[114]

Both the EU and EU member states can learn from Japan's and Germany's financial resource diplomacy to de-risk overseas lithium projects in Western Australia, Sub-Saharan Africa, and Latin America. The Japanese government has been concerned with critical mineral supply shortages since the mid-1980s due to the lack of mineral deposits and domestic upstream capacity.[115] Both the Japanese Ministry of Economy, Trade and Industry (METI), leading the policy work, and the Japan Organisation for Metals and Energy Security (JOGMEC), the implementing actor, are working towards increased security of supply. To help Japanese original equipment manufacturers (OEMs) gain access to overseas mining projects in the exploration, development and production stages, and secure offtake agreements, METI and JOGMEC apply resource diplomacy through equity investments, loans and liability guarantees.[116] By including big downstream players in developing a lithium mine at an early stage, they can de-risk the mining investment in return for an equity share or offtake agreements. For example, JOGMEC has provided financial support of 50% of the total exploration costs for a lithium project in Argentina to Toyota.[117] The Japanese government recently

[108] Western Australian Government, 'Western Australia. A Global Battery and Critical Minerals Hub', 2023, https://www.wa.gov.au/system/files/2023-11/00178_battery-and-critical-minerals_prospectus_v10-web_0.pdf; Dutch Ministry of Foreign Affairs, 'Critical Minerals Opportunities in Australia'.

[109] 'Australia Cautious on Chinese Investment in Vital Lithium Sector', *MINING.COM*, n.d., https://www.mining.com/web/australia-cautious-on-chinese-investment-in-lithium-sector/; Ismail Shakil and Siyi Liu, 'Canada Orders Three Chinese Firms to Exit Lithium Mining', *Reuters*, n.d., https://www.reuters.com/markets/commodities/canada-orders-three-foreign-firms-divest-investments-critical-minerals-2022-11-02/; James Attwood, 'China's Tsingshan Gets Access to Chilean Lithium in Battery Metal Race', *Bloomberg.Com*, 16 October 2023, https://www.bloomberg.com/news/articles/2023-10-16/china-s-tsingshan-gets-access-to-chilean-lithium-in-battery-metal-race.

[110] International Energy Agency (IEA), 'Critical Minerals Market Review 2023'; Sigma Lithium, 'Grota Do Cirilo', n.d., https://sigmalithiumresources.com/grota-do-cirilo/; Bacanora Lithium, 'Sonora Lithium Project - Overview', n.d., https://bacanoralithium.com/sonora_lithium_project/.

[111] 'Will Europe Have Enough Lithium to Meet Demand?', *Fastmarkets* (blog), 25 July 2023, https://www.fastmarkets.com/insights/will-europe-have-enough-lithium-to-meet-demand/; Annie Lee, 'China Jumps Ahead in the Rush to Secure Lithium From Africa', *Bloomberg.Com*, 3 July 2023, https://www.bloomberg.com/news/articles/2023-07-03/china-jumps-ahead-in-the-rush-to-secure-lithium-from-africa.

[112] Harry Dempsey and Joseph Cotterill, 'How China Is Winning the Race for Africa's Lithium', *Financial Times*, 3 April 2023, https://www.ft.com/content/02d6f35d-e646-40f7-894c-ffcc6acd9b25.

[113] Soulé, 'What a U.S.-DRC-Zambia Electric Vehicle Batteries Deal Reveals About the New U.S. Approach Toward Africa'.

[114] United Nations Economic Commission for Africa (UNECA), 'Zambia and DRC Sign Cooperation Agreement to Manufacture Electric Batteries', 2023, https://www.uneca.org/stories/zambia-and-drc-sign-cooperation-agreement-to-manufacture-electric-batteries; Melanie Müller et al., 'From Competition to a Sustainable Raw Materials Diplomacy: Pointers for European Policymakers', *SWP Research Paper*, 2023, https://www.swp-berlin.org/10.18449/2023RP01/.

[115] Jane Nakano, 'The Geopolitics of Critical Minerals Supply Chains' (CSIS, 11 March 2021), https://www.csis.org/analysis/geopolitics-critical-minerals-supply-chains; Müller et al., 'From Competition to a Sustainable Raw Materials Diplomacy'; Jeff Amrish Ritoe and Michel Rademaker, 'The New Great Game'.

[116] Nakano, 'The Geopolitics of Critical Minerals Supply Chains'; IEA, 'JOGMEC & JBIC Financial Support for Overseas Minerals Projects – Policies', n.d., https://www.iea.org/policies/16642-jogmec-jbic-financial-support-for-overseas-minerals-projects.

[117] Japan Organisation for Metals and Energy Security (JOGMEC), 'JOGMEC Provides Financial Support to Toyota Tsusho Corporation for a Lithium Exploration Project in Argentina.', 2010, https://www.jogmec.go.jp/english/news/release/release0036.html.

raised the ceiling on government equity investments from 50 to 75% for battery minerals upstream projects, including lithium.

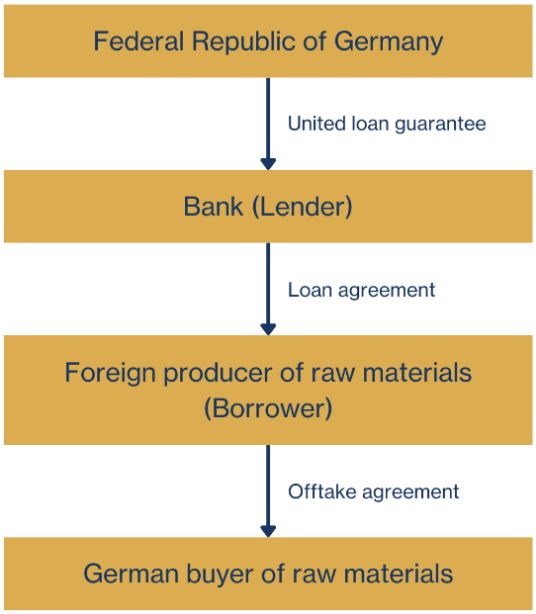

Figure 4: Structure of German Untied Loan Guarantee. Source: Euler Hermes, 2020.

Moreover, the German federal government provides untied loan guarantees through which it secures a certain percentage of a bank loan, in some cases even 80%, for a foreign raw material project against political and commercial risks, provided that the output of the projects is delivered through a long-term offtake agreement to a German company (see Figure 4).[118] European companies need to move quickly to invest in overseas lithium projects and secure lithium offtake agreements, as they face intense competition from Chinese companies, which already largely control lithium offtake agreements in Africa.[119]

Finally, developing lithium-free cathode chemistries can reduce the demand for primary lithium. As explained before, lithium-ion batteries are currently the dominant driver of demand for lithium.

[118] Jeff Amrish Ritoe, 'Tying Critical Materials through the Untied Loan Guarantee | A Proven and Effective Way to Secure Materials Needed for Europe's Energy Transition', (The Hague Centre for Strategic Studies (HCSS), 27 October 2022), https://hcss.nl/report/critical-materials-untied-loan-guarantee/; Euler Hermes and German Federal Ministry of Economic Affairs and Energy, 'Untied Loan Guarantees Granted by the Federal Government for Corporate Finance', 2020, https://www.ufk-garantien.de/_Resources/Persistent/b/6/9/9/b6999e4f31ccbe81eeb0f39b7e21629919b41735/e_pi_ufk_unternehmensfinanzierungen.pdf.

[119] Anthony Barich, 'Europe Risks Losing African Lithium Opportunity to China', *S&P Global Market Intelligence*, 21 September 2022, https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/europe-risks-losing-african-lithium-opportunity-to-china-71754119.

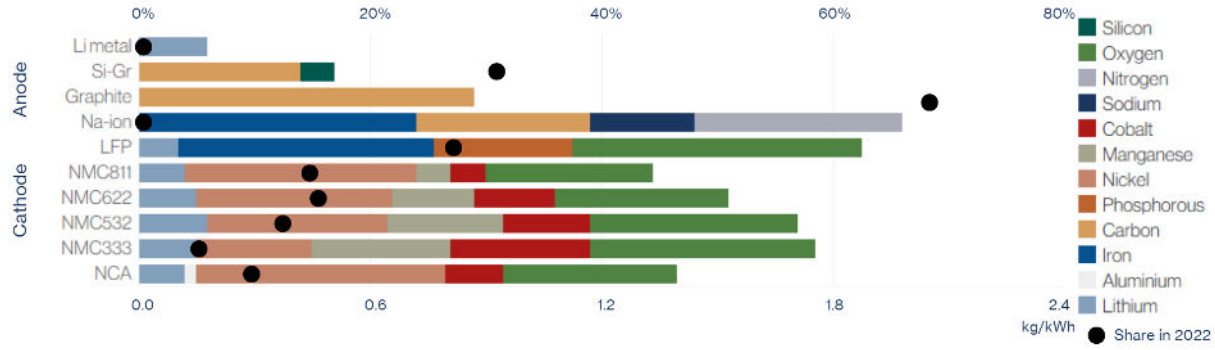

Figure 5: Overview of different anode and cathode chemistries. Data from IEA, 2023

As shown in Figure 5, in 2022, the dominant battery cathode chemistry was lithium NMC (nickel-manganese-cobalt-oxide), accounting for around 60% of the global market share, followed by LFP (lithium-iron-phosphate), with a share of about 30%.[120] LFP batteries do not need nickel and cobalt, they have a lower energy density but also a lower cost and are mainly produced in China. With the evolution to more nickel-rich battery cathode chemistries, NMC 811 is likely to overtake NMC 622 and it is composed of 80% nickel, 10% manganese and 10% cobalt. Although alternatives to lithium-ion batteries have been emerging, no alternative battery chemistry is yet available at a scale that meets the same performance as lithium-ion batteries.[121] However, sodium-ion (Na-ion) batteries, using no lithium, cobalt, or nickel, are progressing, with China leading the race for this next generation of batteries under China's 14th Five-Year Plan. The critical advantage of sodium-ion over lithium-ion batteries is that they rely on abundant and low-cost minerals like sodium, resulting in cheaper batteries. Currently, this is the only viable battery technology that does not need lithium.[122] On the other hand, sodium-ion batteries are less performant than lithium-ion batteries, as they have a lower energy density, making them more suitable for urban EVs and grid-scale storage.[123] Moreover, uncertainties remain around the industrial scalability of production despite the commercial introduction of sodium-ion batteries in China, for instance, by CATL in 2021.

Even if MSP members are lagging in terms of R&D and patents, Europe should foster international R&D cooperation with MSP members like the US, South Korea and Japan, especially given Japan's strong battery R&D capabilities and solid technological track record in critical raw material reduction and substitutes. EIT RawMaterials[124], an innovation community within the European Institute of Innovation and Technology (EIT), could play a key facilitating role in this.

Japan and the US share the same goals as the EU since they aim to decrease their reliance on China by developing alternatives to resource-rich batteries.[125]

[120] International Energy Agency, 'Global EV Outlook 2023: Catching up with Climate Ambitions' (International Energy Agency, 26 April 2023), https://doi.org/10.1787/cbe724e8-en.

[121] International Energy Agency (IEA), 'Global Supply Chains of EV Batteries'.

[122] International Energy Agency, 'Global EV Outlook 2023'.

[123] International Energy Agency (IEA), 'Global Supply Chains of EV Batteries'; Nikkei Staff Writers, 'China Leads Global Battery Patent Race for Post-Lithium-Ion Era', *Nikkei Asia*, accessed 22 December 2023, https://asia.nikkei.com/Business/China-tech/China-leads-global-battery-patent-race-for-post-lithium-ion-era; Keith Bradsher, 'China Could Dominate Sodium Batteries, the Next Big Advance in Power', *The New York Times*, 12 April 2023, https://www.nytimes.com/2023/04/12/business/china-sodium-batteries.html.

[124] See more: https://eitrawmaterials.eu.

[125] Carrara et al., 'Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU ? A Foresight Study'; Nakano, 'The Geopolitics of Critical Minerals Supply Chains'.

4.2. Lithium recycling

4.2.1. Barriers to lithium recycling

Box 4: Summary of barriers to lithium recycling

- Limited commercial viability and historical lack of profitability to recover lithium through recycling.
- Lack of available EOL batteries which will only become widely available after 2030.
- Battery waste leakage (mainly black mass) from Europe to Asia (mainly South Korea and China) resulting in a lack of access to the necessary recycling feedstock in Europe.
- Limits to intra-EU shipment of EOL batteries and black mass due to divergent national interpretations of waste codes and rigid red tape.

Today, lithium recovery through recycling is still minimal due to several barriers. The main obstacle is the limited commercial viability and the historical lack of profitability to recover lithium through lithium-ion battery recycling, given the low lithium prices – until 2022 - compared to the high cost of recycling.[126] Furthermore, the lower purity and grade of recycled lithium contribute to this. In other words, lithium has not been a value driver for lithium-ion battery recycling. As a result, battery recycling has been focusing on recovering the more expensive and valuable raw materials, cobalt and nickel, in the NMC cathodes using pyro processing. Also, this makes recycling more lithium-rich LFP batteries challenging.[127]

Another critical barrier making lithium-ion battery recycling – not just lithium recycling – more challenging is the lack of available end-of-life (EOL) batteries. With batteries assumed to have an average lifetime of between 12 and 14 years, EOL batteries will only become widely available after 2030.[128] Until then, battery recycling will still largely depend on battery production waste.[129]

A further bottleneck is battery waste leakage, mainly black mass, resulting in a lack of access to the necessary recycling feedstock in Europe. Due to a current recycling capacity mismatch in Europe, with numerous pre-treatment plants and only a few processing and material recovery plants operated by different companies, most of the black mass generated in Europe is currently shipped to Asia, mainly South Korea and China, even if China officially restricts imports and exports of black mass given its toxic nature.[130] Despite official Chinese import restrictions, Chinese recyclers manage to indirectly import black mass through other Asian countries, like Indonesia, the Philippines and Laos, for further processing to produce cathode-active materials. While Europe has not introduced any restrictions on black mass exports, China has banned black mass exports.

The last barrier are the divergent national interpretations of waste codes and the rigid red tape needed to ship black mass and EOL batteries, resulting in sluggish and costly transportation procedures for EOL batteries and black mass within the EU. [131]

[126] Makwarimba et al., 'Assessment of Recycling Methods and Processes for Lithium-Ion Batteries'; Association négaWatt, 'Lithium: Towards a Necessary Sufficiency', 2023, https://negawatt.org/IMG/pdf/221104_note_lithium_final__en.pdf.
[127] Rebecca Martineau, 'New Collaboration Balances Sustainability and Profitability of Lithium-Ion Battery Recycling', NREL, 2023, https://www.nrel.gov/news/program/2023/new-collaboration-balances-sustainability-profitability-lithium-ion-battery-recycling.html.
[128] Righetti and Rizos, 'The EU's Quest for Strategic Raw Materials'; Liesbet Gregoir and Karel van Acker, 'Metals for Clean Energy: Pathways to Solving Europe's Raw Materials Challenge'.
[129] Breiter et al., 'Battery Recycling Takes the Driver's Seat'.
[130] Transport and Environment (T&E), 'A European Response to US IRA How Europe Can Use Its Soft and Financial Powers to Build a Successful Electric Vehicle Value Chain'; Ross Yeo, 'European Battery Regulations to Restrict Black Mass Exports to Secure Raw Materials', Fastmarkets, 6 July 2023, https://www.fastmarkets.com/insights/european-battery-regulations-to-restrict-black-mass-exports/.; TELF AG, 'Report on the Growing Demand for Black Mass Battery Materials', 14 July 2023, https://telf.ch/telf-ag-report-on-the-growing-demand-for-black-mass-battery-materials-july-14-2023/.
[131] Avere, Eurometaux, and Recharge, 'Open Letter – Call to Remove Obstacles for Shipping Battery Black Mass for Intra-EU Recycling under the Last Stages of the EU Waste Shipment Regulation Trilogue Negotiations', 3 November 2023, https://eurometaux.eu/media/lsnl5kay/2023-11-06-open-letter-to-address-intra-eu-batteries-black-mass-waste-shipment-avere-recharge-eurometaux.pdf.

4.2.2. Recommendations for lithium recycling

Box 5: Summary of recommendations for lithium recycling

- Effective implementation of the EU Battery regulation by EU member states and adoption of future EU delegated acts to spur lithium recycling in Europe.
- Prioritisation of funding to recycling projects that aim to adopt a so-called integrated 'spoke' and 'hub' model to close the loop and secure enough recycling feedstock.
- Restriction of EU black mass exports through the regulatory classification of black mass as hazardous waste at EU-level.
- Harmonisation of waste codes for lithium-ion batteries and definition of more streamlined intra-EU battery waste shipment procedures at EU-level.

First, the effective implementation of the EU Battery Regulation, with its mandatory lithium recovery and minimum levels of recycled lithium use in battery production, by the EU member states will be critical to help spur lithium recycling in Europe. Considering that some companies, like Northvolt (see section 2.2.) can meet higher lithium recovery targets than those in the EU Battery regulation, the EU Commission can go even further and adopt delegated acts, changing the regulation in consultation with the recycling industry and other EU institutions. This regulatory option is foreseen in the EU Battery regulation.

Secondly, given the aforementioned existing recycling capacity mismatch in Europe, supporting the further integration of the recycling supply chain in Europe remains essential to close the loop, secure enough recycling feedstock and increase lithium supply security. This can be done through the prioritisation of funding to recycling projects that aim to adopt a so-called integrated 'spoke' – performing the first stage of the recycling process - and 'hub' – performing the second stage of the recycling process - business model, whereby a company operates a pre-processing plant feeding the processing and material recovery plant.[132] Vertical integration can also be achieved through JVs or long-term offtake agreements between market players. The partnerships between Veolia and Solvay, and Hydro and Northvolt are clear illustrations.[133] As argued before, a public-private sovereign EU-level CRM Fund could support European integrated recycling projects.

To address the current battery waste leakage to Asia, European black mass exports can be limited through the regulatory classification of black mass as hazardous waste at the EU level.[134]

In conclusion, EU policymakers could harmonise the waste codes for lithium-ion batteries and define a more streamlined battery waste shipment procedure at the EU level to facilitate the restrictive intra-EU transportation of battery waste and EOL batteries.[135]

[132] Thomas Schmaltz and Anne-Catherine Jung, 'Recycling of Lithium-Ion Batteries Will Increase Strongly in Europe'; Ross Yeo, 'Https://Www.Fastmarkets.Com/Insights/European-Battery-Regulations-to-Restrict-Black-Mass-Exports/'; Transport and Environment (T&E), 'A European Response to US IRA How Europe Can Use Its Soft and Financial Powers to Build a Successful Electric Vehicle Value Chain'.
[133] 'Solvay and Veolia Partner to Recycle Electric Vehicle Batteries', Veolia, , 9 September 2020, https://www.veolia.com/en/news/recycling-lithium-ion-batteries-electric-vehicles-solvay-veolia; Northvolt, 'Revolt: Closing the Loop on Batteries'.
[134] Ross Yeo, 'European Battery Regilations to Restrict Black Mass Exports to Secure Raw Materials'.
[135] Avere, Eurometaux, and Recharge, 'Open Letter'.

5. Conclusion and policy recommendations

5.1. Conclusion

Amid the geopolitical competition for access to CRM needed to manufacture lithium-ion batteries, the EU is taking serious steps to increase its open strategic autonomy and address its lithium supply vulnerabilities through its CRM and battery policies, like the CRMA and the EU Battery Regulation. Various lithium mining, processing and recycling projects in Europe are under development and will help increase Europe's lithium supply security. The development of commercially viable lithium-free battery technologies, like sodium-ion batteries may also help alleviate Europe's lithium supply vulnerabilities.

However, even with the development of a local lithium supply chain and growing battery industry in Europe, the lithium-ion battery supply chain is likely to remain Chinese-dominated by 2030. A European lithium supply chain takes time to materialise and particularly the impact of recycling will only be visible after 2030 once more EOL batteries will become widely available. Capital-intensive and risky lithium projects in Europe, especially lithium mines, are also subject to various barriers and uncertainties, like lengthy project development lead times, and environmental and social concerns, resulting in a difficult access to funding. Arguably, a sovereign public-private EU-level CRM Fund directly involving the private sector can help de-risk lithium projects in Europe. As for recycling, funding needs to be focused on recycling projects adopting a an integrated 'spoke' and 'hub' model to close the loop and secure enough recycling feedstock in Europe. In addition, the EU needs to address battery waste leakage to Asia and explore the benefits and challenges of restricting black mass exports.

Regardless of Europe's increasing lithium industry and integrated lithium projects, Europe will still be dependent on imports of battery-grade lithium to feed its growing battery industry. As a result, the EU needs to continue to employ its Global Gateway Investment Agenda and conclude more CRM strategic partnerships with lithium-rich countries to diversify lithium supply, support local battery industrialisation and counter China's deep involvement in the global lithium industry. In doing so, ESG standards need to be met. Furthermore, the EU and EU member states need to de-risk overseas lithium projects and support European companies with securing lithium offtake agreements, using resource diplomatic tools, like equity investments, loans and untied loan guarantees. Finally, the EU needs to strengthen its cooperation with the members of the MSP on the development of integrated lithium supply chains and on R&D to develop commercially viable lithium-free battery technologies, like sodium-ion batteries.

5.2. Policy recommendations for a resilient European lithium supply chain

- A sovereign **European public-private CRM Fund, directly involving private companies,** could de-risk investments in lithium mining, processing and recycling projects in Europe. Setting up a specific **Important Project of Common European Interest (IPCEI) on CRM** is also worth exploring.
- The EU should **provide more development assistance through the Global Gateway** and conclude **more strategic partnerships with Australia and other lithium-rich countries in Africa (Mali, Ghana, Zimbabwe, etc.) and Latin America (Brazil and Mexico)** to diversify lithium supply, support local battery industrialisation and counter China's deep involvement in the global lithium industry. In doing so, it also needs to ensure that ESG standards are met.
- The EU and member states should use resource diplomacy tools like those of **Japan and Germany**, including **equity investments, loans and untied loan guarantees** to de-risk overseas lithium projects in Western Australia, Africa and Latin America and support European companies with securing lithium offtake agreements.
- **Lithium-free cathode battery chemistries**, like **sodium-ion batteries**, can reduce demand for mined lithium and help alleviate Europe's lithium supply vulnerabilities. Besides supporting local R&D in new battery technologies, Europe should foster **international cooperation with other Mineral Security Partnership (MSP) members,** like the US, Japan and South Korea. **EIT RawMaterials** can play a key facilitating role in this.
- EU member states should ensure **effective implementation of the EU Battery Regulation**, with its mandatory lithium recovery and minimum levels of recycled lithium use in battery production, to **support lithium recycling.** If needed, these targets can be enhanced through delegated acts.
- The EU and member states should **prioritise funding** to recycling projects that aim to adopt a so-called integrated **'spoke' and 'hub' model to close the loop and secure enough recycling feedstock**. Again, a **European public-private CRM Fund** could support this.
- **European black mass exports** should be **limited** through the **regulatory classification of black mass as hazardous waste at the EU level** to address the current battery waste leakage to Asia.
- EU policymakers should **harmonise waste codes for lithium-ion batteries** and define a **more streamlined battery waste shipment procedure** at the EU level to **facilitate the restrictive intra-EU transportation of battery waste and EOL batteries.**

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