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Reporting and Supply Chain Transparency in EU Net-Zero Industries: A Critical Raw Materials Perspective

**Author:** Aysu Bastug

**Student ID:** 875603

**Supervisor:** Prof. Giovanni Dotelli

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## English Abstract

The growing population, industrialization and climate change are among the topics that are shaping the world. Accelerating shift towards net zero economy is crucial in Europe to enable sustainable growth, and critical raw material supply will be essential for the strategic sectors. Two sectors that combine strategic importance and clean technology implementation are wind turbines and e-mobility. These industries rely heavily on critical raw materials like lithium, nickel, cobalt and rare earth elements, where availability from European sources are limited. In order to enable the growth of these sectors, European Union has introduced extensive regulatory framework, including European Green Deal, Net Zero Industry Act, Critical Raw Material Act and Corporate Sustainability Reporting Directive, for improving sustainability performance and disclosures. This thesis investigates how European companies in REE, Li, Ni and Co value chains for Wind Turbine and Li-ion industries respond to the sustainability reporting requirements, what level of transparency they provide and how strategies differ in different value chain steps. The research begins with literature review of the regulatory framework and overview of selected critical raw materials and their role in net zero technologies. Then qualitative assessment is applied on the sustainability reports from European companies across wind turbine and Li-ion battery value chains. The analysis showed differences in reporting maturity for companies in different value chains, mainly due to the maturity of the value chain development. Li-ion battery value chain generally exhibits more commitment in stronger sustainability disclosure; however, the vulnerabilities are similar in both value chains in the upstream steps. The findings suggest regulations are driving improvements, and many companies are strengthening their reporting structures and integrating sustainability into their strategies. Overall, the industry's efforts are moving in the right direction, however in order to achieve supply chain transparency and reduction of dependencies further corporate engagement, more consistent disclosure and expansion of circularity and recycling efforts are needed. These improvements are essential to enable sustainability reporting to contribute effectively to Europe's long-term goal of having resilient and climate neutral industries.

**Italian Abstract**

La crescita della popolazione, l'industrializzazione e il cambiamento climatico sono tra i fenomeni che stanno trasformando il mondo contemporaneo. Per l'Europa, accelerare la transizione verso un'economia a zero emissioni è fondamentale per garantire uno sviluppo sostenibile, e la disponibilità di materie prime critiche sarà determinante per i settori strategici. Due ambiti che coniugano rilevanza strategica e l'applicazione di tecnologie pulite sono l'energia eolica e la mobilità elettrica. Queste industrie dipendono fortemente da materie prime critiche come litio, nichel, cobalto e terre rare, la cui disponibilità da fonti europee è limitata. Per sostenere la crescita di questi settori, l'Unione Europea ha introdotto un ampio quadro normativo — tra cui il Green Deal europeo, il Net Zero Industry Act, il Critical Raw Materials Act e la Corporate Sustainability Reporting Directive — volto a migliorare le prestazioni in materia di sostenibilità e la qualità delle informazioni divulgate.

Questa tesi analizza come le aziende europee attive nelle filiere di terre rare, litio, nichel e cobalto per i settori delle turbine eoliche e delle batterie agli ioni di litio rispondano ai requisiti di rendicontazione di sostenibilità, quale livello di trasparenza offrano e come le strategie differiscano lungo le diverse fasi della catena del valore. La ricerca si apre con una revisione della letteratura sul quadro normativo e con una panoramica delle materie prime critiche selezionate e del loro ruolo nelle tecnologie per la neutralità climatica. Successivamente, viene condotta un'analisi qualitativa dei report di sostenibilità delle imprese europee attive nelle catene del valore dell'eolico e delle batterie Li-ion.

L'analisi evidenzia differenze nella maturità del reporting tra le aziende, principalmente legate al diverso livello di sviluppo delle rispettive filiere. La catena del valore delle batterie agli ioni di litio mostra, in generale, un impegno più forte e una rendicontazione più strutturata; tuttavia, le vulnerabilità risultano simili in entrambe le filiere nelle fasi a monte. I risultati indicano che le normative stanno favorendo miglioramenti e molte imprese stanno rafforzando le proprie strutture di reporting e integrando la sostenibilità nelle loro strategie. Nel complesso, gli sforzi del settore si muovono nella direzione giusta, ma per raggiungere una reale trasparenza della catena di fornitura e ridurre le dipendenze saranno necessari un maggiore coinvolgimento delle imprese, una divulgazione più

coerente e un ampliamento delle iniziative di circolarità e riciclo. Questi progressi sono essenziali affinché la rendicontazione di sostenibilità contribuisca in modo efficace all'obiettivo europeo di sviluppare industrie resilienti e climaticamente neutrali.

**Acknowledgements**

Completing this thesis marks the end of the journey that began in 2016 and took far longer than I ever thought it would. Returning to finish what I started required determination, patience and support of people who believed in me.

I am very grateful to Politecnico di Milano for giving me the chance to come back and complete what I started. Walking back into academic work after years felt overwhelming, but the foundation I received during my studies gave me the tools to start again, no matter how much time had passed.

This research relies on publicly available sustainability reports, academic papers and reports that made analyzing this complex topic more manageable. I also acknowledge the role of artificial intelligence, that helped me navigate the vast amount of information needed for this analysis.

My deepest gratitude goes to my parents. Their support, encouragement and belief in my abilities have been my biggest motivation not only during my academic journey, but throughout my entire life. They never stopped believing in me, stood by me through the years and never doubted that I would reach this moment. This achievement is as much theirs as it is mine.

I am also thankful to my partner for his support through this journey. Balancing full-time professional responsibilities with thesis completion presented significant challenges, and I deeply appreciate his understanding and encouragement.

Finally, I acknowledge the perseverance required to return to academic work after several years and to complete this thesis while maintaining professional commitments. This experience has deepened my appreciation for resilience, lifelong learning and the importance of finishing what we start, regardless of how uncertain and hard the path may be.

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## List of Abbreviations

| | |
|---|---|
| CAM | Cathode Active Materials |
| CRM | Critical Raw Material |
| CRMA | Critical Raw Materials Act |
| CSRD | Corporate Sustainability Reporting Directive |
| DESI | Digital Economy and Society Index |
| DRC | Democratic Republic of Congo |
| EAF | Electric Arc Furnace |
| EFRAG | European Financial Reporting Advisory Group |
| ESG | Environment, Social and Governance |
| ESRS | Environmental Sustainability Reporting Standards |
| EU | European Union |
| EV | Electric Vehicle |
| GHG | Green House Gasses |
| H2DRI | Hydrogen Direct Reduced Iron |
| HDS | High Demand Scenario |
| HREE | Heavy Rare Earth Elements |
| ICT | Information and Communications Technology |
| IEA | Internal Energy Agency |
| IPCC | Intergovernmental Panel on Climate Change |
| IR | Import Reliance |
| JRC | Joint Research Centre |
| LCO | Lithium cobalt oxide; battery chemistry |
| LDS | Low Demand Scenario |
| LFP | Lithium iron phosphate; battery chemistry |
| LREE | Light Rare Earth Elements |
| NCA | Lithium nickel cobalt aluminum oxide; battery chemistry |
| NMC | Lithium nickel manganese cobalt oxide; battery chemistry |
| pCAM | Precursor Cathode Active Materials |
| PGM | Platinum Group Metals |
| SCRREEEN | Solutions for Critical Raw Materials - a European Expert Network |
| SDG | Sustainable Development Goals |
| SIEI | Substitution Index for Economic Importance |
| SRM | Strategic Raw Material |
| STEP | Strategic Technologies for Europe Platform |
| SWOT | Strengths, Weaknesses, Opportunities and Threats |
| UN | United Nations |
| UNFCCC | United Nations Framework Convention on Climate Change |

# 1. Introduction

The Industrial Revolution marked a turning point in human history, transformed lifestyles significantly and contributed to rapid population growth. Improvements in healthcare, sanitation, and nutrition caused mortality rates to go down, and similarly, the developments in agriculture and the extraction and usage of fossil fuels supported economies to develop and populations to grow.

As of 2025, the estimated global population is 8.2 billion people, which is more than eight-times the size during early stages of the Industrial Revolution. By the end of this century, the human population is expected to reach around 10.2 billion (United Nations, 2024)

This demographic growth, combined with increasing resource consumption levels, has placed significant pressure on planet's natural systems. For decades, humanity has consumed faster than what Earth can regenerate, which is explained by the phenomenon known as "Ecological Overshoot". This phenomenon is illustrated by Earth Overshoot Day, which marks the point when humanity's resource consumption exceeds the planet's capacity to regenerate those resources for that calendar year. From Earth Overshoot Day onwards, humanity starts borrowing from future, for example by emitting carbon faster than Earth can absorb (United Nations University, 2025).

Humanity's current rate of resource consumption exceeds the planet's regeneration capacity, with global resource use equivalent to 1.7 Earths annually (Global Footprint Network, 2025). This ecological overshoot leads to environmental crises, including climate change, deforestation, air pollution, water scarcity, soil degradation, biodiversity loss and threatens ecosystems. Without significant changes in consumption patterns and resource efficiency, the gap between human demand and Earth's regenerative capacity will continue to widen and will pose serious risks to sustainability and climate resilience.

# 2. Regulatory Framework and Policy Context

In response to these escalating risks, the global community has committed to a series of ambitious climate goals through international agreements. The most prominent of these is the Paris Agreement, a legally binding legislation adopted in 2015 by 195 countries under the United Nations Framework Convention on Climate Change (UNFCCC). As a milestone in global climate governance, it is the first binding agreement that brings nations together to fight against climate change and its impacts. The overarching goal is to limit the temperature increase to below 2℃, while pursuing efforts to keep it at 1.5℃ above pre-industrial levels. According to Intergovernmental Panel on Climate Change (IPCC), exceeding this 1.5℃ threshold would significantly intensify climate related risks, including more frequent and severe droughts, heatwaves and extreme rainfall events (UNFCCC, 2015), (IPCC, 2022).

To meet this target, the IPCC emphasizes the urgency of halving global greenhouse gas (GHG) emissions by 2030 and reaching net-zero emissions by 2050 (IPCC, 2022).

Achieving this requires a profound transformation of economic and social systems, including shifts in energy production, industrial processes, transportation and land use. In line with these goals, an increasing number of countries, regions, cities and companies have adopted carbon neutrality targets, signaling a growing commitment to decarbonization and climate resilience.

In addition to Paris Agreement, as part of the 2030 Agenda for Sustainable Development, United Nations Sustainable Development Goals (SDGs) were adopted in 2015. These goals provide global recognition and initiation for integrating sustainability across sectors and regions and they address 17 challenges in total, such as environmental challenges like climate change, environmental degradation, responsible resource use and social challenges like inequality and poverty.

Goals 7: Affordable and Clean Energy, 12: Responsible Consumption and Production and 13: Climate Action provide grounds for alignment on environmental protection along with industrial development. They guide governments, companies and societies to integrate sustainability thinking into decisions, particularly in industries that depend on resource use and have impacts on environment.

Goal 7 targets to increase universal access to affordable, sustainable, and renewable energy. This is one of the strategic pillars of the sustainability agenda and provides framework and clearly underlines the importance of transitioning away from fossil fuels, improving energy efficiency and expanding renewable energy infrastructure.

Goal 12 emphasizes the importance of the transition to resource-efficient, circular economies by promoting sustainable production practices, reducing waste, and enhancing supply chain transparency. Within the scope of this goal, lifecycle thinking, eco-design and sustainable procurement practices are introduced to ensure economic growth with minimum or no impacts on the environment. The goal emphasizes the importance of strategies like recycling, reusing and redesigning for the reduction of environmental impact in the industries depending on critical raw materials.

Goal 13 underlines the significance of climate ambitions integration into policies, plans and regulations to provide support for the fight against climate change. Closely aligned with the Paris Agreement, it reinforces the need for emissions reduction, climate adaptation, and innovation for lowering carbon emissions. From global supply chains perspective, Goal 13 supports the critical components for achieving net-zero targets in strategic industries, such as carbon-neutral logistics, renewable energy integration, and climate-resilient infrastructure (United Nations Department of Economic and Social Affairs, 2015).

The European Union has also established a comprehensive and legally binding framework as a response to the escalating climate and resource challenges. This framework aims to transform political goals into legitimate obligations and commits to an emission reduction target by 2030 and climate neutrality by 2050. The European Climate Law, launched in 2021, structures these targets into legislation, establishes a carbon budget and requires all EU institutions and Member States to align their policies accordingly (European Commission, 2021). With these initiatives, the law provides clarity on coherence between energy, industry and resource pillars and guidance on prioritizing innovation and investment on low carbon technologies. Regular monitoring, 5-year reviews and best available scientific practices are established as policies, signaling further policy adjustment needs for reaching climate targets iteratively.

The origin of the law traces to the European Green Deal, launched in 2019, which aims to make Europe the first climate-neutral continent by 2050 and provides the strategic roadmap that operationalizes the commitments listed in the Climate Law. It sets out the ambition to reduce greenhouse gas emissions by at least 55% by 2030 and to achieve climate neutrality by 2050, while simultaneously transforming Europe into a resource-efficient, competitive and socially inclusive economy. With the Green Deal climate, energy, industry, agriculture, transport and finance policies are integrated under the same policy. Furthermore, climate energy, circular economy, biodiversity protection, sustainable farming initiatives are promoted while ensuring economic growth. The Green Deal aligns the industrial measures with carbon neutrality objective with the guardrails outlined in the Climate law, and builds policy pathways, proposes different perspective in markets and encourages innovation in low-carbon technologies (European Commission, 2019). In this way, the Green Deal functions as a climate strategy and an economic plan, guides Europe's transformation toward sustainability and builds the foundation on reporting, due diligence and supply-chain transparency.

In order to transform Green Deal's strategic guidance into concrete actions, EU has introduced three complimentary policies, namely the Green Deal Industrial Plan, the Net-Zero Industry Act and the Critical Raw Materials Act.

The Green Deal Industrial Plan (European Commission, 2023a) aims to accelerate the contribution of Europe's innovative clean technology industries to net-zero objective by creating a more supportive more supportive environment for scaling the manufacturing capacity required to meet EU's ambitious climate targets. The four pillars of the plan are establishing a simplified regulatory framework, ensuring faster access to funding, enhancing labor and skills and promoting open trade for resilient supply chains. Together, these measures are translating Green Deal's strategic priorities into actions by shortening permit timelines, providing investments, and securing raw material access and workforce for clean technologies.

The Net-Zero Industry Act (European Commission, 2024a), introduced as part of the Green Deal Industrial Plan, aims to scale up domestic manufacturing of clean technologies that operate with very low, zero or negative greenhouse gas emissions. Its core objective is to reach at least 40% of EU's industrial activities through strategic net zero technologies by 2030. In addition to reducing emissions, the Act is designed to improve competitiveness, create quality jobs, and strengthen energy independence. It focuses on technologies that are available, can be rapidly scaled up and make a significant contribution to decarbonization. These include solar, thermal, wind energy, batteries and storage systems, grid infrastructure, heat pumps and geothermal energy, electrolysers and fuel cells, sustainable biogas and biomethane, and carbon capture and storage. The support on these strategic industries strengthens EU's energy resilience and clean energy transition.

Another critical instrument to the European Green Deal is the European Critical Raw Materials Act (European Commission, 2024b), which introduced to secure the essential inputs that Europe's clean-technology transition depends on. The goal of this Act is to ensure extraction, processing and recycling significant share of strategic raw materials and to avoid reliance on single supply. Figure 1 details the targets of the major pillars that are underlined in the Act. These pillars support strengthening resilience and supporting climate neutrality and regional competitiveness. To achieve these, clear benchmarks for extraction, processing, and recycling are set, list of strategic raw materials such as lithium, cobalt, nickel, and rare earths are identified, and circular economy principles are identified. It also promotes strategic partnerships with reliable suppliers and building inventories and introduces environmental and social protection with sustainability. By combining domestic capacity building with diversification and circularity, the Act provides the resource security backbone for the EU's Green Deal Industrial Plan and Net-Zero Industry Act, ensuring that industrial scaling is not undermined by supply bottlenecks but instead rests on a stable and sustainable foundation.

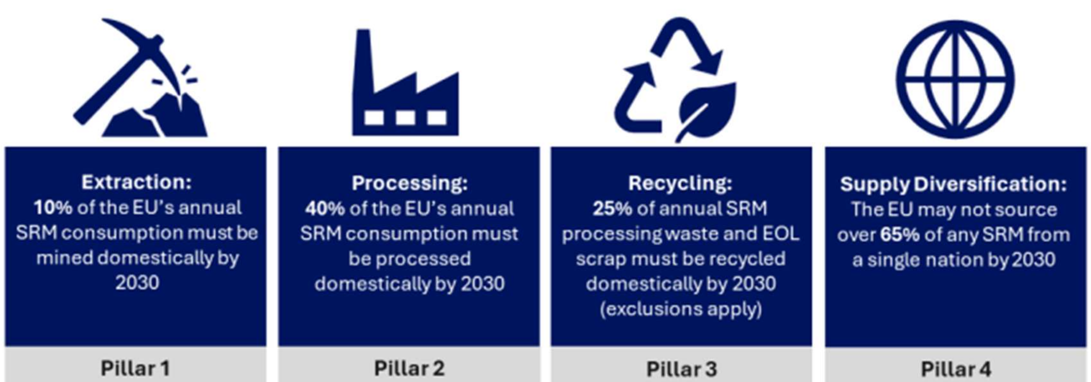


Figure 1: Targets for Domestic Supply and Recycling of CRMs (Adamas Intelligence Inc. and Tradium GmbH, 2024)

Together, the Green Deal Industrial Plan, the Net-Zero Industry Act, and the Critical Raw Materials Act, lay the industrial and resource foundations for Europe's clean-energy transition. These policies provide investment opportunities, suggest adjustment of manufacturing processes, and secure critical inputs. Yet, these measures can only achieve their full impact if companies disclose how they align their strategies and supply chains with these goals. This is where Corporate Sustainability Reporting Directive (CSRD) comes in, and it represents EU's step toward embedding transparency and accountability into corporate governance by obliging standardization, assurance and comparability in sustainability reporting.

## 3. Evolution of Sustainability Reporting in EU

Adopted in 2023, Corporate Sustainability Reporting Directive replaced Non-Financial Reporting Directive that was adopted earlier and extended the scope of mandatory reporting and obligations to approximately 50,000 companies across EU. These include all large EU firms, listed small and medium-sized enterprises, and non-EU companies with large operations in Europe. The directive changed sustainability reporting perspective from being voluntary and driven by reputational intentions to legal obligations. The aim is to establish sustainability reporting as standardized and transparent as financial reporting, and to share comparable and consistent data on corporate environmental, social, and governance (ESG) performance with stakeholders.

The CSRD requires companies to report according to the European Sustainability Reporting Standards (ESRS), which adopts the principle of double materiality. Firms must disclose how sustainability issues affect their financial position and how their activities impact the environment and society. The ESRS framework is comprehensive and covers disclosures on cross-cutting, governance, environmental, and social dimensions. The general standards ESRS1 and ESRS2 are applicable to all companies, ESRS E1 through E5 are environmental standards that cover climate change, pollution, water and marine resources, biodiversity and ecosystems, resource use and circular economy, ESRS S1 through S4 are social standards addressing own workforce, workers in the value chain, affected communities, consumers and end-users, and ESRS G1 signifies governance standards on business conduct. This comprehensive structure enables capturing the true nature of corporate impacts and lays a fundamental baseline for sustainability disclosure initiatives (EFRAG, 2025).

To ensure credibility, the CSRD obliges third-party assurance of sustainability information, initially with limited assurance and progressing toward reasonable assurance. This requirement aims to close the credibility gap in sustainability reporting, enabling systematic verification to dismiss greenwashing and lower confidence in the information.

Another requirement is digital tagging of the reports using the European Single Electronic Format and including sustainability information in the financial or management reports rather than standalone reports. The ambition is to position sustainability information as equally important as financial information and enabling data collection, analysis and comparison of sustainability information to investors and other stakeholders (EFRAG, 2025).

The CSRD ensures transparency on corporate sustainability performance, comparability across firms and sectors and enhances the reliability of disclosures through assurances. Most importantly, it creates the informational infrastructure necessary for the development and improvement of broader EU climate and industrial policies.

In essence, the CSRD provides the informational backbone of the EU's sustainability agenda. The Green Deal Industrial Plan, Net-Zero Industry Act, and Critical Raw Materials Act set industrial and resource targets, whereas the CSRD ensures accountability of the industries and quality of the disclosures. With this directive, the gap between policy targets and corporate practice is closed and the 2030 and 2050 climate targets become easier to track. Through integrated policy development, these measures show EU's ambition to turn climate resilience and sustainability into concrete practice.

# 4. Achieving Net-Zero in the European Union: Strategic Sectors and Technologies for Climate Neutrality

In order to achieve climate neutrality by 2050, EU needs to transform industries at an unprecedented scale and speed. This transformation is driven by set of selected net-zero industries that enable technologies essential for decarbonization. These industries are not only collections of low-carbon technologies, but they are also industrial ecosystems that can produce, scale, and integrate solutions to reduce carbon emissions across energy, mobility, manufacturing, digital infrastructure and aerospace sectors. Their strategic importance is emphasized in the European Commission's Strategic Technologies for Europe Platform (STEP) (European Union, 2025). STEP emphasizes that implementation of low-carbon technologies and strengthening industrial resilience are essential to reach EU's climate objectives.

Joint Research Centre's Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU (European Commission Joint Research Centre, 2023), provides a comprehensive map of the fifteen technologies identified across five strategic sectors that are renewables, electric mobility, industry, information and communications technology (ICT), and aerospace & defense. These sectors and strategies are identified as the backbone of EU's net-zero transition, because they play a big role in achieving climate neutrality and industrial resilience.

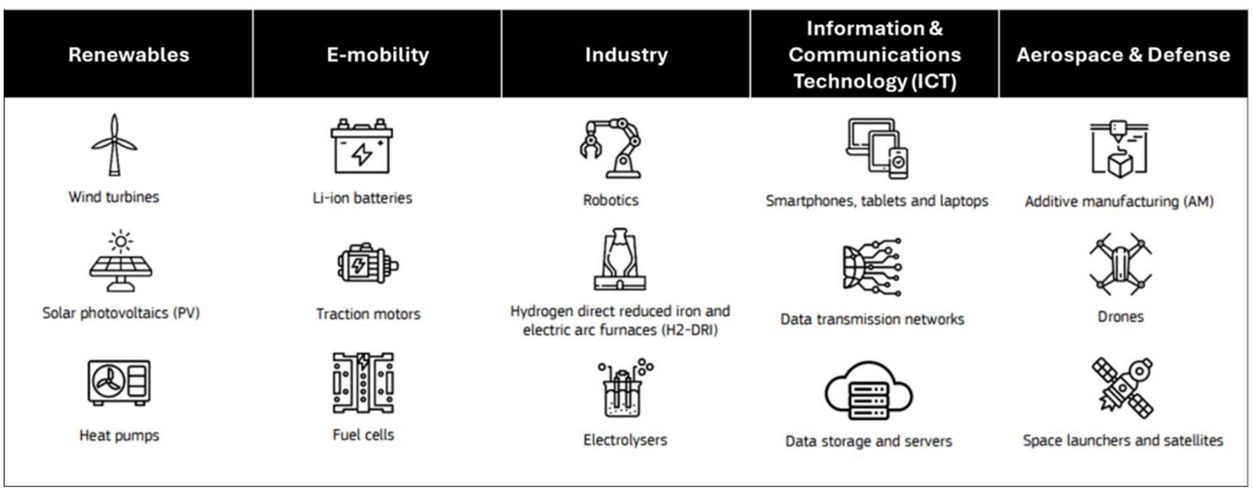


Figure 2: Strategic Sectors and Technologies in the EU (European Commission Joint Research Centre, 2023)

### 4.1. Renewable Energy Sector

The renewable energy sector is the cornerstone of the European Union's decarbonization pathway, that shapes the structure of the energy system and the rate of possible emission reduction. Wind turbines, solar photovoltaics (PV), and heat pumps are at the core of this transformation, as they enable the replacement of fossil-based energy with clean alternatives. In addition to emission reduction opportunities, renewables reduce the dependence on imported fossil fuels and create new value chains which make energy systems more resilient.

The International Renewable Energy Agency emphasizes renewable energy accounts majorly for required reduction of emissions, which highlights their support in meeting climate objectives worldwide (International Renewable Energy Agency (IRENA), 2020).

Wind and solar power are the main technologies for Europe's emerging electricity generation, due to their scalability, modularity, and rapidly declining costs. Wind turbines provide high-capacity, stable output whereas solar photovoltaics offer exceptional implementation flexibility, ranging from rooftop systems to large-scale industrial applications. The expansion of renewable energy facilities and increased output not only enables electrification of mobility, buildings and industry, but also drives development of smart grids and energy storage that allow more efficient interaction with renewable electricity.

Heat pumps play an equally critical role in transforming the heating and cooling sector, which is one of Europe's most energy-intensive processes. Heat pumps reduce dependence on natural gas and other fossil fuels by providing electricity and heat to facilities through capturing ambient thermal energy with high efficiency operation. Their implementation provides flexibility to the power systems as the variable renewable electricity generated by heat pumps helps with demand patterns and provides overall support to the grid. All in all, heat pumps are a technical solution for reducing emissions for heating, moreover they provide important support enabling a dynamic and interconnected system.

In summary, by increasing clean energy supply, enabling electrification and resilience across sectors and alignment with climate goals, these technologies demonstrate the transformation of Europe's energy landscape.

## 4.2. E-Mobility Sector

Electric mobility is one of the central pillars of Europe's pathway to climate neutrality. As transportation is one of the major industries responsible for high levels of carbon emissions, e-mobility reflects the urgency of decarbonizing transport and developing clean-energy industries. The main contributors to this transition are lithium-ion batteries, traction motors and fuel cells, and together, they enable the shift from internal combustion engines to low and zero emission mobility systems. Lithium-ion batteries provide energy storage for battery electric vehicles and offer high energy density, rapid charge-discharge capability and scalability. As complementary, fuel cells enable hydrogen powered mobility, especially when long range, fast refuel and high payload capacity are needed. Traction motors convert stored or generated electric energy into mechanical energy, give energy to the electric drivetrains and overall determine vehicle's efficiency, performance and reliability.

The strategic relevance of these technologies is highlighted by the European Environment Agency's Trends and Projections in Europe report, which identifies the transport sector as one of the EU's most persistent emissions challenges (European Environment Agency (EEA), 2025). Despite improvements in vehicle efficiency, transport emissions remained relatively stable due to rising demand, thus electrification became crucial for achieving significant reductions. The implementation of batteries, fuel cells and traction motors requires not only technological substitution, but also development of charging and refueling infrastructure, grid integration and industrial capacity to support mass production. All these requirements highlight once more why e-mobility is both environmental and industrial priority.

In addition to the emission reduction potential, e-mobility sector also contributes significantly to Europe's technological independence and economic resilience. The global competition in battery production and e-mobility technologies has intensified with the rapid expansion of electric vehicle manufacturing worldwide. European Union aims to strengthen the position in global value chains and reduce dependency on external suppliers by investing in domestic manufacturing capacities, focusing on research and development and forming industrial alliances. This approach emphasizes innovation, supply-chain resilience and strategic autonomy, which aligns with European industrial strategy that is the essential component of the green transition. Once the sector further progresses, Europe's industrial landscape, labor market and technological capabilities will be strongly influenced by the integration of batteries, fuel cells and traction motors, which will make e-mobility an essential element of the climate and economic policy.

### 4.3. Industry Sector

Historically, industrial processes have always been the most difficult to decarbonize, and EU's climate transition relies on the technologies that are capable of reducing emissions from these processes. The most significant technologies are robotics, electrolysers, and hydrogen direct reduced iron combined with electric arc furnaces ($H_2$-DRI + EAF). Robotics enhances manufacturing precision and efficiency, while reducing material loss and energy use and enabling flexibility and digitalized production. As industries shift to cleaner production methods, tighter control over input, energy use and quality standards are required. Therefore, robotics become particularly essential, not only for efficiency gains but also for ensuring compliance with tighter operational requirements. Electrolysers play a different but equally important role by producing renewable hydrogen, which is emerging as one of the few viable options for lowering emissions in sectors where direct electrification is not feasible. The Masterplan for a Competitive Transformation of EU Energy-intensive Industries (High-Level Group on Energy Intensive Industries, 2019) highlights clean hydrogen technologies and advanced robotics are essential to modernize Europe's industries and reduce the dependence on fossil fuels. Especially in steelmaking, which is a very high energy intensive industry, the shift from coal-based to hydrogen-based blast furnaces ($H_2$-DRI) makes a very big difference and represents a fundamental technology advancement with emission reduction potential. Using hydrogen instead of fossil fuels eliminates process emissions, while electric arc furnaces (EAF) allow steel to be melted with renewable energy. Together, robotics, electrolysers, and hydrogen direct reduced iron combined with electric arc furnaces ($H_2$-DRI + EAF) technologies highlight how industrial production is evolving toward cleaner, more adaptable, and technologically advanced systems that support both climate objectives and long-term industrial competitiveness.

### 4.4. Information & Communications Technology (ICT) Sector

With technologies such as smartphones, tablets, laptops, data transmission networks, data storage and servers, the ICT sector remains to be a strategic sector within EU's net zero transition plan. These technologies are the digital layer enabling modern economic activity and functioning clean technology systems. Consumer electronics, such as smartphones, tablets and laptops, act as the primary interface and enable individuals, companies and institutions to access digital services, manage information and coordinate automated processes. Their role extends beyond personal use as they support remote operations, industrial monitoring and data driven management of energy and mobility systems. Data transmission networks provide connectivity and allow reliable information circulation across industries. To integrate renewable energy, coordinate transport flows and enable industrial automation, high capacity communication systems are essential. As highlighted in the European Commission's Digital Economy and Society Index (DESI) (European Commission, 2024c) , the performance of data transition networks directly influences Europe's ability to implement and operate low carbon technologies. Increasing volumes of information are generated by digitalized and electrified systems, and this is where data storage and servers come into the picture. Complementing data transition networks, data storage and servers supply the computational capacity needed to process and analyze high volumes of information. Expansion of data storage and servers highlights the enabling role of ICT in the green transition and necessity to manage the sector's own energy footprint.

These technologies form the digital foundation of Europe's transition, as they enable data flow, connectivity and analytical capacity to manage complex clean technology systems.

### 4.5. Aerospace & Defense Sector

Another strategic component of Europe's emerging clean technology landscape is the aerospace and defense sector, which includes far more capabilities than traditional security operations. Technologies such as additive manufacturing, drones, and space launchers play distinct roles in this sector. Additive manufacturing reduces material use and enables the production of lightweight and high-precision components that contributes to overall improvement of the efficiency of aerospace systems. Drones offer low cost and low emission alternatives to conventional operations and support in wide range of activities such as environmental monitoring, infrastructure inspection and remote sensing. Climate observation, navigation, communication and disaster management are carried out by the essential services provided by space launchers and satellites. All these technologies help the operation of modern energy, mobility and industrial systems. The European Commission's Space Strategy for Europe (European Commission, 2025a) highlights the growing importance of space-based capabilities for economic resilience and environmental monitoring and underlines the sector's relevance to Europe's industrial and climate objectives. These technologies in the aerospace and defense sector strengthen Europe's ability to efficiently monitor the environment, support industrial activities, and maintain the strategic resilience needed in a rapidly evolving technological landscape.

All in all, Europe's transition to a climate focused and technologically advanced economy depends on a diverse set of clean and digital technologies that reshape how energy is produced, how goods are manufactured and how information and strategic capabilities are managed. This is the common pattern across renewable energy, electric mobility, industry, ICT and aerospace & defense sectors. Wind turbines, solar PV and heat pumps expand the supply of clean electricity and enable renewable energy. Batteries, fuel cells and traction motors transform mobility systems and support new industrial value chains. Robotics, electrolysers and $H_2$-DRI + EAF improve production processes and reduce emissions in sectors that have been difficult to decarbonize. Consumer electronics, data transmission networks, data storage and servers provide the digital foundation that allows these technologies to operate in a coordinated and data-driven manner. Additive manufacturing, drones, space launchers and satellites strengthen Europe's capacity for monitoring, precision operations and strategic autonomy.

Collectively, these technologies form the foundation for Europe's economic and climate strategy, but they alone cannot succeed without stable and secure supply of critical raw materials. The widespread implementation of these technologies in Europe brings the underlying material needs into consideration and highlights the importance of establishing reliable access to the raw materials in order to achieve successful and sustainable transformation.

## 5. Critical Raw Materials and Europe's Industrial Transformation for Net-Zero

Europe's path to climate neutrality depends on the large scale implementation of strategic technologies across renewable energy, e-mobility, industry, ICT and aerospace & defense sectors. These technologies cannot be manufactured or operated without a reliable supply of specific raw materials, many of which are extracted and processed only in few countries outside Europe. As Europe advances toward net-zero objectives, the availability of these materials becomes a structural challenge. Supply chains are exposed to geopolitical concerns and increasing global competition, which directly affects Europe's ability to meet the climate targets, maintain industrial resilience and secure the technological capabilities required for the transition.

The IEA's Global Critical Minerals Outlook 2025 shows that demand for minerals used in clean-energy technologies is rising rapidly worldwide, while supply remains highly concentrated and unreliable. The report highlights that extraction and processing of many key raw materials are dominated by a small number of countries, which creates vulnerabilities on all major economies that pursue decarbonization. These global dynamics underscore the urgency for Europe to strengthen the security and sustainability of raw material supply (International Energy Agency, 2025a).

Recognizing this challenge, the European Union has established a comprehensive policy framework to strengthen the security and sustainability of raw material supply. The focus of this framework is the aforementioned Critical Raw Materials Act (CRMA), which emphasizes that all strategic technologies across strategic sectors depend on critical raw materials where the supply is often dominated by single-country suppliers outside Europe. It aims to ensure a secure, resilient and sustainable supply of the materials essential for Europe's green and digital transition. The CRMA sets out measures to expand domestic extraction and processing capacity, diversify imports, improve monitoring of supply risks and promote circularity across the value chain (European Commission, 2024b).

The CRMA identifies 34 critical raw materials and, within this group, 17 are identified as strategic raw materials that are crucial for strategic sectors and technologies. These materials are classified as critical because they combine high economic importance with significant supply risk, reflecting the EU's structured assessment of global production concentration, governance indicators, recycling rates and substitution potential. The European Commission's dedicated portal on critical raw materials highlights that securing access to these materials is essential for competitiveness, innovation and long-term resilience across the European economy (European Union, 2024).

### 5.1. Definition of Critical Raw Materials in the EU

By EU definition, critical raw materials are the materials that combine high economic importance with a high risk of supply disruption (European Commission, 2023b). A material is considered critical when disruptions in the supply would have significant consequences for the EU economy and when alternative sources or substitutes are limited.

The concept of criticality has evolved over more than a decade of EU policy and analysis. The European Commission first introduced a structured approach for the assessment of raw material risks in the Raw Materials Initiative (2008), which underlined Europe's growing dependence on imported minerals and metals. This led to the publication of the first EU Critical Raw Materials List in 2011, identifying 14 materials as critical based on dual assessment of economic importance and supply risk. Since then, the list has been updated every three years to reflect technological developments, market dynamics and geopolitical changes.

### 5.2. Methodology of the Critical Raw Materials Assessment

The identification of critical raw materials in the European Union is based on a structured and quantitative criticality assessment, which evaluates each material along economic importance and supply risk dimensions. This methodology is developed by the European Commission and refined through successive analytical studies, and it provides the foundation for determining which materials should be included on the EU's list of critical raw materials (European Commission, 2024b).

Economic importance indicator evaluates how essential the material is to the EU economy. It evaluates the contribution of the material to end-use applications and to the value added generated by EU manufacturing sectors, classified at the NACE Rev. 2 two-digit level. This indicator is adjusted using the Substitution Index for Economic Importance (SIEI), which reflects the technical feasibility and cost implications of replacing the material in various applications. The adjustment ensures that materials with limited availability or costly substitutes are recognized as more economically significant (European Commission, 2023b).

Supply risk indicator captures the disruption risk in the EU supply of the material. It is calculated by examining how concentrated global production is across raw material producing countries and by incorporating indicators related to governance performance and trade conditions. The assessment weights these producer countries according to the EU's level of import reliance (IR), distinguishing between overall global suppliers and the specific countries from which the EU sources the material. Supply risk is evaluated at the stage in the value chain where the EU is most vulnerable, typically the extraction or processing step, which represents the main bottleneck. Potential mitigation factors, such as the availability of substitutes and the contribution of recycling, are included as elements that reduce the overall risk (European Commission, 2023b).

The criticality assessment serves as the analytical basis for EU raw materials policy. It informs the composition of the CRM list, supports the implementation of the Critical Raw Materials Act and guides policymakers and industry in identifying structural vulnerabilities in supply chains. Only after this methodological evaluation does the EU designate specific materials as critical, which are discussed in the following subsection.

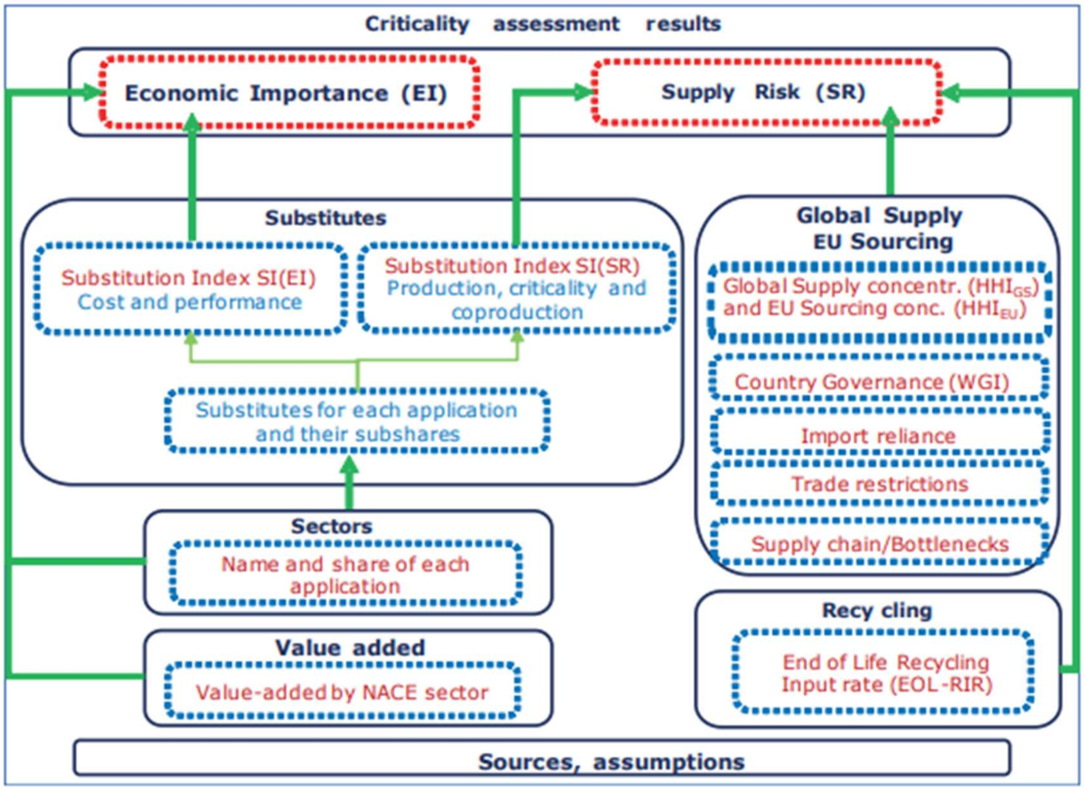


Figure 3: Overall Structure of the Criticality Methodology (European Commission, 2023c)

## 5.3. Overview of the Critical Raw Materials

The last ($5^{th}$) list of critical raw materials was released in 2023, and it identifies 34 materials as critical. For this update, 70 candidate materials have been evaluated, which included 67 substances and 3 grouped categories being heavy rare earth elements (HREEs), light rare earth elements (LREEs) and the platinum group metals (PGMs). In this evaluation, neon, krypton, xenon and roundwood were also assessed, which were not assessed before. Evaluation of titanium metal was done separately from titanium and for methodological consistency, aluminum and bauxite were combined. Copper and nickel were also added to the list as strategic raw materials, even though they do not exceed critical thresholds. Out of the selected 34 CRMs, 17 are classified as Strategic Raw materials (SRMs) (European Commission, 2023b).

This list is prepared in consideration with the expectations for Europe's evolving industrial priorities and increasing material demand for clean energy and digital technologies. Production concentration, limited manufacturing capacity in Europe and geopolitical vulnerabilities highlight the criticality and strategic importance of these materials. The list is a part of CRMA, and it is reviewed every three years, while next review will be by May 2027. This frequency ensures alignment with technological developments and global market dynamics (European Commission, 2024d).


Figure 4: List of 34 CRMs & 17 SRMs (European Union, 2024)

For many CRMs, extraction and processing are dominated by a small number of countries. This significantly intensifies Europe's exposure to external supply risks. The map below illustrates the countries that account for the largest share of global supply across the materials included in EU's 2023 CRM list.

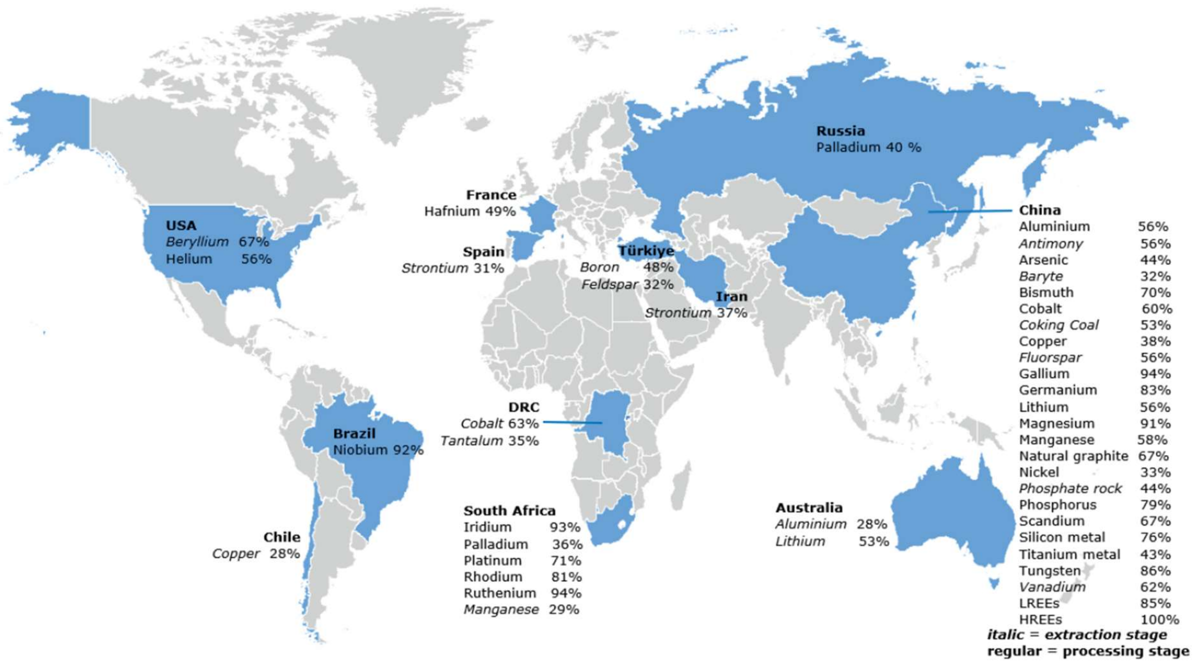


Figure 5: Countries accounting for largest share of global supply of CRMs (European Commission, 2023c)

The map highlights the concentration of global supply for many critical raw materials, and for some of the materials, single country dominates the production. For these, China accounts for more than half of global extraction and processing, therefore, is the leading source country for significant share. This concentrated supply structure increases the exposure to disruptions, and the risk is even more significant for net zero sectors as most technologies depend heavily on critical raw material inputs.  In this context, it is essential to examine the material dependencies shaping the net zero sectors that are the core of Europe's climate and industrial targets.

## 6. Research Focus: Sustainability Reporting across Critical Raw Material Supply Chains for Strategic Technologies

The global supply of many critical raw materials is becoming more and more concentrated, and when combined with their essential role in strategic net-zero technologies, the importance of transparency and sustainability along these supply chains multiply. As climate and industrial regulations advance, the expectation of transparent environmental, social and governance disclosures are increased for the companies active in the extraction, processing and use steps of the critical raw materials. Especially for strategic net zero technologies, these expectations put significant pressure, because the technologies rely on critical raw materials and their sustainability performance is directly influenced by CRM usage.

In this context, examining how companies in EU disclose their sustainability practices provides insight into the resilience, transparency and sustainability of CRM supply chains of strategic net zero technologies.

### 6.1. Method

The main aim of this thesis is to understand how sustainability practices are disclosed by companies in Europe CRM supply chains and how these disclosures match the resilience, transparency and environmental performance requirements set by regulations. To achieve this, the method begins with identification of selected net zero technologies and associated CRMs that form the main focus of the analysis. The technology and CRM selection were made based on their priority and relevance under EU's net zero and industrial decarbonization strategy.

Once the research scope is defined, to review the reporting relevance and commitment of the companies along selected value chains, the publicly available sustainability reports and disclosures were examined. This examination includes company websites, press releases, and industry news to capture both commitments and actual achievements. When sustainability reports were available, they formed the core of the assessment and were analyzed to identify whether they align with the requirements of CSRD and ESRS, or which regulatory frameworks companies claim compliance. The environmental performance of the reports reviewed in depth, using ESRS E1 through E5 as guiding structure. This enabled consistent reviewing and evaluation of companies' disclosures and environmental performance on equal grounds.

After the analytical review structure was established, company selection for this thesis was made based on relevance-based screening process. Companies that have operations in Europe with significant size, strong market presence and high visibility in public sources such as industry news and reports are selected. With this approach, the main aim is to capture the overall sustainability strategies in the respective value chain. Sustainability reporting and public disclosure are also important criteria, however in some cases, companies with limited reporting were also included due to their significant roles in the value chain. In these cases, they provide valuable insights into industry-wide practices and gaps. By combining relevance, recognition and environmental sustainability transparency, the final selection of companies captures a representative picture of the impacts of each value chain step and the main differences and challenges of sustainability practices.

### 6.2. Research Questions

To explore how sustainability is communicated and practiced across critical raw material value chains, this thesis investigates the reporting practices of companies involved in the production and processing of selected critical raw materials. The analysis is guided by the following research questions:

1. Do companies involved in the supply chains of selected critical raw materials publish corporate sustainability reports or policies?
2. What sustainability aspects are addressed by these companies, and which strategies are commonly adopted across the supply chain?
3. How do sustainability strategies differ across companies and supply chain stages, and what factors influence these differences?

These questions are the frame for the analytical approach, and with the method altogether, they provide the basis for the assessment of the process and priority of sustainability reports in critical raw material value chain in Europe.

### 6.3. Selected Critical Raw Materials

In order to provide focus and also comparison between the sustainability challenges that are arising across strategic technologies, a group of critical raw materials are selected and analyzed. The selection considered the strategic relevance to net zero technologies especially, and Rare Earth Elements, Lithium, Cobalt and Nickel are the selected critical raw materials that are in the focus of this study.

### *6.3.1. Rare Earth Elements (REEs)*

Rare earth elements are group of 17 specialty metals (15 Lanthanide elements + yttrium & scandium) that are divided into 2 sub-groups. These sub-groups are light rare earth elements (LREE) and heavy rare earth elements (HREE), and the grouping is made based on physical-chemical properties and commercial reasons. REEs are used in various strategic sectors, such as renewables, e-mobility, telecom, electronics, aerospace & defense. The major properties that enable their usage in wide variety of applications are their unique magnetic, optical and catalytic properties. Even though Europe is at the leading position for the production of most of these technologies (like automotive traction motors and wind turbines), no REE production takes place in Europe yet and most of the demand is supplied from China.

Commonly, LREEs are characterized by lower atomic weights and generally are more abundant in Earth's crust compared to HREEs. Despite their relative abundance, they are still difficult to isolate as they occur together and share similar chemical characteristics. LREEs include Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), Samarium (Sm), Europium (Eu) and Gadolinium (Gr). LREEs are used typically in hybrid vehicle batteries, optical and catalytic properties. Typical uses include hybrid vehicle batteries, optical technologies, catalytic converters, lightbulbs, glass polishing, industrial strength magnets for wind turbines, nuclear batteries, TV screens, LED lights, MRI imaging and many others.

HREEs include Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb), Scandium (Sc), Yttrium (Y). They tend to be less abundant and are often associated with more geographically concentrated deposits. Their applications are typically more niche, such as permanent magnets, nuclear reactors, fiber optic systems, lasers, X-ray devices, seismic monitors and superconductors.

The REE demand is expected to increase with the expansion of renewable energy technologies (wind turbines and solar panels) and electric mobility (traction motors), as these technologies contribute majorly to climate and industrial targets in Europe (European Commission, n.d.).

REE supply is the most geographically concentrated critical raw material among all. In 2024, China accounted for 60% of the global mining output for the REEs used in magnets for various purposes (especially neodymium, praseodymium, dysprosium and terbium), followed by Myanmar, Australia and the United States. China is highly dominant in the separation and refining stages, and accounted for 91% of the global production, where Malaysia followed as second with a large gap. Additionally, China has significantly reinforced their manufacturing position for REE permanent magnets by increasing their share from 50% to 94% in the last two decades, specifically with the production of sintered permanent magnets commonly used in cars, wind turbines, industrial motors, data centers and defense systems. This expansion enabled China to manufacture and supply the key component for most powerful motor used across a wide range of new technologies and supported to hold the globally leading position in supply. This concentrated market situation increases the vulnerability of value chains in strategic sectors and risks of supply disturbances (International Energy Agency, 2025c).

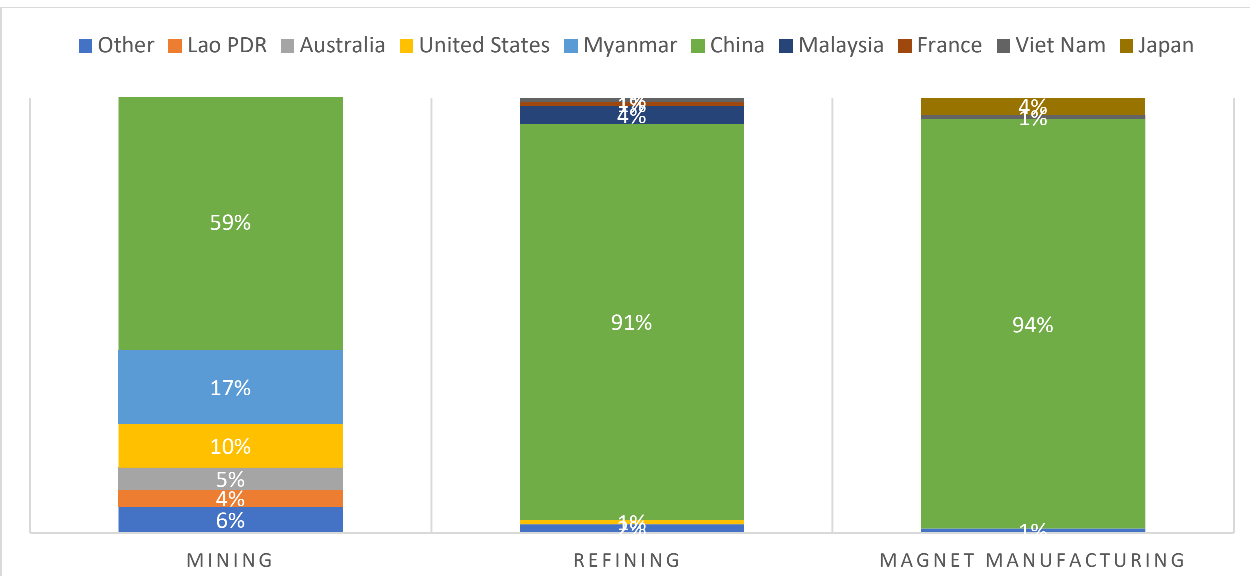


Figure 6: Rare Earth Elements Supply (International Energy Agency, 2025c)

### 6.3.2. *Lithium*

Being the lightest metal in the periodic table and having high electrochemical potential are the main significant electrochemical properties that make Lithium (chemical symbol: Li) an important metal. These properties make lithium uniquely suited for battery technologies, electro-mobility and energy storage in electric vehicles, stationary storage systems and wide range of consumer electronics. Lithium is mostly supplied from primary resources like hard rock mining and brine extraction. In the future, the recovery from end-of-life batteries will be an important source for lithium.

Lithium is essential for expanding strategic sectors and reaching towards net zero ambitions. Most of the global demand comes from lithium-ion batteries, which represents the dominant use of lithium today. Within these batteries, battery grade lithium compounds such as lithium carbonate and lithium hydroxide are used for producing high performance cathode materials. Li-ion batteries are also used in grid-scale storage systems to stabilize electricity systems with variable renewable energy, and the global demand for grid-scale storage systems, therefore Li-ion batteries and lithium are increasing. In addition to all these uses, lithium is commonly used also in traditional applications like glass, ceramics and lubricants manufacturing, however these industries now represent much smaller share compared to battery industry (European Commission, 2025b).

Despite the growing importance of lithium, the global supply is geographically concentrated. Australia carried out more than half of global lithium mining output in 2024, followed by Chile, China and Argentina. Lithium rich hard rock spodumene deposits are available in Australia, enabling access to lithium reserves. Brine resources in salt flats also rich deposits of lithium, and mostly available in South Africa countries. As lithium demand increases, environmental issues like high energy use and waste rock generation from hard rock mining and water use and ecosystem impact from brine extraction raises concerns.

The mining of lithium is relatively geographically diverse, however, refining and processing capacity is dominated in China, which accounted for more than half of processed lithium production globally in 2024. This is a critical structural dependency in the value chain, because the processing of battery grade lithium compounds requires complex processes that are not easily replicated. This combination of rapidly increasing demand and concentrated refining capacity highlights the risks of potential supply dependencies, price volatility and vulnerability to disruptions or geopolitical risks (International Energy Agency, 2025a).

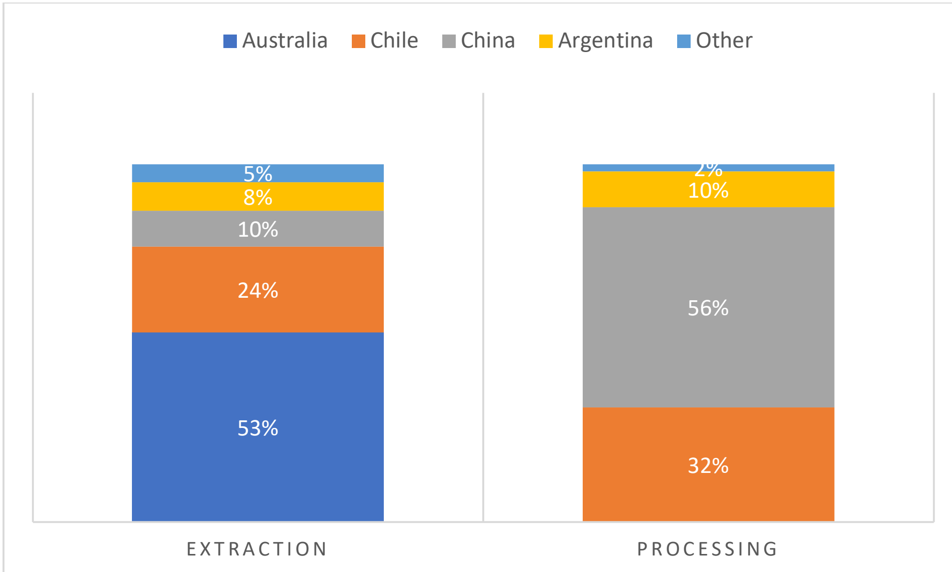


Figure 7: Lithium Supply Overview (European Commission, 2025b)

### *6.3.3. Cobalt*

Cobalt (chemical symbol: Co) is a shiny, silver-grey color transition metal that has relatively low abundance in the Earth's crust and classified between Iron and Nickel in the periodic table. It has a high melting point, retains strength in high temperatures, is ferromagnetic and can form alloys with other metals. Due to these unique properties, it is used in many diverse applications.

Globally, cobalt is used heavily in rechargeable Li-ion batteries used in electric vehicles, energy storage systems and consumer electronics. It is also used in superalloys in turbine engine components, pigments used in paints, magnets used in electric motors, and many other applications (Solutions for Critical Raw Materials - a European Expert Network (SCRREEN), 2020a).

Cobalt mining takes place in several countries, and it is mostly found as a by-product from copper and nickel mines. In 2024, the main primary producer of cobalt is Democratic Republic of Congo (DRC), with 69% of the global production. Russia and Australia are following DRC, with 6% and 4% of the global production respectively. In Europe, Finland is the only producer of cobalt and contributes to 0.8% of the production globally. After the mining and processing, refining is needed for most applications. Primary producer of refined cobalt is China with 78% followed by Finland with 8% (European Commission, 2022a).

European reserves account for 4.4% of world's cobalt reserves, while mining contributes to only 0.8% of world production. Refined production in Europe represents 8.5% of the global refined and processed cobalt (European Commission, 2022a).

From the demand perspective, China has the largest share in global cobalt consumption, 32%, and Europe is the second largest cobalt consumer, which translates to approximately 24% of the global demand. The biggest supplier of Europe's cobalt demand is Russia (25%), and followed by USA and Finland, both accounting for 16% each of the total European supply (Cobalt Institute, 2025).

Cobalt is highly recyclable, and recycling end-of-life products provides a significant source of supply. Recycling is expected to continue rising, as electric vehicle (EV) batteries are expected to reach end-of-life, which will provide significant flows of cobalt supply from scrap.

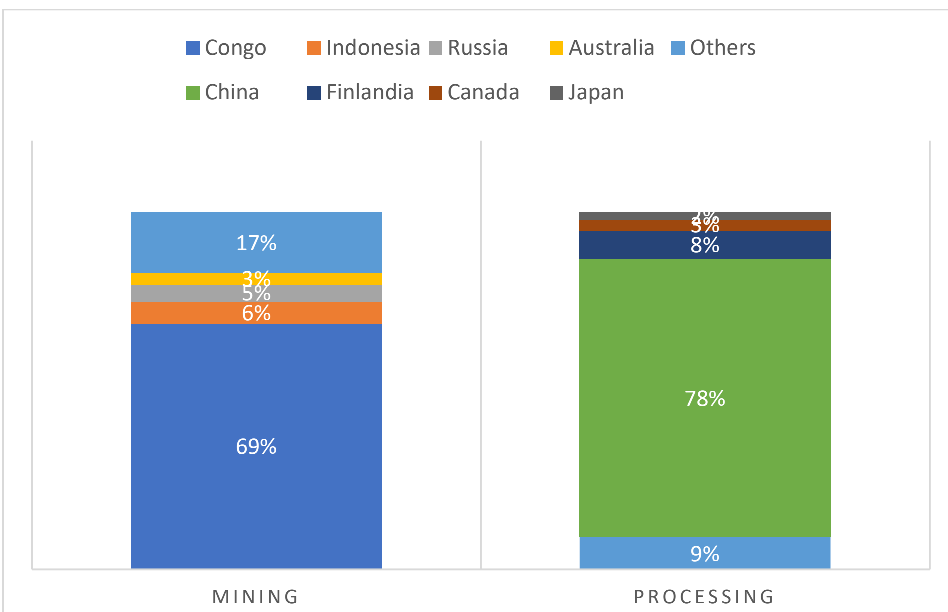


Figure 8: Cobalt Supply Overview (European Commission, 2022a)

### 6.3.4. *Nickel*

Nickel (chemical symbol: Ni) is a white shiny metallic element with typical metallic properties. It has a relatively high melting point and presence of Nickel in Earth's crust is medium, where it is available mostly in combined form. It is used in cathode materials of rechargeable batteries for e-mobility and energy storage, and it also is a key component of the superalloys used in turbines for aerospace and renewable energy technologies. Its resistance to corrosion, ability to enhance mechanical strength and capacity to endure extreme temperatures make it an especially valuable alloying element across multiple industrial applications. Nickel can be infinitely recycled without quality loss (Solutions for Critical Raw Materials - a European Expert Network (SCRREEN), 2020b).

In early 90s, Russia and Canada accounted for the largest global Nickel suppliers, whereas in 2022, Indonesia and Philippines became the leading countries for Nickel mining and extraction, with global share of 42% and 14% respectively. For the processing stage, Indonesia is the leading global producer with 37% share, followed by China with 25%.

Europe has 4.2% of the global world reserves, that contributes 1.5% of the global primary production and 3.3% global production of refined Nickel. The EU primary Nickel demand is sourced from Finland by 38%, Canada by 24% and Greece by 19%. For the processed Nickel materials, Europe mostly imports from Russia by 29%, followed by Finland and Norway, 17% and 10% respectively (European Commission, 2022b).

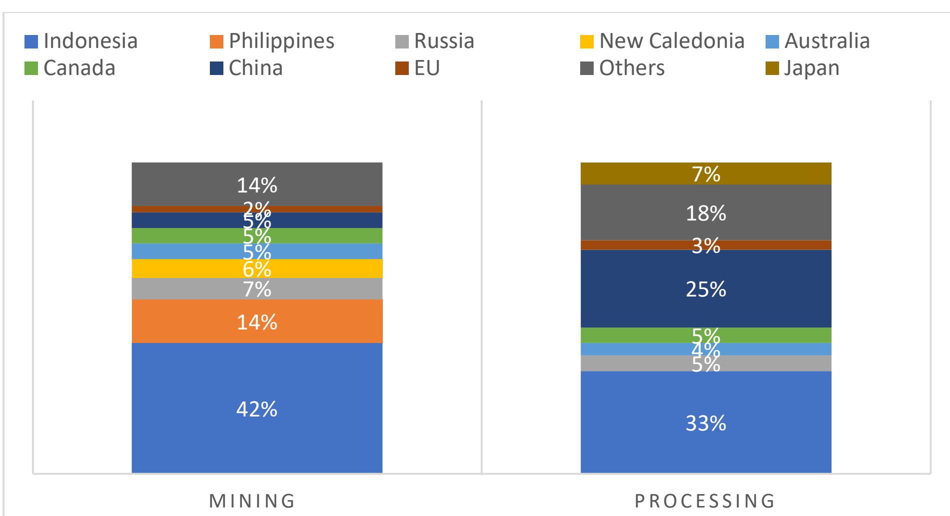


Figure 9: Nickel Supply Overview (European Commission, 2022b)

## 6.4. Selected Strategic Technologies

The selection of aforementioned critical raw materials was made based on their usage in the strategic sectors. The following list highlights the selected strategic raw materials and their presence in strategic industries. While many of these materials are used in multiple industries, this thesis focuses on key strategic technologies for Europe's net zero ambition. These technologies are wind turbines and Li-ion batteries, and they are central to Europe's decarbonization strategy and industrial competitiveness. They rely on critical raw materials with high geopolitical and market disruption risk due to their concentrated and scattered supply.

| Strategic Raw Material | | HREEs | LREEs | Lithium | Cobalt | Nickel |
|---|---|---|---|---|---|---|
| Main EU Supplier Share | Extraction | Japan (55%) | - | - | Russia (70%) | Finland (38%) |
| | Processed | China (100%) | China (85%) | Chile (79%) | Finland (62%) | Russia (29%) |
| Import Reliance | Extraction | 100% | 80% | 81% | 81% | 31% |
| | Processed | 100% | 100% | 100% | 1% | 75% |
| Li-ion Batteries | | | | ☑ | ☑ | ☑ |
| Wind Turbines | | ☑ | ☑ | | | ☑ |
| Solar PV | | | | | | ☑ |
| Electrolysers | | ☑ | ☑ | | ☑ | ☑ |
| Fuel Cells | | ☑ | ☑ | | ☑ | ☑ |
| Traction Motors | | ☑ | ☑ | | | |
| H2-DRI | | | | | | ☑ |
| Heat pumps | | ☑ | ☑ | | | ☑ |
| Data transmission networks | | ☑ | ☑ | ☑ | ☑ | ☑ |
| Data storage & servers | | ☑ | ☑ | | | ☑ |
| Smartphones, tablets, laptops | | ☑ | ☑ | ☑ | ☑ | ☑ |
| Additive manufacturing | | | | | ☑ | ☑ |
| Robotics | | ☑ | ☑ | ☑ | ☑ | ☑ |
| Drones | | ☑ | ☑ | ☑ | ☑ | ☑ |
| Space Applications | | ☑ | ☑ | ☑ | ☑ | ☑ |

Figure 10: Main EU suppliers, import reliance and strategic applications of strategic raw materials selected in this thesis (Righetti & Rizos, 2024)

### 6.4.1. *Wind Turbines*

Wind power is one of the most efficient, cost-effective renewable energy technologies for climate mitigation that is expected to grow further. The growth is influenced by technical and economic performance and support from regulatory frameworks. The cost of electricity generated from wind turbines does not rely on fuel and is mainly driven by capital expenses. In order to assure long term competitiveness and decarbonization of energy industry, it is essential to enable access and stable prices for the critical raw materials.

With the rotational movement of the rotor in wind turbines, the kinetic energy of the wind is converted into mechanical energy and then this energy is converted into electricity in the generator. The components of modern wind turbines are generator, drive train, rotor and blade to produce the lowest possible energy costs. Permanent magnet generators depend heavily on rare earth elements to achieve high efficiency and power density. Neodymium, praseodymium, dysprosium and terbium are key inputs for neodymium-iron-boron (NdFeB) magnets which determines the performance of generator designs. Rare earth permanent magnets are used in almost all of the offshore wind turbines installed in Europe and roughly 72% globally. Their use in onshore wind turbines is also rapidly increasing; however, the implementation is slower with 13% in Europe and 22% worldwide. Wind turbine blades are also another critical component. Their purpose is to maximize energy capture and withstand variable wind loads while maintaining low weight. For this requirement, materials with high stiffness, fatigue resistance and strength to weight ratio are needed. Balsa wood has low density and rigidity and is the preferred material for internal blade structures. Composite materials like glass fiber, carbon fiber, polymers and plastics are used for blade skin and reinforcement. Especially carbon fiber is expected to become significantly important as wind turbine production continues to scale up (European Commission Joint Research Centre, 2023). The figure below lists all the critical raw materials used in the wind turbines and highlights the critical raw materials that are in the focus of this thesis.

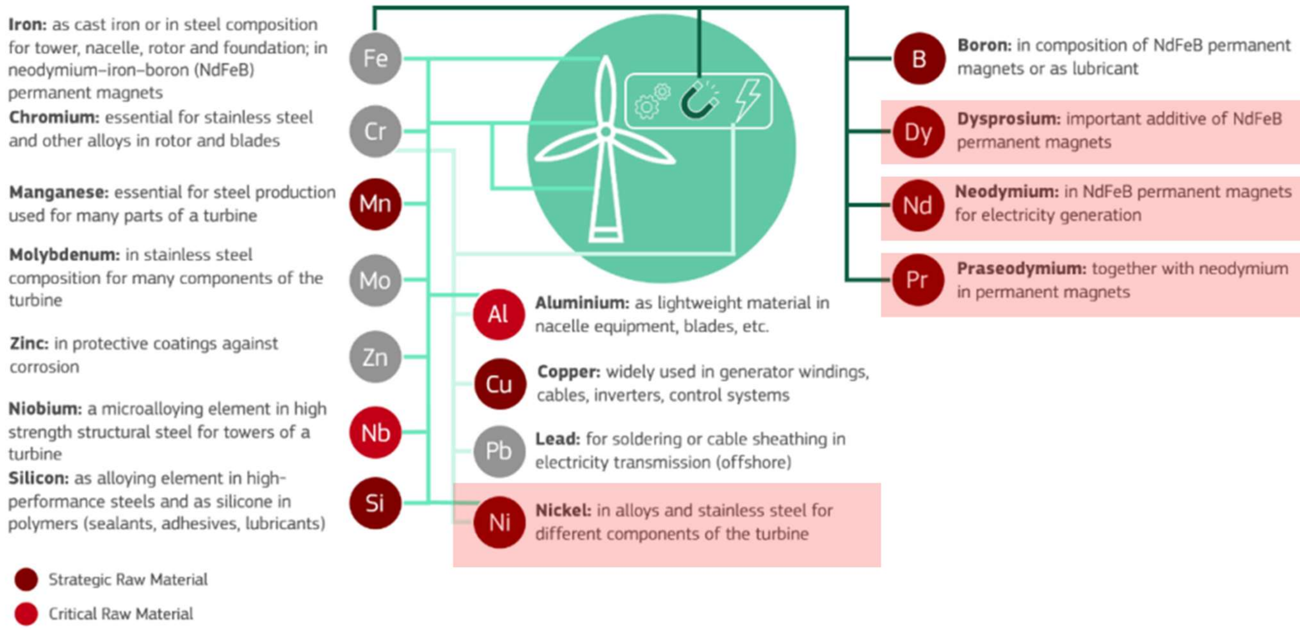


Figure 11: Raw Materials used in Wind Turbines (European Commission Joint Research Centre, 2023)

The highest supply risks and bottlenecks in the wind turbines sector remain concentrated in the upstream stages of the REE and permanent magnet value chain, where China dominates mining, refining, alloying and magnet production. Other materials with high risks include niobium for tower steel and boron for magnets, alongside strategic inputs such as aluminum, copper, manganese, nickel and silicon metal. Europe's position is weakest at the raw materials stage, where it accounts only for 2% of global production, but improves progressively downstream, reaching over 30% in final turbine assembly. Although self-sufficient, Europe's competitive position has weakened in 2023; the share of global turbine production has fallen from 58% to 34%, while China's share has risen sharply from 23% to 52% compared to 2020 levels (European Commission Joint Research Centre, 2023).

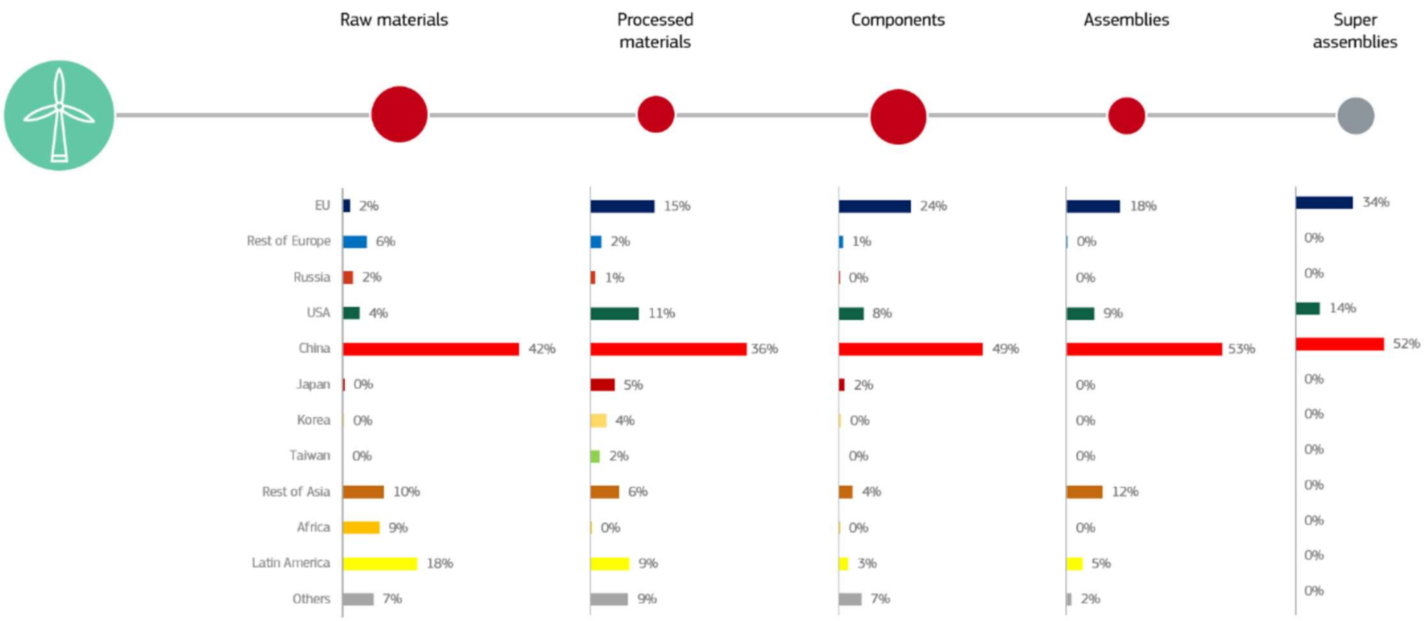


Figure 12: Overview of Key Players along the Wind Turbines Supply Chain (European Commission Joint Research Centre, 2023)

For the material demand projections, 2 pathways are considered for the future of wind power. Low Demand Scenario (LDS) assumes growth will be comparable to historical trends, annual implementation rates will stay close to today's levels, double fed induction designs will dominate, and permanent magnets use will remain limited. In this scenario, material demand for general inputs like steel, concrete and composites remains constant, while REE demand grows until 2030 then declines below 2020 levels by 2050.

In contrast, High Demand Scenario (HDS) considers ambitious climate targets that require sharp acceleration of wind power utilization. In this case, permanent magnet generators will dominate the market, and result in a steep increase in REE demand. For Europe, the REE demand is expected to be up to 6 times higher in 2050; and reaching and in some cases exceeding current global supply levels for certain REE types (European Commission Joint Research Centre, 2023).

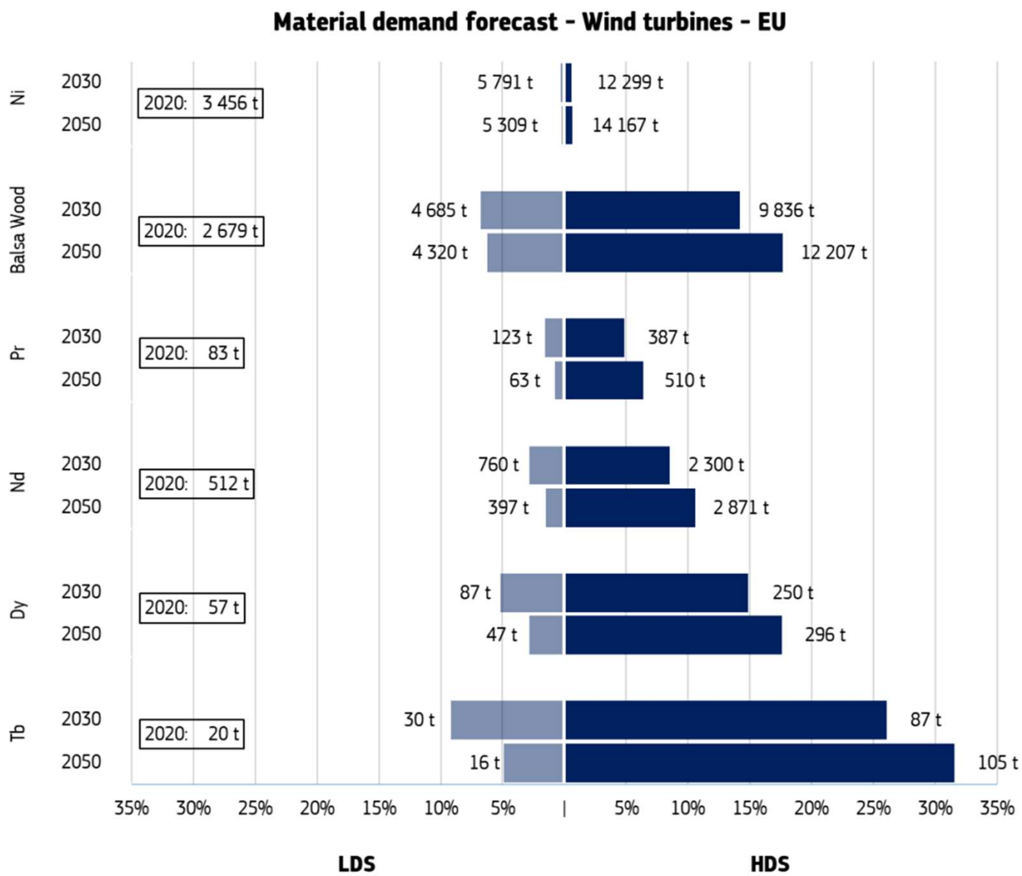


Figure 13: Material Demand Forecast for Wind Turbines – EU (European Commission Joint Research Centre, 2023)

The wind turbine technology is another cornerstone of Europe's clean energy transition. REE based permanent magnet generators are key to the expansion of efficient and reliable wind power. Europe is exposed to significant upstream risks in the REE supply chains, due to the concentrated supply in few countries in combination with geopolitical vulnerabilities. Companies within the value chain play a big role in strengthening the resilience and accountability in this sector, which is essential to achieve net zero targets. Therefore, the companies have responsibility to align with sustainability guidelines, disclose transparent reporting practices, and contribute to net-zero industry objectives.

### 6.4.2. *Li-Ion Batteries*

Lithium-ion battery technology is expanding at a remarkable pace, both for e-mobility and for energy storage for electricity generated from renewable sources. Defense related applications are also gaining importance for li-ion battery applications.

Lithium-ion batteries have matured into a widely used technology, that offers better power and energy performance than traditional acid-lead batteries. Although they are essential for defense applications, the development and market growth were primarily driven by portable electronics, stationary storage solutions and electric vehicles (EVs). Lithium-ion batteries rely on a variety of metals, including nickel, cobalt, aluminum and manganese, in addition to dozens of other different materials that are in anodes, cathodes, electrolytes and separators. Below is the figure that lists the raw materials used in Li-ion batteries and their functions and highlights critical raw materials in the scope of this thesis (European Commission Joint Research Centre, 2020).

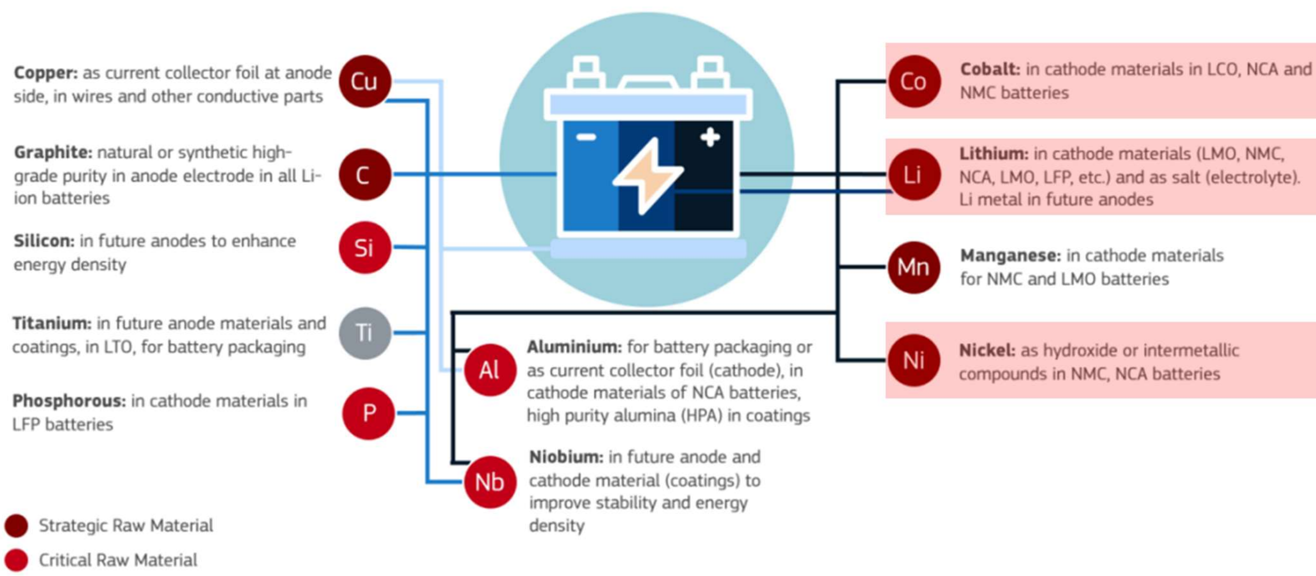


Figure 14: Raw Materials used in Li-Ion Batteries (European Commission Joint Research Centre, 2023)

Li-ion battery composition has been shaped by the technical and economic trends. Current research investigates new anodes, coating materials, new cathodes and closer packing with less electrolyte, thinner separators and thinner current collectors. The overarching goal is to increase specific energy, to reduce weight and volume while maintaining power performance and enabling faster charging.

Europe remains heavily reliant on non-EU countries for the raw materials needed to manufacture Li-ion batteries, and the contribution to global battery production is still very limited. The high concentration of supply in China is a central challenge, and this dominates the global capacity. In 2020, China produced around 60% of refined cobalt, 93% of active graphite materials, 69% of refined lithium, 79% of battery-grade manganese and 63% of nickel sulphate. The most acute vulnerabilities for Europe are lithium and graphite, as the region had no domestic refining capacity for either material in 2021. However, in the case of refined cobalt and battery-grade nickel, Europe performs somewhat better with respectively 8% and 10% of global production capacity (European Commission Joint Research Centre, 2023).

In the case of lithium, Europe currently sources most of its raw materials from Chile, Australia and Argentina. However, several European mining and refining projects are underway and are expected to contribute more significantly to Li-ion battery value chain by 2030. Similarly, the processing of materials, production of components and the assembly of battery parts are dominated by a small group of Asian firms. Chinese companies hold the largest shares across most stages of the supply chain, while Korean and Japanese companies are particularly strong in anode and cathode production. In contrast, Europe and US companies play only marginal roles in these upstream and midstream value chain steps, although Europe has made more progress in cell manufacturing.

Europe remains highly dependent on external suppliers for both the raw materials and the finished cells required for Li-ion battery production. In 2023, overall European battery cell production accounted for 6% of global production, where China is dominating this step with 75%. Below figure shares an overview of the key players along the Li-ion value chain (European Commission Joint Research Centre, 2023).

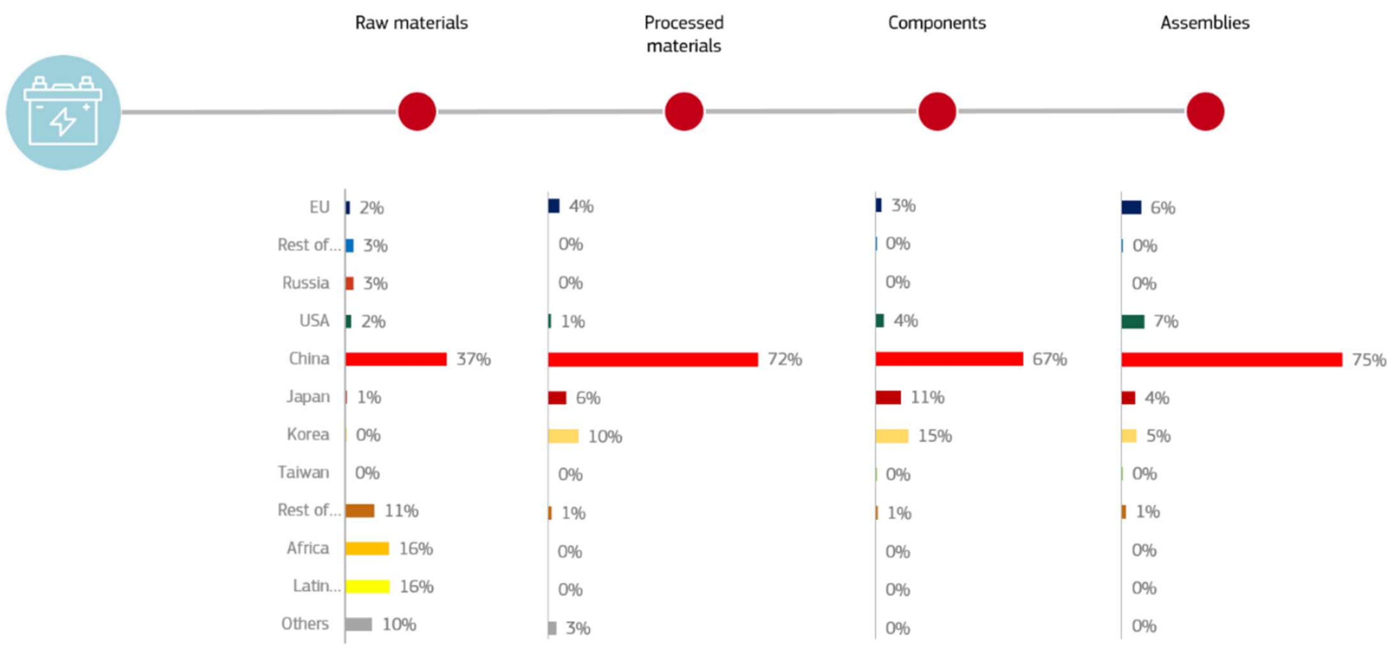


Figure 15: Overview of Key Players along the Li-ion Supply Chain (European Commission Joint Research Centre, 2023)

As electric vehicles are expected to grow and create most of the demand for battery usage, the future of Li-ion battery demand will be driven by the developments in this sector. Similarly, as renewable energy implementation is growing, Li-ion battery demand for the stationary energy storage systems will increase. The material demand and market growth projections are made based on low demand scenario (LDS) and high demand scenario (HDS). Both scenarios assume improvements in battery resource efficiency over time and HDS assumes faster uptake of Li-ion battery systems in the future.

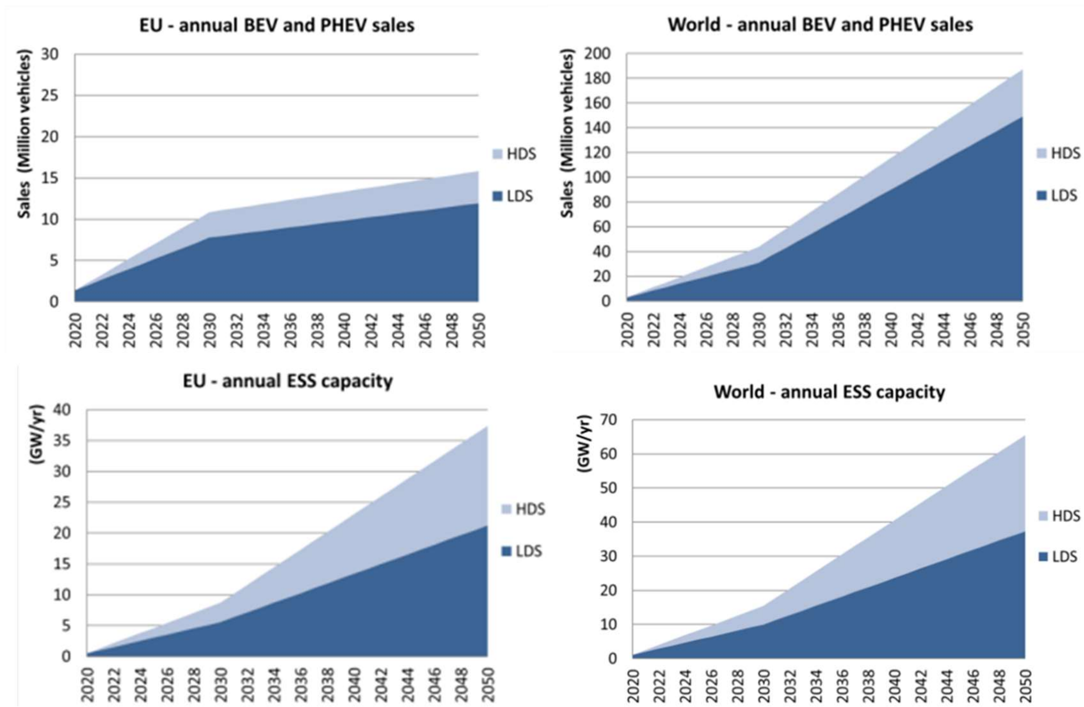


Figure 16: Annual sales of battery (BEVs) and plug-in (PHEVs) electric vehicles & Annual Deployment in Battery Energy Storage System (ESS) in the two explored scenarios (European Commission Joint Research Centre, 2023)

In both scenarios, the material demand is significantly increasing for several critical raw material inputs. Compared to current demand, projected European demand for aluminum, copper, iron and manganese remain relatively flat, below 3% of global supply in both 2030 and 2050. Phosphorus and nickel demand is higher, that ranges between 10 and 30%. The significant increase is observed in graphite and lithium. The scenarios expect European graphite demand to reach 45% by 2035 and 85% by 2050 of the global supply and lithium demand to reach 85% of the global supply by 2030 and exceed it by 170% by 2050. Cobalt demand for batteries is projected as nearly 60% of today's global supply in 2030, although this share is expected to fall to around 40% by 2050 as nickel rich chemistries are becoming more popular. Lithium manganese oxide batteries are widely used in applications beyond electric mobility and stationary storage, meaning that total lithium and manganese demand for batteries will be even higher than the figures associated with Li-ion technology alone.

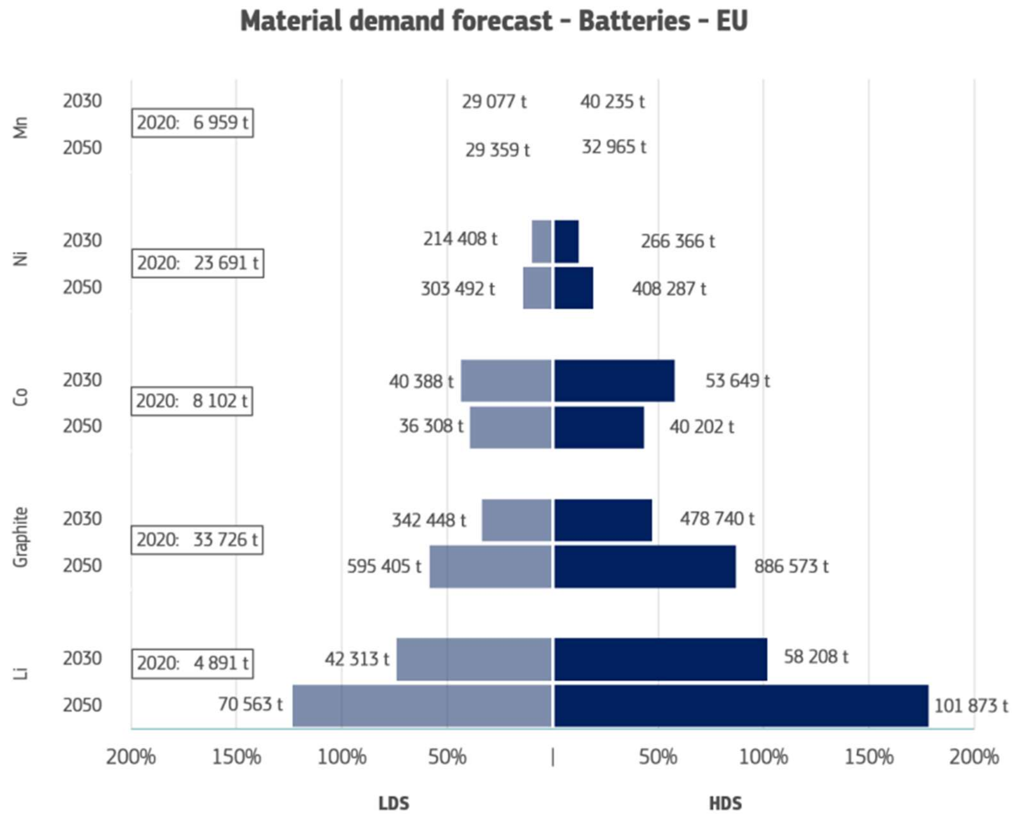


Figure 17: Material Demand Forecast for Li-ion Batteries – EU (European Commission Joint Research Centre, 2023)

It is clear that Li-ion batteries for e-mobility are very critical for achieving Europe's net zero objectives and therefore this technology is one of the focus technologies in this thesis. As Europe expands the Li-ion battery ecosystem and reduces the dependency on external suppliers for energy, companies operating across the Li-ion value chain carry an important responsibility. These companies must align with regulatory frameworks, contribute to the ambitions of the Net-Zero Industry Agenda and provide transparent and consistent sustainability reporting.

# 7. Rare Earth Elements Value Chain for Wind Turbines Technology in EU

Wind turbines are the key part of EU's industrial landscape for climate mitigation and are expected to expand further. As the technology expands, the demand for Rare Earth Elements will increase. Different turbine designs and component configurations require very different quantities of REEs, making technology selection a major driver of material demand.

Wind turbines consist of the following key components: rotor blades, nacelle, tower and foundation. The rotor blades are typically 40 to 100 meters long and made to capture wind energy. The nacelle is where the drivetrain and generator are located, also housing other systems for cooling, lubrication and monitoring. It is mounted at the top of the tower, which enables capturing stronger winds. The foundation is where the turbine is connected to the ground or seabed, and it endures against vibration and wind forces (European Commission Joint Research Centre, 2023).

Wind turbine technology has improved significantly over the years. Advanced blade designs and control systems enable wind turbines to be able to operate even at low speeds with high efficiency. Wind energy is now one of the most attractive renewable energy sources available thanks to the developments in materials, aerodynamics and digital technologies that increased efficiency and reduced costs.

Generator is at the center of every wind turbine and converts the rotor's mechanical motion into electricity. Choice of generator depends on the material price trends, site conditions and grid connection requirements. Main types of generators are Gearbox based systems (GB) which use a gearbox to increase rotational speed and Direct-drive systems (DD) which eliminate gearbox and have simplified design. Gearbox systems are also suitable for smaller generators; they have different speed drives and can combine magnets to reduce dependence on REEs. On the other hand, direct drive systems are preferred for increased reliability and lower maintenance needs. There are different types of drive train combinations, which are:

- Squirrel Cage Induction Generators (SCIG): These gearbox type generators represent the traditional type of wind turbines with simple design. Operation is at a fixed speed level and external power source is needed for magnetization. Their easy maintenance and cost effectiveness make them a good choice; however, their efficiency is limited due to having fixed speed under variable wind. They are used in smaller applications where efficiency is not prioritized.
- Wound Rotor Induction Generators (WRIG): These are another gearbox type generator that is more developed than SCIGs. The connected wound rotor allows variable speed operation and enables higher efficiency and grid integration. They are more efficient and more flexible but require more maintenance due to having additional components.
- Doubly-fed induction generators (DFIG): These gearbox type wind turbines are the most widely used ones where variable speed operation is enabled with high grid integration. They are cost effective and suited for moderate wind environments, but less durable compared to other types of generators.
- Electrically Excited Synchronous Generators (EESG): These systems can either be with a gearbox or as direct drive systems, and an external electrical source is used for magnetizing the rotor to enable control of the magnetic field. GB-EESG are cost effective and lighter, while DD-EESG are reliable and have less maintenance need.
- Permanent Magnet Synchronous Generators (PMSG): Like EESG, these systems can have a gearbox or direct drive systems, and they eliminate the external source with permanent magnets to generate rotor's magnetic field. Rotational speed is optimized in gearbox systems, whereas for direct drive systems reliability is improved with lower maintenance needs. Both configurations rely heavily on REEs, such as Neodymium and Dysprosium, making them vulnerable to supply chain disruptions.
- High-Temperature Superconductors (HTS): These systems represent the newest technology where superconductors are used for the reduction of electrical resistance. Higher efficiency can be achieved with these types of wind turbines, with reduced REE dependency, however they are still in the experimental phase and not commonly preferred yet (European Commission Joint Research Centre, 2025).

## 7.1. Role of Rare Earth Elements in Wind Turbines

Permanent magnets generate continuous magnetic fields even without the presence of continuous electric current. Due to this characteristic, their use is essential in electric motors, generators and electronics. Rare Earth Elements (Nd, Dy, Pr, Tb) incorporated permanent magnets are exceptionally stronger and more efficient, as the magnetic properties of the magnet are enhanced by high resistance to demagnetization and magnetic energy density. Hence, they enable lightweight magnets that generate powerful magnetic fields and are widely used in strong motors in wind turbines and electric vehicles.

The rare earth magnets are primarily Neodymium, Iron, Boron (NdFeB) or Samarium-Cobalt (SmCo) alloys, and based on cost efficiency and performance to weight comparison; NdFeB magnets are more preferred than SmCo magnets.

One of the first widely used REE magnets were Samarium-Cobalt magnets due to their ability to resist temperatures above 300°C, and corrosion and demagnetization, however they are very expensive. Thanks to these abilities, they are the perfect choice for special applications like aerospace and defense, where high performance is prioritized over cost.

The strongest permanent magnets available today are Neodymium-Iron-Boron (NdFeB) magnets, thanks to their high energy density and superior performance to weight ratio. Wind turbines, electric vehicles, robotics, medical technologies are few key industries where NdFeB magnets are preferred to fulfill the powerful and compact magnet requirement. They are suitable for both gearbox or direct drive type systems for wind turbines, but they provide exceptional great benefits to direct drive turbines by reducing mechanical complexity, improving reliability and offering cost advantages (European Commission Joint Research Centre, 2025).

## 7.2. REE Supply Chain Structure and EU Companies along the Wind Turbine Value Chain

The wind turbine value chain includes many interlinked steps with numerous stakeholders for each raw material used in the wind turbines. Below table lists these elements considered in the wind turbine supply chain.

Table 1: Elements Considered in the Wind Turbine Value Chain (European Commission Joint Research Centre, 2025)

| Stage of the Supply Chain | Elements |
|---|---|
| Raw Materials | Aggregates, aluminum, boron, chromium, copper, **dysprosium**, iron ore, lead, manganese, molybdenum, **neodymium**, nickel, niobium, **praseodymium**, silica, silicon metal, **terbium**, zinc |
| Processed Materials | Balsa wood, carbon fibers, cement, copper semis, epoxide resins, glass fibers, **NdFeB permanent magnet alloys**, Polyurethane, PE (polyethylene), PET (Polyethylene terephthalate), PS (Polystyrene), steel (crude) |
| Components | Bearings, blades, gearbox, nacelle casing, **NdFeB permanent magnets**, shafts, tower (concrete), tower (steel) |
| Assemblies | Power generator & **Wind Turbine** |

The high-performance permanent magnet generators that are used in wind turbines require REEs, and the elements with REE in the wind turbine value chain are highlighted in above table. Similar to the wind turbine value chain, the REE supply chain also includes many steps, each with own technical requirements, environmental impacts and strategic vulnerabilities. Below figure shows the major steps of the REE supply chain for wind turbine industry.

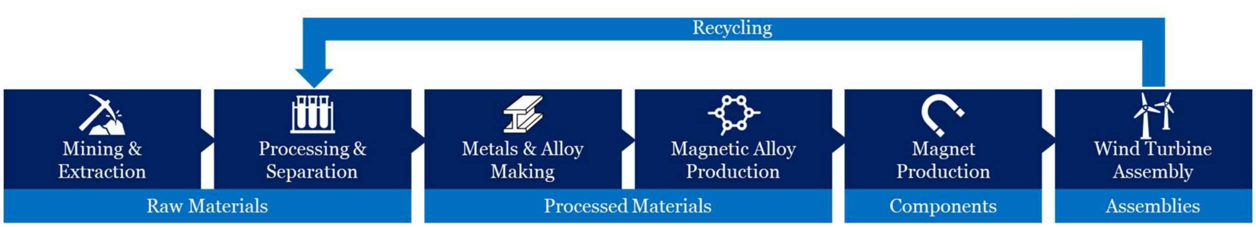


Figure 18: Simplified REE Supply Chain in Wind Turbine Industry

The REE supply chain begins with mining & extraction, where REE-ores are extracted and concentrated. Processing & separation step follows and as a result, high purity oxides are produced. In the following step, the high purity oxides are converted into metals and magnetic alloy, which are the basis for the NdFeB permanent magnets. As the last step, these magnets are incorporated into power generators and then wind turbines to convert wind energy into electricity.

### *7.2.1. Extraction & Processing*

Neodymium (Nd), dysprosium (Dy), praseodymium (Pr) and terbium (Tb) are the rare earth elements that are used in producing permanent magnets used in wind turbines. They are extracted from mineral deposits: monazite, bastnasite, xenotime and ion adsorption clays. The extraction could be carried out in underground or open-pit mines. After extraction, beneficiation takes place where the ores are crushed, grinded, and processed chemically to separate rare earth oxides. Mixed rare earth concentrate is produced after beneficiation, which then requires further separation processes to isolate individual REE oxides. As REEs have very similar chemical behavior, separation of mixed rare earth concentrates to individual rare earth oxides is highly energy, solvent and capital intensive and generates high levels of waste. Similarly, end of life products also return to the processing & separation step to recycle their REE content. Once the individual rare earth oxides are formed, they are sent to further processing to produce metals and alloys. China is the leading REE mining country where over 90% of global REE extraction & processing takes place, leverages the presence of significant amounts of reserves in the country. In Europe, various rare earth deposits are also present, while no active mining site is yet established (European Commission Joint Research Centre, 2025).

One of the key sustainability issues at the mining stage is the radioactive by products, that also creates worker safety and waste management concerns. Many rare earth deposits are co-occurring with radioactive elements like thorium and uranium, and they are mobilized during extraction and beneficiation processes. Due to the low concentration of REE in the deposits, tailings management brings up another critical sustainability issue. These tailings contain not only radioactive elements but also heavy metals, fluorine compounds and residual processing chemicals. Without proper containment, these materials might seep into surface and groundwater through acidic leachate that mobilizes contaminants, known as the acid mine drainage. As REE mining and processing requires high volumes of water, apart from contamination risks, high water consumption adds another layer to the environmental risks. Mining operations impact habitats directly through habitat fragmentation, noise, dust pollution and hydrological alterations. Therefore, permitting requirements are highly challenging to ensure environmental and social safety of the mining region (World Nuclear Association, 2026).

China Northern Rare Earth Group High-Tech Co. Ltd. is the largest mining company worldwide, operating in the Bayan Obo Deposit in Inner Mongolia and leading the global production of light REEs. Outside China, the leading rare earth mines are operated by MP Materials in the United States Mountain Pass mine and by Lynas Rare Earths in the Australia Mount Weld mine. All these major global rare earths extraction & processing companies have sustainability or ESG reports that provide detailed disclosures on environmental impacts, emissions, energy use, water and waste management and occupational health and safety performance (Adamas Intelligence Inc. and Tradium GmbH, 2024).

In Europe, although there are no active mining sites, many advanced exploration and mining development projects are present. Top companies involved in these mining projects are: Rare Earths Norway in Norway with Fen Carbonatite complex, LKAB in Sweden with Per Geier deposit and Leading Edge Materials in Sweden with Nora Kärr deposit. These projects are at different stages of exploration and development, and they represent most significant potential for increasing Europe's upstream rare earth elements extraction capacity.

The processing stage of REE in Europe, is one of the most structurally underdeveloped segments of the value chain. Large scale processing capacity is still limited compared to China, where China provides over 90% of the global demand (European Commission Joint Research Centre, 2025). As a result, Europe relies heavily on imported REE oxides, and this creates strategic vulnerabilities for downstream industries. Companies such as LKAB, Solvay and Neo Performance Materials represent major processing companies in Europe, however they are not capable to cover processed REE European demand.

*REE Extraction Companies in Europe*

Rare Earths Norway (REN)

Rare Earths Norway AS is a privately held Norwegian mineral industrial company, which was established to develop the Fen Complex. It is owned by two companies active in mining and mining investment. Their major REE site is Fen Carbonatite Complex in Norway which is estimated to be the largest deposit of rare earth elements in continental Europe. Rare Earths Norway holds the exploration permits and aims to progress Fen deposit into a lasting source of rare earth elements for European mining to magnet production value chain. REN will produce mixed rare earth concentrate through mining, beneficiation and hydrometallurgy processes. Project is currently at the exploration and permitting phase and the mining at the site is aimed to start by 2030, with significant investment support. The reported resource figures indicate that the deposit contains 8.8 million tons of total rare earth oxides, of which about 1.5 million tons are estimated to be rare earths relevant to permanent magnet production (Rare Earths Norway, 2024).

Norway is not in the European Union, but is a member of the European Economic Area, hence there is a requirement to align with EU legislation. As a Norwegian pre-mining exploration company, whether CSRD requirements apply to REN or not depends on the company size thresholds (250+ employees, €50M turnover or €25M balance sheet total) and implementation of equivalent legislation in Norway. Current information suggests REN is below the mandatory CSRD thresholds as the major company operations like exploration, permitting and feasibility are carried out with a limited number of employees and the company financial statements are currently below the financial thresholds. Therefore, it is not yet mandatory for REN to report sustainability reports structured according to Global Reporting Initiative, European Sustainability Reporting Standards or other frameworks.

Currently, REN does not have a standalone sustainability or ESG report, however the public disclosures outline the company's commitment to responsible rare earth production through environmental management, stakeholder engagement and proper permitting, with special attention to radioactive waste management, residue control, water management, biodiversity and community protection.

REN's environmental management strategy is centered around reduction of the mining and processing operations' footprint by adopting the best available technologies, preparing comprehensive and compliant environmental impact assessments, and developing mitigation strategies for waste management, biodiversity conservation, and water quality concerns. The company emphasizes that the radioactive waste management complexity is reduced thanks to the low radioactive element content of the Fen deposit, however thorium and uranium will still require proper handling (Coint, Niiranen, & Sadeghi, 2024). For tailings management, modern facilities are designed with the consideration of the learnings from global mining projects, and perfected to avoid seepage and resist extreme weather events.

Company's community engagement strategy includes consulting with local stakeholders, municipalities and landowners. The project is in an agricultural and recreational land area where local acceptance is crucial and the company publicly discloses the details of these engagement processes, however the overall content is limited compared to the ESRS Social section (Rare Earths Norway, n.d.).

Overall, Rare Earths Norway has a very strong position to help reduce European dependence on China rare earth supply, especially for REE that are essential to produce high performance magnets used in wind turbines and strategic industries. The company supports EU's industrial resilience and net zero ambitions with the domestic production of REE. REN does not have a structured sustainability report, they communicate environmental and social commitments voluntarily via project documentation, however this should not undermine the strategic importance of company's operations. Despite the environment impacts of mining, REN's contribution to EU's decarbonization path is eventually climate positive as it enables expansion of renewable energy infrastructure. As the project is more developed and moves to further stages of mining, establishing formal sustainability reporting will be very important for transparency, stakeholder engagement and data traceability.

LKAB

LKAB (Luossavaara-Kiirunavaara AB) is a state-owned Swedish mining group, focusing on iron ore and steel-grade products historically. The company repositioned themselves to secure REEs for green transition, with the exploration of large REE mine in Per Geijer deposit in Kiruna, Sweden. The deposit is reported to contain 2.2 million tons of in situ REE oxides. LKAB's deposit contains all 17 rare earth elements and in recognition to its strategic relevance, European Commission granted the status of special project to Per Geijer mine under the Critical Raw Materials Act (LKAB, 2023). LKAB intends to develop mining, beneficiation, hydrometallurgical processing steps to produce rare earth concentrates to feed the permanent magnet feedstocks with service life of at least 20 to 30 years. The Per Geijer mine is still under exploration, and the commercial start date for mining is not yet defined. Once successful metallurgical validation, feasibility, environmental permits and construction of processing plant steps are completed, the REE production is expected to start. Based on LKAB's published information, earliest large-scale mining activities would start early 2030s, but European Commission grant might help to accelerate permitting (LKAB, 2023).

Apart from mining, LKAB now started building a new processing plant for REE in Luleå and with this new plant, they aim to reduce REE import dependency of Europe while enabling access to critical raw materials for the future. The plant will commence operations in 2026 and will utilize the material flows from deposits and further refine them (LKAB, 2025a).

The company has been publishing sustainability reports since 2008, as an integral part of its annual report. The company stated that Corporate Sustainability Reporting Directive implementation actions are ongoing since 2023, and from 2025 onwards, sustainability report will be in accordance with CSRD. The sustainability reports disclose company's strategy towards climate action, resource efficiency and biodiversity protection with clear links to Swedish national climate goals and EU decarbonization agenda.

The major commitment about climate is achieving net-zero emissions by 2045, which includes comprehensive roadmap for replacing fossil fuels with renewable electricity in production and improving energy efficiency in the mines. Another commitment is to minimize environmental impact by monitoring and improving emissions to air and water, and prioritize positive contribution to biodiversity through vegetation, greening with improved conditions, and reducing erosion and leaching pollutants initiatives. Resource efficiency and circularity is also a very important commitment from LKAB, particularly through extraction of REE from existing mine tailings (LKAB, 2025b).

In general, LKAB demonstrates strategic importance to improve the sustainability and resilience of Europe's REE value chain. By developing capability to extract and process rare earth elements, the company helps Europe to reduce dependence on sources outside EU. Company's broader sustainability strategy further complements next steps in the supply chain and sets a benchmark for environmental performance of upstream players. In this way, LKAB not only contributes to regional CRM security but also supports sustainability and decarbonization of EU REE industry.

<u>Leading Edge Materials</u>

Leading Edge Materials Corp is a publicly traded Canadian company, focusing on securing critical raw materials in the EU that are essential for the energy transition in Europe. They own 100% of the Norra Kärr deposit located in Sweden, which is estimated to contain around 0.5 million tons of total rare earth oxides, and particularly significant for its high HREE content. Since discovery, there has been extensive research and study on the project: exploration, resource definition, economic feasibility, etc. A mining lease was first granted in 2013 but then overruled by Swedish Supreme Court in 2016 due to concerns on the environmental permit. The project is then redesigned significantly to address these concerns, reducing its footprint by 65%, lowering environmental impacts and improving sustainability aspects. Currently, the 25-year mining lease has been requested for the Norra Kärr deposit, and the decision is underway by the Swedish Mining Authorities (Leading Edge Materials, 2025a).

Leading Edge Materials has environmental responsibility claims like low-impact mining, reduced land usage and water conservation, but as a Canadian listed exploration company with no production revenues in Europe and having a small organizational structure, the company is currently not subject to CSRD requirements and does not publish a sustainability report to list down all measures.

The environmental commitments are centered on the risk reduction through project redesign and careful mine planning, including separation of mining from chemical processing to protect nearby fresh water sources, limiting ecological disturbance in the project area and ensuring responsible waste and tailings management. Detailed disclosure of company's social engagement process is limited; nevertheless, consultation of local stakeholders is acknowledged. Leading Edge Materials encountered delays in the project permit due to concerned local opposition, hence advanced the emphasis of commitment to environmental protection. Overall, however, the level disclosure remains very limited and not comparable to ESRS structure sustainability reporting (Leading Edge Materials, 2025b).

Although the company lacks sustainability disclosures, Leading Edge Materials has increasingly strategic position in EU's REE value chain and has the potential to become a significant source of European REE supply. Once operational, the company will reduce EU's dependency on overseas suppliers and support supply chain resilience. The company is accepted as a project partner of European Institute of Innovation and Technology (EIT) Raw Materials, which signals collaborative efforts for creating stronger regional raw material capabilities (Leading Edge Materials, 2025c).

*REE Processing Companies in Europe*

Solvay

Solvay S.A. is a multinational chemical company that has headquarters in Belgium and specializes on specialty polymers, composite materials, soda ash, peroxides and rare earth processing. The facility located in La Rochelle, France is one of the few rare earth separation plants in Europe. The facility produces light rare earth oxides through processing of monazite concentrates. Solvay's processing capacity provides a strong ground for having a resilient rare earth value chain in Europe, even though the production volumes are not sufficient to meet projected demand growth in Europe.

Sustainability is a core driver of Solvay's strategy, and the company communicates clear sustainability targets for climate change, nature protection, circularity, health and safety, ethics, compliance, social care and community dialogue. The progress reports are also enabling transparency for the progress the company makes on these sustainability targets (Solvay, 2025a).

As publicly listed European company, Solvay is subject to CSRD requirements. The company publishes sustainability progress in annual integrated reports since 2008 and issued Sustainable Development reports that are in line with Global Reporting Initiative until 2016. From 2017 onwards, sustainability and financial progress have been reported together in the annual integrated reports.

For REE operations specifically, Solvay's sustainability strategy includes achieving net zero by 2050, decarbonization commitments, circular economy practices like resource efficiency, recycling, responsible sourcing, and preventive programs for chemical and radiation exposure during processing. The published Scope 1, 2, 3 emissions are reported at company level, reduction targets are verified by Science Based Targets initiative (SBTi), and the pathway for the reduction is through energy transition to renewable energy, energy efficiency initiatives and process innovation to tackle emissions released by the chemical processes, Water and wastewater management is another important sustainability strategy, given the water intensive nature of chemical processing, and company emphasizes resource efficiency focus in the processes and compliance with discharge and treatment permits. Circular economy strategy includes increased recycled material use, reduced waste generation and developing further recycling technologies. Solvay discloses in their latest annual report published in 2025, that a technology to separate REE to be used in producing innovative rare earth permanent magnet solutions for electric vehicles and wind turbines is under development (Solvay, 2025b).

Solvay's annual report discloses sustainability progress and is in line with CSRD requirements and follows the ESRS structure, however the disclosures are at corporate level and not at granular level per plant or per project. As a result, Solvay does not provide specific sustainability information for REE processing activities in Europe and does not reflect environmental or social performance of these plants.

Solvay has a pivotal position in the European REE value chain and combines historical expertise with strategic commitment to mid-stream processing. Company's technological capabilities and industrial footprint make it one of the few actors capable of delivering high-purity oxides within Europe, and important partner for EU transition toward resilient REE value chain.

Neo Performance Materials

Neo Performance Materials is a Canadian company but operates few vertically integrated rare earth processing companies in Europe with significant production capacity. The Sillamäe facility in Estonia, operated by company's subsidiary Silmet, represents one of the biggest rare earth separation and processing capacities outside China. The facility can process rare earth concentrates from global suppliers to produce rare earth oxides that are rich both LREE and HREE, which positions the company strategically significant for the permanent magnet value chain in Europe. Neo recently launched a sintered NdFeB magnet facility in Narva, Estonia (Neo Performance Materials, 2025).

Being a Canadian listed company, Neo Performance Materials is not currently subjected to CSRD until company's European subsidiaries fall within the thresholds. Nevertheless, the company publishes annual sustainability reports disclosing performance on environmental, social and governance topics. The reporting methodology is in line with Sustainability Accounting Standards Board (SASB), Global Reporting Initiative (GRI) and UN Sustainable Development Goals (Neo Performance Materials, 2024). The report is less comprehensive compared to full ESRS compliant report, however, exceeds minimum Canadian standards and indicates voluntary commitment to sustainability.

The company has set energy efficiency and emission reduction targets, and the reported environmental performance shows reduction in Scope 1 and 2 GHG emissions at global company level. These targets are not formulated as SBTi acknowledged targets as ESRS E1 would encourage. Water management is acknowledged by disclosing water consumption levels and wastewater treatment systems at processing facilities, and the strategies to reduce consumption is the integration of water recycling and closed loop systems. An important element of Neo Performance Materials' sustainability strategy is circular economy initiative with company's developed process which enables REE recovery from permanent magnet manufacturing waste and end of life magnets (Neo Performance Materials, 2024).

All of the sustainability data are reported as companywide values, and specific data for Sillamäe facility or other REE facilities are not disclosed.

Neo Performance Materials stands out as one of the advanced European producers of rare earth oxides, offering integrated capabilities from processing to magnet grade alloys. Although being a Canadian company, the established processing expertise, sustainability commitments and contributions to build more resilient REE value chain in Europe make Neo a valuable partner.

### *7.2.2. Metals & Magnetic Alloy Production*

The rare earth metals and magnetic alloy production step consists of the transformation of metal oxides to high performance permanent magnets. The REE oxides are converted into specialized alloys through advanced metallurgical techniques. China dominates magnetic alloys market, with 90% market share, and European production is very limited with market share only below 1% (EIT Raw Materials, 2021).

Treibacher Industrie AG

Austria based private company Treibacher Industrie AG has broad experience in the inorganic chemistry and metallurgy sectors and produces high-purity rare earth metals, alloys and magnetic alloy powders for permanent magnet applications. The company produces mainly NdFe, PrFe, DyFe alloys for permanent magnet industry, and although the capacity is limited, it represents one of the most established Europan players. These master alloys for permanent magnet applications represent only one segment and the company has broader metallurgical portfolio (Treibacher Industrie AG, n.d.).

The most recent published sustainability report of the company is for 2023-2024, that is voluntary and in accordance with GRI standards. CSRD requirements currently do not apply to Treibacher Industrie AG, but the company acknowledges the preparation need for the future.

The company established emissions reduction target (-30% vs. base year 20201) and describes multiple energy efficiency initiatives in detail, including photovoltaic installation. Quantitative scope 1,2 and 3 GHG emissions are not disclosed in the report, which shows a gap compared to ESRS E1 requirements. Company’s new recycling facility has high performing circular economy practices and enables resource recovery and helps avoiding mining of high volumes of ore. The overall waste and water management strategies include remediation of historical groundwater contamination by company operations (Treibacher Industrie AG, 2025).

The company invests in advanced recycling, renewable energy generation, circular economy solutions and energy efficiency projects, which demonstrate tangible sustainable commitment and not symbolic participation. However, switching from voluntary GRI scope reporting to ESRS compliant reporting will require significant enhancement in GHG quantification, double materiality analysis, REE specific environmental metrics and overall supply chain transparency.

Less Common Metals

United Kingdom based Less Common Metals Limited (LCM) is a producer of rare earth alloys and permanent magnets for strategic industries and represents one of the few manufacturers based outside of Asian dominance. The company has been recently acquired by US based company USA Rare Earth, Inc. in 2025. LCM produces rare earth metals through oxide reduction, alloys, and sintered NdFeB magnets. The company's scale is modest compared to Asian producers which reflects the niche market position and challenges of European REE manufacturers trying to compete against low-cost Asian production (Less Common Metals, n.d.).

As a private non-listed UK company, LCM is not subject to CSRD or current UK Sustainability Disclosure Requirements which apply to large companies. LCM does not publish structured sustainability reports, and the publicly available sustainability information is only the brief communications and website content. Hence, key ESRS metrics like GHG emissions, water use, waste generation and recycling are not published.

The published environmental strategy of LCM covers continuously improving their environmental management system, ensuring ethical sourcing, improving energy efficiency by investing and using best available technology, minimizing waste generation and increasing resource efficiency. However, as mentioned before, the sustainability information and progress disclosed by the company is very limited.

### *7.2.3. Magnet Manufacturing*

Magnet manufacturing represents most technologically demanding stage of the rare earth value chain, where magnet alloys transform into permanent magnets for e-vehicles, wind turbines and advanced electronics. This step involves powder milling, pressing, sintering and surface treatment steps, that determine magnetic strength, durability and efficiency of the permanent magnet. China dominates this market also, and similar to metal and magnet alloy processing step, Europe has less than 1% market share (Alves Diaz, Bobba, Carrara, & Plazzotta, 2020).

<u>Vacuumschmelze (VAC)</u>

Vacuumschmelze, founded in Germany, is one of Europe's leading NdFeB and SmCo permanent magnet manufacturer. The company has facilities in and outside Europe, operates globally and has one of the largest capacities among permanent magnet manufacturers in Europe (VACuumschmelze, n.d.).

As China dominates the magnet alloy production in the value chain, VAC depends on sourcing from China. However, the company is exploring diversification of the supply chain and developing relationships with rare earth magnet alloy suppliers outside China.

Considering the size and revenue, VAC likely falls in CSRD scope, however does not publish a sustainability report. There is a sustainability statement published, yet it does not give full visibility to the company's sustainability initiatives. As a major sustainability initiative, in October 2025, company announced its decarbonization strategy and ambitious targets to achieve net zero by 2050 (VACuumschmelze, 2025). This target setting signals comprehensive sustainability disclosure is underway, but the transparency and detailed information as per ESRS is currently lacking.

The sustainability strategy of VAC includes increasing green energy usage to reduce GHG emissions, and recycling valuable resources in magnets when possible, switching to electric company cars and replacing natural gas with alternatives. VAC is a strategic partner to create resilient European REE value chain for wind turbines and is a part of EU's European Raw Material Alliance and UK's flagship CirculaREEconomy project (VACuumschmelze, 2023).

Neorem Magnets

Neorem Magnets Oy is a Finland based NdFeB permanent magnet manufacturer that has cooperation with Vacuumschmelze and serves renewable energy, e-mobility and special applications sectors. As a relatively small player in the European permanent magnet industry, Neorem Magnets is capable of technical customization, rapid prototyping, short lead times and customer collaboration especially with manufacturers and clean energy companies within the Nordic region. The company sources REE from global suppliers and has similar dependencies on Chinese REE processing and magnetic alloys production that is common in European magnet manufacturing market (Neorem Magnets, 2026a).

Neorem does not have a standalone sustainability report, and as a Finnish company whether CSRD is applicable or not depends on if company meets the EU thresholds. The financial information and workforce data of the company is not publicly disclosed, and the information about the company is very limited in publicly available sources. This signals as a small to medium Finnish company with private ownership, the company operates below the thresholds and not subject to CSRD.

The main sustainability related information shared through corporate communication channels is company's contribution to clean energy transformation by supplying permanent magnets to wind turbines, electric vehicles and energy efficient drives. Neorem is fully certified according to quality and environmental management system, improves processes continuously to minimize environmental impacts and pays attention to ethical and environmentally responsible sourcing (Neorem Magnets, 2026b).

However, detailed operational data, strategies on sustainability and environmental performance metrics are not disclosed in public resources, which create challenges and lack of transparency in assessing sustainability of the European REE value chain.

Magneti Ljubljana d. d.

Headquartered in Slovenia, Magneti Ljubljana is one of EU's established magnet manufacturers with several hundred tons of permanent magnet production capacity in Slovenia and produces NdFeB permanent magnets, SmCo magnets and magnetic assemblies for automotive, renewable energy, consumer electronics and medical sectors.

The operations include complete magnet manufacturing from magnetic powder processing through sintering, machining, coating, magnetization and assembly integration for standard and customized magnet solutions (Magneti Ljubljana d.d., n.d.). The company participates in many EU-funded projects to advance magnet efficiency, REE availability and recycling withing Europe REE value chain. Similarly, the strategic relevance of the company and its role to support European permanent magnet demand is acknowledged by integration to Global Rare Earth Industry Association (REIA) (REIA, 2023).

Magneti Ljubljana does not publish a sustainability report, and as a family-owned company the documentation does not indicate the necessity to prepare for CSRD compliance. Although sustainability performance is not formally reported, the company shares important environmental initiatives such as environmental management systems compliance, GHG emission reduction, circular economy and recycling projects. In 2025, company published a Carbon Footprint Declaration, that shows significant minimization of environmental impact and reduced carbon emissions (Magneti Ljubljana d.d., 2025). In addition, the company takes part in many circularity related innovation projects like magnet recycling and REE recovery and demonstrates strong partnership in building a robust European REE value chain.

#### *7.2.4. Wind Turbine Assembly*

Wind Turbine Assembly represents the final stage of the REE wind turbine value chain, where REE permanent magnet, nacelle, power generator and tower components are combined as a complete renewable energy system. As wind turbines are strategically important for net zero target achievements for Europe, the dependence of REE imports makes wind turbine value chains vulnerable to disruption (Alves Diaz, Bobba, Carrara, & Plazzotta, 2020). China has the leading market share in this value chain step as well, but Europe performs better compared to other value chain steps, with 21% market share (Strategic Energy, 2025).

<u>Vestas</u>

Vestas Wind Systems A/S, founded in Denmark, is world’s largest wind turbine manufacturer with over 189 GW of total installed wind power capacity globally. The company is one of the major downstream consumers of NdFeB permanent magnet generators in their wind turbines and is a significant partner in the REE value chain (Vestas, 2025).

Vestas is a large, publicly listed EU company and is within the scope of CSRD. The company publishes environmental statements since 2000 and extensive sustainability reports from 2010, reporting progress on their sustainability performance. Vestas positions sustainability as a core pillar and is now reporting sustainability as part of the annual report, in accordance with CSRD and with fully integrated ESRS framework.

Major environmental goals of company's sustainability strategy are achieving net-zero emissions by 2030, producing zero waste wind turbines by 2040 and leading the global sustainable energy transformation. The carbon neutrality target is confirmed by SBTi, and Vestas aims to reduce Scope 3 emissions by supporting suppliers for reducing their emissions and designing less carbon intensive wind turbines. Scope 1 and 2 emission reduction plan includes switching to sustainable biofuels for all service vehicles, transitioning to renewable energy and improving energy efficiency in factories. The plan to reach the zero-waste target by 2040 includes designing for circularity, innovating fully circular blades with the help of Circular Economy for Thermosets Epoxy Composites (CETEC) and Aarhus University & Danish Technological Institute, redesigning the wind turbine to create recycling pathways for difficult to recycle materials, optimizing production methods and expanding reuse and refurbish infrastructure to avoid waste (Vestas Wind Systems A/S, 2026).

Vestas has one of the most mature sustainability reporting among the REE value chain players and has very ambitious sustainability targets. All environmental performance metrics are publicly disclosed in the sustainability report, enabling transparency in progress. As one of the world's largest wind turbine manufacturer with strong sustainability ambitions, Vestas uses their influencing power throughout the REE value chain in wind turbine industry, enforces upstream suppliers to provide transparency to their environmental performance, and functions as a critical support to elevate accountability across the entire industry.

Siemens Gamesa Renewable Energy

Siemens Gamesa is established through merger of Siemens Wind Power and Gamesa Corporación Technólogica and later fully acquired by Siemens Energy. It is headquartered in Spain and is world's second-largest wind turbine manufacturer after Vestas with 150 GW installed wind power capacity (Siemens Gamesa, 2025a). As a major wind turbine manufacturer, the company uses large quantities of NdFeB permanent magnets especially for offshore direct drive wind turbine configurations.

Prior to Siemens Energy acquisition, as a large EU-based company, Siemens Gamesa published annual sustainability reports subject to EU Non-Financial Reporting Directive. Within this scope, company disclosed sustainability related financial information, quantitative insights on environmental metrics like GHG, energy consumption and waste generation. After the merger, the sustainability reporting is consolidated within parent company Siemens Energy's umbrella. As a large, publicly listed EU company, Siemens Gamesa publishes CSRD compliant sustainability reports with ESRS, and the report includes broader information on the corporate portfolio.

Siemens Energy has ambitious decarbonization targets, which are 30% emission reduction from their supply chain (Scope 3 upstream), 60% emission reduction from own operations (Scope 1 + 2) and 50% emission reduction from sold products (Scope 3 downstream) by 2030 (Siemens Energy, 2026). To achieve Scope 3 upstream emission reduction, Siemens Gamesa introduced Carbon Reduction@ Suppliers Program to increase transparency of suppliers' environmental performance reporting and put mitigation strategies to improve their performance. To achieve carbon neutrality in own operations, Siemens Gamesa has different strategies in place, such as enabling energy efficiency through automation, smart meters and heat recovery systems, increasing renewable energy generation with additional solar power systems, reducing $SF_6$ (used as insulation) emissions through inspection and maintenance and promoting new e-mobility concepts. As the largest share of emissions come from the use phase, company's decarbonization strategy includes innovation to improve the efficiency of existing portfolio, improving carbon capture and storage for emission removal technologies, shifting to carbon neutral technologies and advancing renewable energy deployment. Specifically for rare earths, the company underlines that they are conducting mineral risk assessment in accordance with the OECD Due Diligence Guidance's five-step framework. As a concrete action towards decarbonization, the company showcases their usage of GreenerSteel for their wind towers, which has 63% lower $CO_2$ emissions compared to conventional steel (Siemens Energy, 2025). Siemens Gamesa also has ambitions towards circularity, aims to deliver fully recyclable wind turbines by 2040 and have already started recycling wind turbine blades (Siemens Gamesa, 2025b).

Overall, Siemens Gamesa established strong climate and circularity commitments that are clearly communicated through CSRD aligned reporting, and actions on improving the transparency and environmental performance of the complete wind turbine supply chain.

Nordex SE Group

Nordex SE Group, headquartered in Germany, has strong presence in global wind turbine industry. With the production sites all over the world, the company produces nacelles, rotor blades and concrete towers. Nordex currently has around 57 GW of installed wind power capacity in more than 40 countries worldwide (Nordex Group, 2026).

As a publicly listed European company, CSRD requirements are fully applicable for Nordex, and their report must comply with ESRS. The company publishes sustainability performance for a long time, and firstly in 2024 annual report, they disclosed sustainability statement in line with CSRD and ESRS. They have analyzed double materiality to address sustainability issues and integrating in the decision-making process.

Nordex's sustainability strategy is built around climate mitigation, resource efficiency, circularity and responsible supply chain management. The company aims to provide fully recyclable blades by 2032, to reduce carbon footprint of wind turbines by 25% by 2025, to reach net zero GHG emissions by 2050, to achieve zero production waste by 2025, to minimize hazardous materials, and to increase waste recovery and water efficiency. Nordex's offerings include low-emission steel towers produced with new methods to reduce GHG emissions by 75% compared to conventional methods. Furthermore, up to 97% of the materials used in Nordex wind turbines are recyclable. Their annual corporate carbon footprint analysis lists all Scope 1, 2, and 3 emissions in detail to enable most suitable emission reduction strategy for decarbonization. The company also pays attention to environmental protection by reducing their waste generation, increasing waste recovery, and decreasing water use. Not many details are available on the processes that took place to reach these achievements or any mitigation regarding rare earth elements, but overall Nordex has high ambition to contribute to EU's sustainability agenda (Nordex, 2025).

Nordex's sustainability strategy positions the company as a reliable partner to Europe's renewable energy transformation. Going forward, the company will contribute to the transparency and resilience of Europe's wind turbine value chain.

#### *7.2.5. Recycling*

Recycling is a strategic lever for improving material security and reducing environmental impacts. The recovery rates for REE elements from NdFeB magnets in end-of-life wind turbines, however they will represent a meaningful secondary supply as volumes of end-of-life products grow. Initiatives highlighted by EIT show more and more domestic recycling projects are needed to reduce dependency on primary imports and support more circular, resilient REE value chain for wind turbine industry (EIT Raw Materials, 2021).

Heraeus Remloy

Heraeus Remloy is a German private company that operates in metals and recycling, healthcare, semiconductor and electronics and Industrials business platforms. The Heraeus Group provides solutions for sustainable uses of REE magnets and ensures resource conservation (Heraeus Remloy , 2026).

Heraeus Group has large multinational corporate structure that is subject to CSRD and publishes sustainability reports at group level. The recent sustainability report is aligned with CSRD and ESRS requirements. The group has a comprehensive sustainability strategy focused on climate action, resource efficiency and value chain management. The climate targets include reaching neutrality in Scope 1 and 2 emissions by 2033 through energy efficiency, renewable energy transformation and facility emission reduction initiatives. Heraeus also sets Scope 3 decarbonization targets and aims to engage suppliers and reduce the overall value chain emissions with operational design improvements. The group sets goals to promote circular economy for REE, aiming to increase material efficiency, minimize waste, keep as much REE volume in the loop as possible and support development of REE recycling value chain (Heraeus , 2025).

Overall, the group's commitments to climate neutrality, circularity and responsible sourcing places Heraeus Remloy as a strategic partner to support Europe's circular REE value chain.

MagREEsource

MagREEsource is a French company that specializes in NdFeB magnet recycling. They recycle scraps of sintered magnets to contribute to European circular economy. The company has developed recovery of REE from end-of-life magnets and industrial scrap for remanufacturing high performance permanent magnets. They are listed in European Institute of Innovation & Technology (EIT) Raw Materials network for REE recycling companies from permanent magnets (EIT Raw Materials, 2025).

Company does not disclose much information regarding their processes and scope. As a small private company, MagREEsource is not yet in the scope of CSRD and does not publish sustainability reports. The company's sustainability strategy centers circularity principles, recovering REE from waste magnets, reducing carbon footprint of magnet production and lowering the environmental impact associated with mining and processing steps (MagREEsource, n.d.). MagREEsource reinforces the development of resilient European REE value chain aligned with EU CRM and decarbonization objectives.

# 8. Lithium, Cobalt and Nickel Value Chain for Li-Ion Batteries for E-Mobility

As explained in the previous sections, Lithium, Nickel and Cobalt are among the most critical raw materials in Li-ion value chain for e-mobility and are in focus for this thesis. Since these CRMs are a part of the same value chain, then ultimately converge into a single stream; they will be reviewed under the same section.

## 8.1. Role of Lithium, Cobalt and Nickel in Li-ion Batteries

In the Li-ion batteries, Lithium is the core charge carrier and while Lithium ions move between anode and cathode, reversible electrochemical reactions enabled and energy is stored and released. In the Cathode Active Material (CAM), Nickel is used to increase energy density, enabling longer driving ranges, where Cobalt is used for stabilization of the crystal structure, enhancing thermal safety and reducing degradation. Li-ion batteries become the most suitable technology for e-mobility, because of their combination of high energy density, long cycle life, high operating voltage and strong power capability offerings. Thanks to its well-developed technology, scalability, flexibility and reducing production costs, Li-ion technology is prioritized over other battery chemistries for e-mobility applications. Considering all these properties and advantages, Li-ion batteries will remain the leading solution for electric vehicle batteries and securing Li, Ni, Co supplies are very important to ensure European e-mobility transition.

## 8.2. Lithium, Cobalt and Nickel Supply Chain Structure and EU Companies along the Li-ion Batteries for e-Mobility

The li-ion battery value chain starts from raw material mining and extraction, then refining to produce active chemicals, production of cathode active material (CAM), battery cell manufacturing and for large capacity requirements, pack assembly and integration. Battery cell manufacturing is the most technologically demanding and costly step, due to extreme precision, special equipment and strict production environment requirements (European Commission, n.d.).

Lithium, Nickel and Cobalt all need to be extracted and refined into battery-grade materials before contributing to the CAM production step, and further downstream steps. Following figure illustrates the key stages of the li-ion battery value chain for e-mobility, emphasizing how the three CRMs in scope flow into the same midstream process.

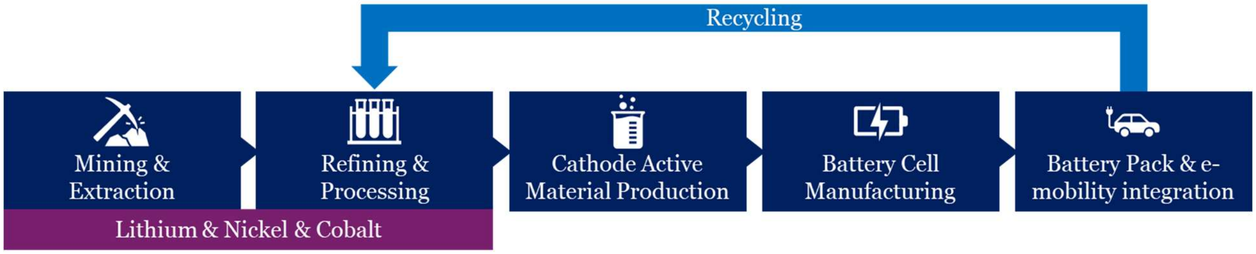


Figure 19: Simplified Li, Co and Ni Value Chain for E-mobility Li-ion Batteries

In Europe, lithium, nickel and cobalt mining and processing capabilities are limited. However, recent research shows that Europe has substantial mining reserves, especially for li-ion battery raw materials. Portugal has world's seventh largest lithium reserves worldwide, additionally to the mines in France, Czechia, Serbia, Spain, Finland and Austria, where this potential corresponds to about 6.5% of world's total reserves. Similarly for Cobalt, mines have been identified in Finland, central and northern Europe. For Nickel, not many economically viable resources are available, however the reserves all around Europe account for 4.2% of total world Nickel reserves (Righetti & Rizos, 2024).

Below table represents the research results for cobalt, lithium and nickel reserves in European countries. As further exploration continues continuously, these estimates might grow in the future.

Table 2: Resource Availability Estimates in Europe (European Commission, 2018)

| European Countries | Cobalt | Lithium | Nickel |
|---|---|---|---|
| Austria | | ✓ | |
| Czech Republic | | ✓ | |
| Finland | ✓ | ✓ | ✓ |
| France | ✓ | ✓ | ✓ |
| Germany | ✓ | | |
| Greece | | | ✓ |
| Ireland | | ✓ | |
| Poland | ✓ | | ✓ |
| Portugal | ✓ | ✓ | ✓ |
| Slovakia | ✓ | | ✓ |
| Spain | ✓ | ✓ | ✓ |
| Sweden | ✓ | ✓ | ✓ |
| United Kingdom | | | ✓ |

### 8.2.1. *Mining & Extraction – Lithium*

Globally, lithium extraction is carried out through two major pathways: brine extraction and hard rock mining. Brine extraction includes pumping lithium rich brine that are on the surface or underground to large evaporation ponds, and once water evaporates lithium and other elements remain. Compared to other lithium mining methods, brine extraction requires less energy, therefore lower costs and lower environmental impact. The major sustainability challenges would be the intensive water usage during extraction, and the usage of acids and solvents for brine processing. Hard rock mining is an open pit extraction, which requires blasting and crushing of spodumene ores that are lithium rich minerals. Spodumene ores typically have higher lithium content and fewer impurities, which minimizes the need for extensive processing. However, open pit mining can impact the landscape, posing a threat to wildlife and ecosystem. Combined with energy intensive operations, high volumes of water requirement and preventive tailings management perspectives, sustainable approaches should be incorporated into mining processes (Krishnan & Gopan, 2024).

Globally, Australia, Chilie and China has the leading position in lithium mining & extraction, with 43%, 32% and 17% of global supply respectively (European Commission, 2022c). Australia and China lead in hard-rock mining whereas in Chile, brine extraction is the main method for lithium mining. In contrast, Europe contributes only a small fraction of global lithium supply and heavily relies on imports. In order to support Europe's expanding e-mobility sector, it is strategically crucial to develop local extraction and refining capabilities.

In Europe, active lithium extraction is limited, and Portugal is the only European country that has active lithium mining sites in Mangualde. Much of the lithium extracted from here goes to industrial applications, for ceramics and glass industry. Several advanced projects are underway to extract lithium in the region (Adamas Intelligence Inc. and Tradium GmbH, 2024).

Vulcan Energy Resources

Vulcan Energy Resources is based in Germany and holds the Europe's largest lithium resource reserves in Upper Rhine Valley Brine Field. The Upper Rhine Valley is 300km graben system reserve with geothermal lithium reservoirs in sedimentary rock and has 27.7 million tonnes of Lithium Carbonate Equivalent. This lithium extraction and processing project is called Lionheart, and Vulcan is currently in the first phase, aiming to start first production in 2028 (Vulcan Energy, 2025a).

The process flow includes passing high temperature geothermal brines from deep underground to the surface. This process enables using the thermal energy of brine to generate renewable electricity and heat and includes direct lithium extraction (DLE) via absorption or ion-exchange to selectively capture Li ions. After the extraction phase, the brine is reinjected into the reservoir to keep the system closed loop. The overall process differs from conventional hard-rock mining or evaporation basin brine extraction, and offers advantages like lower land use, reduced water consumption and lower carbon emissions (Vulcan Energy, 2025b).

Vulcan publishes comprehensive sustainability reports and completed CSRD aligned double materiality assessment; however, is no longer in the scope for CSRD due to the EU Omnibus update.

Vulcan's sustainability claims are clustered around decarbonization, resource efficiency and circularity initiatives. Vulcan's emissions have been increasing mainly due to construction of the new facilities, and the company has concrete plans to reduce emissions in the future of operations. Another initiative is to minimize impacts on biodiversity, and thanks to the process adopted, the land use is limited to well sites, power and processing plant only. Similarly, water protection is also in scope, and as the process reinjects the brine back to the reservoirs, the impact on groundwater is negligible (Vulcan Energy, 2025c).

Overall, Vulcan is a strong partner for sustainable lithium extraction in Europe and reduces dependency on external suppliers. As the operational phase ramps up, reporting and transparency will be critical for measuring environmental performance and impact Vulcan brings to the European footprint.

Keliber – Sibanye-Stillwater

Sibanye-Stillwater group is active in mining and processing of diverse metals portfolio which are mainly platinum, palladium, rhodium, gold, iridium, ruthenium, nickel, chrome, copper and cobalt. The group has also projects and investments in circular economy operations, mainly recycling and mine tailing retreatment. Keliber is a Finnish subsidiary of the group and with their lithium project in Finland, and together, Sibanye-Stillwater and Keliber are strategically stepping into li-ion battery metal sector to contribute to the greener future of Europe. Sibanye-Stillwater and Finnish Minerals Group are the main shareholders of Keliber and are working towards first battery grade lithium hydroxide production (mining & processing) in Europe (Sibanye Stillwater, 2025a). The Keliber lithium ore reserve is located in Central Ostrobothnia and is estimated to annually produce 15,000 tons of battery-grade lithium hydroxide for at least 18 years. The project claims to be sustainable with low carbon and $SO_x$ footprint and aims to become a sustainable supplier for growing European battery market (Sibanye Stillwater, 2025b). Currently the project is under staged commissioning phase and the full scope lithium extraction from Keliber project will start in the first quarter of 2026, once construction and commissioning phases are completed (Sibanye Stillwater, 2026a). The group also has cobalt and nickel production in their Sandouville Refinery in France, however they ceased their operations and currently investigating the feasibility of the project GalliCam which aims to upscale the refinery to a cathode active material production plant (Sibanye Stillwater, 2026b).

Since the project is still under construction phase, Keliber is not yet a fully operational mining company that is generating value falling within CSRD thresholds. Moreover, Keliber does not publish standalone sustainability reports, but the parent company Sibanye-Stillwater publishes integrated annual reports and sustainability documents. Although these reports and documents are in line with standards like Global Reporting Initiative, Task Force on Climate Related Financial Disclosures and Sustainability Standards Board's Metals and Mining Standards, they are not in line with CSRD requirements and ESRS standards. In the latest annual integrated report for 2024, there are no remarks on the commitments towards CSRD compliant reporting with comprehensive ESRS standards integration. Nevertheless, the group reports concrete sustainability initiatives to underline their commitment to climate leadership. Sibanye-stillwater's sustainability agenda includes decarbonization of operations, water and biodiversity protection, tailings management and increasing circularity. The ultimate decarbonization target is to achieve carbon neutrality by 2040, and the main commitments to achieve this target include expansion of renewable energy usage in operations, optimization of processes for eliminating energy waste and addressing Scope 3 emissions to encourage decarbonization of the value chain. Water and biodiversity protection strategies include reduction of water use through efficiency improvements, amelioration of water and wastewater treatment processes to improve water quality, advancement of biodiversity with restoration initiatives and upgrading the facilities in accordance with the Global Industry Standard on Tailings Management for reduction of risks related to tailings. As per circularity commitments, company has recently acquired Reldan recycling business and is actively seeking opportunities to increase retreatment of tailings and advancing recycling capabilities (Sibanye Stillwater, 2025c). The environmental performance reporting is done based on the region of operation, and the Keliber project has not yet started, therefore the metrics related to lithium extraction are not separately disclosed.

Sibanye-Stillwater is a strong actor in Europe li-ion battery value chain with its current cobalt and nickel mining capabilities, upcoming Keliber operations for lithium and initiatives for CAM production. This has been verified by EU as both projects Keliber and GalliCam have been classified as strategic projects under Critical Raw Materials Act. While Keliber and Sibanye-Stillwater are neither subject to nor reporting in line with CSRD requirements, they are committing themselves to Europe's net zero industry and decarbonization agenda.

European Lithium Limited

European Lithium Limited is a listed Australia based company that underwent a merger and established Critical Metals Corp. The aim of the restructuring was to secure the financing for the Wolfsberg Lithium project located in Austria that has been owned by the company. This project is one of the most mature hard rock projects within Europe, and designed with conventional hard rock mining methods to extract spodumene concentrate and then to process into lithium hydroxide through a dedicated conversion facility. This project is strategically important for the European li-ion battery value chain, and the company is developing partnerships with European battery manufacturers for regionally sourced lithium hydroxide. The estimated total production of lithium hydroxide monohydrate over 18 years will be 129,000 tons (European Lithium, 2023). Recently, the government renewed the mining license of the company is renewed by 2 more years, however the decision of starting mining operations will be made towards end of 2026 (Critical Metals Corp, 2026).

As the company headquarters is outside Europe and the mining has not yet started in the Austrian Wolfsberg Lithium project, most likely, European Lithium does not fall within the mandatory scope of CSRD. Neither European Lithium nor Critical Metals Corp. publishes information about company and project related sustainability information. In the Environmental Impact Assessment of the Wolfberg Lithium project, the company states there has been no commitments made to be aligned with environmental standards yet (European Lithium, 2023). Nevertheless, Wolfberg Lithium Project has strategic importance to strengthen Europe's li-ion battery value chain resilience. As the demands are increasing, lithium sourced from European locations will be critical to ensure electrification of the mobility industry. Therefore, European Lithium will be required to provide transparency and sustainability reporting to align with the European regulations.

### 8.2.2. *Refining & Processing – Lithium*

During the lithium refining and processing stage the extracted hard rock concentrates or brines are chemically transformed into battery grade lithium hydroxide (LiOH) or lithium carbonate ($Li_2CO_3$). The first step in refining is pretreatment, such as high-temperature conversion for spodumene and evaporation for brines, then followed by hydrometallurgical leaching, purification, advanced filtration and crystallization.

The main sustainability challenges associated with Li refining and processing are mainly GHG emissions and water use. Refining and processing require high energy input and generates high GHG emissions. Similarly, high water and chemical use is required for this step, raising concerns about water and waste management in the locations near facilities (European Federation for Transport & Environment, 2024a).

Even though aforementioned lithium mining and extraction companies also have processing capabilities within their operations, overall European output is far from meeting the li-ion battery demand and achieving value chain resilience. The leading processing country for lithium is China. While the extraction in China remains at 22% of world's lithium reserves, the lithium refining performed represents 70% of the world's capacity (International Energy Agency, 2025a).

The refining of Li to battery grade LiOH and $Li_2CO_3$ is crucial to enable li-ion battery integration. In order to reduce the dependency of imported refined lithium products, it is essential to increase the European processing capacity and to ensure environmental standards are met. Integrated projects for lithium extraction and processing are in plan, like Vulcan, Keliber and European Lithium projects, in addition, some European chemical producers are refining imported lithium intermediates. All these developments show Europe is on the way to enable autonomy in li-ion battery value chain.

AMG Lithium

AMG Lithium is a Germany based company focusing on development of high-quality battery grade lithium hydroxide for li-ion battery sector. The company is one of the subsidiaries of AMG Critical Materials N.V. that headquartered in Netherlands. The feedstock is technical grade LiOH, which comes from lithium spodumene extracted by AMG Brazil from the Mibra mine located in Brazil, and further processed in AMG Lithium refining facility in Germany to produce battery grade LiOH. The facility commenced its operations in 2024 and is Europe's first LiOH refinery. The company recently invested in Barroso Lithium project in Portugal, and together with the refining facility, AMG Lithium aims to significantly contribute to the domestic extraction and processing targets set by the EU CRMA (AMG Lithium, 2025).

AMG Lithium does not publish sustainability reports, but the parent company AMG Critical Minerals publishes annual reports that integrate CSRD and ESRS requirements. The report outlines AMG Group's overarching sustainability strategy, specifically these are, conserving water, energy and ecosystems, reducing carbon emissions, minimizing waste and supporting overall environmental sustainability. In the recent annual report for 2024, for carbon emissions reduction, main pillars include optimizing metallurgical processes for more efficiency, implementing energy management programs to improve energy use, increasing renewable energy usage and engaging with suppliers to reduce their carbon footprints. The group already achieved their target of 20% Scope 1 & 2 emission reduction and committed to revise their targets and communicate in future reports. As per circularity initiatives, the group is minimizing their waste with waste management programs promoting reuse and recycling and increasing the usage of recycled, sustainably sourced and renewable resources. For water and biodiversity protection, group's main initiatives include water conservation and recycling, and avoiding impacts on ecosystems and biodiversity (AMG Critical Materials N.V., 2025).

Although the AMG Critical Materials Group discloses environmental performance in detail, specific information regarding AMG Lithium's refining operations is not disclosed. However, overall, AMG Lithium is an important partner for Europe Raw Materials Alliance (ERMA) and plays a significant role in domestic processing of LiOH for Li-ion batteries.

<u>Nobian</u>

Headquartered in the Netherlands, Nobian is a chemical company specialized on salt and chlor-alkali chemicals. The company processes LiCl through electrolysis to produce battery grade LiOH. Nobian does not have lithium mining facilities, and acts purely as a processor, supplying battery grade lithium to downstream Li-ion value chain manufacturers. The company is in partnership with many other European companies to support the global and European Li-ion battery stream. For example, Nobian and Veolia recently collaborated to advance and to scale Li production to contribute EU's strategic independence in Li supply (Nobian, 2025a). Similarly, the company has partnered with Vulcan Energy to produce LiOH from Vulcan's extracted brine, combining expertise in electrolysis with Li resources (Nobian, 2022).

Nobian clearly communicates their ambition towards sustainable future and already has set specific environmental targets under climate and circularity pillar. Moreover, the company publishes sustainability reports and underlines that CSRD compliance has been achieved voluntarily before it is mandatory for the company (Nobian, 2026). Under climate commitments, the company has targets for achieving net zero emission of Scope 1 & 2 by 2040 and 90% reduction of Scope 3 emissions by 2050, switching to 100% renewable energy by 2040 and increasing energy efficiency and storage. Circular commitments include having a green product portfolio, reusing residual resources in processes and introducing circular feedstock for production. From water protection perspective, the company aims to reduce freshwater consumption and eliminate using drinking water as process water by 2040 (Nobian, 2025b). All these ambitions are clearly stated in the sustainability report with detailed information on environmental performance. However, these details reflecting company level, and specific lithium processing data are not disclosed.

All in all, Nobian is a strong contributor to European Li-ion battery value chain with its technical expertise, partnerships with regional partners and commitment to sustainability.

Eramet Lithium

Eramet is a major French mining and metallurgy group, focusing on exploration, mining and processing services. The company produces essential metals such as manganese, nickel, lithium and mineral sands for steelmaking, stainless steel, batteries, e-vehicles, renewables, construction and electronics industries. The company has operations in Argentina since 2024 for lithium mining and production and transferring the knowledge and expertise to operations in Europe (Eramet, 2026a). With the Ageli project located in

France, the company will extract lithium from geothermal brines, utilizing their patented world's most efficient battery grade lithium extraction process. The project will be fully in operation by 2030, with 10,000 tons of $Li_2CO_3$ production capacity that corresponds to yearly production of 250,000 electric vehicle batteries (Eramet, 2023). Beyond lithium, Eramet is also active in nickel mining and processing, and operating world's largest nickel mine in volume in Indonesia (Eramet, 2026b). In 2023, the company investigated battery recycling project in Europe also, however due to uncertainties and slow ramp up of the market, decided to suspend the project until market fundamentals evolve (Eramet, 2024).

The company publishes detailed sustainability reports, and their latest 2024 Universal Registration Document is completely in line with the CSRD and ESRS requirements. The major environmental sustainability themes mentioned in the report include climate change mitigation, circularity and preservation of water and biodiversity. Under the climate change mitigation initiatives, Eramet targets to reach -40% reduction by 2035 in scope 1 & 2 emissions and ambitions to decarbonize the value chain with supplier and customer engagement. Their emission reduction actions include increasing carbon capture and reuse projects, expanding renewable energy use and innovating for energy efficiency. For the contribution to circular economy, Eramet has set management plans for improving mineral resource use to avoid waste, enhancing material recovery systems in plants and designing recycling units. The main water and biodiversity protection actions are treatment of wastewater, rehabilitation initiatives, supporting research institutes for protection of biodiversity and community engagement to raise awareness (Eramet, 2025).

Altogether, Eramet has stated strong sustainability commitments and integrates these principles into their global operations. Considering Eramet's production capabilities and technical expertise, the company is in a strategically important position to contribute to Europe's net-zero plans and overall resilience of the Li-ion value chain.

### *8.2.3. Mining & Extraction – Cobalt*

Cobalt cooccurs in copper, nickel and iron ores as a combined element and for its extraction, integrated mining methods are needed. Even though the cobalt content in these mines is low, their broad availability designates them as a prominent source of cobalt. Once extracted, the ore is crushed, grinded and further steps include gravity or magnet separation and floatation to produce cobalt hydroxide and cobalt concentrates, and then processed further to produce Li-ion battery grade cobalt sulfate ($CoSO4_x$) (Wang, Fu, He, & Wang, 2025).

The Democratic Republic of Congo (DRC) owns over 40% of global Co reserves and supplies over 70% of global Co demand. Other contributors are Indonesia, Cuba and Australia; however, their contribution is minimal compared to the supply levels of DRC. Europe owns only 4.4% of global Co reserves and extracts only 0.7% of global demand (European Commission, 2022a). As a result, Europe remains dependent on imports of Co and Co intermediates to feed the European Li-ion battery value chain (import reliance is 81%), and this dependency underlines the importance of developing independent mining, processing and recycling facilities to ensure supply security.

<u>Glencore Nikkelverk</u>

Glencore is headquartered in Switzerland, and is a global producer of metals and minerals, mainly copper, cobalt, nickel, zinc, lead, aluminum and iron. The company has mining, extraction, processing, refining and recycling facilities in over 30 countries. For cobalt extraction and processing, Glencore has operations in Democratic Republic of Congo, Australia, Norway and Canada. For nickel extraction and processing, Glencore's main operations include New Caledonia, Australia, Norway and Canada. Mostly, cobalt and nickel are found together in these reserves, which is the case in Nikkelverk, that is Glencore's mine in Norway, where high grade nickel, copper and cobalt is produced (Glencore, 2026). In addition, the company is active in recycling all these critical metals from electronics and Li-ion batteries that reached their end of life.

Both Glencore and Nikkelverk publish sustainability reports or disclosures. Glencore's sustainability report is much more detailed, outlining the sustainability performance of global operations. In the last published annual report for the year 2024, Glencore stated they will adapt to the requirements of the CSRD in due course (Glencore, 2025). Nikkelverk's ESG report is only published in Norwegian, and the report does not follow CSRD or ESRS requirements. Nikkelverk's environmental sustainability strategy includes achieving climate neutrality by 2050, contributing to circularity by significantly reducing resource use, reducing waste, improving waste sorting and protecting air and water by strictly controlling emissions to the environment (Nikkelverk, 2025). Similarly, Glencore publishes comprehensive reports with detailed information on environmental targets and performance. Glencore's main environmental targets for climate protection include achieving 50% of reduction in Scope 1,2 and 3 emissions and reaching net zero by the end of 2050. For water and biodiversity protection, the company has management plans to reduce their impact on water, land and habitats and improve overall performance (Glencore, 2025).

Overall, Glencore and Nikkelverk's commitment to improving their environmental performance and contributing to sustainability is clear. In addition, Glencore has considerable influence on the Li-ion value chain, with their operations on cobalt and nickel mining, extraction, refining, processing and recycling. The company has active supply agreements with battery manufacturers and automotive OEMs, and Glencore's expertise and strong relationships with downstream suppliers will enable Europe's energy transition towards more resilient Li-ion value chain.

Terrafame

Terrafame is a Finnish company engaged in extraction, mining and processing of metals and manufacturing battery chemicals such as nickel and cobalt sulphates. Company's production capacity of nickel sulphate is able to cover the yearly demand for 1,000,000 electric car batteries. The ore is extracted from Kuusilampi mine and follows bioleaching for extraction of the metals then precipitated to produce nickel-cobalt sulphide. This process is 90% less energy intensive than other methods, therefore enables Terrafame to have smallest carbon footprint in the nickel sulphate industry. Recently, the company is at the application phase for the permit of the Kolmissopi mine, which is planned to start operations in 2028 and will be a significant reserve for nickel in Europe (Terrafame, n.d.).

Terrafame publishes comprehensive sustainability reports that outline their environmental performance. Their latest 2024 sustainability report is aligned with CSRD and ESRS requirements. Terrafame's environmental sustainability commitments include targets such as achieving carbon neutrality by 2039, with the actions that are significantly related to replacing fossil fuels with fossil-free and electric solutions, recycling the process water fully into the solution, and minimizing the waste generation (Terrafame, 2025).

Terrafame holds strategic importance for Europe's Li-ion battery value chain. The company is one of the few producers of cobalt and nickel in Europe that helps reduce Europe's dependency on imported intermediates, and with their low carbon extraction method and sustainability commitments, supports Europe's sustainability and industrial policy objectives.

### *8.2.4. Refining & Processing – Cobalt*

After mining and extraction step, concentrated cobalt hydroxide and cobalt concentrates follow a series of refining steps to produce high purity cobalt materials. These hydrometallurgical processes include acid leaching, solvent extraction and controlled precipitation, which enable selective dissolution of cobalt to remove impurities.

Although DRC has the highest share of world cobalt reserves and mining operations, China dominates refining and processing step with almost 80% of coverage. Finland is also one of the key players in this step, delivering 8% of world's refining operations. With this refining and processing capability, Finland supplies 62% of European cobalt demand and supports Europe's supply resilience (European Commission, 2022a).

Umicore

Umicore is a global materials technology company headquartered in Belgium, that is active in various industries with their metal technologies, recycling, cleaner mobility, and advanced materials for energy, consumer electronics and aerospace operations. For battery solutions value chain, their core activities include refining and processing battery grade cobalt and nickel sulfates, also called as precursor cathode active materials (pCAM) for the production of cathode active materials (CAM), mainly nickel cobalt aluminum (NCA) and nickel manganese cobalt (NMC) oxides (Umicore, 2026). Apart from Li-ion battery materials, Umicore also offers materials to produce other types of batteries. In addition to pCAM production in Finland facility, which has annual capacity of 20,000 tons, the company also produces CAM in their Poland facility, that has potential to rise to provide materials for 3 million electric vehicles (Umicore, 2023).

Umicore has very clear sustainability messaging, Let's Go for Zero, that aims to decrease their environmental footprint and to increase positive contribution to people and the planet. The company publishes detailed climate transition plans, ESG Databook that presents key figures regarding environment, social and governance topics, and sustainability reports that are in compliance with CSRD and ESRS. Umicore aims to reach 50% reduction in scope 1 & 2 emissions by 2030 and ultimately net zero by 2035, and 42% reduction in scope 3 emissions. The decarbonization strategy includes increasing energy efficiency, replacing fossil fuels with carbon neutral fuels, electricity or renewable energy, and maximizing reuse of materials. The company's voluntary pollution prevention target includes reducing diffuse emissions by 25% by 2025 and already had been achieved in 2022 with the support of operational excellence and innovative technologies at facilities. Although Umicore has not set any targets on resource use and circular economy, they already embedded circularity in their business model and their strategy. The closed loop strategy maximizes recycling from scrap and residues as well as waste streams (Umicore, 2025). Overall, Umicore has firm commitments towards sustainability, and clearly outlines the path to reaching their targets.

With nickel and cobalt intermediates and cathode active materials production and battery materials recycling, Umicore plays an integral role in Europe's strategy to build resilient and sustainable Li-ion battery value chain. Company's strong commitments towards climate and circularity assigns Umicore as one of the biggest European partners for the value chain decarbonization and autonomy.

### *8.2.5. Mining & Extraction – Nickel*

Nickel is found in nature as nickel oxide, sulfide and silicates. The types of nickel ores are sulfide and laterite deposits, and these decide on the extraction technique for nickel. Sulfide ores contain nickel, copper and iron together, and they are mined typically by underground techniques. The extraction includes crushing the mined ore and mixing with special reagents to produce nickel concentrate. Laterites have different nickel content, but initially small percentage, and they are mined by open-pit techniques. Due to the low concentration of nickel and high concentrations of water, the water is dried in the furnaces and undergoes smelting process (Britannica, 2013).

The world's major reserves are located in Indonesia, followed by Canada, Russia and Philippines. Consequently, Indonesia is world's major nickel mining country with covering 50% of the global nickel mining activity. In Europe, 4.2% of world's nickel reserves are located, and Finland is the top EU producer of Nickel in 2022. Almost 40% of Europe's extracted nickel demand is provided by Finland, followed by Canada and Greece. EU's import reliance (IR) for nickel is 31%, which is significantly lower than other Li-ion battery raw materials like lithium and cobalt. Nevertheless, to support resilience in Li-ion battery value chain both nickel mining & extraction and other downstream steps should be reinforced (European Commission, 2022b).

Boliden

Boliden is a publicly listed company from Sweden. Company owns mines and smelters to produce copper, zinc, nickel and lead. Boliden extracts nickel from Kevitsa open pit mine in Finland and extracted concentrates include also some low amounts of cobalt. These concentrates are sent to Boliden's own processing and refining facility, Harjavalta. This facility is the only nickel processing facility in Western Europe, and thanks to the latest technology deployed, nickel intermediates are produced in a single step. In this facility, recycled metals and concentrates purchased from other mines are also processed (Boliden, n.d.).

Boliden has sustainability reports, but they are not yet in compliance with CSRD requirements. The company highlighted this fact in the latest sustainability report for 2024 and committed to be compliant in the upcoming reports. Boliden is working towards environmental sustainability and has set certain targets as commitment. These targets include reducing 42% of scope 1 & 2 and 30% of scope 3 emissions by 2030 and eventually reaching to net zero by 2050, avoiding metal emissions to soil, air and water, and supporting transition to circular society. To reach these targets, the company plans to improve energy efficiency, increase renewable energy utilization, develop a detailed water management plan, recycle process water, reduce waste and contribute to biodiversity (Boliden, 2025). The sustainability performance is reported at the group level, and the performance of each individual facility is not disclosed in detail.

With nickel extraction and processing facilities in Europe, and further recycling operations for other critical metals, Boliden strongly supports Europe's decarbonization ambition. The company's sustainability reporting and commitments demonstrate alignment with European environmental and governance expectations, and in broader context, Europe's strategic autonomy ambitions in Li-ion battery value chain.

Eurobattery Minerals

Eurobattery Minerals is a listed mining company from Sweden, focusing on nickel, cobalt and copper, that has ongoing battery minerals projects in Finland and Spain. Currently, both projects are in exploration and early development stages, but are both promising to be a major asset for production of nickel and cobalt concentrates for Li-ion battery industry.

As Eurobattery Minerals' projects are in exploration and permitting phase, and the company is not yet a large-scale producer, CSRD requirements do not apply yet. Company does not publish standalone sustainability reports. However, on their website, company publishes sustainability-oriented commitments, such as ethical sourcing and full traceability, alignment with EU environmental and social standards, and following responsible exploration practices (Eurobattery Minerals, n.d.).

Although Eurobattery Minerals does not produce nickel and cobalt yet, they have strong ambition and commitment to supply responsibly mined battery minerals to European Li-ion value chain. Moreover, they have applied for being CRMA strategic project, which reflects their sense of responsibility to contribute to the resilience of the European battery minerals value chain (Eurobattery Minerals , 2026).

### 8.2.6. *Refining & Processing – Nickel*

After the mining and extraction step, the intermediate nickel concentrates from sulfide ores typically contain 40-70% nickel undergo various processes to obtain high purity nickel. These processes are pyrometallurgical smelting, electrorefining and hydrometallurgical leaching. On the other hand, laterite intermediates contain 0.5-2.5% nickel, and are refined through hydrometallurgy processes such as pressure leaching, solvent extraction, crystallization, and pyrometallurgy (Britannica, 2013). These processes lead to refined products like nickel oxide, nickel pig iron and ferronickel, where the nickel content varies from 5 to 75% (Saegert, Witni, & Nerreter, 2022).

Globally, Indonesia and China are dominating the nickel refining and processing step with over 60% of global coverage. Europe produces 3.3% of global refined nickel demand, and sources its demand mainly from Russia, Finland and Norway. Similar to mining and extraction step, Finland is EU's top producer of refined nickel. Unlike the previous step, the import reliance of refined nickel is 75%, which signals significant dependence to suppliers outside EU, and needs further attention and support to strengthen overall Li-ion battery value chain (European Commission, 2022b).

<u>Nornickel Harjavalta</u>

Nornickel Harjavalta is a part of Russian Nornickel and represents the only European site the company owns. Located in Finland, the facility operates to produce nickel and cobalt intermediates for Li-ion batteries (Nornickel Harvalta, n.d.). The parent company Nornickel claims to be the leader in metals and mining industry globally and has 2nd place in high grade nickel production globally (Nornickel, 2026).

Nornickel Harjavalta does not publish separate sustainability reports and whether Nornickel Harjavalta needs to publish CSRD relevant reports or not depends on if company falls within the thresholds, however there are no publications to review this. Nornickel Harjavalta's environmental sustainability disclosures are limited and include brief statements like increasing energy efficiency, improving waste recycling and reducing emissions to environment (Nornickel Harjavalta, n.d.). The parent company Nornickel does publish detailed sustainability reports and climate change reports. However, the reports follow GRI and IFRS standards and are not in line with CSRD and ESRS requirements yet. In the annual report, there are no disclosures about operations of Nornickel Harjavalta. The overall sustainability commitments of Nornickel are increasing production volume but keeping GHG emissions at the same level through renewable energy and energy efficiency initiatives, modernization of waste and tailings management system to reduce environmental risks, ensuring waste treatment and biodiversity conservation (Nornickel, 2025).

Overall, Nornickel is a strategic player in European Li-ion value chain, with their large-scale facilities in Finland for high purity nickel, nickel and cobalt sulfate production. The company is already a supplier to major cathode active material producers in Europe and will continue to be an important supplier. Despite the geopolitical sensitivities associated with the Russian parent company, Nornickel's operations are strategically relevant for the resilience of European Li-ion supply chain. Nornickel Harvalta will need to have more detailed sustainability strategy and reporting, just like their parent company, to be in line with European reporting regulations and further contribute to decarbonization of European battery industry.

### *8.2.7. Cathode Active Material (CAM) Production*

Cathode active materials are the most important components for determining voltage and capacity of the Li-ion batteries and represent the largest cost component, totaling up to 55% of total battery cell cost. Different types of CAMs are available, and these contain refined lithium, nickel, cobalt and manganese (European Federation for Transport & Environment, 2024b). The major CAM types in commercial use are nickel manganese cobalt oxide (NMC), nickel cobalt aluminum oxide (NCA), lithium cobalt oxide (LCO) and lithium iron phosphate (LFP). 70% of the CAM market was dominated by NMC and NCA cathodes in 2024, however due to ethical concerns and production challenges, LFP is preferred as a viable option in the future. The selection of the CAM depends on the cost, cycle performance and energy density requirements (Fraunhofer ISI, 2025).

CAM production follows steps like precursor synthesis, filtration, calcination, milling and surface coating. These operations are capital and energy intensive and require specialized equipment with high purity inputs. As these steps involve complex chemical engineering steps, the number of producers that are capable to operate remains limited. The global largest CAM producers are China, Japan and Korea with almost 90% of global coverage, especially with LFP cathodes, however new production capacity is ramping up in Europe and North America (Fraunhofer ISI, 2025). Based on European Federation of Transport & Environment's study, the announced European CAM capacities would cover half of the EU demand in 2030, however as the projects are still in the early stages of development, they are subject to uncertainties.

The major sustainability challenges of CAM production would be high energy intensity, thus high carbon footprint and environmental pollution risks due to the chemical and solvent usage (Fraunhofer ISI, 2023).

BASF

BASF is a one of world's leading chemical company originated and headquartered in Germany. Under surface technologies segment, the main operations of the battery materials business unit consist of producing CAM globally, innovating for the battery industry and providing solutions for recycling of Li-ion batteries. BASF has highly capable CAM production facilities with large capacity along with technical expertise, that are located in China, Japan, Germany and Finland. In 2023, the company established first fully automated large scale European CAM production plant in Germany (BASF, 2026).

BASF publishes detailed sustainability reports, integrated in annual reports, that are fully compliant with CSRD and ESRS requirements. In the report, the main environmental sustainability topics mentioned are climate protection targets, that include renewable energy and efficiency improvement initiatives, which are backed up by significant level of investments. The overall emission targets are 25% reduction by 2030 in scope 1 & 2 emissions and reaching net zero by 2050. As per environmental protection targets, BASF aims to halt and reverse biodiversity loss through nature regeneration, process optimization and water stewardship. Furthermore, the company plans to establish sustainable water management plans that include initiatives like sustainable water abstraction, good water quality maintenance and cooperation with local authorities and so on. Another sustainability contribution is circularity, that mainly focuses on using renewable or recycled materials, or enabling recyclability, prolonging the lifespan of the products and minimizing waste. Overall, BASF has strong disclosures about their sustainability approach and is committed to enable green transformation for a sustainable future (BASF, 2025).

BASF is one of Europe's most capable and strategically important partners in the Li-ion value chain. One of Europe's most underdeveloped and strategically sensitive stage, CAM production, is covered with their advanced CAM production facilities in Europe. Further additional value chain operations, such as pCAM production and battery recycling, enhance the importance of the company to enable circular and resilient value chain. Overall, BASF combines technological capability and expertise, regulatory compliance and sustainability commitments for strengthening Europe's Li-ion battery value chain.

IBU Tec

IBU Tec is a German specialty chemicals and materials producer company with a strong strategic focus on battery materials. The CAM facility is located in Germany and produces high quality CAMs under IBUvolt brand, that were developed as a result of extensive product and process development studies. Through the IBUvolt brand, company offers different CAM like lithium iron phosphate (LFP), sodium manganese oxide (NMO) and lithium manganese iron phosphate (LMFP) (IBU Tec, n.d.). The company also has battery recycling operations, focusing on recovery of valuable materials from batteries to integrate into new ones.

IBU Tec does not meet the CSRD reporting thresholds, therefore does not need to publish integrated reports disclosing sustainability performance. However, the company publishes voluntary non-financial statements as a part of their annual report. Environmental sustainability disclosures include operating with 100% renewable electricity, optimizing production processes for resource efficiency and lower emissions and implementing efficient recycling processes to minimize waste (IBU Tec, 2025).

IBU Tec is a strong actor in European Li-ion value chain resilience, even though they do not disclose environmental performance in detail. The company underlines their supply strategy focus is on building European value chain. Once the company starts reporting in line with CSRD and ESRS requirements, with their strategic CAM production and recycling operations, IBU Tec will support strengthening the value chain.

### *8.2.8. Battery Cell Manufacturing*

Battery cell production has three main steps which are electrode production, cell assembly and cell finalization. Electrode production refers to the slurry formation of anode and cathode materials mixed with solvent, additives and binder. Then the slurry is applied to a metal foil and undergoes drying process to remove the solvent. Afterwards, calendaring, slitting and drying takes place to form electrodes. The resulting electrode then is stacked, welded in cell housing and filled with electrolyte. Once the cell is formed structurally, electrochemical activation is performed by charging and discharging. The cell is ready once it passes the quality control (Fraunhofer ISI, 2023).

Although China is dominating the global Li-ion battery cell manufacturing with over 80% market share, European production is ramping up as a result of the large domestic market and EU initiatives like European Battery Alliance. Many battery cell manufacturing plans have been announced in Europe, totaling up to 1.7 TWh by 2030, whereas the expected demand for Li-ion batteries would be around 1 TWh by 2030. However, more than half of these plans have the risk of delay, scale down or cancellation (European Federation for Transport & Environment, 2024b).

The sustainability challenges in battery cell production include pollution risks due to solvent use, high carbon footprint due to energy intensive process, considerable amount of water consumption and waste generation from scrap.

<u>Verkor</u>

Verkor is a French battery cell manufacturer that has been established in 2020 with a clear goal of building Europe as a key battery manufacturing hub for the future. Verkor currently established a gigafactory with annual 16 GWh production capacity for Li-ion batteries in France and aims to expand the capacity further to 50 GWh by 2030 (Verkor, 2026a). The company has strong partnerships with companies like Renault Group and Sibanye-Stillwater Group, that are active in European Li-ion value chain (Verkor, 2026b).

The company publishes sustainability reports adopting CSRD and ESRS requirements and underlines the efforts to have CSRD compliance before it is due by 2028. In the sustainability report, the planned initiatives and targets are disclosed in detail to achieve sustainable operations. These initiatives include carbon footprint reduction through optimized process efficiency, lower carbon energy supply, usage of low carbon raw materials and maximization of recycling. Environmental protection related targets are mainly aiming avoidance of negative impacts by respecting regulatory discharge with proper waste treatment systems and preventing and minimizing impacts on biodiversity. Recycling and material recovery is also a very prominent topic. Moreover, Verkor discloses full recognition of recycled content and material recovery target outlined in European Battery Regulation and aims to overachieve recycling efficiency targets (Verkor, 2025).

In summary, the company combines advanced capabilities in cell design, cell manufacturing, digitalized production systems, responsible resourcing and recycling. Verkor's special focus on rapidly building capacities to enable low-carbon manufacturing and strong ambition towards building a resilient European value chain, makes Verkor strategic partner for localization and decarbonization of the Europe Li-ion battery value chain.

Automotive Cells Company (ACC)

Automotive Cells Company is headquartered in France, and a joint venture between Stellantis, Mercedes-Benz and Saft a subsidiary of TotalEnergies, for battery cell manufacturing. ACC's first gigafactory with 13 GWh capacity is located in France and started operations in 2023. The factory will increase the capacity in phases and eventually will reach 40 GWh capacity which corresponds to yearly 800,000 battery production. Two more gigafactories with 40 GWh capacity each are in plan and will be located in Germany and Italy. All these factories are planned to reach full capacity by 2030 and will produce more than 2 million batteries to generate 120 GWh power (ACC Automotive Cells Co, 2026).

ACC's corporate sustainability reports are not yet aligned with CSRD and ESRS requirements, however the company completed double materiality analysis and ESRS correspondence of topics. The major climate sustainability themes mentioned in the report are to achieve carbon neutrality by 2050 by engaging with suppliers to reduce their emissions, optimizing process energy, redesigning the product to reduce raw materials and waste and increasing recycled materials in the cells. The water and biodiversity themes are mentioned as priorities and actions are listed as improving high efficiency water treatment plants to recover water as much as possible, reusing rainwater and avoiding dust and noise pollution not to disturb the ecosystems (ACC Automotive Cells Co, 2025).

Being a joint venture of Europe's largest electric car manufacturers and energy supplier, ACC has downstream support and strategic partnerships to contribute to Europe's resilient Li-ion value chain objectives. Combined with low-carbon manufacturing, responsible sourcing, environmental protection focus and high production capacities, ACC is a valuable partner in energy transition of EU battery ecosystem.

Leclanché

Leclanché is a listed Swiss energy storage solutions provider, mainly focusing on Li-ion cell systems. In their German facility, the company manufactures battery cells, modules and packs along with energy management software. The company is active not only in e-commercial vehicles industry, but also in the e-marine and e-rail industries as well. Partnered with important vehicle producers like Alstom, Skoda and Toyota, Leclanché contributes to the decarbonization of the e-mobility industry (Leclanché, 2024).

The company publishes sustainability reports and working towards alignment with CSRD and ESRS requirements. It is mentioned that thanks to Leclanché's special water-based production method along with solvent free nickel cathode processing, company's impact on the environment is reduced. The carbon footprint of Leclanché battery has been improved by 35% by using renewable electricity, integrating recycled materials into batteries produced and saving energy from water-based production processes. The company aims to reduce the carbon footprint of their battery by 70% in total, by implementing further footprint reduction initiatives. Furthermore, the company is working on further increasing the recycled content in the batteries, along with the end-of-life recyclability (Leclanché, 2025).

Overall, Leclanché plays an important role for Europe's battery sector with their expertise, special processes and sustainability commitments. In addition, company's attention towards other e-mobility sectors like e-marine and e-rails and energy storage solutions adds additional value and support to Europe's Li-ion value chain.

### 8.2.9. *Battery Pack Assembly & e-Mobility Integration*

Once the battery cells are produced, they are converted into battery packs. This process includes mainly mechanical and electrical integration, rather than chemistry intensive processes. There are different structural battery designs, including assembly of cells to pack with and without modules, or direct integration to vehicle chassis. The cell type is decided depending on the weight, space, cost, energy density requirements. In general, battery pack assembly steps are grouping cells into modules, installing thermal management, integrating battery management systems (BMS), adding structural casings and performing quality, safety and performance assurance. The e-mobility integration refers to where battery packs are incorporated into electric vehicles. This step includes fixing the battery pack into vehicle chassis, connecting high voltage systems, calibrating BMS with vehicle's software and complying with automotive safety standards (Fraunhofer ISI, 2023).

Most of the major automotive manufacturers are performing battery pack assembly in house. China has the first place in this value chain step as well, followed by North America Japan, South Korea and Europe. Europe's battery supply chain weakened in 2024, majorly due to slow growth of battery manufacturing capacity (International Energy Agency, 2025b).

The major sustainability challenges of these steps would be the high carbon footprint, caused by all the upstream raw materials and all the energy intensive procedures like welding, thermal management integration and so on. The complexity of the battery packs makes the end-of-life treatment complicated, so recycling and recovery is another major challenge to be addressed.

Volkswagen Group

The Volkswagen group is Germany based and one of the biggest mobility companies globally, focusing on electric vehicle transformation. With brands such as Volkswagen, Audi, Skoda, Cupra and Porsche, the group brings wide range of electric vehicle options to the market. In addition to the electric vehicle manufacturing, Volkswagen group focuses on key parts of electric vehicle value chain like Li-ion battery cell production with their subsidiary PowerCo, charging stations with Elli and battery recycling (Volkswagen Group, 2026).

The group publishes detailed annual reports for all group companies where sustainability information is also reported in detail. In their latest annual report, VW Group applied the CSRD and ESRS requirements in full and achieved compliance. The reported figures belong to the whole group, not only the e-mobility related operations. The group puts decarbonization as their main focus, however group wide decarbonization plans are not yet in place. The main decarbonization levers discussed in the report include e-mobility, transformation to renewable energy, improving energy efficiency and emission reduction in value chain. The group target is to reach net carbon neutrality in the production sites by 2040. Volkswagen also aims to procure only renewable energy and furthermore generate some renewable energy in production sites. Moreover, the group intends to reduce the carbon footprint of the passenger and light commercial vehicles by 30% in the use phase, and 30% emission reduction in the retail and service network by 2030. In terms of protection of water, air, soil and biodiversity, the main actions are waste treatment, encouraging suppliers to provide transparency for the production of the raw materials, reducing water consumption by minimum 30% across the group by 2035, and supporting ecosystem preservation and reforestation projects. From circularity perspective, the targets include increasing the use of renewable, recycled and reconditioned materials in the vehicles up to 40% from 2040 and expanding circular product design (Volkswagen Group, 2025). Even though the group discloses all environmental related performance information, the disclosure is at group level and does not represent a certain value chain step.

In summary, with carbon footprint reduction commitments and electric vehicle production, Volkswagen Group plays a major role in the shift toward e-mobility in Europe. The group has broad investments also in upstream and downstream Li-ion battery value chain, like in battery cells and charging stations. The global presence of the group for sure provides the industrial scale, know-how and strength, and supports efforts for shaping future mobility in Europe and contributing to value chain resilience.

Stellantis

Another player that is shifting toward electric mobility in European market is Stellantis, headquartered in the Netherlands. PSA Group and Fiat Chrysler Automobiles have merged to create Stellantis with broad portfolio of brands like Fiat, Jeep, Peugeot, Citroen and so on. The group focuses on sustainable mobility, electrification and software development. With their share in the battery cell producer Automotive Cells Company (ACC), they also have a direct link to the battery cell value chain.

The group is publishing integrated annual reports that are in line with CSRD and ESRS. Stellantis also prepared a strategic plan as a further commitment to sustainability. This plan includes targets as reducing 30% of GHG emissions by 2030 and reaching carbon net zero by 2038. Main initiatives to reach these targets are decarbonization of the energy and grid infrastructure. The major water protection initiative is avoiding water withdrawal by establishing water recycling in facilities. For resource use and circular economy policies, the group prioritizes product redesign and eco-design for reducing environmental impact, optimization of material cycles, and collaboration with suppliers, recyclers and recycling associations to enable end-of-life battery recycling (Stellantis N.V., 2025).

Overall, Stellantis is another key contributor to Europe's transition towards cleaner and more sustainable mobility. With their brands and extended range of e-vehicle options, the group answers the demands of the market. The partnership with battery cell manufacturer ACC and French Alternative Energies and Atomic Energy Commission (CEA) strongly highlights Stellantis's intentions to secure advanced battery technologies and contribute to its improvement. The battery investments and sustainable commitments of the group help Europe build more resilient and greener position in the e- mobility Li-ion battery value chain.

Renault Group

Renault Group is a French global automobile manufacturer, with ambitions to become high technology and low carbon emissions focused. The group was the first full line manufacturer switching to all electric vehicles. With brands like Renault, Dacia, Alpine and Nissan, the group contributes to conventional and electric vehicle production with many locations in Europe. Group also is developing solutions with other alternative energy sources, like dual-energy (electric and hydrogen) and pure hydrogen motor vehicles. Their new brand Ampere is only focusing on electric vehicle and software manufacturing for contribution to decarbonization (Renault Group, 2026). Renault group emphasizes the importance of a strong value chain and has partnerships with many companies along different steps of the Li-ion value chain, for example with mining companies like Terrafame, Vulcan Energy and battery cell producers like Verkor. Verkor's Dunkirk gigafactory is in partnership with Renault and symbolizes the commitment the group gives to decarbonization (Renault Group, 2023).

The group publishes yearly universal registration documents, and the last one published for the year 2024 is in line with CSRD and ESRS. The group is very transparent and outspoken about their sustainability commitments. The major commitment is for carbon neutrality, and the group aims to achieve net zero emissions by 2040 in Europe and by 2050 worldwide. The decarbonization of manufacturing sites is achieved through facility and process optimization and switching to renewable energy sources like PV, biomass and geothermal. Carbon emissions during vehicle use are reduced by designing to integrate recycled materials more into the automobiles, and the overall target is to achieve 33% recycled content by 2030. Another decarbonization and circular economy strategy comes from responsibly sourcing low carbon, recycled or bio-based raw materials and developing low-carbon supply chains for Ni, Li and Co. The group aims to reuse 80% of recycled Ni, Co and Li ores in EV battery production by 2030. The major circular economy initiative is the foundation of Future Is NEUTRAL company, which is the first circular economy automotive company, initiated by Renault Group and SUEZ. This initiative focuses on recycling materials from end-of-life vehicles in manufacturing new ones. As per environmental protection aspect, the group pays attention to preserving biodiversity at facility sites, treats waste to minimize impact and cooperates with stakeholders to contribute to biodiversity. Renault demonstrates a strong sense of environmental responsibility, particularly through its careful assessment of bio-sourced materials. The group explicitly evaluates these resources to ensure they do not compete with food production or contribute to deforestation, biodiversity loss, or pollution, which reflects a high level of commitment to responsible and sustainable procurement (Renault Group, 2025).

Altogether, Renault group is not only complying with the regulatory requirements but also actively contributing to a more responsible automotive industry. Their strong commitment to decarbonization, low carbon manufacturing, circularity, responsible sourcing and biodiversity conservation initiatives show a well-structured sustainable development plan for the future. The group highlights the core element of sustainable and resilient battery value chain is recycling lithium, nickel and cobalt, and works towards strengthening Europe’s autonomy and resilience in battery value chain.

#### *8.2.10. Recycling*

Once the battery reaches end of its life cycle, the valuable components in the batteries are recovered to be used for different purposes. This step is crucial in the Li-ion battery value chain because it closes the loop between the batteries and the critical raw materials and enables growth of electric vehicle industry. Recycling processes can be categorized in three groups, that are pyrometallurgical, hydrometallurgical and mechanical recycling. Initially, pyrometallurgy was preferred, but in the long term, hydrometallurgical processes are expected to be the main recycling method. The main reasons for this shift are higher efficiency in the recovery of materials and lower carbon emissions. High temperature requirement in pyrometallurgical processes, solvent use and wastewater from hydrometallurgical processes are the main sustainability challenges of the Li-ion battery recycling step (Fraunhofer ISI, 2023).

The EU Battery Regulation, published in August 2023, is a milestone for circularity of batteries. Detailed recycling, recovery and recycled content expectations and requirements are disclosed with their expected timeline. According to the regulation, average weight of 65% of batteries should be recycled by end of 2025, and 70% by end of 2030 (European Federation for Transport & Environment, 2024b). According to Adamas Intelligence, only 50% of batteries reaching the end of their lifecycle find their way into recycling facilities. By 2030, the recycling capacity in Europe is expected to rise significantly, driven by the increasing production levels at giga factories and increasing number of batteries reaching end of life (Adamas Intelligence Inc. and Tradium GmbH, 2024).

Umicore is one of the major recyclers in Europe, and the company has developed special processes for recycling batteries and was one of the first to invest in recycling plants in Europe. The companies BASF, Glencore, Eramet, and Volkswagen can be listed among major companies that are active in battery recycling step, and the sustainability reports and strategies of these companies are already investigated in the previous chapters of this thesis.

All in all, recycling stage is essential for decarbonizing and strengthening Li-ion value chain. Despite challenges, recycling remains the most effective way to recover critical raw materials like lithium, nickel and cobalt and reduces dependency on mining and extraction. As the electric vehicle industry, hence the battery demand grows, efficient recycling streams will create resilient value chains while lowering the environmental impacts.

# 9. Discussion

For the thesis review, the sustainability strategies and targets reported by the companies are clustered under 5 groups, aligned with EU taxonomy for sustainability activities approach (European Commission, 2025c). These clusters are defined as:

- Climate: For initiatives clearly defining decarbonization and energy efficiency
- Water Protection: For any initiative or target referring to sustainable use and protection of water and marine resources.
- Circularity: For initiatives including recycling and circular economy
- Pollution prevention: For initiatives avoiding waste discharge to environment.
- Biodiversity & Ecosystems Protection: For initiatives aiming to protect and restore biodiversity and ecosystems.

## 9.1. Summary of the Findings: REE Value Chain Companies for Wind Turbines in Europe

The assessment of the major European companies along the REE value chain in wind turbine industry shows fragmented sustainability landscape. Particularly in early stages of the value chain, like extraction, processing and magnet alloy production Europe depends heavily on suppliers outside Europe (especially China). However, recent policy developments such as European Critical Raw Materials Act, have encouraged new local market entries across these upstream steps. These initiatives are strengthening Europe's position to secure the REE value chain and enhance long term resilience and strategic independence. However, most upstream companies in the value chain have limited sustainability disclosures, further market maturity and regulatory push would improve companies' commitment to sustainability in the REE wind turbine value chain.

Across the companies investigated, climate and circularity are observed as the most prominent strategies, consistently reflected in upstream and downstream steps of the REE value chain. The level of importance given to these strategies differs between upstream and downstream players. Upstream companies emphasize their water protection and pollution prevention strategies, which are in line with managing the environmental challenges of the extraction, processing and alloy production steps. These companies also represent smaller size or early-stage companies and do not have concrete sustainability reports and are not yet subject to CSRD. In contrast, downstream companies for wind turbine manufacturing have more comprehensive climate strategies like net zero targets, energy efficiency initiatives and renewable energy commitments reflecting the market and regulatory expectations. These companies represent large actors with significantly more mature structures, and they publish comprehensive sustainability reports, mostly in line with CSRD requirements including net zero targets, energy efficiency and renewable energy commitments and circularity strategies. Their reports reflect both regulatory obligations and expectations of the public stakeholders and investors in European renewable energy sector. This contrast between upstream and downstream highlights the effect of market orientation and regulations on the depth and quality of the sustainability reporting.

The lack of comprehensive reporting in the early stages of the value chain creates challenges on transparency and traceability for environmental performance assessment. As these segments continue to develop in Europe, more companies will fall under CSRD and ESRS scope and detailed reporting will likely emerge. This evolution will bring transparency and overall strengthen the resilience of EU REE value chain. Below table summarizes the findings for the REE value chain in Europe wind turbine industry.

Table 3: Summary Table of Findings from REE Value Chain Companies in Europe Wind Turbine Industry

| Step | Description | Company | Location | CSRD Scope | Report Status | Sustainability Strategy & Details | |
|---|---|---|---|---|---|---|---|
| Mining & Extraction | Neodymium, Praseodymium, Dysprosium and Terbium are mined from hard-rock deposits by crushing and grinding.<br>In Europe, there are no active mining sites yet, but projects are ongoing.<br>Main sustainability challenges of this step are: high volumes of waste, radioactive by products, ecosystem interference and high water use. | Rare Earths Norway (REN) | Norway | No | Sustainability report is not published. | Climate:<br>Water, Biodiversity & Ecosystems Protection:<br>Pollution Prevention: | Reduce carbon footprint by adopting Best Available Technologies<br>Develop mitigation strategies for waste management, biodiversity and water quality<br>Manage tailings properly to avoid seepage to soil and water bodies |
| | | LKAB | Sweden | Yes | Sustainability report is published but not yet in line with CSRD. | Climate:<br>Water, Biodiversity & Ecosystems Protection:<br>Circularity: | Reach net zero emissions by 2045: switch to renewable energy and improve energy efficiency<br>Minimize environmental impact: monitor emissions into water & air and contribute to biodiversity<br>Increase resource efficiency and circularity |
| | | Leading Edge Materials | Sweden (Canada owned) | No | Sustainability report is not published. | Water Protection:<br>Pollution Prevention: | Protect nearby freshwater resources<br>Ensure responsible waste and tailings management to limit ecological disturbance |
| Processing & Separation | Mixed rare earth concentrates are chemically separated into rare earth oxides using chemical processes.<br>In Europe, separation capacities are very limited, only around 2% globally.<br>Major sustainability challenges include: high energy requirement, chemical use and complex waste streams. | Solvay | France | Yes | Sustainability report is published and in line with CSRD. | Climate:<br>Water Protection:<br>Circularity: | Reach net zero emissions by 2050: transition to renewable energy, improve process innovation and energy efficiency<br>Water and wastewater management<br>Increase recycled material use, reduce waste and develop further recycling technologies |
| | | Neo Performance Materials | Estonia (Canada owned) | No | Sustainability report is published but not yet in line with CSRD. | Climate:<br>Water Protection:<br>Circularity: | Reduce Scope 1 & 2 GHG emissions<br>Manage water consumption and proper treatment systems<br>Recover REE from magnet waste and end of life magnets |

| Step | Description | Company | Location | CSRD Scope | Report Status | Sustainability Strategy & Details | |
|---|---|---|---|---|---|---|---|
| Metals & Magnetic Alloys Production | Separated rare earth oxides are alloyed with Iron and Boron to produce NdFeB magnet alloys.<br>In Europe, large scale facilities are not present, and production only covers less than 1% globally.<br>Major challenges are: energy intensive process, carbon emissions and supply chain risks. | Treibacher Industrie AG | Austria | No | Sustainability report is published but not yet in line with CSRD. | Climate:<br><br>Circularity:<br><br>Water Protection: | Reduce GHG emissions by 30% vs. base year 2021<br><br>Enable resource recovery<br><br>Remediate historical groundwater contamination by company operations |
| | | Less Common Metals | United Kingdom | No | Sustainability report is not published. | Climate:<br><br>Circularity: | Improve energy efficiency<br><br>Increase resource efficiency |
| Magnet Manufacturing | The magnet alloys are milled, pressed, sintered and coated to produce NdFeB permanent magnets.<br>Europe has small manufacturing capacity and far from self sufficiency.<br>Main challenges include: limited recycling of magnet scrap, manufacturing waste and supply chain risks. | Vacuumschmelze | Germany | Yes | Sustainability report is published but not yet in line with CSRD. | Climate:<br><br>Circularity: | Reach net zero emissions by 2050<br><br>Recycle valuable resources in magnets |
| | | Neorem Magnets | Finland | No | Sustainability report is not published. | Water, Biodiversity & Ecosystems Protection: | Improve processes to minimize environmental impacts |
| | | Magneti Ljubljana | Slovenia | No | Sustainability report is not published. | Circularity:<br><br>Climate: | Prioritize innovation projects for magnet recycling and REE recovery<br><br>Reduce GHG emissions |

| Step | Description | Company | Location | CSRD Scope | Report Status | Sustainability Strategy & Details | |
|---|---|---|---|---|---|---|---|
| Wind Turbine Assembly | The permanent magnets are integrated into power generators and then integrated to wind turbines. Europe lost the global leader status to China very recently and losing market share. Major challenges are: responsible sourcing and supply chain risks. The permanent magnets are then integrated into power generators and then integrated to wind turbines. Europe lost the global leader status to China very recently and losing market share. Major challenges are: responsible sourcing and supply chain risks. | Vestas | Denmark | Yes | Sustainability report is published and in line with CSRD. | Circularity:<br>Climate: | Reach net-zero emissions by 2030<br>Reach zero-waste wind turbines by 2040 |
| | | Siemens Gamesa | Spain | Yes | Sustainability report is published and in line with CSRD. | Circularity:<br>Climate: | Reduce Scope 1,2, 3 GHG emissions<br>Deliver fully recyclable wind turbines by 2040 |
| | | Nordex | Germany | Yes | Sustainability report is published and in line with CSRD. | Climate:<br>Circularity:<br>Water Protection: | Reach net-zero emissions by 2050<br>Deliver fully recyclable blades by 2032<br>Increase water efficiency |
| Recycling | Magnet scraps and end-of-life turbines undergo metallurgical processes to recycle their REE content. Industrial scale recycling in Europe is still very limited. The main challenges are: low collection rates and technical difficulties in recycling processes. | Heraeus Remloy | Germany | Yes | Sustainability report is published and in line with CSRD. | Climate:<br>Circularity: | Reach net-zero at Scope 1&2 emissions<br>Promote circular economy and increase material efficiency |
| | | MagREEsource | France | No | Sustainability report is not published. | Circularity: | Prioritize REE recovery from magnets |

## 9.2. Summary of the Findings: Lithium, Cobalt, Nickel Value Chain Companies for Li-ion Batteries in e-Mobility in Europe

The assessment of European companies in Li-ion battery value chain shows more mature and structured sustainability landscape compared to REE wind turbines value chain. The Li-ion value chain is more developed with European active companies in all value chain steps. Moreover, many companies operate across multiple steps which creates a more integrated and aligned sustainability approach across operations. Combined with strong market development and growth in e-mobility, this contributes to higher level of sustainability performance transparency and reporting maturity. Hence, most of the companies within this value chain have sustainability reports and are already in line with CSRD and ESRS requirements.

Li-ion battery value chain is connected to business to consumer (B2C) market through automotive industry. E-vehicle manufacturers face strong expectations from consumers, and this translates into more comprehensive sustainability disclosures. The persistent sustainability theme is climate, with clear emission reduction, renewable energy and net zero commitments. Circularity is also another central theme, particularly among mid and upstream companies for resource recovery. Importantly, downstream companies play an important role in shaping the sustainability behavior of upstream suppliers. Through responsible resourcing policies, they require upstream companies to provide environmental performance data, reduce emissions and demonstrate compliance with sustainability standards. Moreover, the EU battery regulation further accelerates sustainability commitments and transparency by setting carbon footprint and recycled content thresholds and traceability obligations. Together, these push companies to report and improve their environmental performance across the entire value chain.

Overall, Li-ion battery value chain benefits from combination of strong regulatory pressure, integrated industrial operations and market expectations. These factors contribute to higher levels of sustainability performance transparency and reporting maturity. As the CSRD, ESRS and EU battery regulation become fully implemented, the performance across the value chain becomes more harmonized and further strengthen the resilience of the European Li-ion battery ecosystem for e-mobility. Below table summarizes the findings for the European Li-ion battery value chain for e-mobility sector.

Table 4: Summary Table of Findings from Li-ion Value Chain Companies in Europe e-Mobility Industry

| Step | Description | Company | Location | Other Activities | CSRD Scope | Report Status | Sustainability Strategies & Details | |
|---|---|---|---|---|---|---|---|---|
| Lithium Mining & Extraction | Lithium is extracted from brines or hard rock mining. Europe relies heavily on imports and contributes to only 0.1% of extracted Li volume. Main sustainability issues include high water use and energy demand and ecosystem disruption risk. | Vulcan Energy Resources | Germany | - | No | Sustainability report is published but not yet in line with CSRD. | Climate:<br>Biodiversity and ecosystems:<br>Water protection: | Develop decarbonization roadmap to reduce carbon emissions<br>Responsible operation and limited land use<br>No significant impact on subsurface and terrestrial water resources, and mitigation plan is in place to reduce any impacts. |
| | | Keliber - Sibanye Stillwater | Finland | Lithium, Cobalt and Nickel Refining, pCAM production | No | Group sustainability report is published and in line with CSRD. | Climate:<br>Circularity:<br>Water protection: | 42% reduction in Scope 1 & 2 emissions by 2030<br>30% increase in renewable energy utilization<br>All regions will build net positive plans<br>15% of sales from recycled materials<br>49% reduction in purchased water |
| | | European Lithium Limited | Austria | - | No | Sustainability report is not published. | No sustainability commitments were identified. | |
| Cobalt Mining & Extraction | Cobalt is a by product of copper and nickel mining, and after the ore is crushed it is concentrated to isolate cobalt. Europe depends on imports and contributes to less than 1% of global Co production. Main sustainability challenges include hazardous toxic waste and pollution risk and ecosystem disruption. | Glencore Nikkelverk | Switzerland | Nickel mining and extraction Nickel and Cobalt refining and processing Battery Recycling | Yes | Group sustainability report is published but not yet in line with CSRD. | Climate:<br>Circularity:<br>Water protection:<br>Biodiversity and ecosystems: | Reach net zero by 2050<br>Recycle key commodities to support circular economy<br>Minimize operational water footprint and protect water resources<br>Reduce physical footprint on land, implement biodiversity management plans |
| | | Terrafame | Finland | Nickel mining and extraction Nickel and Cobalt refining and processing | Yes | Sustainability report is published and in line with CSRD. | Climate:<br>Pollution:<br>Biodiversity and ecosystems:<br>Circularity: | Reach carbon neutrality in own operations by 2039, prepare climate change mitigation plan<br>Recycle all sulfate back into the solution cycle to avoid discharge to nearby water bodies<br>Follow guidelines for the protection of biodiversity<br>Use ores effectively, avoid waste rock generation, recycle side streams |

| Step | Description | Company | Location | Other Activities | CSRD Scope | Report Status | Sustainability Strategies & Details |
|---|---|---|---|---|---|---|---|
| Nickel Mining & Extraction | Nickel extraction is through sulfide or laterite ore processing.<br>Europe produces less than 2% of global nickel volume, but further mining projects are developed to increase volume.<br>High energy use, significant waste generation and ecosystem disruption risks are the main sustainability challenges. | Boliden | Sweden | Nickel refining and processing | Yes | Sustainability report is published but not yet in line with CSRD. | Climate: Reach net zero by 2050<br>Biodiversity and ecosystems: Contribute to biodiversity net gain by 2030<br>Water protection: Create water management plan<br>Pollution: Avoid increase in emissions to air or water<br>Circularity: Extract value from waste, increase waste utilization rates, reduce volume of waste |
| | | Eurobattery Minerals | Sweden | Cobalt mining and extraction | No | Sustainability report is not published. | No sustainability commitments were identified. |
| Lithium Refining & Processing | Through purification, chemical conversion and crystallization processes, lithium carbonate and lithium hydroxide are formed.<br>In Europe, very limited processing capacity is available.<br>Main sustainability issues include GHG emissions, water use and waste management. | AMG Lithium | Netherlands | Lithium mining and extraction | Yes | Group sustainability report is published and in line with CSRD. | Climate: Optimize processes to reduce combustion need<br>Expand renewable energy use<br>Circularity: Increase use of recycled materials<br>Water Protection: Recycle tailings & water<br>Biodiversity: Action to mitigate or lessen the severity of adverse impacts |
| | | Nobian | Netherlands | - | Yes | Sustainability report is published and in line with CSRD. | Climate: Reach carbon neutrality in Scope 1 & 2 by 2040<br>Switch fully to renewable energy by 2040<br>Increase energy efficiency<br>Circularity: Supply low carbon products at least 40% of portfolio<br>Recycle battery chemicals<br>Water Protection: Reduce water consumption and eliminate drinking water intake for process purposes |
| | | Eramet Lithium | French | Lithium and Nickel mining and extraction | Yes | Sustainability report is published and in line with CSRD. | Climate: Reduce emissions by 40% by 2035<br>Engage with suppliers to reduce downstream emissions<br>Circularity: Optimize mineral resources consumption<br>Water protection: Control and optimize water consumption<br>Biodiversity: Act towards a net positive biodiversity impact |

| Step | Description | Company | Location | Other Activities | CSRD Scope | Report Status | Sustainability Strategies & Details | |
|---|---|---|---|---|---|---|---|---|
| Cobalt Refining & Processing | High purity cobalt is produced through hydrometallurgical processes like acid leaching, solvent extraction and controlled precipitation.<br>In Europe, 8% of global refined cobalt volume is produced, mainly in Finland and import reliance is very low.<br>High energy use, chemical waste generation and water pollution risks are the main sustainability challenges. | Umicore | Belgium | Nickel refining and processing CAM production | Yes | Sustainability report is published and in line with CSRD. | Climate:<br>Pollution:<br>Water protection: | Reach net zero in scope 1 & 2 emissions by 2035<br>Reduce diffuse emissions by 25% by 2025<br>Implement water action plan for production sites facing water stress by 2025 |
| Nickel Refining & Processing | Intermediate nickel concentrates undergo various hydrometallurgical and pyrometallurgical processes to produce refined nickel like nickel oxide.<br>In Europe, 3% of global refined nickel volume is produced.<br>High energy use, chemical waste generation and water pollution risks are the main sustainability challenges. | Nornickel Harjavalta | Finland | - | Unknown | Group sustainability report is published but not yet in line with CSRD. | Water protection:<br>Pollution:<br>Biodiversity: | Comply with regulatory discharge requirements<br>Reduce emissions to air<br>Achieve net zero biodiversity loss resulting from operations |

| Step | Description | Company | Location | Other Activities | CSRD Scope | Report Status | Sustainability Strategies & Details |
|---|---|---|---|---|---|---|---|
| Cathode Active Material (CAM) Production | CAM production involves refined Li, Ni, Co combination through chemical synthesis. Majority of CAM production globally is out of Europe. Major sustainability challenges include high energy intensity and carbon footprint and environmental pollution risks due to chemical usage. | BASF | Germany | Battery Recycling | Yes | Sustainability report is published and in line with CSRD. | Climate: Reach net zero by 2050<br>Water protection: Introduce sustainable water management at production sites in water stress areas by 2030<br>Circularity: Increase use of renewable and recycled materials; Design new material cycles to enable circularity |
| | | IBU Tec | Germany | Battery Recycling | No | Sustainability report is published but not yet in line with CSRD. | Climate: Reduce energy consumption and switch to renewable energy sources<br>Circularity: Increase recycling business to contribute circularity<br>Water protection: Minimize water consumption through process optimization |
| Battery Cell Manufacturing | Battery cells manufacturing steps are electrode production, cell assembly and finalization. European production is ramping up, although main global production is outside Europe. Energy intensity, water consumption, waste generation and pollution due to solvent use are the main sustainability challenges. | Verkor | France | Battery Recycling | Yes | Sustainability report is published and in line with CSRD. | Climate: Reduce carbon footprint per kWh of the cells<br>Circularity: Recycle 95% of own waste by 2027<br>Water protection: Limit the quantity of water withdrawal<br>Biodiversity: Prevent or minimize impact of Gigafactory project on biodiversity |
| | | Automotive Cells Company (ACC) | France | - | Yes | Sustainability report is published but not yet in line with CSRD. | Climate: Reach net zero by 2050<br>Circularity: Prioritize waste prevention and reduction; Implement zero landfill policy; Recycle production scrap<br>Water Protection: Limit drinking water consumption to sanitary requirements<br>Biodiversity: Avoid, reduce and compensate the impact on biodiversity |
| | | Leclanché | Switzerland | Battery Recycling | No | Sustainability report is published but not yet in line with CSRD. | Climate: Reduce battery carbon footprint by 70% by 2027 (compared to standard battery); Use renewable electricity in production<br>Circularity: Increase recycled material usage in battery production; Track consumption in detail for resource management and waste minimization<br>Pollution: Improve emissions monitoring |

| Step | Description | Company | Location | Other Activities | CSRD Scope | Report Status | Sustainability Strategies & Details | |
|---|---|---|---|---|---|---|---|---|
| Battery Pack Assembly & e-Mobility Integration | Battery cells are mechanically and electrically integrated to form battery packs and integrated to vehicle chassis.<br>Europe was once leading producer, but since 2024 this position has weakened.<br>Major sustainability challenges are energy intensity and end-of-life treatment of batteries. | Volkswagen Group | Germany | Battery Cell Manufacturing<br>Recycling | Yes | Sustainability report is published and in line with CSRD. | Climate:<br><br>Water protection & Pollution:<br><br>Circularity: | Reach net zero by 2050<br>Reduce emissions of passenger cars in use phase by 30% by 2030 (compared to 2018)<br>Increase energy efficiency of production sites and achieve 4.9 million MWh/year energy saving by 2030<br><br>Treat water, air, soil properly to avoid damage to environment<br>Implement Zero Impact Factory strategic plan<br><br>Use at least 40% circular material in vehicle production from 2040 onwards<br>Introduce incentives for production sites to reduce volume of waste per vehicle |
| | | Stellantis | Netherlands | Battery Cell Manufacturing | Yes | Sustainability report is published and in line with CSRD. | Climate:<br><br>Water protection:<br><br>Biodiversity:<br><br>Circularity: | Reach carbon net zero by 2038<br>Switch to fully renewable electricity by 2038<br><br>Reduce water withdrawal and commit to responsible wastewater discharge<br><br>Contribute to wildlife and biodiversity conservation projects<br><br>Recover the total waste generated by 2050 |
| | | Renault Group | France | Lithium, Nickel and Cobalt mining and processing<br>Battery Recycling | Yes | Sustainability report is published and in line with CSRD. | Climate:<br><br>Circularity:<br><br>Biodiversity: | Achieve net zero in Europe by 2040 and globally by 2050<br><br>Reduce and implement eco-design principles<br>Recycle end-of-life vehicles<br><br>Prepare and implement biodiversity action plan<br>Cooperate with stakeholders for enhancement of biodiversity |

Altogether, the findings from REE for wind turbines and Li-ion battery value chains show how different sustainability practices evolve depending on market dynamics, regulations and maturity of the industrial ecosystem. The Li-ion battery value chain benefits from strong regulatory framework, market influence from e-mobility and more integrated European presence. These combine the favorable conditions for transparency, responsible sourcing and performance improvement. On the other hand, the upstream dependency of REE value chain on non-European suppliers and limited maturity of European projects lead to less disclosures and limited traceability. These differences highlight not only the uneven progress across the two value chains but also underline the challenges and opportunities. To capture the key similarities and differences between value chains, strengths, weaknesses, opportunities and threats (SWOT) analysis is implemented. Below tables summarize the results of SWOT analysis for both value chains.

Table 5: SWOT Analysis for European REE Wind Turbine Value Chain

| **Strengths** | **Weaknesses** |
|---|---|
| ▪ Growing support through the CRMA for new upstream projects<br>▪ Presence of strong European downstream actors with mature sustainability reporting and clear climate strategies<br>▪ High strategic relevance for Europe's renewable energy and decarbonization goals<br>▪ Emerging circularity and recycling initiatives within the value chain | ▪ Heavy dependence on non-EU suppliers, especially in upstream steps<br>▪ Fragmented upstream sustainability reporting with limited transparency<br>▪ Very limited European extraction and processing capacity for REE in Europe<br>▪ Lack of CSRD compliance for European upstream companies that are not yet subject to requirements<br>▪ Significant environmental impacts associated with REE mining (radioactive waste, tailings, water, etc.) |
| **Opportunities** | **Threats** |
| ▪ Expansion of European extraction, processing and magnet production capacity<br>▪ Increasing adoption and implementation of CSRD and ESRS<br>▪ Growing wind energy demand supporting development of European REE value chain<br>▪ Development of recycling and recovery infrastructure | ▪ Continued dominance of China in REE supply and processing<br>▪ Challenges in supply diversification<br>▪ Environmental and social concerns slowing approval of new European mining projects<br>▪ Geopolitical tension affecting global REE availability<br>▪ Limited recycling volumes and slow scaling of recovery technologies |

Table 6: SWOT Analysis for European Li-ion Battery Value Chain for e-mobility

| **Strengths** | **Weaknesses** |
| --- | --- |
| ▪ Established European presence across upstream and downstream activities<br>▪ Strong EU policy framework (EU Battery Regulation, CSRD, ESRS) driving transparency and performance<br>▪ High reporting maturity with well-developed sustainability strategies<br>▪ Downstream disclosure requirements pushing ambitious sustainability commitments across the value chain<br>▪ Availability of advanced recycling technology and growing infrastructure | ▪ Continued reliance on imported raw materials (no Li mining, minimal Co & Ni mining in Europe)<br>▪ Significant upstream environmental impacts requiring mitigation<br>▪ Complex global supply chains that hinder transparency<br>▪ Rapid demand growth potentially outpacing European domestic capacity expansion<br>▪ High production costs driven by labor, energy and regulatory compliance |
| **Opportunities** | **Threats** |
| ▪ Expansion of European upstream and midstream capacity supported by the CRMA<br>▪ Strong expectation of electric vehicle growth<br>▪ Reduction of import dependency and environmental impacts with recycling and circularity practices<br>▪ Technological innovation in battery chemistry and recycling efficiency<br>▪ Rising consumer expectations for sustainable mobility | ▪ Intense global competition for lithium, nickel and cobalt<br>▪ Price volatility of CRMs affecting long term planning<br>▪ Geopolitical tensions risking supply security<br>▪ Insufficient availability of CRMs to keep pace with the rapid growth, creating bottlenecks<br>▪ Battery production and charging infrastructure inefficiencies<br>▪ Strong cost competition from Asian battery manufacturers limiting Europe's ability to scale competitively |

## 10. Conclusion

Altogether, the pressures of climate change, the ambition to reach climate neutrality by 2050 and the strategic need to secure access to critical raw materials have significantly shaped the regulatory landscape in Europe to support the move towards decarbonization and industry resilience. Regulations such as European Climate Law, European Green Deal, Net Zero Industry Act, Critical Raw Materials Act and Corporate Sustainability Reporting Directive indicate the shift toward a more integrated approach that centers transparency, circularity and responsible sourcing. It is clear that Europe cannot reach climate neutrality or industrial resilience without deep transformation and commitment from industries, therefore as a start, it is essential to standardize the transparency approach on the sustainability performance of the companies. In this context, sustainability reports become a foundational tool for identifying value chain and sustainability risks and enabling structural changes required to secure commitment and resilience.

This thesis focuses on strategic sectors that will enable decarbonization of Europe's major industries, and among them e-mobility and wind turbines were selected as the main sectors. Similarly, lithium, cobalt, nickel and rare earth elements are selected as the main critical raw materials since they are indispensable for these two sectors, and represent raw materials with the highest import reliance, supply constraint and vulnerabilities along the value chains of the selected sectors. In this context, the sustainability reporting of the companies along Li-ion battery for e-mobility and REE permanent magnet wind turbine value chains was reviewed to identify risks and structural challenges to enable decarbonization and increase regional independence for the supply of the critical raw materials. By this, this thesis captures the steps of value chain where sustainability reporting is most needed and assesses the broader implications of the regulatory push.

For the analysis, many companies from the value chains of selected sectors were reviewed and 15 companies from REE permanent magnet wind turbine value chain and 20 companies from the Li-ion batteries for e-mobility value chain were selected. The selection was based on company size, presence of European operations, strong market presence and sustainability disclosures. With this approach, the main aim is to capture the overall sustainability strategies and gaps in the sector-wide value chains.

To guide the investigation, three research questions are formulated to capture the extent of corporate disclosure, the most relevant sustainability aspects, and the factors that shape differences in reporting behavior. These questions provide the analytical framework for interpreting the thesis findings and enable a structural assessment.

The first question asked whether companies operating in the selected value chains publish corporate sustainability reports or policies. The results show most companies publish sustainability information, but the level of detail varies significantly. Companies closer to end customer markets, especially in e-mobility value chain, tend to provide more structured and comprehensive reports. In contrast, upstream actors often disclose limited information or high-level policy statements rather than sustainability reporting. Another important factor shaping differences in upstream value chain reporting across sectors is the maturity and activity level of these steps. For REE, there are no fully operational rare earth processing or extraction sites in Europe, and the value chain depends on external suppliers until the facilities are extending their operations. Companies in REE upstream are either not yet fully developed and falling within the CSRD thresholds, or the activities take place in countries where reporting requirements differ and transparency expectations are lower. For lithium, cobalt and nickel, Europe hosts a small but growing number of extraction, refining and processing projects, and the companies active in these steps are mature and already subject to European regulations and stakeholder expectations. Overall, the current commitment level of sustainability reporting is significant, but still uneven. As upstream activities expand within Europe and value chain steps become less dependent on external suppliers, the level of transparency and consistency of sustainability reporting is expected to increase. Companies will become more committed and provide detailed reporting not only to meet regulatory requirements but also to support decarbonization and resilience of the value chains.

The second question examined the sustainability aspects addressed by companies across the selected value chain and the strategies commonly adopted. The analysis shows that ESRS already provides a clear structure for environmental topics and helps companies define their sustainability initiatives within these themes. Climate-related aspects, especially emission reduction and energy use, emerge as the most consistently reported themes across all companies in the value chain. However, most upstream companies reflect the risks most relevant to their activities and focus primarily on pollution prevention, biodiversity conservation and environmental compliance. Downstream companies closer to end customers emphasize circularity, recycling and responsible sourcing. Overall, sustainability aspects are widely acknowledged and ESRS implementation creates common ground across sectors. As the adoption of CSRD and ESRS becomes more widespread across European companies, sustainability strategies are expected to become more standardized, comparable and tangible. This will push companies toward clearer targets with measurable progress and more consistent reporting across all value chains.

The third research question explored how sustainability strategies differ across companies and supply chain stages, and which factors shape these differences. The analysis shows that reporting practices are strongly influenced by a company's position in the value chain, proximity to end-customer markets, and the regulations it must comply with. One of the most relevant findings is the clear difference in the level of adaptation and transparency of sustainability disclosures and reports across value chains. As Li-ion battery value chain serves a business-to-consumer (B2C)-oriented market, consumer expectations, brand reputation and public perception create strong motivation for companies to demonstrate sustainability commitment and transparency. Companies operating in B2C environments tend to invest more in sustainability reporting because their customers, investors and regulators expect it. This dynamic contributes to the comparatively higher maturity of sustainability disclosure observed in the Li-ion battery value chain for the e-mobility sector. In contrast, the REE value chain for wind turbines is based on business-to-business (B2B) relationships where consumer pressure to disclose sustainability information is weaker. Hence, as reflected in their reporting, many companies operating at upstream or midstream steps of the value chain provide limited sustainability information. The result is a fragmented landscape in which some companies provide detailed environmental data while others offer minimal information.

This structural difference between B2B and B2C markets helps to explain the uneven reporting maturity observed across the value chains.

Another factor contributing to the stronger sustainability commitment in the Li-ion battery value chain is the industry's structure. Many companies that operate in this value chain operate across multiple steps, such as extraction, refining and precursor production or battery manufacturing and recycling together, which creates a more interconnected landscape that strengthens sustainability commitments. Also, the EU Battery Regulation further reinforces this maturity by setting clear requirements for carbon footprint and circularity, pushing companies to be more transparent about their sustainability performance. Similar regulatory support might push the REE wind turbines value chain as it develops. With this, sustainability data availability, consistency and performance could be improved across upstream and midstream companies.

These differences in sustainability strategies between the two value chains are also reflected in the strategic targets assessment for extraction, processing, recycling and supply dependency. As shown in the figure below, the Li-ion battery value chain is generally well positioned to reach most of these targets with strong performance across all stages. This also aligns with the developed regulatory landscape, the maturity of the company operations across multiple value chain steps and the strong market pull from the e-mobility sector. On the other hand, rare earth value chain faces challenges as extraction capacity is below European targets, processing and recycling capabilities are still emerging, and the supply is mainly dependent. Together, these findings reinforce that regulatory pressure, market orientation and industrial maturity are key drivers of both sustainability transparency and progress towards EU industry resilience goals.

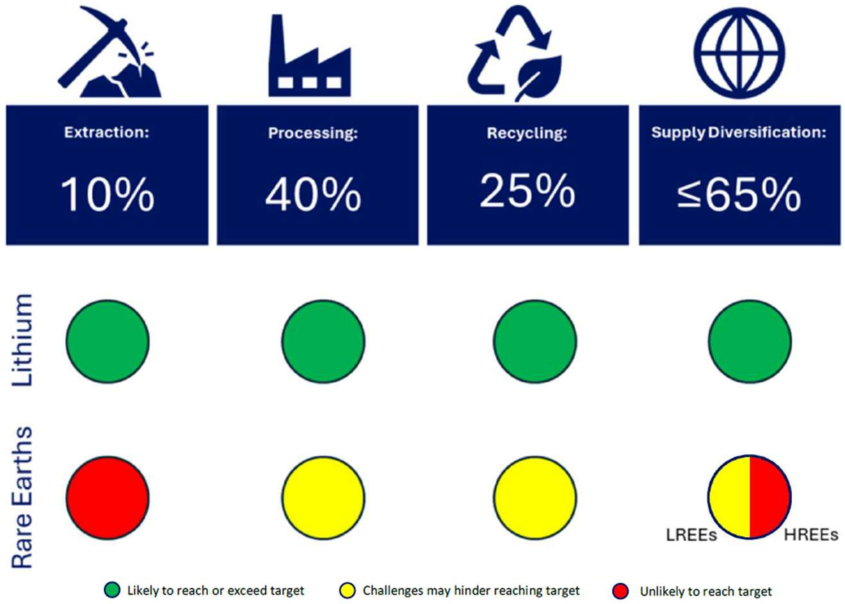


Figure 20: Expectations of CRMA Target Achievements for Lithium and REE (Adamas Intelligence Inc. and Tradium GmbH, 2024)

The findings of this thesis highlight that progress in sustainability reporting contributes significantly to the policy implementation needed to build resilient, accountable and climate-focused European value chains. The transition to climate-neutral and autonomous European industry depends on technological innovation, industrial capacity, and the transparency and responsibility of the value chains with critical raw materials. Therefore, sustainability reporting is a key enabler of this transition. As regulatory requirements tighten and industrial activities, especially upstream, expand within Europe, companies will be expected to provide clearer sustainability commitments, measurable progress and more consistent reporting. Strengthening these foundations is essential to ensure that both the REE wind turbine and Li-ion battery value chains are in line with the EU's climate ambitions and long-term economic resilience.

## 11. References


ACC Automotive Cells Co. (2025). *CSR Report 2024.*

ACC Automotive Cells Co. (2026). *Accelerating Sustainable Mobility for All*. Retrieved from ACC | About Us: https://www.acc-emotion.com/about-acc

Adamas Intelligence Inc. and Tradium GmbH. (2024). *Critical Raw Materials Act: Opportunities, Challenges, Viability, Next Steps*.

Alves Diaz, P., Bobba, S., Carrara, S., & Plazzotta, B. (2020). *The Role of Rare Earth Elements in Wind Energy and Electric Mobility*. Luxembourg: Publication Office of the European Union.

AMG Critical Materials N.V. (2025). *Annual Report 2024.* Amsterdam: AMG Critical Materials N.V.

AMG Lithium. (2025). *LiOH - Lithium Hydroxide*. Retrieved from AMG Lithium: https://amglithium.com/products/lithium-hydroxide

BASF. (2025). *2024 BASF Report*. BASF .

BASF. (2026). *About BASF Battery Materials*. Retrieved from BASF Battery Materials: https://battery-materials.basf.com/global/en/about-us

Boliden. (2025). *Annual and Sustainability Report 2024.* Stockholm: Boliden in cooperation with Narva Communications.

Boliden. (n.d.). *Nickel*. Retrieved from Boliden: https://www.boliden.com/products/our-products/nickel/

Britannica. (2013, September 5). *Nickel Processing*. Retrieved from Britannica: https://www.britannica.com/technology/nickel-processing

Cobalt Institute. (2025, July). *About Cobalt*. Retrieved from Cobalt Factsheet: https://www.cobaltinstitute.org/wp-content/uploads/2025/07/Cobalt-Factsheet_July-2025.pdf

Coint, N., Niiranen, T., & Sadeghi, M. (2024). *Nordic Mining Day 2024.* Retrieved from Rare Earth Elements in the Nordic Countries: https://www.gtk.fi/app/uploads/2024/03/Rare-Earth-Elements-in-the-Nordics-Nolwenn-Coint.pdf

Critical Metals Corp. (2026, January 30). *Austrian Government Extends Critical Metals Corp's Wolfsberg Mining License*. Retrieved from Critical Metals Corp: https://www.criticalmetalscorp.com/austrian-government-extends-critical-metals-corps-wolfsberg-mining-license/

EFRAG. (2025, November 30). *EFRAG Knowledge Hub*. Retrieved from https://knowledgehub.efrag.org/eng#draft-simplified-esrs-technical-advice-30-november-2025

EIT Raw Materials. (2021). *Rare Earth Magnets and Motors: A European Call for Action*. Retrieved from A report by the Rare Earth Magnets and Motors Cluster of the European Raw Materials Alliance: https://www.eit.europa.eu/sites/default/files/2021_09-24_ree_cluster_report2.pdf

EIT Raw Materials. (2025). *Recycling*. Retrieved from MagREEsource The green Rare Earth magnet Company: https://eitrawmaterials.eu/startups/magreesource

Eramet. (2023, December 7). *Geothermal lithium project in Alsace: where do we stand?* Retrieved from Eramet News: https://www.eramet.com/en/news/geothermal-lithium-project-in-alsace-where-do-we-stand/

Eramet. (2024, October 24). *Eramine, ReLieVe: discover the interview with Geoff Streeton*. Retrieved from Eramet News: https://www.eramet.com/en/news/eramine-relieve-interview-with-geoff-streeton/

Eramet. (2025). *Universal Registration Document 2024.* Paris: Labrador.

Eramet. (2026a). *Eramet, Europe's leading producer of battery-grade lithium*. Retrieved from Eramet Activities: https://www.eramet.com/en/activities/products/lithium/

Eramet. (2026b). *Eramet, a leader in the nickel market*. Retrieved from Eramet Activities: https://www.eramet.com/en/activities/products/nickel/

Eurobattery Minerals . (2026, January 15). *Eurobattery Minerals submits CRMA Strategic Project applications for San Juan and Hautalampi*. Retrieved from Eurobattery Minerals | Investors: https://investors.eurobatteryminerals.com/en/press-releases/eurobattery-minerals-submits-crma-strategic-project-applications-for-san-juan-and-hautalampi/

Eurobattery Minerals. (n.d.). *Sustainability*. Retrieved from Eurobattery Minerals Investors: https://investors.eurobatteryminerals.com/en/sustainability/

European Commission. (2018). *Commission Staff Working Document: Report on Raw Materials for Battery Applications.* Brussels.

European Commission. (2019). *European Green Deal*. Retrieved from https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

European Commission. (2021, July 29). *European Climate Law*. Retrieved from https://climate.ec.europa.eu/eu-action/european-climate-law_en

European Commission. (2022a). *RMIS - Raw Materials Information System*. Retrieved from Raw Materials Profiles - Cobalt: https://rmis.jrc.ec.europa.eu/rmp/Cobalt

European Commission. (2022b). *RMIS - Raw Material Information System*. Retrieved from Raw Materials Profiles - Nickel: https://rmis.jrc.ec.europa.eu/rmp/Nickel

European Commission. (2022c). *RMIS – Raw Materials Information System*. Retrieved from Raw Materials Profiles - Lithium: https://rmis.jrc.ec.europa.eu/rmp/Lithium

European Commission. (2023a, February). *Green Deal Industrial Plan*. Retrieved from https://commission.europa.eu/topics/competitiveness/green-deal-industrial-plan_en

European Commission. (2023b). *Critical Raw Materials*. Retrieved from https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en#the-methodology-to-identify-crms

European Commission. (2023c). *Study on the Critical Raw Materials for the EU*. Luxembourg: Publications Office of the European Union.

European Commission. (2024a, June 13). *The Net-Zero Industry Act*. Retrieved from https://commission.europa.eu/topics/competitiveness/green-deal-industrial-plan/net-zero-industry-act_en

European Commission. (2024b, April 11). *European Critical Raw Materials Act*. Retrieved from https://commission.europa.eu/topics/competitiveness/green-deal-industrial-plan/european-critical-raw-materials-act_en

European Commission. (2024c, August 7). *Shaping Europe's digital future*. Retrieved from The Digital Economy and Society Index (DESI): https://digital-strategy.ec.europa.eu/en/policies/desi

European Commission. (2024d). *RMIS - Raw Materials Information System*. Retrieved from https://rmis.jrc.ec.europa.eu/critical-and-strategic-materials

European Commission. (2025a). Retrieved from Space: https://commission.europa.eu/topics/space_en

European Commission. (2025b). *Strategic Projects under the Critical Raw Materials Act*. Retrieved from Strategic Raw Materials Lithium - Battery Grade: https://webgate.ec.europa.eu/circabc-ewpp/d/d/workspace/SpacesStore/760da134-e3de-4421-a3d4-751cbea62e9a/download

European Commission. (2025c, December 17). *Finance*. Retrieved from EU taxonomy for sustainable activities: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

European Commission Joint Research Centre. (2020). *Critical Raw Materials for Strategic Technologies and Sectors in the EU: A Foresight Study*. Luxembourg: Publications Office of the European Union.

European Commission Joint Research Centre. (2023). *Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU: A Foresight Study*. Luxembourg: Publications Office of the European Union.

European Commission Joint Research Centre. (2025). *Deep Dive on Critical Raw Materials for Wind Turbines in the EU*. Luxembourg: Publications Office of the European Union.

European Commission. (n.d.). *Rare earth elements, permanent magnets, and motors*. Retrieved from https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/rare-earth-elements-permanent-magnets-and-motors_en#:~:text=Rare%20earth%20elements%20are%20a,LEDs%2C%20electric%20motors%20and%20more.

European Commission. (n.d.). *RMIS - Raw Material Information System*. Retrieved from Raw Materials in the Battery Value Chain: https://rmis.jrc.ec.europa.eu/bvc#/

European Environment Agency (EEA). (2025). *Trends and projections in Europe 2025*. Luxembourg: Publications Office of the European Union.

European Federation for Transport & Environment. (2024a). *Briefing Unlocking lithium's potential How to do it sustainably in Europe*.

European Federation for Transport & Environment. (2024b). *An industrial blueprint for batteries in Europe: How Europe can successfully build a sustainable battery value chain*.

European Lithium. (2023). *Wolfsberg Lithium Project Definitive Feasibility Study* . European Lithium.

European Union. (2024). *Implementing the EU's Critical Raw Material Act*. European Parliamentary Research Service.

European Union. (2025, June). *Strategic Technologies for Europe Platform*. Retrieved from https://strategic-technologies.europa.eu/about/step-nutshell_en

Fraunhofer ISI. (2023). *Lithium-Ion Battery Roadmap – Industrialization Perspectives Toward 2030*. Karlsruhe: Fraunhofer Institute for Systems and Innovation Research ISI.

Fraunhofer ISI. (2025, March 13). *Battery materials: Market leaders, technologies and costs*. Retrieved from Blog | Battery Update: https://www.isi.fraunhofer.de/en/blog/themen/batterie-update/batterie-materialien-kosten-technologien-markt-fuehrer.html?utm_source=copilot.com

Glencore. (2025). *2024 Annual Report*. Baar: Glencore.

Glencore. (2026). *What we do: Metals and Minerals*. Retrieved from Glencore: https://www.glencore.com/what-we-do/metals-and-minerals

Heraeus . (2025). *Sustainability Report 2023 - 2024*. Hanau: Heraeus Business Solutions GmbH.

Heraeus Remloy . (2026). *About Us*. Retrieved from Get to Know Heraeus Remloy: https://www.heraeus-remloy.com/en/about-us/

High-Level Group on Energy Intensive Industries. (2019). *Masterplan for a Competitive Transformation of EU Energy-intensive Industries Enabling a Climate-neutral Circular Economy by 2050*. Luxembourg: Publications Office of the European Union.

IBU Tec. (2025). *Annual Report 2024*. Weimar: IBU-tec advanced materials AG.

IBU Tec. (n.d.). *IBU-tec Battery Materials & Products*. Retrieved from IBU Tec Products: https://www.ibu-tec.com/products/

International Energy Agency. (2025a). *Global Critical Minerals Outlook 2025*. IEA.

International Energy Agency. (2025b). *Global EV Outlook 2025*. IEA Publocations.

International Energy Agency. (2025c, October 23). *With new export controls on critical minerals, supply concentration risks become reality*. Retrieved from https://www.iea.org/commentaries/with-new-export-controls-on-critical-minerals-supply-concentration-risks-become-reality

International Renewable Energy Agency (IRENA). (2020). *Reaching Zero with Renewables: Eliminating CO2 emissions in industry and transport*. Abu Dhabi: International Renewable Energy Agency.

IPCC. (2022, April 4). *The evidence is clear: the time for action is now. We can halve emissions by 2030*. Retrieved from IPCC: https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/

Krishnan, R., & Gopan, G. (2024). A comprehensive review of lithium extraction: From historical perspectives to emerging technologies, storage, and environmental considerations. *Cleaner Engineering and Technology*.

Leading Edge Materials. (2025a). *EUROPEAN CRITICAL RAW MATERIALS PROJECTS*. Retrieved from Nora Kärr HREE: https://www.leadingedgematerials.com/projects

Leading Edge Materials. (2025b, October). *Company Presentation*. Retrieved from Building Critical Supply Chains in Europ: https://www.leadingedgematerials.com/_files/ugd/f9767f_cfce986dce6646c0a20673d3a72153f0.pdf

Leading Edge Materials. (2025c, December 14). *News & Media*. Retrieved from LEADING EDGE MATERIALS ACCEPTED AS A PROJECT PARTNER BY EIT RAWMATERIALS: https://www.leadingedgematerials.com/_files/ugd/f9767f_cf15b974f8f443e5a53aa5310725619c.pdf

Leclanché. (2024). *About Us*. Retrieved from Leclanché Energy Storage Solutions: https://www.leclanche.com/about-us/

Leclanché. (2025). *Sustainability Report 2024 - Non-Financial Report*.

Less Common Metals. (n.d.). *About Us*. Retrieved from https://lesscommonmetals.com/about-us/

LKAB. (2023, January 12). *Europe's largest deposit of rare earth metals located in Kiruna area*. Retrieved from https://lkab.com/en/press/europes-largest-deposit-of-rare-earth-metals-is-located-in-the-kiruna-area/

LKAB. (2025a, January 28). *LKAB constructs facility for critical minerals – the first of its kind in Europe*. Retrieved from https://lkab.com/en/press/lkab-constructs-facility-for-critical-minerals-the-first-of-its-kind-in-europe/

LKAB. (2025b). *LKAB Annual and Sustainability Report 2024*. Sweden: LKAB.

Magneti Ljubljana d.d. (2025, May 15). *Newsletter - Carbon Footprint Declaration*. Retrieved from Our Commitment to Reducing Carbon Intensity: https://www.magneti.si/wp-content/uploads/2025/05/NEWSLETTER-CARBON-FOOTPRINT-DECLARATION-Magneti-Ljubljana-d.d.-16.5.2025.pdf

Magneti Ljubljana d.d. (n.d.). *Company*. Retrieved from https://www.magneti.si/en/company/

MagREEsource. (n.d.). *About Us*. Retrieved from https://www.magreesource.com/sell-your-scraps

Neo Performance Materials. (2024). *Sustainability Report 2023*. Retrieved from https://www.neomaterials.com/wp-content/uploads/2024/11/NPM_SustainabilityReport_2023_small.pdf

Neo Performance Materials. (2025, September 18). *Investor Day*. Retrieved from Solving Critical Materials Supply for Future Facing Technologies: https://www.neomaterials.com/wp-content/uploads/2025/09/Neo-Estonia-Investor-Day-September-2025.pdf

Neorem Magnets. (2026a). *A Vital Magnet Company*. Retrieved from Your European Partner in High-Quality Permanent Magnets: https://neorem.fi/company/

Neorem Magnets. (2026b). *Neorem's Expertise in Magnetism*. Retrieved from Quality: https://neorem.fi/neorem-expertise/

Nikkelverk. (2025). *ESG Rapport 2024*. Kristiansand: Glencore Nikkelverk AS.

Nobian. (2022, January 11). *Nobian and Vulcan sign agreement for unique lithium project to supply European EV-battery production*. Retrieved from Nobian News: https://www.nobian.com/news/nobian-and-vulcan-sign-agreement-for-unique-lithium-project-to-supply-european-ev-battery-production

Nobian. (2025a, July 10). *Nobian joins forces with Veolia to advance lithium production for batteries*. Retrieved from Nobian News: https://www.nobian.com/news/nobian-joins-forces-with-veolia-to-advance-lithium-production-for-batteries

Nobian. (2025b). *Sustainability Report 2024*. Amersfoort: Nobian Industrial Chemicals B.V.

Nobian. (2026). *Our sustainability reporting*. Retrieved from Nobian Sustainability: https://www.nobian.com/sustainabillity/sustainability-reporting

Nordex. (2025). *Annual Integrated Report 2024*. Hamburg: Nordex SE Investor Relations.

Nordex Group. (2026). *At a Glance*. Retrieved from https://ir.nordex-online.com/at-a-glance

Nornickel. (2025). *Annual Report 2024*. Moscow: MMC Norilsk Nickel.

Nornickel. (2026). *Meet Nornickel*. Retrieved from Nornickel About: https://nornickel.com/company/about/

Nornickel Harjavalta. (n.d.). *Environmental matters are*. Retrieved from Nornickel Harjavalta The Environment: https://www.nornickel.fi/en-gb/responsibility/the-environment

Nornickel Harvalta. (n.d.). *Nornickel Harvalta* . Retrieved from Nornickel Harvalta : https://www.nornickel.fi/en-gb/our-products

Rare Earths Norway. (2024, June 6). *Press release from Rare Earths Norway AS*. Retrieved from Europe's largest deposit of rare earth elements discovered at Fen, Norway: https://rareearthsnorway.com/europes-largest-deposit-of-rare-earth-elements-discovered-at-fen-norway

Rare Earths Norway. (n.d.). *Sustainability*. Retrieved from https://rareearthsnorway.com/our-project/sustainability

REIA. (2023, September 19). *News*. Retrieved from Magneti Ljubljana Joins the Global Rare Earth Industry Association: https://global-reia.org/reia-news/magneti-ljubljana-joins-the-global-rare-earth-industry/

Renault Group. (2023, May 16). *Building a European Battery Industry*. Retrieved from https://assets.renaultgroup.com/uploads/2024/10/battery-day-exane-bnp_vdef.pdf

Renault Group. (2025). *Universal Registration Document 2024 Including the Annual Report*. Boulogne-Billancourt.

Renault Group. (2026). *Towards a next-generation automotive company*. Retrieved from Renault Group: https://www.renaultgroup.com/en/group/

Righetti, E., & Rizos, V. (2024). *Reducing Supply Risk for Critical Raw Materials: Evidence and Policy Options*. Brussels: CEPS.

Saegert, J., Witni, V., & Nerreter, M. (2022). *Nickel for the Energy Transition*. Bonn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Sibanye Stillwater. (2025a, October). *Investor factsheet*. Retrieved from About Sibanye-Stillwater: https://thevault.exchange/?get_group_doc=245%2F1759495791-ssw-corporate-fact-sheet-2025-10-01.pdf

Sibanye Stillwater. (2025b). *Keliber lithium project*. Retrieved from Sibanye Stillwater: https://www.sibanyestillwater.com/business/europe/keliber/

Sibanye Stillwater. (2025c). *Combined Integrated Report*. Sibanye Stillwater.

Sibanye Stillwater. (2026a, January 19). *Sibanye-Stillwater update on the Keliber lithium project*. Retrieved from Sibanye Stillwater: https://thevault.exchange/?get_group_doc=245%2F1768830824-LogoSibanye-StillwaterupdateontheKeliberlithiumproject19-01-2026.pdf

Sibanye Stillwater. (2026b). *Sandouville*. Retrieved from Sibanye Stillwater: https://www.sibanyestillwater.com/business/europe/sandouville/

Siemens Energy. (2025). *Annual Report 2025*. München.

Siemens Energy. (2026). *Our Commitment to Decarbonization*. Retrieved from We have set ambitious decarbonization targets across the entire value chain: https://www.siemens-energy.com/global/en/home/company/sustainability/decarbonization-goals-commitments.html

Siemens Gamesa. (2025a). *Wind power business*. Retrieved from Our products and services: https://www.siemensgamesa.com/global/en/home/products-and-services.html

Siemens Gamesa. (2025b). *Sustainability Information*. Retrieved from Action to deliver a fully recyclable turbine by 2040: https://www.siemensgamesa.com/global/en/home/sustainability.html

Solutions for Critical Raw Materials - a European Expert Network (SCRREEN). (2020a). *Cobalt Factsheet*. SCRREEN.

Solutions for Critical Raw Materials - a European Expert Network (SCRREEN). (2020b). *Nickel Factsheet*. SCRREEN.

Solvay. (2025a). *Sustainability*. Retrieved from Our Sustainability Program: https://www.solvay.com/en/sustainability

Solvay. (2025b). *Annual Integrated Report 2024*. Cousto: Solvay Communications.

Stellantis N.V. (2025). *Annual Report for the year ended December 31, 2024*. Amsterdam.

Strategic Energy. (2025, May 19). *Top 15 wind turbine manufacturers in 2024: China dominates the top 4, and Vestas holds its ground in the top 5*. Retrieved from https://strategicenergy.eu/turbine-manufacturers/

Terrafame. (2025). *Sustainability Report 2024*. Terrafame.

Terrafame. (n.d.). *Battery Chemicals*. Retrieved from Terrafame: https://www.terrafame.com/offering/battery-chemicals.html

The Assay. (2025, December). *European Lithium Hit By Austrian Court Ruling As Wolfsberg Permit Annulled*. Retrieved from The Assay Mining Investment news, insights and company profiles: https://www.theassay.com/news/european-lithium-hit-by-austrian-court-ruling-as-wolfsberg-permit-annulled/

Treibacher Industrie AG. (2025). *Sustainability Report 2023 | 2024*. Althofen.

Treibacher Industrie AG. (n.d.). *Company*. Retrieved from https://treibacher.com/en/company/

Umicore. (2023, March 21). *Umicore accelerates European E-Mobility with Nysa Gigafactory*. Retrieved from Umicore News: https://www.umicore.com/en/media/newsroom/umicore-accelerates-european-e-mobility-with-nysa-gigafactory/

Umicore. (2025). *Annual Report 2024*. Brussels: Umicore.

Umicore. (2026). *Cobalt and nickel precursors*. Retrieved from Umicore Battery Materials: https://www.umicore.com/en/markets-products/automotive-mobility/battery-materials/cobalt-nickel-precursors/

UNFCCC. (2015). *United Nations Climate Change*. Retrieved from Process and Meetings: The Paris Agreement: https://unfccc.int/process-and-meetings/the-paris-agreement

United Nations. (2024, July 11). *UN projects world population to peak within this century*. Retrieved from United Nations Department of Economic and Social Affairs: https://www.un.org/en/UN-projects-world-population-to-peak-within-this-century

United Nations Department of Economic and Social Affairs. (2015). Retrieved from The 17 Goals: https://sdgs.un.org/goals

United Nations University. (2025, July 24). *What is Earth Overshoot Day and Why does it Matter?* Retrieved from UNU Institute for Environment and Human Security: https://unu.edu/ehs/article/what-earth-overshoot-day-and-why-does-it-matter

VACuumschmelze. (2023). *Sustainability*. Retrieved from A Statement for Sustainability: https://vacuumschmelze.com/01_Pictures/Sustainability/VAC%20Sustainability%20Statement.pdf

VACuumschmelze. (2025, October 29). *Newsroom*. Retrieved from VACUUMSCHMELZE Commits to Science Based Targets - Ambitious Decarbonization Strategy on the Path to Net Zero by 2050:

https://vacuumschmelze.com/Newsroom/vacuumschmelze-commits-to-science-based-targets-ambitious-decarbonization-strategy-on-the-path-to-net-zero-by-2050-n2850

VACuumschmelze. (n.d.). *About Us*. Retrieved from VACUUMSCHMELZE is a Leading Manufacturer of Magnetic Materials and Solutions: https://vacuumschmelze.com/company/about-us

Verkor. (2025). *Sustainability Report 2024*.

Verkor. (2026a). *A future-focused company project*. Retrieved from Verkor Ambition: https://verkor.com/en/ambition/

Verkor. (2026b). *A consortium of leading industrial players*. Retrieved from Verkor | Partners: https://verkor.com/en/the-team/our-partners/

Vestas. (2025). *This is Vestas*. Retrieved from The global leader in sustainable energy solutions: https://www.vestas.com/en/about/this-is-vestas

Vestas Wind Systems A/S. (2026). *Annual Report 2025*. Aarhus: Vestas Wind Systems A/S.

Volkswagen Group. (2025). *Annual Report 2024*. Wolfsburg: Volkswagen AG Group Financial Publications.

Volkswagen Group. (2026). *Group*. Retrieved from About Us: https://www.volkswagen-group.com/en/group-15765

Vulcan Energy. (2025a). *Phase One Lionheart Project*. Retrieved from https://v-er.eu/phase-one-lionheart/

Vulcan Energy. (2025b). *Sustainable Lithium*. Retrieved from Providing a domestic and sustainable supply of lithium: https://v-er.eu/sustainable-lithium/

Vulcan Energy. (2025c). *Sustainability Report 2024*. Vulcan Energy.

Wang, S., Fu, Y., He, D., & Wang, T. (2025, November 19). Comprehensive review of mineral processing and metallurgical technologies for cobalt ores. *Minerals Engineering*.

World Nuclear Association. (2026, January 20). *Uranium from Rare Earth Deposits*. Retrieved from https://world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/uranium-from-rare-earths-deposits