



**IMPROVING THE SUSTAINABILITY AND CIRCULARITY OF BATTERY  
PRODUCTION AND CRITICAL RAW MATERIALS  
- THE EU CRITICAL RAW MATERIALS ACT AND ITS EFFECTS ON THE  
FINNISH BATTERY INDUSTRY**

Lappeenranta–Lahti University of Technology LUT

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## ABSTRACT

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Keywords: Critical raw material, CRMA, Critical Raw Materials Act, Battery,  
Sustainability

Batteries come with many benefits and are an essential element in reaching the climate neutrality goals, but the manufacturing of batteries have several sustainability issues which need to be tackled. The battery industry also requires a lot of critical and strategic raw materials. The EU Critical Raw Materials Act was introduced in 2024. The Act aims to ensure that the EU can rely on strong, resilient, and sustainable value chains for critical raw materials. The CRMA introduces several sustainability approaches to critical raw materials and the production of battery materials. Sustainability is seen to be one of the biggest competitive advantages for the Finnish battery value chain and battery production, hence the CRMA is estimated to have a significant effect on companies working in the battery value chain in Finland. For this thesis, an online survey was conducted, to find out how the companies and different stakeholders in Finland see the possible effects the Act will have. The results of the survey reflect many discussions there have been during the CRMA process with companies, different stakeholders and especially the European Commission by the Finnish Battery Industries Association (Akkuteollisuus ry). The CRMA is seen to bring competitive advantages to the companies and to open up new business opportunities.

## TIIVISTELMÄ

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VASTUULLISUUS JA KIERTOTALOUS AKKUJEN ARVOKETJUSSA JA

KRIITTISTEN RAAKA-AINEIDEN KÄYTÖSSÄ

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Akut ovat merkittävässä roolissa yhteiskunnan sähköistymisessä ja tätä kautta ilmastotavoitteisiin pääsemisessä. Akkujen tuotantoon liittyy kuitenkin ympäristöön ja vastuullisuuteen liittyviä ongelmia. Akkuihin käytetään myös paljon EU:ssa kriittiseksi ja strategiseksi luokiteltuja raaka-aineita.

EU:n Kriittisten raaka-aineiden Asetus CRMA astui voimaan virallisesti toukokuussa 2024. Sen tavoitteena on parantaa EU:n omavaraisuutta kriittisiin raaka-aineisiin liittyen sekä parantaa toimitus- ja tuotantoketjujen läpinäkyvyyttä. Asetus sisältää myös paljon vastuullisuuteen liittyviä vaatimuksia. Koska vastuullisuus nähdään suomalaisen mineraali- ja akkutuotannon kilpailuvalttina, asetuksella nähdään olevan suuri vaikutus suomalaisessa akkuarvoketjussa toimiviin yrityksiin. Tätä opinnäytetyötä varten toteutettiin vaikutuksia kartoittava kysely alan yrityksille sekä keskeisille sidosryhmille. Kyselyn tulokset vastaavat hyvin lainsäädäntöä luotaessa käytyjä keskusteluja eri toimijoiden kanssa. CRMA:n nähdään parantavan suomalaisten yritysten kilpailukykyä ja tuovan uusia liiketoimintamahdollisuuksia.

## TABLE OF CONTENTS

1	Introduction .....	6
2	Critical raw materials .....	8
2.1	The methodology to define critical raw materials.....	13
2.2	Recycling of critical raw materials .....	13
3	Mining and refining of raw materials in Finland.....	16
4	The sustainability of battery manufacturing and critical raw materials .....	21
4.1	Carbon footprint of LIBs.....	24
4.2	Increasing the circularity of battery materials.....	26
4.3	Recycling of Lithium-ion batteries .....	28
4.4	Design for recycling .....	32
5	The EU Critical Raw Materials Act .....	34
5.1	Background for legislation.....	34
5.2	The objectives of CRMA .....	35
6	The Battery Industry.....	37
6.1	Battery value chain in Finland .....	39
7	The effects of the Critical Raw Materials Act on Finnish companies .....	40
7.1	The methodology .....	40
7.2	The survey and results.....	41
7	Discussion.....	54
7.1	CRMA promotes sustainability in the battery sector .....	54
7.2	Timelines for permitting and access to finance were considered important .....	55
7.3	Strategic Project status brings benefits to the investment projects .....	56
7.4	Are the set targets possible to meet – deviations in replies between groups .....	57
7.5	Next steps .....	57
7.6	Research limitations and further research needs .....	58
8	Conclusions .....	59
9	References .....	61

Abbreviations:

CRM	Critical Raw Material
CRMA	Critical Raw Materials Act
ELV	Electric Vehicle
EU	European Union
GHG	Greenhouse Gases
HREE	Heavy Rare Earth Element
LCA	Lifecycle analysis
LIB	Lithium-ion battery
LREE	Light Rare Earth Element
PGM	Platinum Group Metal
SRM	Strategic Raw Material

# 1 Introduction

Energy storage is essential to the rapid decarbonization of the electric grid and transportation sector. Rechargeable batteries play an important role in satisfying the need for short-term electricity storage on the grid and enabling electric vehicles (EVs) to store and use energy. (World Economic Forum, 2019).

Energy storage represents key enabling technology in the energy transition, especially with batteries being promising technology for the zero pollution ambitions of the European Green Deal and climate neutrality targets for 2050. (EU, 2024 c).

The EU Strategic Action Plan on batteries was adopted in 2018. In the plan, there is a comprehensive set of measures to develop an innovative, sustainable and competitive battery “ecosystem” in Europe. (EU, 2018).

Although there are relevant benefits in the battery use phase, the exploitation of critical raw materials, such as cobalt, lithium, manganese, nickel and graphite, needed to produce batteries, involves not negligible impacts. (Sharma et al, 2020). In 2023, the European Commission put forth a new battery regulation, which includes compulsory sustainability requirements, and supply chain due diligence for minerals utilised in batteries. (EU, 2023 d).

The sustainability and availability of critical raw materials is key to meeting climate targets through green transition. “The green transition means a shift towards economically sustainable growth and an economy that is not based on fossil fuels and overconsumption of natural resources. A sustainable economy relies on low-carbon solutions that promote the circular economy and biodiversity.” (YM, 2024).

The green transition requires investments in clean energy production, circular economy solutions and battery and hydrogen technology, and the introduction of different kinds of new services and operating models. (World Economic Forum. 2019).

These new and innovative technologies require a lot of materials, out of which several are listed as critical raw materials by the European Union. The purpose of this thesis is to look into the sustainability and availability of these critical (and strategic) raw materials. In order to safeguard the availability and sustainability of these important materials, The European Union has adopted legislative measures specifically for critical raw materials.

The EU Critical Raw Materials Act (CRMA) came into force in May 2024. It seeks to strengthen the EU's CRM capacity, reduce dependency, increase preparedness, and promote the sustainability and circularity of the supply chain. The Act will also reduce the administrative burden, streamlining permitting procedures for critical raw materials projects in the EU while ensuring high social and environmental protection. (EU, 2020 c).

As the battery industry requires a lot of critical and strategic raw materials, it is estimated that The Critical Raw Materials Act will have a significant effect on companies working in the battery value chain. In addition to introducing faster permitting procedures and funding options for selected projects, the CRMA also introduces several sustainability approaches to critical raw materials and the production of battery materials.

Sustainability is seen to be one of the biggest competition advantages for the Finnish battery value chain and battery production. As Finland has large resources of critical raw materials needed in battery production, and there will be a lot of new investments into the battery value chain in Finland, this thesis and the research was limited to Finnish companies, and Finland is also studied as a case country. The results will be used in advocacy work for the Finnish battery value chain companies.

For this thesis, an anonymous online survey was conducted, to find out how the companies and different stakeholders see the possible effects CRMA will have. The questions include for example respondents' views on different targets included in the Act. Also the importance of a strategic project status and the new strict timelines were included in the research questions. Overall, there were 7 questions. The survey was sent to 12 members of the Finnish Battery Industry Association (Akkuteollisuus ry), and also to 20 key stakeholders in different ministries, industry associations and research organisations.

In this thesis, chapter 2 describes the importance of critical raw materials, while chapter 3 introduces mining and raw materials in Finland. Chapter 4 looks into the sustainability of battery manufacturing in the context of circularity and recycling of batteries. The EU Critical Raw Materials Act CRMA, its background and objectives are described in chapter 5. Chapter 6 introduces the concept of the battery industry in general and the value chain in Finland. In chapter 7 the effects of the CRMA are studied and the results of the survey introduced. Chapter 8 looks into the results in the discussion part. Finally, the findings are summarized in the concluding chapter.

## 2 Critical raw materials

EU defines critical raw materials as materials which are critical to the industry. This includes metals and minerals that cannot be replaced by a more common material, that have a significant supply risk, and if there is a disruption of supply, there will be economic consequences. (EU, 2023 a). Materials such as lithium and rare earths are indispensable for key products of Europe's green and digital future, such as solar panels, windmills, electric cars and computer chips. (EU, 2023 b). Out of these, several materials are critical for the battery industry. Depending on the battery chemistry, the main CRMs used in batteries are antimony, cobalt, natural graphite, indium and some rare earth elements. Antimony is mainly used in lead-acid batteries, and its use has declined due to new battery technologies. Also indium, lanthanum and cerium are used in batteries. (EU, 2020 b).

The supply chain for critical raw materials is very vulnerable. In some cases, there is only one supplying country for certain raw materials (EU 2024 a):

- China supplies 100 % of heavy rare earths, like dysprosium, yttrium and terbium. They face low supply and increasing importance in the development of clean energy technologies.
- Turkey supplies 98 % of boron.
- South Africa covers 71 % of platinum needs.

Raw materials are crucial to Europe's economy. They form a strong industrial base, producing a broad range of goods and applications used in everyday life and modern technologies.

Reliable access to certain raw materials is a growing concern within the EU and also globally. To address this challenge, the European Commission has created a list of critical raw materials (CRMs) for the EU, which is reviewed and updated every three years. CRMs combine raw materials of high importance to the EU economy and of high risk associated with their supply. (EU, 2020 a).

The list of critical raw materials updated in 2023 includes the materials listed in Table 1. (Nickel and copper have been marked with an asterisk. They are classified as strategic

materials, but not critical raw materials). New additions compared to the 2020 list are arsenic, feldspar, helium and manganese.

aluminium/bauxite	coking coal	lithium	phosphorus
antimony	feldspar	LREE	scandium
arsenic	fluorspar	magnesium	silicon metal
baryte	gallium	manganese	strontium
beryllium	germanium	natural graphite	tantalum
bismuth	hafnium	niobium	titanium metal
boron/borate	helium	PGM	tungsten
cobalt	HREE	phosphate rock	vanadium
copper*	nickel*		

*Table 1. EU list of critical raw materials. Source: EU, 2023 a.*

Out of the 34 critical raw materials identified, a specific strategic raw materials (SRMs) list has been created for the materials expected to grow exponentially in terms of supply, which have complex production requirements and thus face a higher risk of supply issues. (EU, 2023b). They are: bismuth, bor/borate, cobalt, copper, gallium, germanium, lithium, magnesium, manganese, natural graphite, nickel, platinum group metals (PGM), rare earth elements (HREE and LREE), titanium and tungsten. (EU, 2023b).

The reasons why critical raw materials are important are listed in Overview of the Critical Raw Materials Act (EU, 2023c):

- Link to industry - non-energy raw materials are linked to all industries across all supply chain stages.
- Modern technology - technological progress and quality of life rely on access to a growing number of raw materials. For example, a smartphone might contain up to 50 different kinds of metals, all of which contribute to its small size, light weight and functionality.
- Environment – raw materials are closely linked to clean technologies. They are irreplaceable in solar panels, wind turbines, electric vehicles, and energy-efficient lighting.

China is the largest supplier of several critical raw materials. Other countries are also important global suppliers of specific materials. For instance, Russia and South Africa are the largest global suppliers for platinum group metals, Australia for lithium, the USA for beryllium and helium, and Brazil for niobium. (SGU, 2023).

There are also European producers. The EU extracts 34 % of global supply of strontium in Spain, 14 % of feldspar in Italy, Spain, France, Czechia, Germany and others, 3 % of tungsten in Austria, Portugal and Spain. The EU processes and refines 49 % of global supply of hafnium in France; 18 % of antimony in Belgium, France, Spain and many others; 17 % of cobalt in Finland, Belgium and France; 7 % of germanium in Germany and Belgium; 5 % of silicon metal in France, Spain and Slovakia; 4 % of nickel in Finland, Greece and France. (EU, 2023 b). The global production of critical and strategic raw materials is shown in Figure 2 and Figure 3.

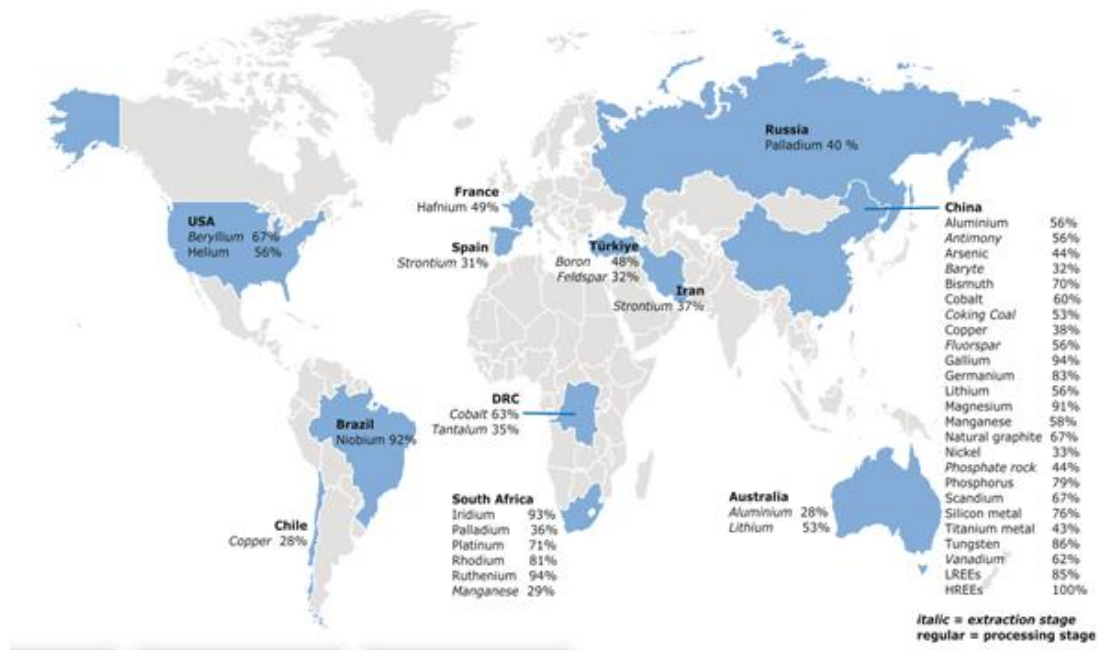
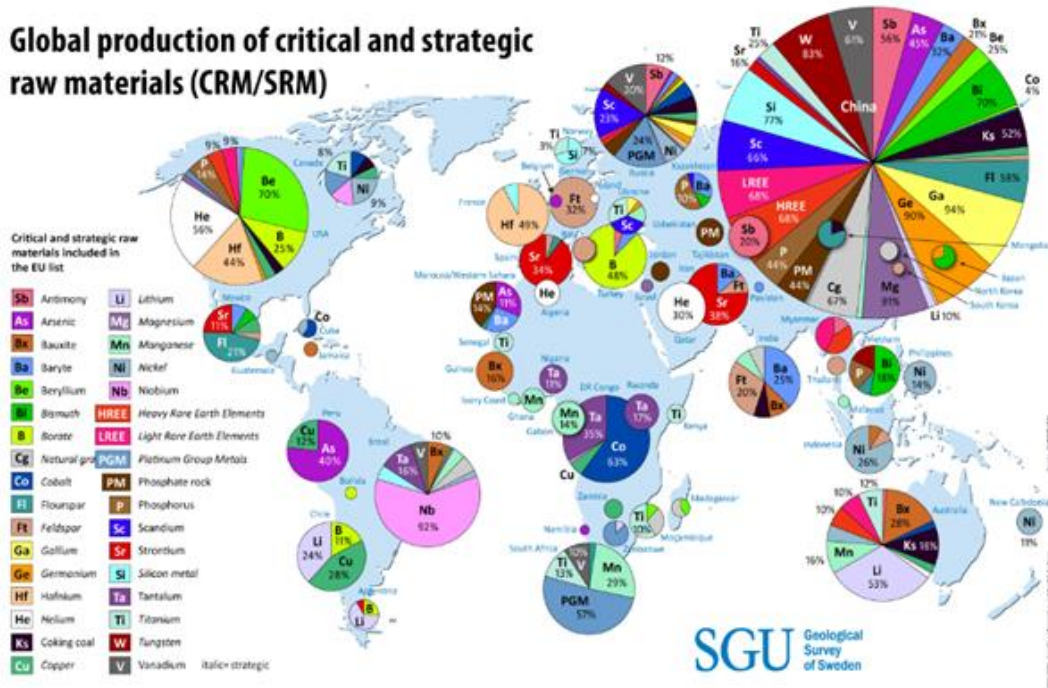


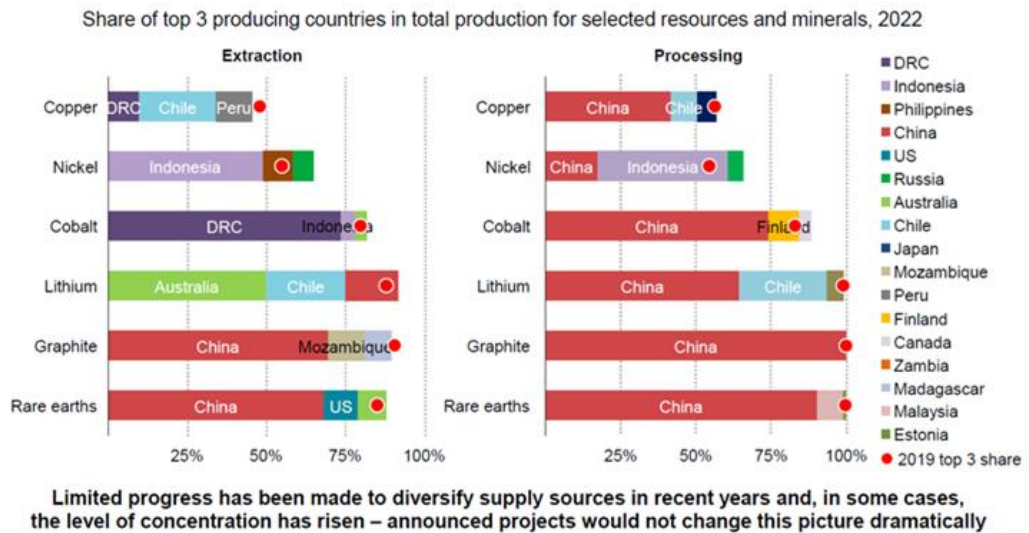
Figure 1. Sources of critical raw materials (EU, 2023 b)

**Global production of critical and strategic raw materials (CRM/SRM)**



**Global production of critical and strategic raw materials (CRM/SRM)**

Figure 2. Global production of critical and strategic raw materials (SGU, 2024)



Limited progress has been made to diversify supply sources in recent years and, in some cases, the level of concentration has risen – announced projects would not change this picture dramatically

Figure 3. Share of top 3 producing countries for selected resources and minerals in 2022 (Source, IEA 2024).

The new and innovative technologies needed to reach the climate neutrality goals for 2050 (Net Zero Emission Strategy) require a lot of materials, out of which several are listed as critical raw materials by the European Union. As shown in Figure 4 below, the demand for these materials has doubled in the past 5 years.

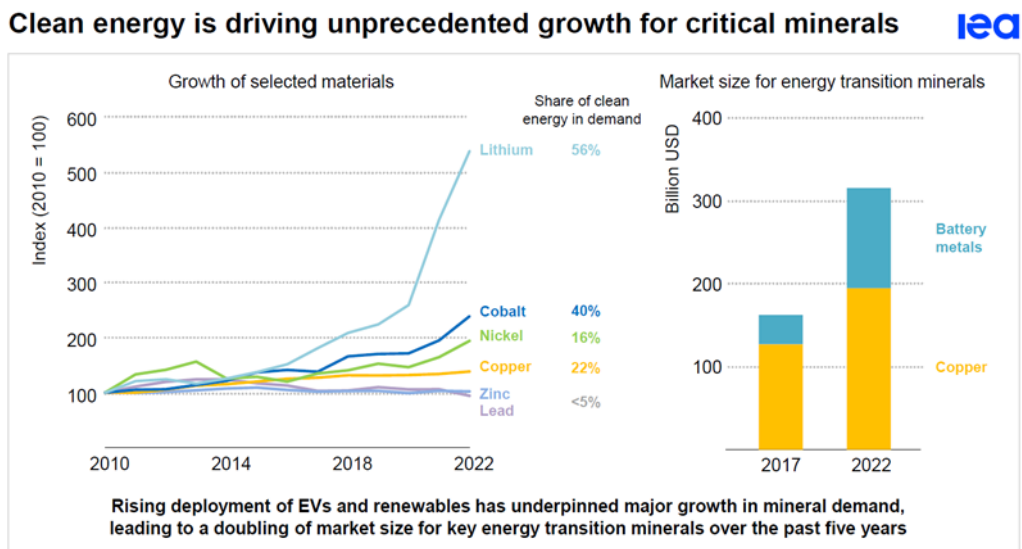


Figure 4. The growth of selected critical raw materials 2010-2022. (Source IEA, 2024).

Figure 5 shows the estimated growth for the demand of CRMs by 2030. The demand for lithium is estimated to grow the most.

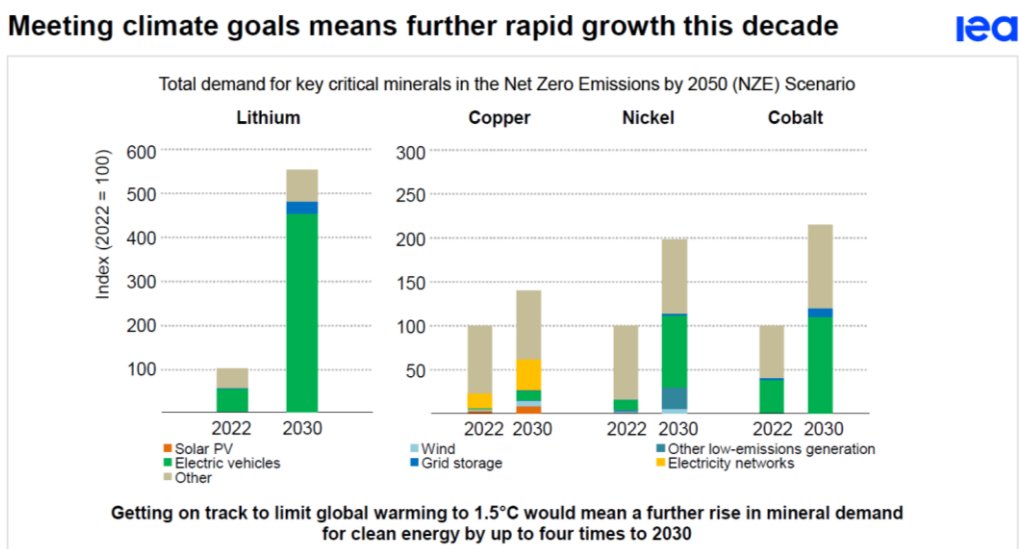


Figure 5. Total demand for critical minerals in Net Zero Emissions scenario. (Source IEA, 2024).

## 2.1 The methodology to define critical raw materials

Economic importance and supply risk are the two main parameters used to determine raw material criticality for the EU. “Economic importance” looks at the allocation of raw materials to end-uses based on industrial applications. “Supply risk” looks at the country-level concentration of global production of primary raw materials and sourcing to the EU, the governance of supplier countries, including environmental aspects, the contribution of recycling (i.e. secondary raw materials), substitution, EU import reliance and trade restrictions in third countries. (EU, 2023 a).

The resulting list of critical raw materials provides a tool to support EU policy development. The Commission takes the list into consideration when negotiating trade agreements or seeking to eliminate trade distortions. The list helps to identify investment needs and to guide research and innovation under the EU’s Horizon 2020, Horizon Europe and national programmes, especially on new mining technologies, substitution and recycling. It is also relevant for the circular economy to promote sustainable and responsible sourcing, and for industrial policy. Member States and companies can also use it as an EU reference framework for developing their own specific criticality assessments. (EU, 2023 a).

## 2.2 Recycling of critical raw materials

Recycling of critical materials is considered a key strategy for achieving the net-zero targets and supply diversification, and it is becoming mandatory for downstream sectors to include recycled materials in the products (EU, 2020a).

For CRMs, recycling can be one option to lower the demand on primary raw materials. Nevertheless, the complexity of devices is making recycling for technology metals complicated. Therefore, the generation of concentrated fractions is an important step in the process chain of treating secondary raw materials. In addition to the established classification and sorting processes based on physical principles there is an increasing demand for intelligent solutions to meet the growing complexity and heterogeneity of material flows. (Auerbach et al, 2019).

Several CRMs have a high technical and economic recycling potential, but despite the encouragement from governments to move towards a circular economy, the recycling rate of CRMs is generally low. There are many reasons: the sorting and recycling technologies for many CRMs are not yet available at competitive costs; the supply of many CRMs is currently locked up in long-life assets, which implies long delays between manufacturing and scrapping; the demand for many CRMs is growing in various sectors, and the contribution from recycling is largely insufficient to meet the demand. (EU, 2020 b). The economic incentive for recycling depends heavily on the cathode chemistry of vehicle batteries. For example, recovering battery-grade manganese and lithium from  $\text{LiFePO}_4$  and  $\text{LiMn}_2\text{O}_4$  batteries via recycling is more expensive than mining these materials. (Olivetti et al, 2017).

A few CRMs, like vanadium, tungsten, cobalt and antimony already have a high recycling rate. Some other CRMs have a good rate of recycling at end-of-life (e.g. recycling rates for Platinum Group Metals reaches up to 95 % for industrial catalysts and 50-60 % for automotive catalysts), but this is insufficient to meet the growing demand and thus the recycling input rate is low (e.g. 14 % for PGMs). (EU, 2020 b).

The extraction of primary CRMs in Europe helps to ensure the security of supply of raw materials to the European industry, as also does their resource efficient management throughout the lifecycle and the recycling of waste into secondary CRMs. Substitution and recycling are considered as risk reducing measures in the methodology for establishing the EU list of Critical Raw Materials. Environmental benefits of a more circular use may include for instance lower impacts on the biosphere (rainforests, arctic regions, ocean floors etc.) and/or less waste produced per tonne of material extracted. (EU, 2020 b)

The recycling of CRMs is considered to become a significant source of supply after 2030. It is estimated that by 2040, recycling could reduce primary supply requirements by 15-30 %. Figure 6 shows the estimated sources of supply in 2022, 2030 and 2040.

## Recycling becomes a significant source of supply after 2030

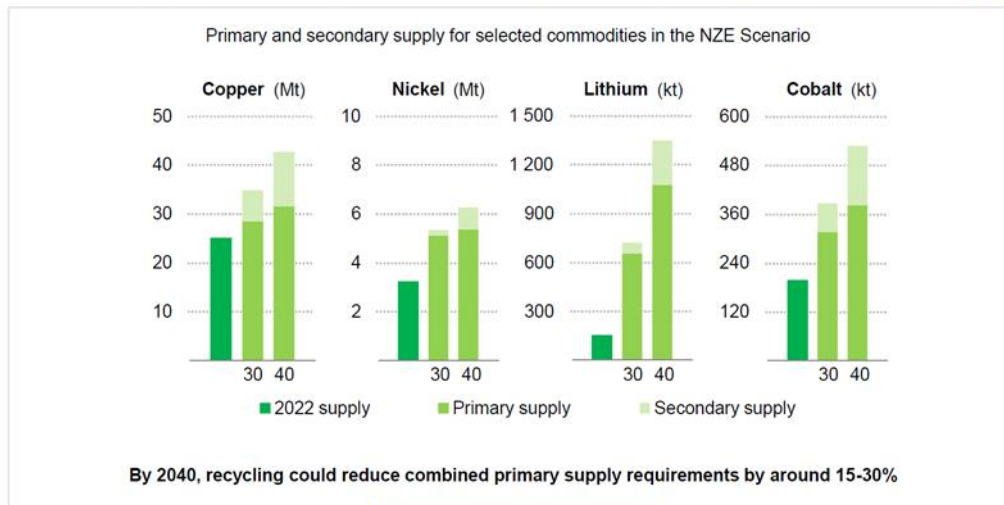


Figure 6. The estimated sources of supply for copper, nickel, lithium and cobalt in 2022, 2030 and 2040. (Source: IEA, 2024).

### 3 Mining and refining of raw materials in Finland

Finland is one of the few countries in Europe to produce critical raw materials, and this is why Finland is examined further as a case study. Finland's bedrock is known to have good mineral potential, but due to the weak exposure of the bedrock, the mineral potential is not fully known. Finnish bedrock contains substantial deposits of various critical metals and minerals and has significant potential for new resource discoveries. (GTK, 2023).

The European Geological Surveys have jointly prepared maps of the currently known deposits and occurrences of Critical Raw Materials (CRM) in Europe. The map of onshore CRM deposits shows 67 different mineral deposits for Finland, with antimony, arsenic, beryllium, graphite, cobalt, copper, lithium, manganese, niobium, nickel, phosphate, platinum group metals, rare earth elements, scandium, titanium, and vanadium as Critical Raw Materials. Of these, cobalt, copper, nickel, phosphate, platinum metals and feldspar are currently produced in Finland. (GTK, 2024).

Offshore, numerous manganese deposits are known from the Gulf of Finland and the Gulf of Bothnia, but currently, they are not being utilized. These deposits consist of iron-manganese precipitates and also contain significant concentrations of phosphates and rare earth metals. (GTK, 2024).

Figure 7 below shows mining and mining projects in Finland in 2023, and the minerals for each mine.

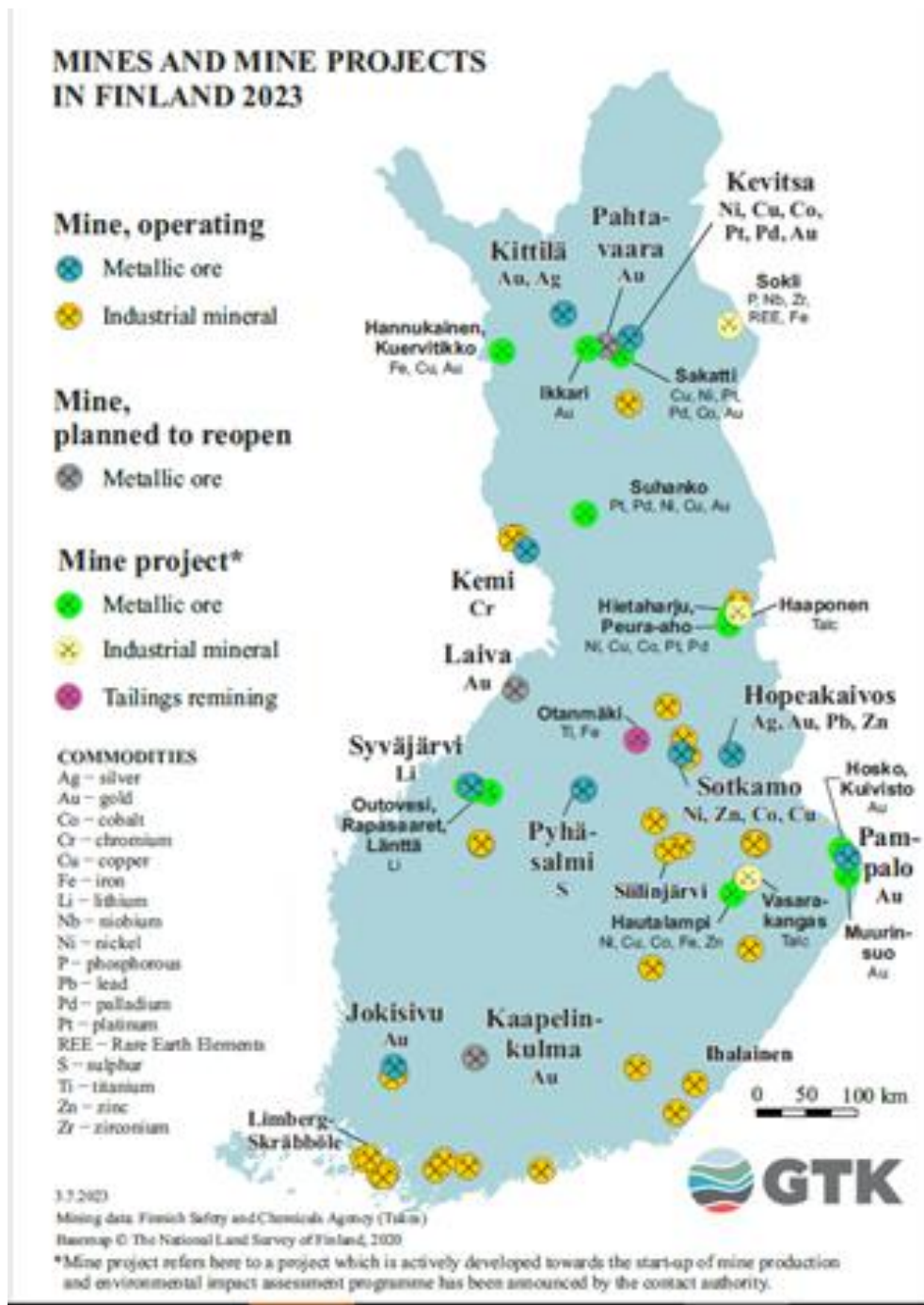


Figure 7. Mining in Finland in 2023 and the mined minerals (Source: GTK, 2024)

Finland has a broad-based metal processing and mineral processing sector. The minerals cluster also includes the manufacturers of machinery, equipment and technology for the sector, services, research and training. (TEM, 2024).

Many of the mining and metal processing companies are international players. In the aggregate and natural stone industries, there are also a large number of local-level SMEs. The Finnish machinery, equipment and technology know-how is globally recognised. In addition to large companies with global operations, Finland also has an increasing number of SMEs offering special technologies. New business is generated for the recycling of raw materials and the use of side streams. (TEM, 2024).

Mineral refining industry is also substantial in Finland. For example, Lapland has significant mineral resources, and metal refining is Lapland's largest industry in terms of turnover. Lapland accounts for more than a third of the turnover of metal processing and a quarter of the turnover of mining in whole Finland. (Lapland, 2024).

Figure 8 below shows the battery mineral mines and processing plants refining operations in Finland.

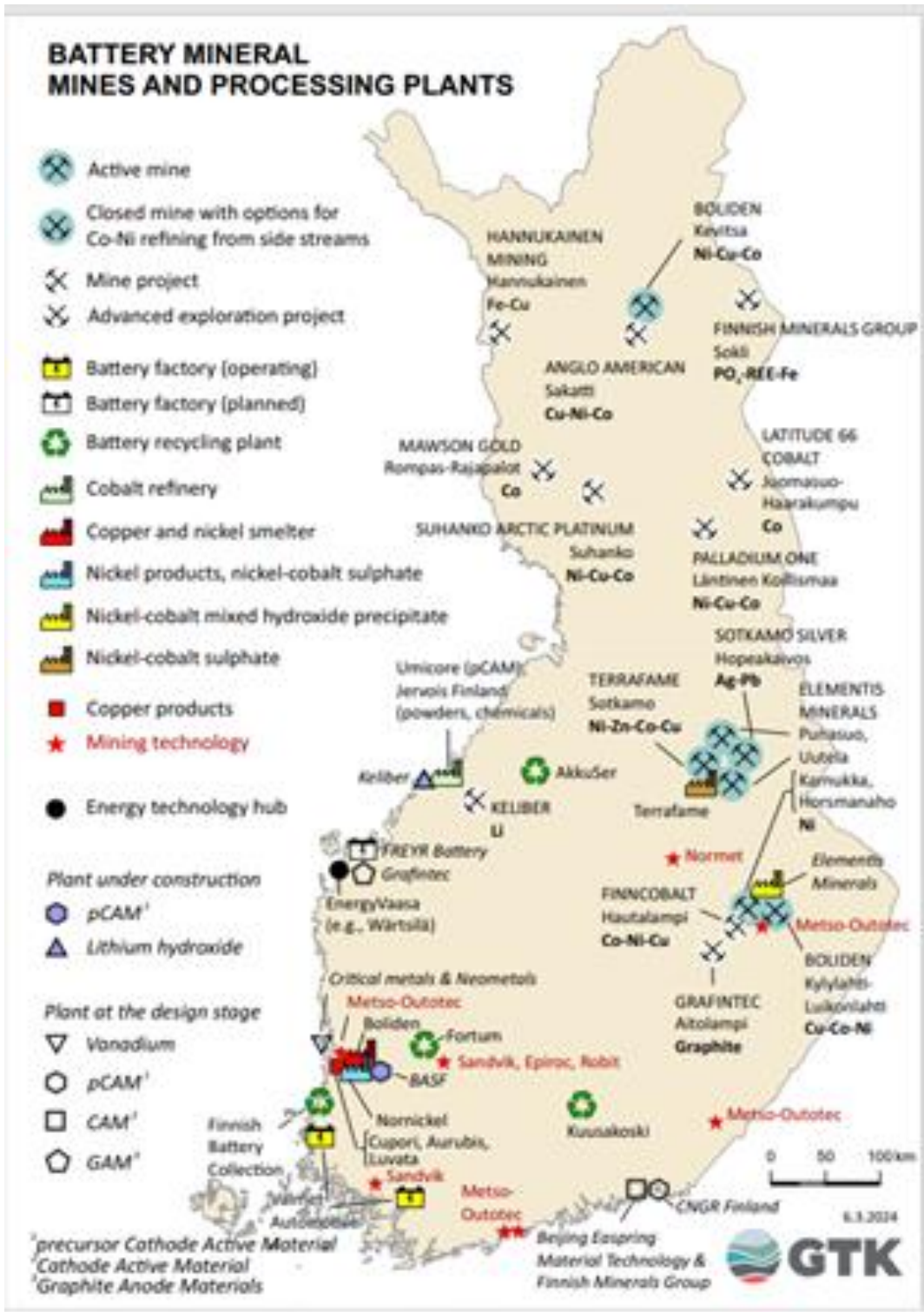


Figure 8. Battery mineral mines and processing plants in Finland (Source: GTK, 2024)

In table 2, deposits, mining and refining of strategic raw materials are shown.

Strategic Raw Material	Mining in Finland	Refining in Finland	Processing in Finland
Cobolt	Yes	Yes	Yes
Copper	Yes	Yes	Yes
Nickel (metal)	Yes	Yes	Yes
Platinum Group Metals	Yes	Yes	Yes (at least as byproduct), also recycled sources
Lithium	Yes	Planned	Planned
Germanium	No	No (byproduct in cobalt exports)	Yes (byproduct of cobolt)
Gallium	Traces (in zinc and silver ores)	No (may be found in zinc imports)	Potential based on current zinc processing
Bismuth	No	No (may be found in copper imports)	Potential based on current copper processing
Silicon (metal)	Yes (quartz)	Refining of quartz	No
Graphite	Yes	No (has been previously)	No (has been previously)
Wolfram	Yes (scheelite)	No (scheelite produced as Cu-ore byproduct)	No
Titanium (metal)	Yes (ilmenite)	No	No
Aluminium	(kaolin, in theory)	No	From recycled sources
Manganese	Traces	No	No
HREE, LREE (Nd, Pr, Tb, Dy, Gd, Sm, Ce)	Traces in Sokli mine (Ce, Nd, Pr, Gd, Sm)	No	No
Bor/borate	No	No	No

Table 2. Strategic raw materials: deposits, mining and refining in Finland. (Source: GTK)

## 4 The sustainability of battery manufacturing and critical raw materials

Rechargeable batteries are key to unlocking the potential held by both electric vehicles and clean energy technologies. In the electricity sector, batteries can smooth out the intermittency of solar and wind power. In the transportation sector, batteries are the core technology that enables electric mobility. (Sharma&Manthyram, 2020).

Global battery demand is expected to grow by 25 % annually to reach 2,600 GWh in 2030. (Global Economic Forum, 2019).

Although batteries come with many benefits and are an essential element in reaching the climate neutrality goals, the manufacturing of batteries have several sustainability issues which need to be tackled. According to Robison et al. (2023), key sustainability challenges of the battery sector might be summarised as follows:

1. Battery production has non-negligible GHG emissions.
2. The battery value chain bears also significant social risks.
3. The viability of battery-supported applications is uncertain.

Innovation along the value chain is needed to improve value creation and to reduce environmental impacts. Applying them, for example in the production of active materials, other components and cell manufacturing, these levers address 70 % of total GHG emissions in battery production. The following four levers are the most important: switching to cleaner battery production through renewables; innovating the battery technology; improving application technology; and leveraging the value chain and finance to address sustainable impact in local communities. (World Economic Forum, 2019).

Battery manufacturing requires energy and produces emissions that contribute to climate change. In addition to emissions, the raw materials used in batteries are obtained through brine evaporation, mining or oil and gas extraction projects. Also, toxicity is a serious concern present throughout the battery production process. Toxicity concerns can extend beyond the mining site or factory to the local environment, where unregulated effluents and

pollution can pose a severe threat to the well-being of the surrounding communities and ecosystems. (Sharma&Mantrhiram, 2020).

Battery materials like cathodes, anodes, the separator and electrolyte, connectors, casing and housing, safety equipment, and the battery management system cause environmental impacts in their supply chain, in the mining, processing and manufacturing stage. These environmental impacts cause concern, not only because of the greenhouse gas (GHG) emissions related to resource extraction and processing but also exposure to toxic substances, air pollution, water depletion and land use. One strategy to reduce these material related impacts is to use products longer and use more recycled materials in their production.

Some of the issues causing sustainability concerns, can be reduced by circularity (ie. recycling of batteries or replacing materials). For example, batteries of electric vehicles can still be used in stationary applications if their capacity is not satisfactory for mobility applications anymore.

Circularity of Lithium-ion battery production can be improved in several stages, as shown in Figure 9.

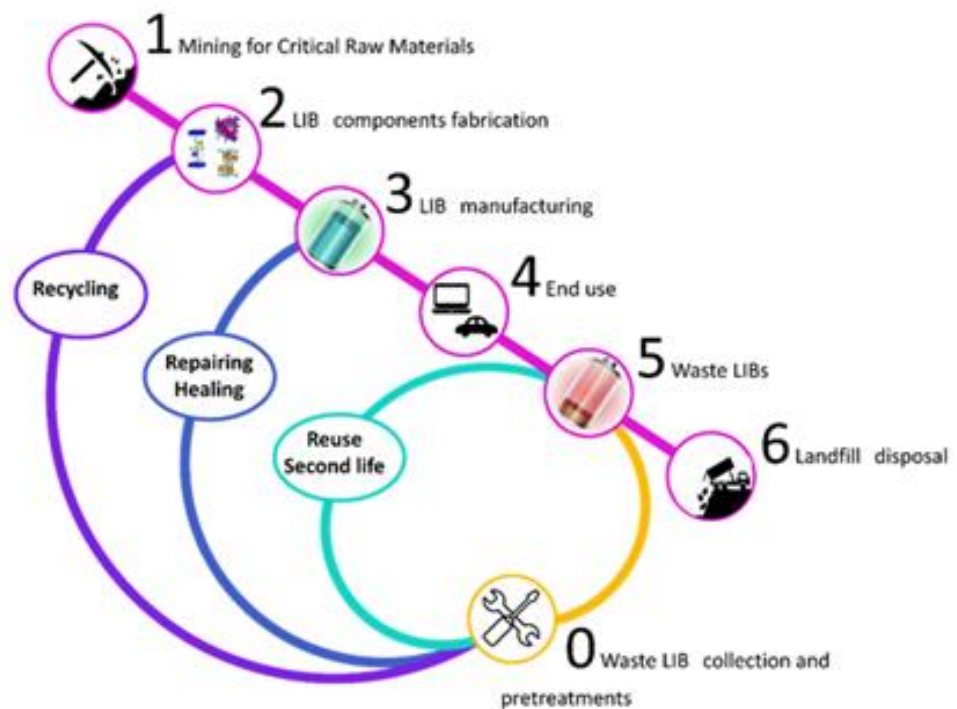


Figure 9. Different stages of the Lithium-ion battery and possibilities for their circularity. (Zanoletti et al, 2024).

The World Economy Forum (2019) has proposed 10 concrete actions to develop a circular battery value chain, to accelerate sustainable business and technology development and to improve responsibility in the value chain:

- Implement design and systems for life extension and end-of-life treatment. International convention bodies, regulators, battery manufacturers and vehicle manufacturers need to work together to: 1) enable the exchange of data among key stakeholders to improve the economics of life extension through repair and refurbishment, and recycling; 2) foster product design and technical development to facilitate disassembly for repurposing, repair and recovery of materials; and 3) harmonize national and international rules to ensure the safe and economic transport of batteries.

A battery passport would support data sharing on dimensions such as materials chemistry, origin, the state of health of batteries or chain of custody. It could provide means to identify and track batteries throughout the life cycle and, in the near term, support the establishment of systems for life extension and end-of-life-treatment.

- Scale up electric shared mobility: Vehicle manufacturers need to accelerate the development and commercialization of purpose-built EVs for sharing. Regulators should incentivize electric shared mobility, e.g. via preferred public procurement for EVs, fleet regulations (e.g. on taxis) and incentives for electric shared mobility.
- Increase the share of renewable energies and energy efficiency measures in the battery value chain. Companies in the value chain should switch from fossil fuels and conventional power to renewables, as well as reduce leakages and waste during production.
- Public stakeholders and private companies should take concerted action to increase public charging infrastructure for EVs, to enable a smooth economic transition to sustainable mobility.
- Adjust regulation for battery-enabled renewables as a dispatchable source of electricity for the grid. Regulators should review and revise the regulatory framework for battery-enabled renewables as a dispatchable source of electricity.

- Finance the sustainable expansion and support value creation and economic diversification in local communities. Investors (both private and public) should require the noted sustainability elements in the development of the value chain. Instruments like “green bonds” and “blended financing” will shift the value chain to provide financial, environmental and social returns.
- Ensure consistent performance and transparency based on established sustainability norms and principles along the value chain to improve the social, environmental and economic performance of batteries. Stakeholders across the battery value chain need to commit to established international expectations and key performance indicators on social and environmental practices, ensuring transparent impact measurement as well as the exchange of best practices.
- Establish integrated GHG disclosure and emission regulations. To increase the focus on Scope 3 emissions, policymakers should establish regulations based on life cycle emissions. Private-sector companies alike, need to commit to verified GHG disclosure based on life cycle considerations.
- Support the deployment of batteries for energy access. Financial institutions, energy utilities and public policymakers, in partnership with battery manufacturers, need to advance the design and deployment of affordable battery applications in areas so far lacking access to electricity.

#### 4.1 Carbon footprint of LIBs

The need for low-carbon transport has significantly increased the demand for lithium-ion batteries (LIBs), which also increases the demand for critical raw materials such as lithium, nickel and cobalt. While EVs offer significant emission savings compared to competing technologies (Knobloch et al., 2020), it is evident that unlocking the full climate benefit of electrification requires further decarbonisation of LIB production.

The electricity source is a strong link between the carbon footprint of a LIB and its production location (Kallitsis et al., 2020). In addition, since batteries demand substantial material input, a significant portion of their carbon footprint originates from material mining

and processing operations. The carbon footprint varies significantly depending on the type and ore grade at source, and also on the production location. For example, batteries produced in China come with 26 %–140 % higher carbon footprint compared to those produced in Europe or the United States (Kallitsis et al, 2020). The carbon footprint also depends on the battery chemistry, as different types of materials and energy densities affect the material demand to produce LIBs.

Most environmental impacts during the battery manufacturing process are directly linked to energy use (on-site combustion and off-site electricity generation. For perspective, battery materials are estimated to comprise approximately one third of total primary energy demand to produce an LMO-graphite battery pack, with the remaining energy demand almost entirely owed to battery manufacturing (Porzio&Scown, 2021). This ratio can vary considerably based on the specifics of the manufacturing process and facility scale.

The development of LIBs needs to be driven in a more sustainable direction to satisfy the rising energy demand and simultaneously meet the criteria for net-zero carbon emissions. In this regard, it is crucial to assess the environmental impact and energy consumption of LIBs throughout the lifecycle. (Zhang et al, 2022).

Life-cycle assessment (LCA) is a widely used approach for examining the potential impacts of large-scale battery production, use, recycling and disposal. LCA is a methodology for quantifying the direct and indirect environmental burdens associated with a product or service. (Porzio&Scown, 2021). Applying LCA to batteries is challenging for a lot of reasons, ranging from methodological choices to the scarcity of sufficient data on battery manufacturing. Also, impact assessments have not achieved consensus on the environmental impacts of producing batteries. Nonetheless, LCA is a useful tool for the development of better-performing batteries with reduced environmental burden. (Porzio&Scown, 2021).

Currently, lithium-ion battery (LIB) is the most commonly used battery chemistry. Due to the scarcity of lithium, a lot of research has been focused on the development of other battery technologies, including sodium-ion batteries, potassium-ion batteries, solid-state batteries (Li-metal, Li-sulfur and rechargeable zinc alkaline), flow batteries, and multivalent batteries, but LIBs are likely to continue to dominate the market in the near-term. (Porzio&Scown, 2021). Lithium-ion batteries are typically differentiated based on their cathode material: lithium manganese oxide (LMO), lithium nickel manganese cobalt oxide (NMC), lithium

iron phosphate (LFP) and lithium nickel cobalt aluminium oxide (NCA). Most batteries use a graphite carbon anode.

Olivetti et al. explored the potential bottlenecks in critical material supplies for LIB manufacturing. In their study, they point out that there is a time lag between when batteries are manufactured and when they reach the end of their life. So, regardless of what can be recovered, recycling is unlikely to address any near-term (10–20 year) material supply constraints. Battery technologies have to evolve away from reliance on these critical materials in the coming decades, but recycling can be an important long-term strategy.

LCA studies show that cathode materials are a substantial contributor to GHG emissions and energy consumption for manufacturing LIBs. Therefore, cathode design at the materials level is essential to the sustainability of the Lithium-ion battery industry. (Zhang et al, 2022).

#### 4.2 Increasing the circularity of battery materials

In the future, new battery technologies are expected to make additional raw materials and materials necessary, for example, sodium, calcium or aluminium. Some of these developments are undertaken to reduce the dependence on critical raw materials, like cobalt, or other expensive metals, like nickel. It is crucial to close the material loops to meet future material demands and to reduce the environmental impact of battery production, especially for expensive, scarce, or potentially environmentally harmful materials. (Porzio&Scown, 2021).

In the broad definition of the circular economy, more sustainable material cycles for batteries are not only a question of recycling. The goal is a holistic implementation of circular economy measures to reduce overall resource requirements and materials related environmental impacts. (Dunn et al, 2021).

While circular economy strategies have the potential to reduce demand for the primary material, their capacity to do so hinges on the demand, use, and retirement patterns of EV batteries over time, as well as evolutions in LIB chemistry. (Dunn et al, 2021).

A number of practical barriers exist for the circularity of battery materials. The first is of geography, as the demand does not correspond to current manufacturing capacity in most

regions. Recycling and manufacturing facilities will need to be developed in each region if they are to meet a greater portion of their own demand, rather than perpetuating the concentration of production and demand in different regions that exists today. (Dunn et al, 2021).

The second barrier is of economics and policy. Cobalt is the most expensive cathode material, and its recovery is a key motivator for recycling. However, due to high economic and social cost, future batteries will evolve to lower or zero Co content, thus presenting a problem for a sustained market-driven recycling industry.

The need for policy intervention is heightened given the likelihood of lower-value materials in future EV LIBs. More robust policies are needed to encourage circularity. (Dunn et al, 2021).

In 2023, The European Commission adopted a new Battery Regulation with several implications for the circular economy of batteries. Among other things, the regulation also addresses various issues concerning the material cycles of batteries and requirements for recycled contents in battery manufacturing. These requirements will be implemented in 2030 and raised in 2035. The regulation also proposes a battery passport with information on repair, disassembly, and, importantly, the carbon footprint of the battery from raw material extraction to the end-of-life phase, without the use phase. Such mandatory carbon footprint, and in the future also carbon footprint classes and a threshold for marketing batteries in the European Union, supports the goal to reduce the overall environmental footprint of battery production. (EU, 2023d).

While LIBs have been generally found to be significantly less toxic compared with for example lead acid and nickel-cadmium batteries, potential impacts from end of life remain. The European Battery Regulation requires second-life use for batteries. There is often as high as 80 % capacity left in the battery after EV use. These batteries can be used in other applications, such as stationary power and grid load levelling. Reuse and cascaded use have the potential to reduce the overall environmental impacts of these products. (Zhang et al, 2022).

### 4.3 Recycling of Lithium-ion batteries

In order to meet the demand for LIBs while minimizing climate-impacting emissions, the reuse, recycling, and repurposing of LIBs is a critical step toward achieving a sustainable battery economy. With growing battery production, also a massive increase in recycling volume can be foreseen. Recent estimates of the volume of lithium-ion batteries components in Europe amount to 230 kilotons per year in 2030 and about 1500 kilotons per year in 2040. (Neef et al, 2021).

LIBs are made of several materials, such as mixed crystalline oxides (containing lithium, nickel and cobalt), organic solvents (flammable and explosive), polymers and fluoride-based materials, and none of these should be disseminated in the environment (Zanoletti et al, 2024).

The recycling of LIBs is inadequate, compared to for example lead-acid batteries that are usually recycled over 90 % of the time in Europe. (Zanoletti et al, 2024).

Reuse for a second life and less demanding applications (such as static applications) can prolong the life of the battery. When reuse is not possible, the recovery of single components (cathode and anode materials) has been proposed for the healing and use in the assembly of new batteries. If healing is not possible due to the degradation of the considered components, recycling for the recovery of critical raw materials is the desirable solution; the recovered critical raw materials can be implemented into the production of new components for the assembly of new batteries. (Zanoletti et al, 2024).

Major efforts are focused on the recovery, recycling, and/or repairing of cathode materials due to the high concentration of valuable critical raw materials. Recycling anode materials and electrolytes has been an area that has not received as much attention as the recycling of other battery components. This is a significant issue, because the recovery of these materials is crucial to closing the materials loop and achieving a sustainable battery economy.

The choice of recycling routes may vary with different types of LIBs and the material of interest to be recycled. For example, recycling can mainly focus on recovering Co initially due to its high value. Subsequently, recycling at the cathode level may offer higher value than recycling particular metal constitutes, as the Co-content becomes lower and other cell components are in higher demand. Direct recycling may offer additional benefits in this

regard, although maintaining the performance of recycled materials to the level of virgin materials remains challenging. Overall, the technical obstacles need to be tackled to make recycling more economically attractive (Zhang et al, 2022).

Figure 10 shows the different routes for battery recycling.

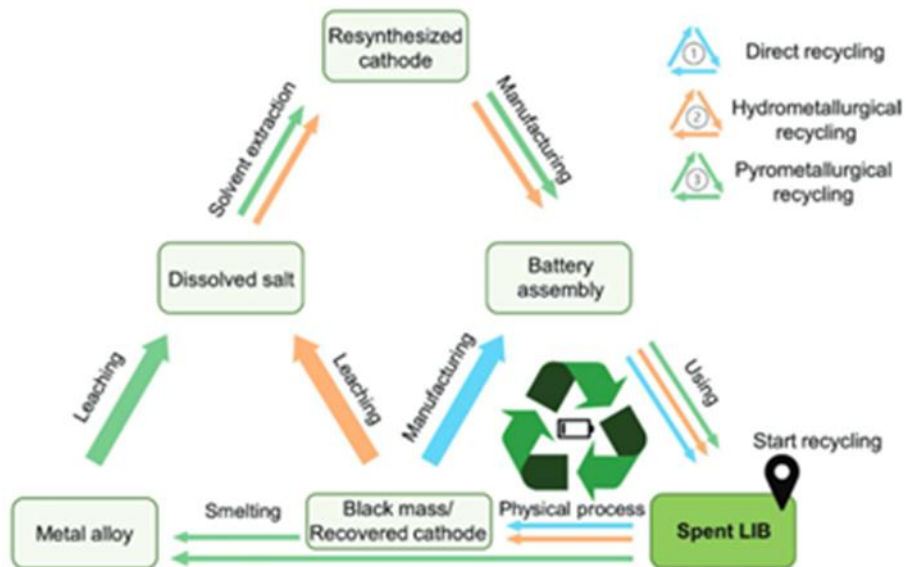


Figure 10. Different routes for battery recycling (Zhang et al, 2022).

The potential environmental impact of the recycling process has not been given sufficient attention in most studies. There are concerns about the negative impact of the process on the environment due to the generation of toxic and hazardous waste materials during the recycling process. (Zanoletti et al, 2024).

In figure 11, the recycling process and the different stages is explained in more detail.

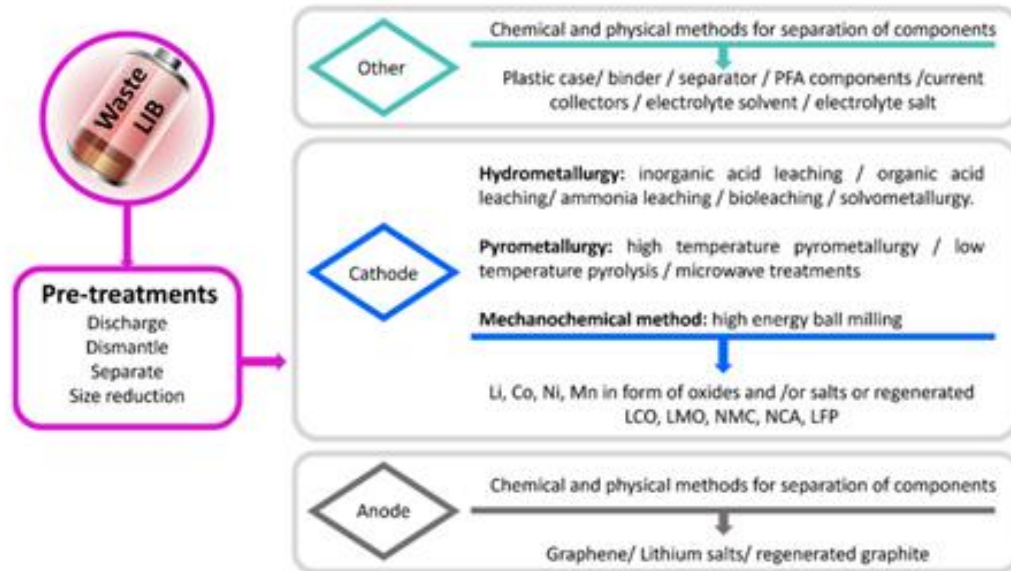


Figure 11. The battery recycling process in detail (Source: Zanoletti et al, 2024).

Currently, almost all metals utilized in batteries, such as nickel, manganese, cobalt, and lithium, can be recuperated and recycled. However, more advancements are necessary to recycle other battery components such as graphite, liquid electrolytes, and plastic separators between the cathode and anode surface. (Zanoletti et al, 2024).

The most commonly used technologies for the recycling of batteries are pyrometallurgy, hydrometallurgy, biometallurgy and solvometallurgy. The advantages and disadvantages of these technologies are explained below in Table 3.






					
	Pyrometallurgy	Hydrometallurgy	Biometallurgy	Solvometallurgy (Ionic Liquid)	Solvometallurgy (DES)
Advantages	Short process flow, low equipment requirements, strong operability	Low energy consumption, great versatility, high product purity, high recovery efficiency	Complete metal recovery, simplicity, cost-effectiveness, low energy consumption, mild conditions	Nonflammable, low volatility, tunable	Nonflammable, low recovery cost, green process, cheap and easy preparation, low toxicity
Disadvantages	High energy consumption, poor metal purity, difficulty in lithium recovery	Need to dispose of large amount of acid and toxic wastewater, long recovery process	Long processes and low kinetics, vulnerability to pollution	Expensive	Difficulty to scale-up, low cathode/DES ratio

Table 3. Comparison of different recycling technologies for battery materials (Zanoletti et al, 2024).

Hydrometallurgy is a widely used method in battery recycling. One potential disadvantage of hydrometallurgy is the generation of large amounts of wastewater containing chemical reagents and impurities, which require treatment and disposal. Additionally, the recovery of certain metals, such as lithium, can be challenging due to their high solubility and reactivity. Overall, however, hydrometallurgy offers a promising approach to the sustainable recycling of used LIBs. (Zanoletti et al, 2024).

Anode recycling is becoming an increasingly important aspect of LIB recycling. At present, anodes for LIBs can be manufactured using a variety of materials, such as natural or artificial graphite, carbonaceous materials or even silicon. Among these options, graphite is the most widely used material in commercial applications due to its excellent conductivity, stability, and low cost. (Zanoletti et al, 2024).

Anode recycling has the potential to reduce the demand for virgin graphite and other raw materials, as well as decrease the environmental impact of producing new anodes. However, the challenge with anode recycling is that the graphite particles can become contaminated with metals and other impurities during the cycling process, which can affect the performance of the recycled anode material. (Zanoletti et al, 2024).

Recovered materials from used LIBs can be reused in various ways, such as the production of new batteries, electronic components and other energy storage devices or applications. (Neef et al 2021).

The environmental impact of the recycling processes is an important factor to consider, especially regarding air pollution, wastewater and waste. The monitoring and managing emissions during the recycling process is critical to ensure the environmental sustainability of LIB recycling. It is essential to collect quantitative data on the emissions and to explore treatment options to minimize their impact on the environment and human health. (Neef et al, 2021).

#### 4.4 Design for recycling

A comprehensive strategy for battery recycling, known as “design for recycling”, is required to optimize both the batteries and the recycling processes simultaneously. This process extends from the physical design and assembly of batteries to simplify recycling, increase yields and optimize materials, thereby supporting cost-effective battery recycling processes. (Yang et al, 2023).

Unstandardized battery labelling results in tremendous additional efforts during recycling. Regulation can significantly enhance the efficiency of battery recycling. There are several national schemes to improve the recycling of batteries. For example, the Chinese government issued Interim Measures requiring battery manufacturers to keep their products standardized. The Measures recommend cooperation between battery manufacturers and vehicle manufacturers for easy tracking of battery life cycles. (Yang et al, 2023).

As part of the Battery Regulation, the European Commission proposed a Battery Passport to increase the transparency and traceability of batteries throughout the entire cycle life by using IT technologies. According to the Battery Regulation, every industrial or electric vehicle (EV) battery on the EU market with a capacity of over 2 kWh will require a battery passport. This means that regardless of the origin of the battery, it will require a battery passport in order to be put in the European market. It will be the responsibility of the party placing the battery on the market, to ensure that all data required is entered in the digital record and that the information is correct and up to date. The battery passport must contain information on: 1) Identification of the battery in the form of a unique identifier, 2) Basic characteristics of the battery including type and model, 3) Statistics on performance and durability (must also be updated over the battery lifecycle by parties conducting repair or

repurposing of the battery). Technical documentation on the electrochemical performance and durability of the battery must be provided, including details on how this data was obtained. This is to ensure the batteries meet the minimum requirements for battery performance and capacity in order to guarantee batteries on the market are operational and efficient over a sufficient lifetime. The battery must have a QR code printed or engraved on it to act as a unique product identifier. (Circularise, 2023).

## 5 The EU Critical Raw Materials Act

Critical raw materials are of high economic importance for Europe while being also highly vulnerable to supply disruptions. The demand for critical raw materials is increasing rapidly. For instance, the EU demand for rare earth metals is expected to increase six-fold by 2030 and seven-fold by 2050. For lithium, the EU demand is expected to increase twelve-fold by 2030 and twenty-one-fold by 2050. Europe relies heavily on imports, often from a single third country, and recent crises have underlined EU strategic dependencies. EU efforts to meet its climate and digital objectives are at risk. (EU, 2023 a).

The Critical Raw Materials Act is a comprehensive response to these challenges. The Act aims to ensure that the EU can rely on strong, resilient, and sustainable value chains for critical raw materials. The regulation will strengthen all stages of the European critical raw materials value chain, diversify the EU's imports to reduce strategic dependencies, improve the EU capacity to monitor and mitigate risks of disruptions to the supply of critical raw materials, and improve circularity and sustainability. (EU, 2023 c).

### 5.1 Background for legislation

To address the growing concern of securing valuable raw materials for the EU economy, the Commission launched the European Raw Materials Initiative in 2008. It is an integrated strategy that establishes targeted measures to secure and improve access to raw materials for the EU. One of the priority actions of the initiative was to establish a list of Critical Raw Materials (CRMs) at the EU level. (EU, 2020 b).

The European industry is dominated by the manufacturing industry, and also refining industry, compared to the extractive industry. The value chain of CRMs is not fully and homogeneously covered by the European industry. Pronounced imbalance exists between the upstream steps (extraction / harvesting) and the downstream steps (manufacturing and use). Considering the very limited supply of CRMs from secondary sources, the need for access to primary sources, is huge and crucial for the European industries. (EU, 2020 b).

The majority of these primary raw materials are produced and supplied from non-European countries. For many CRMs the upstream steps of the value chain are not present in the EU. This is due either to the absence of those materials in the European ground or to economic and societal factors that negatively affect the exploration or the extraction. (EU, 2020 b).

To access those primary CRMs, the EU has currently no other choice than to import the ores and concentrates or the refined materials from other countries to feed its industries. Hafnium is the only CRM for which an EU Member State (France) is the global main producer. For hafnium and indium, the Member States produce enough primary materials to avoid significant extra-European imports. (EU, 2020 b).

## 5.2 The objectives of CRMA

The Critical Raw Materials Act has a number of objectives. It aims to strengthen the EU's CRM capacity, reduce dependency, increase preparedness and promote the circularity and sustainability of the supply chain. (EU, 2023a).

The Act also sets the following benchmarks along the value chain:

- at least 10 % of the EU's annual consumption for extraction
- at least 40 % of the EU's annual consumption for processing
- at least 25 % of the EU's annual consumption for recycling
- no more than 65 % of the EU's annual consumption from a single third country.

Critical Raw Materials Act aims to reduce EU's dependency on China and other countries for key metals like rare earths. The reduction of dependency essentially means the diversification of Europe's supply of materials.

The Act will also reduce the administrative burden, streamline permitting procedures for critical raw materials projects in the EU while ensuring that we keep high social and environmental protection. In addition, selected strategic projects will benefit from support for access to finance and shorter permitting timeframes (27 months for extraction permits

and 15 months for processing and recycling permits). EU countries will also have to develop national programmes for exploring geological resources. (EU, 2024 b).

EU countries will also have to take measures to improve the collection of critical raw material-rich waste and to ensure its recycling into secondary critical raw materials. EU countries and private operators will have to investigate the potential for recovery of critical raw materials from extractive waste. The Act empowers the Commission to establish rules for the environmental footprint of critical raw materials. This will help to increase the circularity and sustainability of critical raw materials placed on the EU market, allowing customers to make informed choices about products containing critical raw materials. (EU, 2023 c).

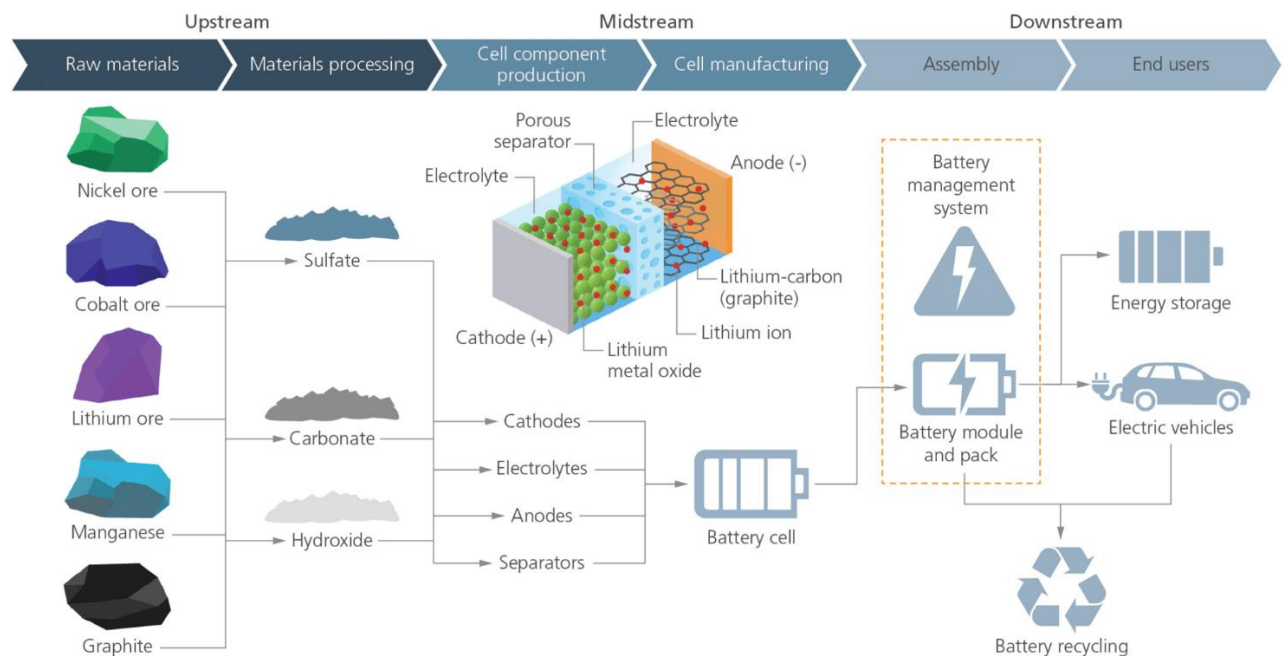
## 6 The Battery Industry

One of the major users of critical raw materials, especially lithium, cobalt and nickel, is the battery industry. The battery industry is growing rapidly in Finland, as well as in other European countries, and that is why securing the supply of critical raw materials and the legislative measures concerning them are important.

The battery value chain consists of several stages:

1. Mining and refining of minerals
2. Battery chemicals production
3. Battery cell production
4. Battery manufacturing
5. Recycling of batteries

The Battery value chain for ELVs is explained in more detail in Figure 13.



Source: L.E.K. research and analysis

Figure 13. Battery value chain for ELVs. (source: L.E.K. research and analysis).

There are basically three types of batteries: portable, industrial and automotive batteries. In the last decades, new battery chemistries have appeared on the market due to the development of new applications, like electric vehicles and e-bikes. (EY, 2020 b).

Depending on the battery chemistry, the main CRMs used in batteries are antimony, cobalt, natural graphite, indium and some rare earth elements. Antimony is mainly used in lead-acid batteries, and its use has declined due to new battery technologies. In recent years, the battery market has seen an increase in the use of cobalt. This is mainly related to specific Li-ion chemistries like Li-NMC (lithium nickel manganese cobalt oxides). Almost 10 % of worldwide uses of natural graphite in 2010 was in the battery sector, and it has grown since. Graphite is widely used in several rechargeable and non-rechargeable batteries as anode material. Also indium, lanthanum and cerium are used in batteries. (EU, 2020 b)

In order to save valuable virgin CRMs, the recycling of used batteries is increasing. The collection rates of waste batteries depend on the battery technology/type (e.g., rechargeable/nonrechargeable batteries, Lithium/Ni-Cd batteries), on the lifetime of different batteries, and on the second-life and end-use. For example, the EU Battery regulation, which came into force in 2023, requires the second life use of batteries, and also specific amounts of recycled content in battery materials.

For automotive lead-acid batteries, the collection and the recycling rates are much higher than for other batteries. Materials like cobalt produced from battery recycling can be used in the battery industry. Recycling of cobalt mainly occurs due to the lower costs of the recovered cobalt compared to cobalt extraction from ores. The recycling of graphite is quite limited. In the recycling process of batteries, graphite is usually lost in the recovery process. For lanthanum and cerium, the recycling rates are below 1%. (EU, 2020 b).

The export flow of waste batteries to non-EU Member States is low; on the contrary, there is significant movement of waste batteries and accumulators between the Member States. However, batteries contained in WEEE, especially rechargeable portable batteries, can enter into a second-hand market outside Europe. (EU, 2020 b)

## 6.1 Battery value chain in Finland

Finland is of the key players in the battery industry in Europe, especially in the field of ELV batteries. Finland has its own resources of CRMs, like lithium and cobalt, which are mined in northern Finland and central Finland. Finland is also the largest supplier of cobalt for global markets. (GTK, 2024 b).

The battery industry in Finland is under rapid development. According to the Finnish Battery Industry Association, there are already several mines and large battery chemical facilities in Finland, and also several large factories under construction of at planning stage. The future investments for this industry is estimated to be approximately 15 billion euros by the end of this decade.

Bloomberg NEF has evaluated different lithium-ion battery producing countries in 45 different categories and rated them based on their performance. This rating is shown below in Figure 14. Finland has done remarkably well in this rating: in 2022 Finland was rated 4<sup>th</sup> after China, US and Canada, and in 2023 Finland was rated 5<sup>th</sup>. The high ranking is mainly due to the high performance in sustainability issues.

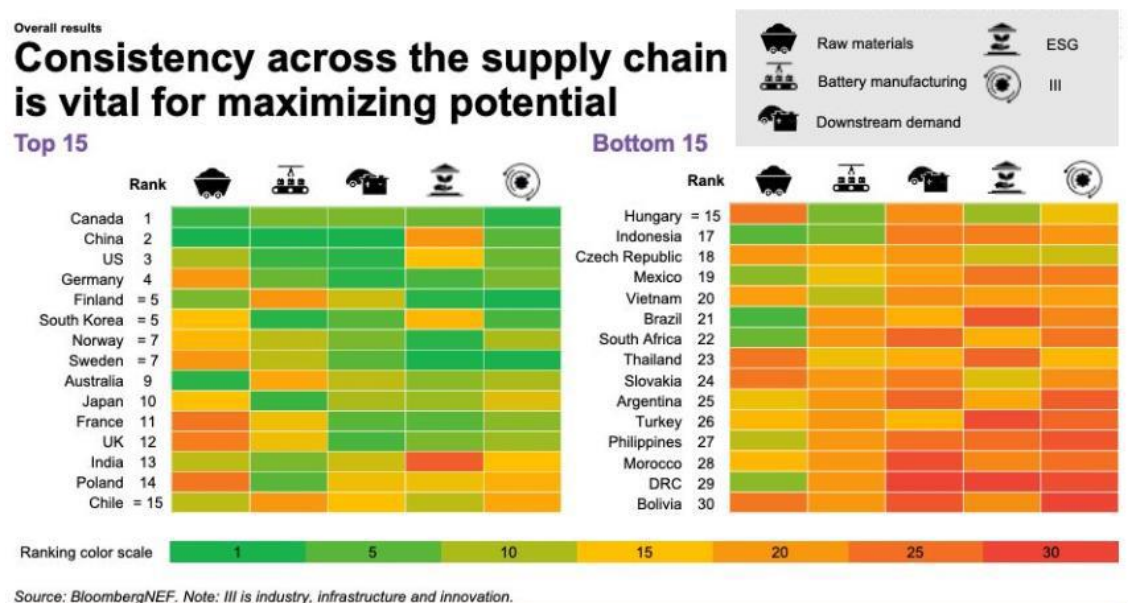


Figure 14. Ranking of 30 Lithium-ion battery producing countries in 2023.  
(Source: Bloomberg NEF).

## 7 The effects of the Critical Raw Materials Act on Finnish companies

The Critical Raw Materials Act will have significant effects on the Finnish battery value chain, especially when it comes to the new standards for material sustainability. Also, the possibility to gain a status of a Strategic project and through that speedier permitting procedures and better access to financing, will have a positive effect on the industry and the investments. This is why a survey was conducted to find out what kind of effects CRMA will have. The methodology and the results are described in chapters 7.1. and 7.2.

### 7.1 The methodology

For this thesis, a survey was conducted, in order to find out how the companies in the battery value chain and also different key stakeholders in Finland see the possible effects of the Act.

It was done in Finnish and translated into English for this thesis.

The survey was anonymous as it could be estimated that this would give the most direct and honest results, and also a lot of open answers. Unfortunately, this method does not allow for any cross-evaluation of the results. Checking the results against the respondents' background would be interesting and give more important information.

The survey was sent to 12 member companies of the Finnish Battery Industry Association (Akkuteollisuus ry), their field ranging from mining to the recycling of batteries. To get a wider picture, the survey was also sent to several stakeholders, like Finnish Mining Association, The Association of Finnish Steel and Metal Producers, The Ministry of Economics and the Employment (several respondents), The Ministry of Foreign Affairs (one respondent), Geological Survey of Finland GTK (several respondents) and Business Finland (2 respondents). Basically, the stakeholder group involved every stakeholder that has had an influence on the CRMA in Finland during the legislative process and also stakeholders who are working to get the battery value chain investments into Finland. The total number of stakeholders was 20. The survey was conducted in March-April 2024.

The survey got 10 replies from companies and 13 replies from different stakeholders. Even though the number of replies is not large, most of the key operators were involved in the replies.

Overall there were 7 separate questions. The same questions were sent to both groups. The questions were chosen to represent the different aspects of CRMA, like the targets for critical raw material recycling, mining and refining in Member States. The questions also included a lot of insights in the Strategic Project status and its effects on the investments and the companies. The questions are introduced in chapter 7.2. with the results.

## 7.2. The survey and results

The survey included 7 questions related to CRMA. The results for these questions are explained in detail and also by using graphs.

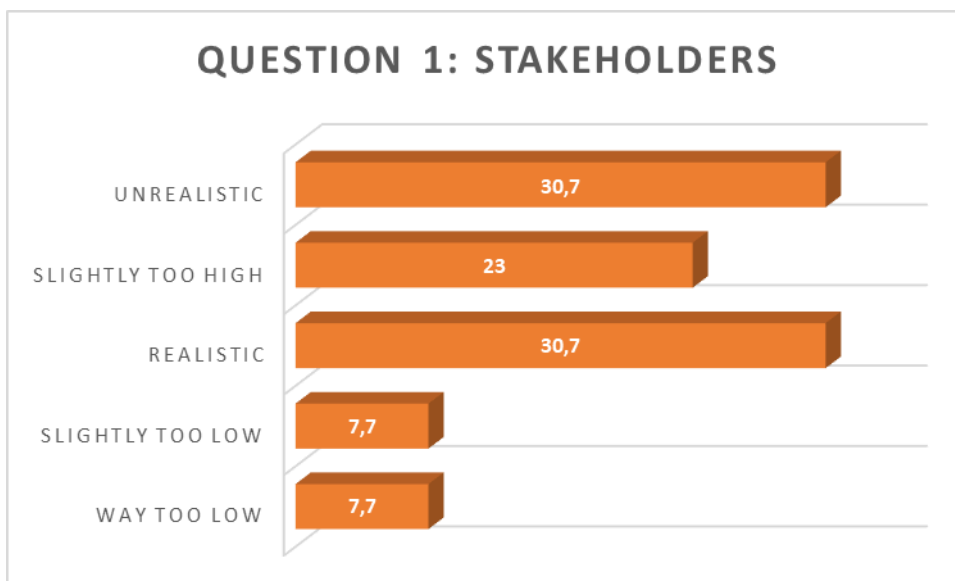
***Question 1:** The EU Critical Raw Materials Act was accepted 18.3.2024. It aims to reduce EU's dependency on China and other countries for key metals like rare earths. The reduction of dependency essentially means the diversification of Europe's supply of materials. The Act sets these benchmarks along the strategic raw materials value chain and for the diversification of the EU supplies:*

- *at least 10 % of the EU's annual consumption for extraction*
- *at least 40 % of the EU's annual consumption for processing*
- *at least 25 % of the EU's annual consumption for recycling*
- *no more than 65 % of the EU's annual consumption from a single third country.*

***Question: How realistic do you see the set targets?***

- 1) *the targets are way too low*
- 2) *the targets are slightly too low*
- 3) *the targets are realistic*
- 4) *the targets are slightly too high*
- 5) *the targets are unrealistic*

The companies and other stakeholders saw these targets slightly differently. There was more deviation in replies within the stakeholder group, which reflects the different background of the respondents. The majority saw the targets as unrealistically high or too high, but some also saw them as too low. The results of the stakeholder group are shown in figure 15.



*Figure 15 Stakeholder: How realistic do you see the set targets?*

Open comments from stakeholders:

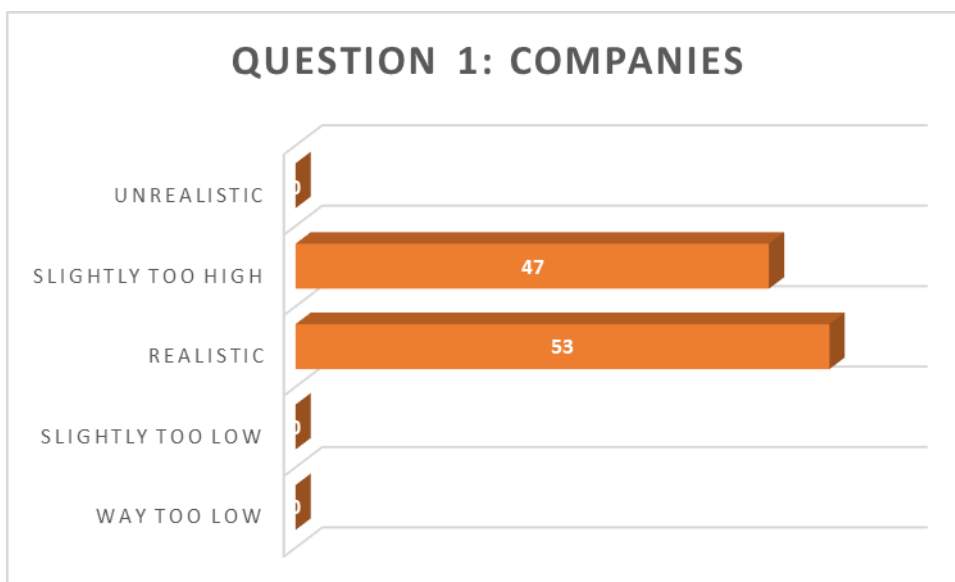
“To achieve these targets, the mining capacity in Europe would need to double in 6 years – unrealistic. “

“Targets are ambitious, as they should be, but the timeline is too ambitious.”

“I think the targets for CRMs could jeopardize the production of sustainable raw materials, as the demand is so high.”

“The timeline 2030 is unrealistic, when you consider the time it takes to make investment decisions and investments”.

There was also some deviation in the opinions within the company group, although all the companies saw the targets as realistic or slightly too high. None saw them as too low. This probably reflects the fact that the companies have a clear picture of what can be done within the set timelines in order to fulfill the targets. The company answers are shown in Figure 16.



*Figure 16. Companies: How realistic do you see the set targets?*

Open comments from companies:

“The targets are good, but it will be challenging to reach them as a lot of investments are late due to for example IRA (Inflation Reduction Act).”

## Question 2:

**How would you rate these objectives in CRMA** (1=most important, 5=least important)

*Strengthening the EU raw material supply*

*Risk management*

*Diversification of supply and reducing dependency in imports*

*Advancing sustainability and circular economy*

*Building necessary administration to achieve set targets*

In the **stakeholder** group, the objectives were rated:

1. Strengthening the EU raw material supply
2. Diversification of supply and reducing dependency in imports
3. Advancing sustainability and circular economy
4. Risk management
5. Building necessary administration to achieve set targets.

The **companies** rated the objectives almost the same, but numbers 1 and 1 were in different order by a slight difference:

1. Diversification of supply and reducing dependency in imports
2. Strengthening the EU raw material supply and
3. Advancing sustainability and circular economy
4. Risk management
5. Building necessary administration to achieve set targets.

The slight difference in the order of the targets is not prominent, as both “Diversification of supply and reducing dependency in imports” and “Strengthening the EU raw material supply” are more or less the same objective, and the overall aim of CRMA is to strengthen the EU self sufficiency on raw materials. The administration objective was seen the least important, which could be expected, as there already is a lot of administration in EU and the Member States.

### Question 3:

#### How important do you see the possibility to achieve the Strategic Project status introduced in the CRMA?

The majority of the stakeholders (80 %) thought it is very important or important for the companies to gain the status of a strategic project. Probably the respondents who answered “slightly important” are not involved in the actual investments and are not familiar with the concept of the strategic project. The stakeholder answers to question 3 are shown in Figure 17.

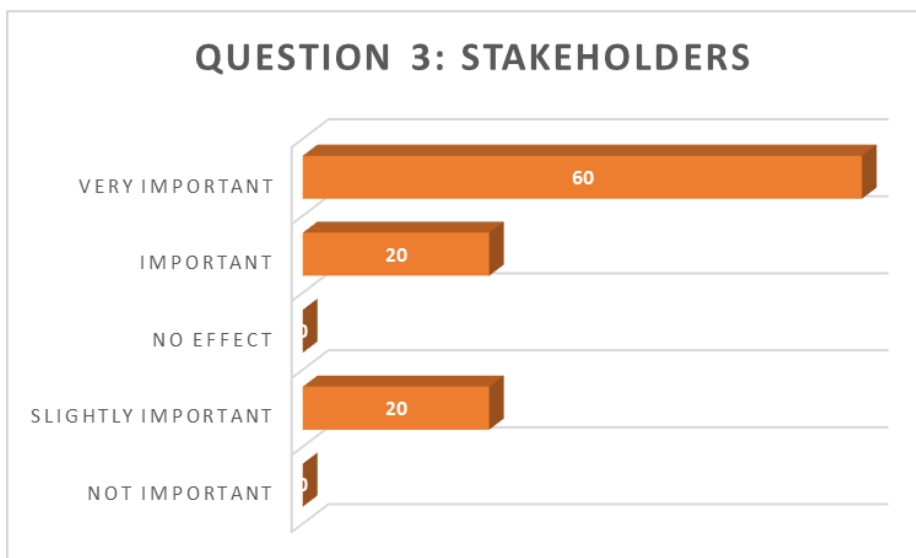


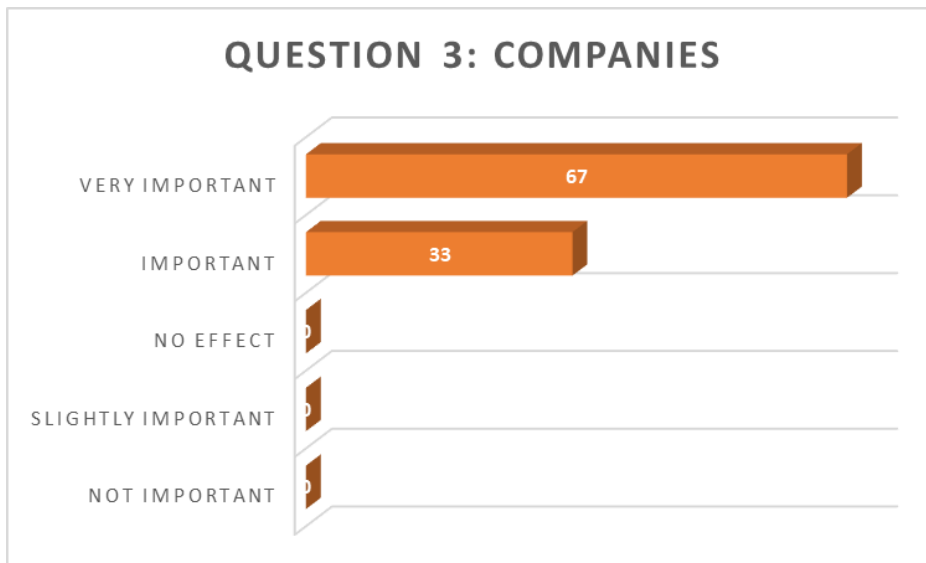
Figure 17. Stakeholder: How important do you see the Strategic Project status?

#### Open comments:

“Time will tell what the actual benefit will be, especially concerning financing and permitting procedures. At least the status will have PR value.”

“The most important benefits will be the speeding up of the permitting procedures.”

All of the companies saw the status of a strategic project very important or important. This reflects well the conversations there have been during the CRMA process. Gaining the status would be extremely important to get the investments finished on time and to compete with other countries who are also competing for these investments. The company answers to question 3 are shown in Figure 18.



*Figure 18. Companies: How important do you see the Strategic Project status?*

Open comments from companies:

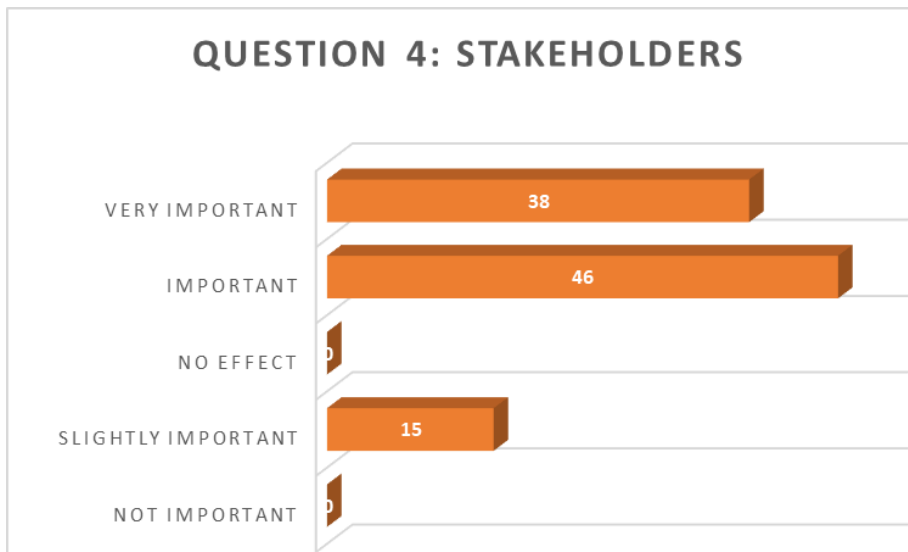
“This is very important in communications.”

“Without the faster permitting procedures it is impossible to compete with for example US for investments.”

#### **Question 4:**

*Selected Strategic Projects will benefit from support for access to shorter permitting timeframes (27 months for extraction permits and 15 months for processing and recycling permits). **How important do you see the set timelines in advancing the projects?***

The stakeholder group saw the new timelines for permitting very important (38 %) or important (46 %). Only 15 % of the stakeholders saw them as “slightly important”, and no-one saw them as “not important”. The stakeholder answers to question 4 are shown in Figure 19.



*Figure 19. Stakeholders: How important do you see the set timelines in permitting?*

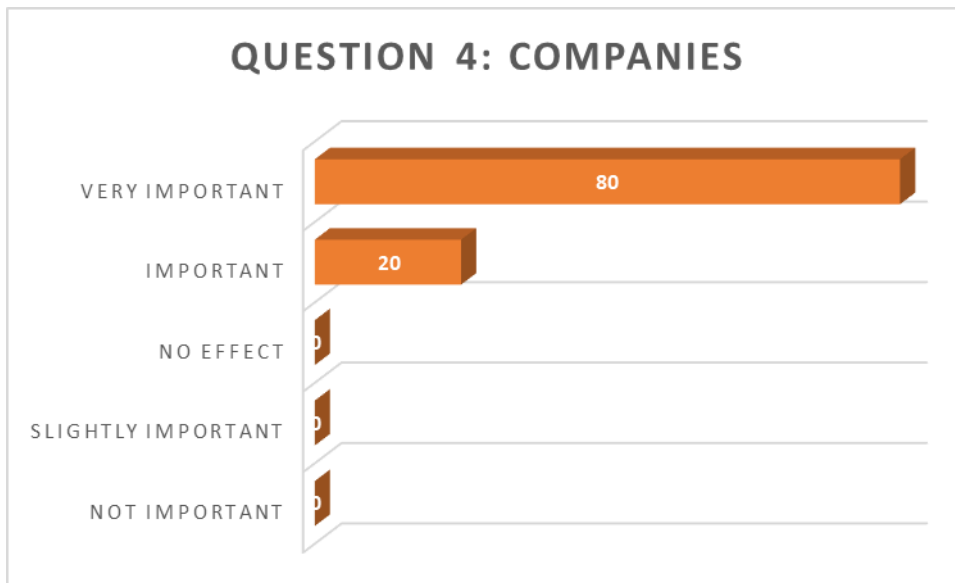
Open comments from stakeholders:

“Permitting in the EU is such a complicated issue (so many different legislations affecting), that I don’t think CRMA will be able to speed up the process.”

“The current permitting situation in Finland diverts investments to other countries.”

“ Also the procedures for complaints should be made faster.”

Also, the companies see the new strict timelines as very important (80 %) or important (20 %). The environmental permitting procedures are currently way too long and delay the investment projects. There are still a lot of uncertainties concerning the timelines, and this could be seen in the open answers. The company answers to question 4 are listed in Figure 20.



*Figure 20. Companies: How important do you see the set timelines in permitting?*

Open comments from companies:

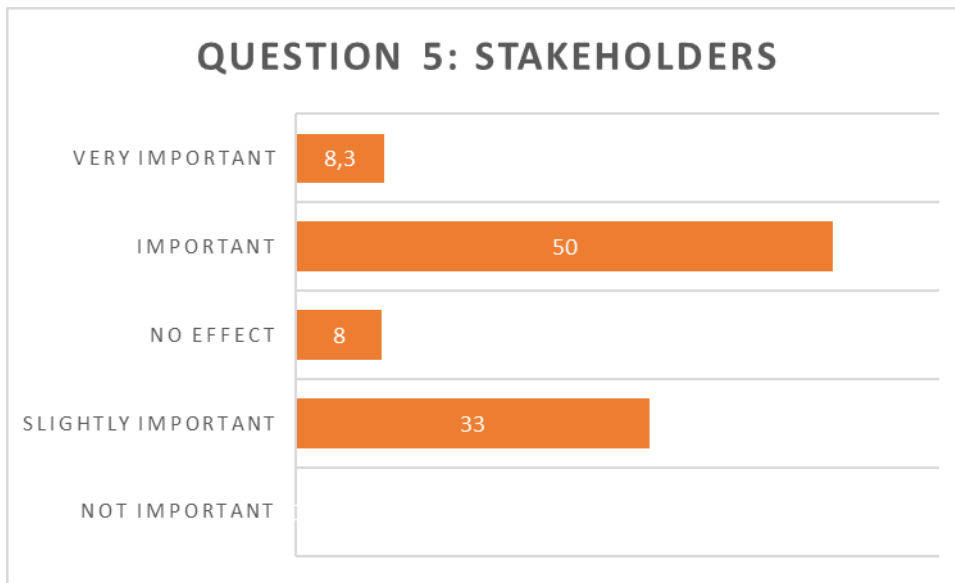
“It is unclear whether the complaints will be included in the timeline or not.”

“The permitting procedures in Finland are ok timewise, but different administrative actors and courts have different opinions on things, and this makes the procedure unpredictable.”

#### **Question 5:**

**One of the main objectives is to give Strategic Projects better and more coordinated access to financing. How important do you see this?**

There was a lot of deviation in the answers of the stakeholders concerning the importance of the strategic project status in achieving financing for the projects. 8,3 % of the respondents saw this as very important and 50 % important. 33 % saw that this is only slightly important. This probably reflects the background of the respondents. Not all of the stakeholders are involved in the financing of these large investments. The stakeholder answers to question 5 are shown in Figure 21.



*Figure 21. Stakeholders: How important do you see coordinated access to financing?*

Open comments from stakeholders:

“Public funding helps these projects to get private funding.”

“I believe the funding can be found if the project is important and well thought of.”

The companies saw this differently, and 90 % of the companies thought that the status of a strategic project will have a considerable effect on being able to get financing in the future. The companies are probably the best experts in what kind of aspects will have the most importance in the investment sector. The company answers to question 5 are shown in Figure 22.

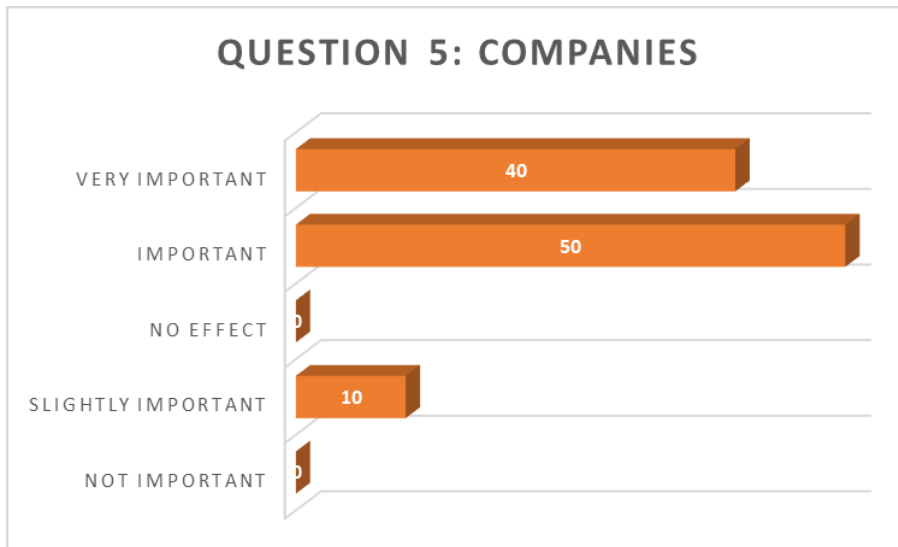


Figure 22. Companies: How important do you see coordinated access to financing?

Open comments from companies:

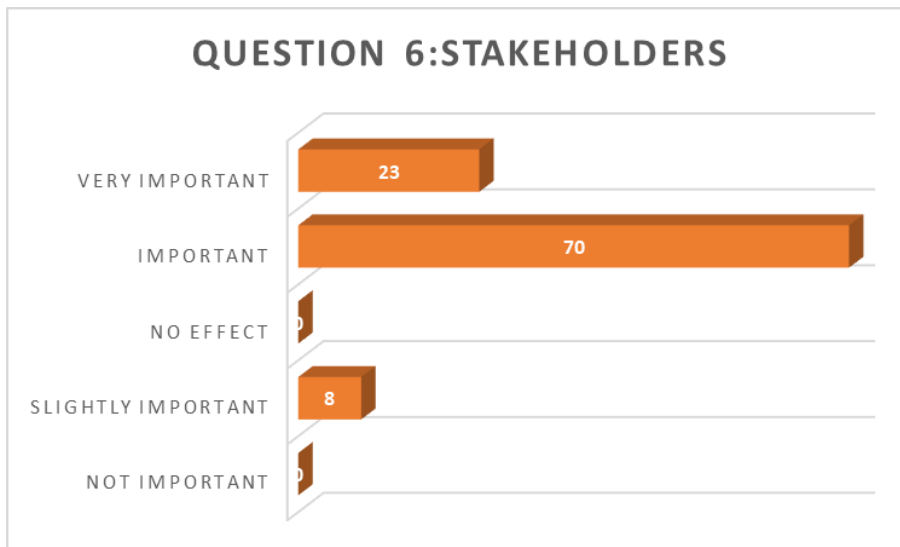
“There are a lot of startups involved in these projects, who have difficulties in finding funding.”

### **Question 6:**

*Previously for example mining wastes have been seen from the environmental risk perspective. Now they are being evaluated as potential sources for critical raw materials. There will also be other sustainability and circular economy criteria introduced in CRMA, like the calculation of footprints and certified criteria for the sustainability of the products.*

### **How important do you see these new sustainability aspects?**

The new sustainability criteria in the CRMA were seen very important (23 %) or important (70 %) by the stakeholders. Sustainability issues concerning mining has been an important topic of conversations in the past few years in Finland, and this can be seen in the answers. The stakeholder answers to question 6 are shown in Figure 23.

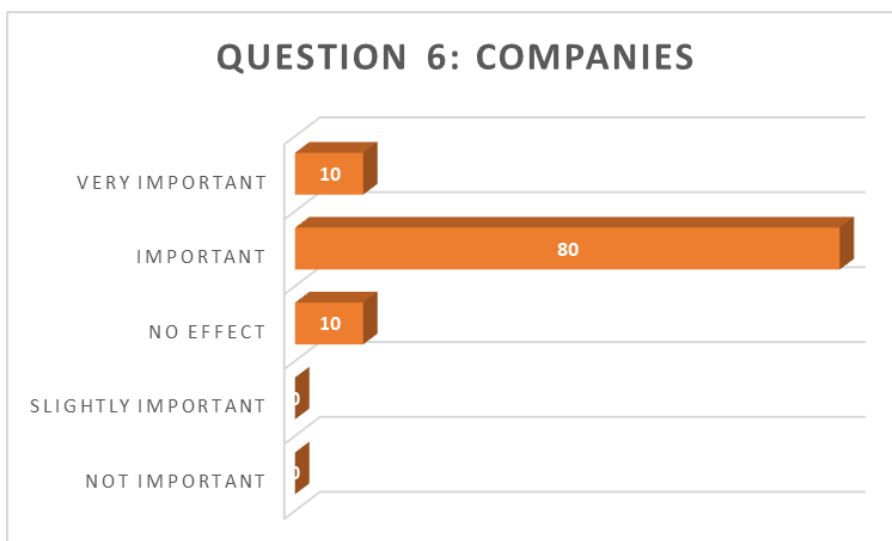


*Figure 23. Stakeholders: How important do you see the new sustainability aspects?*

Open comments from stakeholders:

“There is a lot of similar targets in the EU Battery Act, but they are not the same. It will be interesting to see which legislation will be followed in the end. Obviously there will be a lot of new administration and costs for companies.”

Also companies saw the new sustainability criteria as very important (10 %) or important (80 %). Sustainability of the raw materials and also the production of batteries are seen as a clear competitive advantage for Finnish companies. This is seen to bring new business into Finland. The company answers to question 6 are shown in Figure 24.



*Figure 24. Companies: How important do you see the new sustainability aspects?*

Open comments from companies:

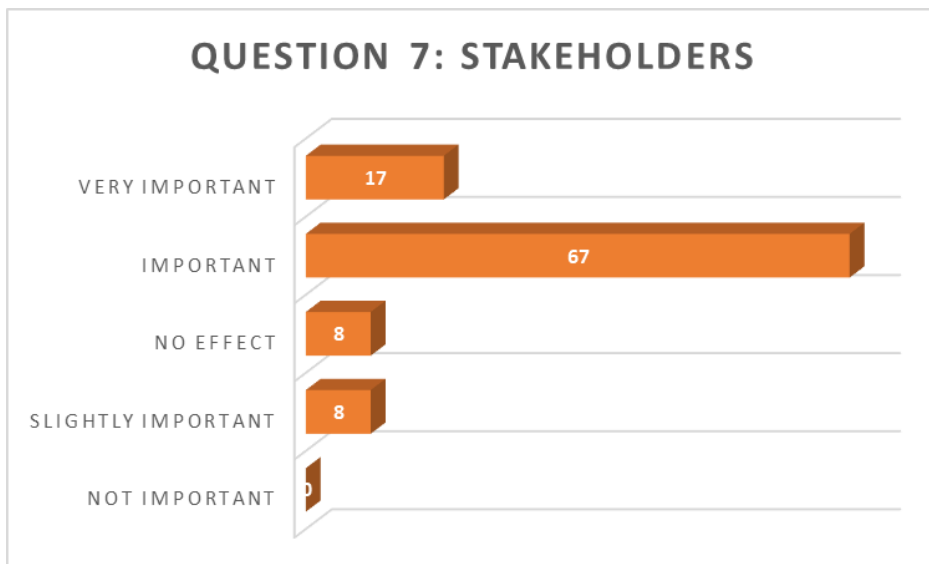
“This is a great opportunity to get new business into Finland.”

**Question 7:**

*As part of the CRMA, a board will be established to evaluate for example the applications for Strategic Projects. There will be one member per Member State in this board.*

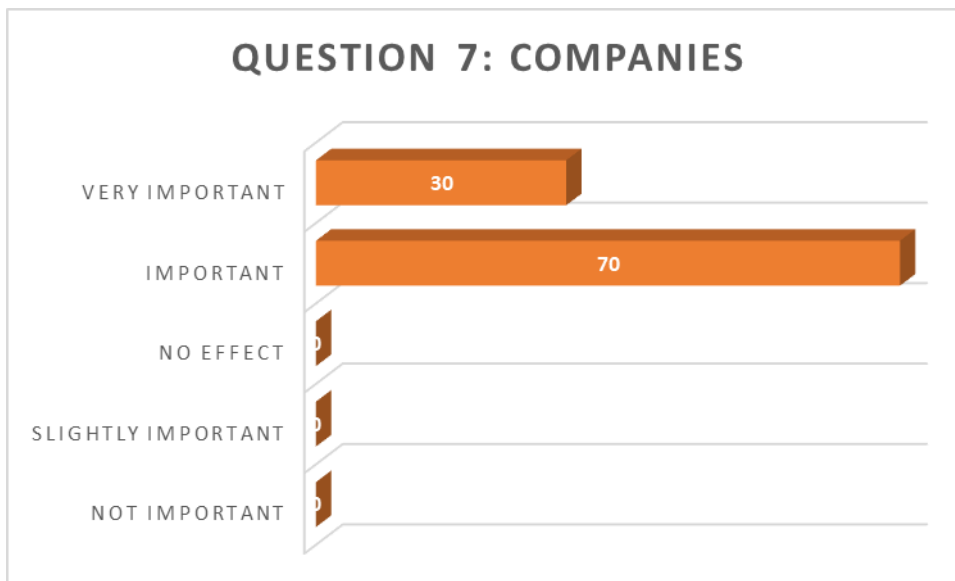
**How important do you see the work of this board and the nomination of the board member for the Finnish battery industry?**

84 % of the stakeholders saw the position of a Board member as important or very important for the success of the Finnish battery industry. The stakeholder answers to question 7 are shown in Figure 25.



*Figure 25. Stakeholders: How important do you see the work of this board and the nomination of the board member for the Finnish battery industry?*

In the company group, 100 % saw the member as very important or important for the success of the Finnish battery industry. The company answers to question 7 are shown in Figure 26.



*Figure 26. Companies: How important do you see the work of this board and the nomination of the board member for the Finnish battery industry?*

Open comments from companies:

“It is great if the industry can be involved in this.”

“We have to be involved in all EU “clubs”.”

## 7 Discussion

The aim of this thesis was to look into the sustainability of the battery industry and critical raw material use. As batteries are getting more and more important in for example decarbonising the mobility sector and storing renewable energy, there are several issues concerning the sustainability of battery production and the materials used in batteries which need to be tackled. According to Robison et al. (2023), key sustainability challenges of the battery sector might be summarised as follows: 1. Battery production has non-negligible GHG emissions, 2. The battery value chain bears also significant social risks, 3. The viability of battery-supported applications is uncertain.

As described in more detail in Chapter 4, circularity can be seen in one of the most important issues to solve these, as well as the production of different raw materials in countries with better environmental protection. The World Economy Forum (2019) has proposed 10 concrete actions to develop a circular battery value chain, to accelerate sustainable business and technology development and to improve responsibility in the value chain.

Finland is currently one of global forerunners in sustainable battery manufacturing. (BNEF, 2024), and this is why Finland was chosen as a case country. Sustainability is one of the key competitive advantages for the Finnish battery value chain. For example, Finland has the lowest carbon footprint in battery chemical (nickel sulphate) production in Terrafame site in Sotkamo. Fortum operates Europe's largest closed-loop hydrometallurgical battery recycling facility in Harjavalta. Their low-CO<sub>2</sub> battery recycling solution makes it possible to recycle over 80 % of the battery, and 95 % of the valuable metals contained in the battery's black mass can be put back into circulation.

### 7.1 CRMA promotes sustainability in the battery sector

The EU Critical Raw Materials Act was introduced in April 2024 and finally came into force in late May. It includes a lot of sustainability aspects, and now was a perfect time to see how Finnish battery value chain companies and stakeholders see the new sustainability targets and requirements, and also to see how they see the importance of the new Strategic Project

status and the different positive aspects in for example permitting and financing the status will bring to the chosen projects.

The results of the survey were very interesting and reflect many discussions there have been during the CRMA process with companies, different stakeholders and especially the European Commission. The Finnish Battery Industry Association (Akkuteollisuus ry) took part in many EU consultations and stakeholder events during the legislative process, as did the other relevant industry associations in Finland. This helped the companies, who are members of these organisations, to give their opinion on different proposals and also to stay informed about different aspects of the new legislation before it was officially accepted. The results of this survey will be used in advocacy work for battery value chain companies in Finland.

In the survey results, the sustainability requirements and standards introduced in the Act were considered very important by the companies and the stakeholders. As stated in the open answers by the companies: “This is a great opportunity to get new business into Finland.”

## 7.2 Timelines for permitting and access to finance were considered important

The Critical War Materials Act came into force on the 23<sup>rd</sup> of May 2024, and is now in the process of being put into force in national legislation. Especially the permitting procedure timelines have to be coordinated with the existing legislation for environmental permitting. It remains to be seen how the national permitting authorities can keep up with the strict timelines introduced in the Act. This will have a considerable effect on the investments.

Currently, lengthy permitting procedures are generally seen to delay the projects. There is already a “fast track” for green investment projects in Finland, but the investments still suffer from unforeseen delays permitting procedures due to complaints to higher courts. Currently the permitting procedures can take years. For mines, the entire process with Environmental Impact Assessments and other requirements can take up to 10 years. The new timelines in CRMA are 15 months for general investments like battery chemicals production and 27 months for mining projects.

In the survey, the stakeholder and company groups both shared the same vision over permitting. In question 4: How important do you see the set timelines in environmental permitting, 80 % of the stakeholder group rated this very important or important. In the company group, 100 % rated it very important or important. In the open answers, the importance to the companies was explained in more detail “Without the faster permitting procedures it is impossible to compete with for example US for investments.”. In the stakeholder group, some respondents voiced out their concern on the speed of permitting possibly meaning compromises in the permit requirements. It is clear, that a lot more resources are needed in the Environmental Agencies to meet the strict permitting deadlines.

Financing is very important, as battery value chain investments are very large. In recent years, there has been a lot of competition globally on State Aids, especially between different EU Members States and USA, and this has had an effect on the location of the new investments. It is quite clear that those countries, who are able to give large aids to the companies who wish to invest, get these investments. In question 5 about better and more coordinated access to financing, over 80 % of respondents in both groups thought this was important or very important. The companies obviously see the need to get better access to financing for their investments.

### 7.3 Strategic Project status brings benefits to the investment projects

In CRMA, a new Strategic Project status is introduced. It will be very interesting to see how many Finnish projects there will eventually be on the list of Strategic Projects, and what can be achieved by getting the Strategic Project status. In the survey, all the companies saw getting the status of a strategic project very important or important, especially with the access to faster environmental permitting and finance. The stakeholders saw the status more as a PR thing, but some said that the status will be important, especially for permitting reasons.

It is quite clear that there will be a lot of applications to receive the status, from a lot of Member States. The expected high number of applications makes the work of the designated new Raw Material Board very important, and also the nomination of the national members of the board is very important.

#### 7.4 Are the set targets possible to meet – deviations in replies between groups

The CRMA introduces targets for extraction, recycling, processing and dependency on a single country. In Question 1 on the targets, there was a lot of deviation in the stakeholder group replies. Some saw them as unrealistically high and some way too low. This deviation is probably caused by the different backgrounds of the respondents. In open answers, a few of the respondents said that the timeline of 2030 for these targets is impossible to meet. Some were concerned about the sustainability requirements being compromised if the targets are too high. In the company group, these targets were considered slightly too high or realistic. This indicates that the companies are more involved in the recycling processes and the supply chain of CRMs. It is clear, that these targets will be very difficult to meet, but they have to be met in order to reduce Europe's dependency on countries like China.

About the importance of the different objectives of the CRMA, both groups had very similar thoughts. In both groups, the most important targets were “strengthening the EU raw material supply” and “diversification of supply and reducing dependency in imports”. This reflects well the original idea of introducing the Critical Raw Materials Act, ie. to secure the European material supply.

As mentioned before, also a new Raw Material Board will be introduced. This board will, among other duties, examine and supervise projects which have been given the Strategic Project status. There will be one person per Member State on this board and one person from the Commission. Question 7 was: How important do you see the work of this board and the nomination of the board member for the Finnish battery industry? Both the stakeholder and company groups saw this to be very important or important. The board members have not been nominated yet, but it can be estimated that these board members will have a lot of influence on which project will be awarded the Strategic Project status.

#### 7.5 Next steps

It remains to be seen what the effects of the CRMA will be on the critical raw material supply and the European battery industry in the short and in the long run. It will probably result in

some kind of bilateral agreements between EU and some CRM producing countries for the supply of raw materials. The global competition for these materials is fierce.

Finland is in a good position, as it has some of these required materials, unlike the rest of Europe. Still, the resources are not enough to meet the needs, or even the required 10 % of the mining. Also, a lot of new mines will have to be established, and this is not an easy task. The mining projects take time, and the public acceptance is not always in their favour.

Currently, also a Mineral Strategy for Finland is being created. It will be published by the end of 2024. In that strategy, a lot of the requirements of the CRMA will be taken into consideration, as the Act also includes tasks for the Member States. The Finnish Battery Industry Association (Akkuteollisuus ry) and all the other relevant industry associations and other stakeholders have been involved in this strategy work to deliver messages from the companies involved in the mineral value chain.

## 7.6 Research limitations and further research needs

No previous research could be found on this subject, as the field of large-scale battery production is still relatively new, and the European Critical Raw Materials Act was just introduced. Therefore, no comparison could be made to other studies or literature.

There were also other limitations to the research. The survey was sent to only 12 companies and 20 stakeholders, so the number of respondents was not high, but the stakeholder group included all the key players who have taken part in the legislative CRMA process and also are familiar with the battery value chain investments into Finland. The 12 companies included in the survey represent most of the key players in the battery sector in Finland at the time this thesis was written.

The survey was kept anonymous in order to get direct and honest replies, especially to the open questions. For this reason, the background of the respondents could not be used to examine the answers more thoroughly. This would have been interesting to examine as well.

At a later stage it would be interesting to conduct a new survey to see how the companies and stakeholders see the effects CRMA has had by the target year 2030 and also if the set targets in the Act have been met.

## 8 Conclusions

Rechargeable batteries are key to unlocking the potential held by both electric vehicles and clean energy technologies. (Sharma&Manthiram, 2020). Global battery demand is expected to grow by 25 % annually to reach 2,600 GWh in 2030. (Global Economic Forum, 2019).

Although batteries come with many benefits and are an essential element in reaching the climate neutrality goals, the manufacturing of batteries have several sustainability issues which need to be tackled. Some of the issues causing sustainability concerns, can be reduced by circularity (ie. recycling of batteries or replacing materials). (Sharma et al, 2020).

The sustainability and availability of critical raw materials and battery production is key to meeting climate targets through green transition. In 2023, The European Commission adopted a new Battery Regulation with several implications for the circular economy of batteries. Among other things, the regulation also addresses various issues concerning the material cycles of batteries and requirements for recycled contents in battery manufacturing. These requirements will be implemented in 2030 and raised in 2035. The regulation also proposes a battery passport with information on repair, disassembly, and, importantly, the carbon footprint of the battery from raw material extraction to the end-of-life phase, without the use phase. Such mandatory carbon footprint, and in the future also carbon footprint classes and a threshold for marketing batteries in the European Union, supports the goal to reduce the overall environmental footprint of battery production. (EU, 2023d).

The EU Critical Raw Materials Act (CRMA) was officially accepted April 2024 and came into force in May 2024. CRMA seeks to strengthen the EU's critical raw material capacity, reduce dependency, increase preparedness and to promote supply chain sustainability and circularity. The Act will also reduce the administrative burden, streamlining permitting procedures for critical raw materials projects in the EU while ensuring high social and environmental protection. (EU, 2023 b).

CRMA is estimated to have a significant effect on companies working in the battery value chain in Finland. For this thesis, an online survey was conducted, to find out how the

companies and different stakeholders see the possible effects the Act will have. The survey was carried out anonymously.

In the results, the importance of CRMA to the Finnish battery value chain can be seen in the replies. Especially the companies seem to acknowledge the value of the new Act, but also the stakeholders see the Act as very important. Some differences could be found between the 2 respondent groups. The companies felt that the Act would have more effect on their business than the stakeholders. Especially the sustainability and circular economy targets were seen to bring new business opportunities for the companies.

The Finnish battery value chain has clear competitive benefits from sustainability requirements of battery materials. Finland has been ranked very high in BNEF Lithium-ion battery manufacturing global ranking, especially in sustainability.

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