BRINGING BATTERIES PRODUCTION TO EUROPE – IN A GREEN AND RESPONSIBLE WAY

HOW THE EU CAN DEVELOP A WORLD CLASS BATTERY INDUSTRY IN AN ENVIRONMENTALLY RESPONSIBLE WAY.

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FOREWORD

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In an era defined by the urgency to combat climate change, the European Union (EU) stands at a pivotal juncture, tasked with the formidable challenge of fostering green growth within its burgeoning battery industry. The report before you illuminates a comprehensive analysis conducted to chart a course toward a best in class battery sector, one that aligns with the EU's ambitious environmental and sustainability goals.

As the demand for batteries, particularly in the realm of transportation, is poised for exponential growth until 2030, the EU has responded with regulations such as the Critical Raw Materials Act (CRMA) and the Net-Zero Industry Act (NZIA), set to come into force in early 2024.

This analysis delves into the environmental and climate implications of achieving key benchmarks outlined in the CRMA and NZIA, focusing on refining raw minerals within the EU and increasing battery manufacturing on European soil. The results presented are both enlightening and challenging, urging the EU to strategically position itself in the global battery landscape. Relocating parts of the battery supply chain to Europe not only supports strategic autonomy but also provides a unique opportunity to exert control over production parameters, aligning them with the EU's rigorous environmental and climate policies. The insights gleaned from this analysis reveal a shifting landscape in battery chemistries, with a move towards lithium iron phosphate (LFP) and other cobalt and nickel-free alternatives. However, challenges arise in meeting the CRMA benchmark of refining 40% of raw materials within the EU, necessitating a careful consideration of environmental implications.

The report underscores the critical role of EU regulations in mitigating environmental impacts, particularly in the refining of key minerals like cobalt and nickel. As the EU advances its Green Deal, WWF offers key recommendations aimed at bolstering the sustainability of the battery industry. From defining stringent carbon threshold categories to incentivizing renewable energy use in battery production, WWF advocates for a holistic approach that aligns technological advances with demand reduction strategies. Crucially, the report advocates for robust EU legislation, emphasizing that strong, stringent regulations are fundamental to realizing the potential for responsible batteries. In the pursuit of green growth, it is imperative that environmental considerations take precedence, ensuring that the CRMA does not compromise existing environmental legislation and due diligence obligations. The path to a best-in-class battery value chain requires a harmonious blend of technological innovation, stringent regulations, and an unwavering commitment to sustainability.

As the EU navigates this transformative journey, the insights and recommendations outlined in this report serve as a guiding light, urging policymakers, industry stakeholders, and citizens alike to collectively forge a path towards a greener, more sustainable future.

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LIST OF ABBREVIATIONS

CO_2 eq	CO_2 equivalents
CRMA	Critical Raw Materials Act
CSDDD	Corporate Sustainability Due Diligence Directive
BEV	Battery Electric Vehicles
ECF	European Climate Foundation
EoL	End of life
ESG	Environmental, Social and Corporate Governance
ESS	Energy Stationary Storage
EU	European Union
GHG	Greenhouse Gas
GWh	Gigawatt hours
GWP	Global Warming Potential
ICE	Internal Combustion Engine
IEA	International Energy Agency
ILCD	International Reference Life Cycle Data System
IRMA	International Responsible Mining Assurance
LCA	Life Cycle Analysis
LFP	Lithium Iron Phosphate
LIB	Lithium Ion Battery
Mt	Million tonne
NCA	Lithium Nickel Cobalt Aluminium Oxide
NECD	National Emission Reduction Commitments Directive
NMC	Lithium Nickel Manganese Cobalt Oxide
NZIA	Net Zero Industry Act
PM	particulate matter
PPA	Power Purchase Agreement
SIB	Sodium Ion Battery

EXECUTIVE SUMMARY

This analysis was conducted to examine the environmental and climate implications of achieving the benchmarks stipulated by the CRMA and NZIA, specifically of two elements: first the aim to refine 40% of the raw minerals within the EU, and second, to increase battery manufacturing in Europe. Relocating parts of the battery supply chain, apart from supporting strategic autonomy goals, offers the **EU the possibility to control production parameters – including social and environmental – within its borders and to apply its ambitious environmental and climate policies to set the highest global standards for sustainable battery production**, compatible with the Paris Agreement and also with the Global Biodiversity Framework.

RELOCATING PARTS OF THE BATTERY SUPPLY CHAIN OFFERS THE EU THE POSSIBILITY TO CONTROL PRODUCTION PARAMETERS - INCLUDING SOCIAL AND ENVIRONMENTAL - WITHIN ITS BORDERS AND TO APPLY ITS AMBITIOUS ENVIRONMENTAL AND CLIMATE POLICIES TO SET THE HIGHEST GLOBAL STANDARDS FOR SUSTAINABLE BATTERY PRODUCTION.

The analysis shows the following results for the processing and battery manufacturing sector in Europe:

- Shift from NMC and NCA batteries to LFP battery chemistries - with a less pronounced demand of cobalt and nickel.
- Necessity to relocate refining and processing capacities to Europe - only 180 kt of battery materials refining and processing could be reached by 2030 - a shortfall of 380 kt to fulfil the CRMA benchmark of 40%.
- 9.5 million tonnes CO_2 eq per year from ICE vehicles could be displaced by securing the production of 6.7 million passenger BEVs.
- Depending on the origin of raw materials, GHG emissions from lithium and nickel refinery in the EU can vary by a factor of 5.
- Environmental impacts of refining key minerals need to be mitigated by EU regulations - cobalt and nickel implicate the greatest potential of local environmental impact.
- Shifts in the mix of battery chemistries will have a limited effect on overall emissions by 2030.

The EU, pushing forward with the implementation of the Green Deal, has proposed and is bringing into force an increasing number of legal instruments designed to ensure the sustainability of products and supply chains. From an environmental and global sustainable development perspective, to support the EU's aim to install capacity for refining at least 40% of its transition materials in an environmentally responsible way, WWF recommends the following:

- **Battery regulation:** WWF recommends defining the maximum carbon threshold categories of the performance classes as low as possible to push battery producers and stakeholders in the battery value chain in Europe towards the use of green electricity.
- **Critical Raw Materials Act:** Instead of prescribing blanket benchmarks for relocating production processes to the EU, WWF recommends for policymaker to consider fact-based assessments of the potential environmental implications of the types of ore imported for further processing.
- WWF recommends that technological advances need to go hand in hand with demand reduction for transition materials. Resource reduction targets needs to be implemented in EU Green Deal policies and needs to foster innovation encouraging the designs that require fewer resources to provide similar services.
- WWF recommends that key EU environmental policies are strong, stringent and are kept updated and aligned with the requirements of the CRMA and that the CRMA does not provide any leeway for overriding environmental legislation, or for sidestepping environmental and social corporate due diligence obligations, such as environmental impact assessments.

1. INTRODUCTION

The drive to decarbonise economies is provoking a major shift in global energy systems towards clean energy. The transportation sector currently contributes about one quarter of global greenhouse gas (GHG) emissions (UN 2021). However, this sector is undergoing disruptive changes. Battery electric vehicle (BEV) markets are growing exponentially, with a share of 14% of all new car sales in 2022, up from around 9% in 2021 and less than 5% in 2020 (IEA 2023), and this trend is projected to continue. The International Energy Agency (IEA) predicts that in 2030, globally, 35% of all new cars sold will be electric (IEA 2023). In the EU, BEVs will capture 62 to 86% of the passenger car market by 2030 (RMI 2023). Battery production relies on so-called energy-mobility transition materials (hereafter referred to as transition materials) such as lithium, nickel, cobalt, manganese and graphite, and demand for these is equally projected to increase over the next years (IEA 2021, ETC 2023).

As BEV demand increases, governments are seeking to position themselves in global car and battery supply chains, with the aim to secure supply of transition materials, reduce reliance on imports and increase domestic battery production capacity (IEA 2023). Within the framework of the European Green Deal, alongside the Net Zero Industry Act (NZIA), the European Union (EU) proposed the Critical Raw Materials Act (CRMA) in 2023, which aims to achieve an extraction capacity of 10% of the EU's annual consumption of transition materials, a processing capacity for 40%, and recycling capacity for 15% by 2030 (European Parliament 2023a). The CRMA will be voted, published and enacted in Spring 2024. The general consensus is that the stated benchmarks are unlikely to be met for all transition materials.

This report summarises the results of an analysis of the potential environmental impacts from the refining of battery materials and manufacturing of different battery chemistries in the EU, under consideration of the requirements of the CRMA for domestic production capacities. The aim is to answer the question of what impact the predicted 40% processing capacity in Europe could have on the climate and the environment.

This analysis can be seen in the context of a larger project commissioned by WWF on the battery value chain in Europe and funded by the European Climate Foundation (ECF). The aim of the project is to analyse the environmental impacts of the entire value chain of battery production for the European market and to identify ways of minimising them. The analysis for this part of the project was done by Systemiq.

The battery value chain consists of five main steps: mining, processing and refinement, active material and precursor production, cell production and module and system production. This first report focuses on the processing and refinement steps of the value chain. In the next project step, the value chain segments of mining and recycling of end-of-life (EoL) batteries will be analysed in more detail.

Results are presented in sections 2 to 4. Section 2 shows the expected demand for transition materials for electric vehicle battery production in the EU until 2030. In Section 3, environmental impacts of processing and refining transition materials for batteries in the EU are analysed. Section 4 compares GHG emissions from manufacturing processes of different battery chemistries and introduces leverage possibilities for reducing the climate impact of batteries produced and sold in the EU. **Section 5 discusses the results, including the presented policy instruments, and draws conclusions to ensure a high standard of environmental performance for battery production within the EU.**

IN THE EU, BEVS WILL CAPTURE
62 TO 86%
OF THE PASSENGER CAR MARKET BY 2030.

2. EU BATTERY AND TRANSITION MATERIALS OVERVIEW AND 2030 FORECAST

Until 2030, lithium-ion battery chemistries are likely to remain the economically and energetically most viable energy storage solutions. The European demand for energy storage by BEVs and energy stationary storage (ESS) lithium-ion batteries (LIBs) is expected to grow from 195 GWh per year to 1,050 GWh annually in 2030 (T&E 2023) (see fig. 1).

Figure 1: EU battery demand forecast for BEV and ESS application (GWh p.a.)

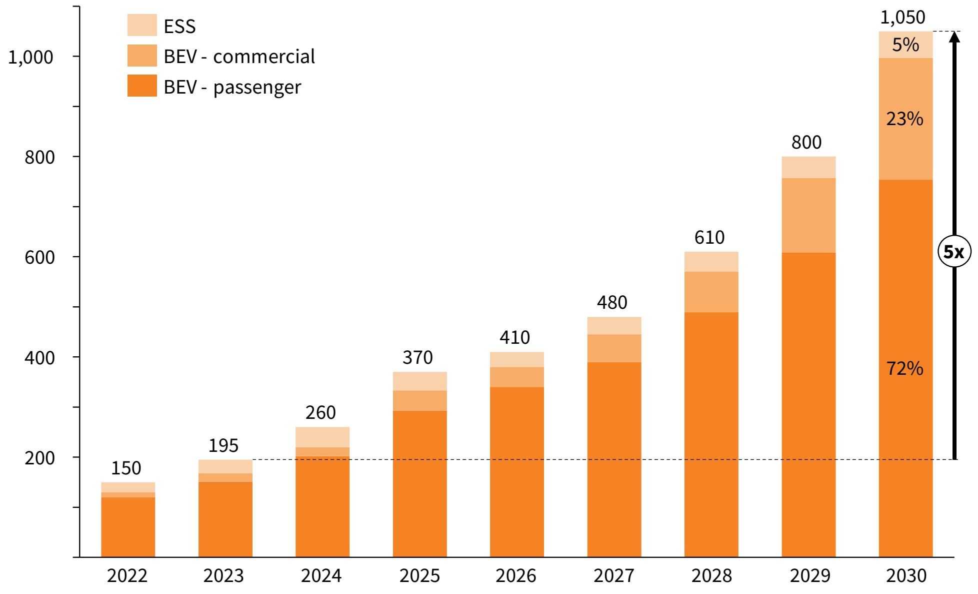

Fig. 1: EU battery demand forecast for BEV and ESS application (GWh/a) until 2030. ESS= Energy Stationary Storage; BEV= Battery Electric Vehicle. *Sources: Systemiq analysis; T&E (2023), IEA (2023).*

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2030
LITHIUM-ION BATTERY CHEMISTRIES ARE LIKELY TO REMAIN THE ECONOMICALLY AND ENERGETICALLY MOST VIABLE ENERGY STORAGE SOLUTIONS.

KEY RESULT 1: SHIFT FTROM NMC AND NCA TO LFP BATTERY CHEMISTRIES AND ITS IMPLICATIONS FOR TRANSITION MATERIALS DEMAND

Currently, Lithium Nickel Manganese Cobalt Oxide (NMC) batteries dominate the market, followed by Lithium Iron Phosphate (LFP) and Lithium Nickel Cobalt Aluminium Oxide (NCA) batteries (IEA 2023). By 2030, the EU is expected to ramp up production capacities for LFP, NMC, NCA and SIB batteries to around 1,200 GWh per year[1]. The European annual demand for lithium-ion batteries (LIBs) by BEVs and energy stationary storage (ESS) is expected to grow for the different battery chemistries (see fig. 2).

Battery chemistries such as NMC and NCA are decreasing in popularity due to their dependence on cobalt and nickel and price fluctuations as well as ethical mining concerns surrounding these minerals. Market shares of NMC and NCA batteries will decline from 85% in 2022 to 33% in 2030 because of the large environmental burden of nickel and cobalt mining and exposure to price volatility of lithium, cobalt, and nickel. By 2030, LFPs will experience a 17-fold increase in demand, growing its market share from 15% in 2022 to 35% and replacing NMC as the market leader (see fig. 3).

Figure 2: **Annual EU demand for LIB cathode chemistries (GWh)**

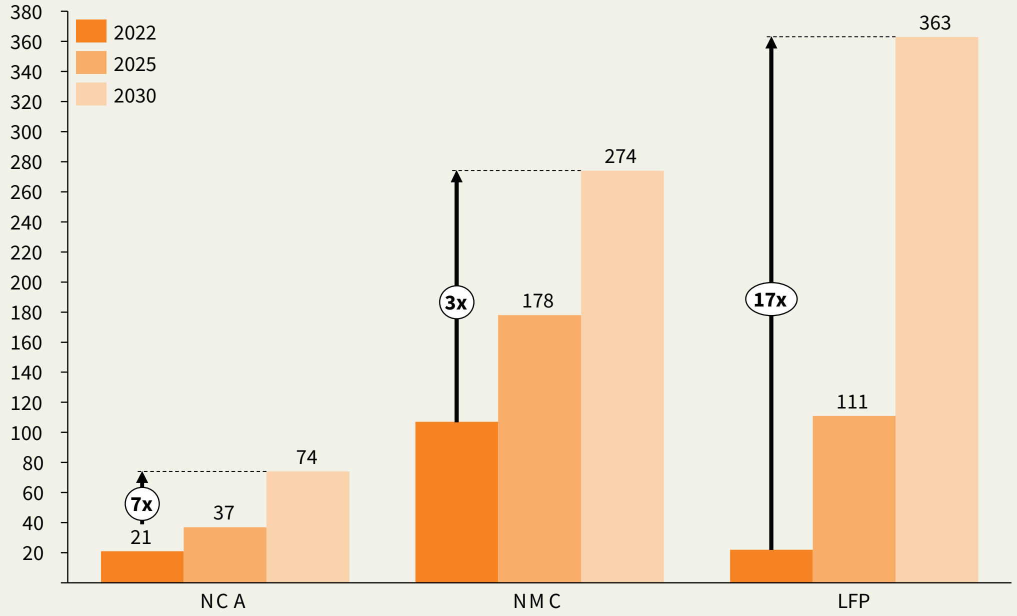
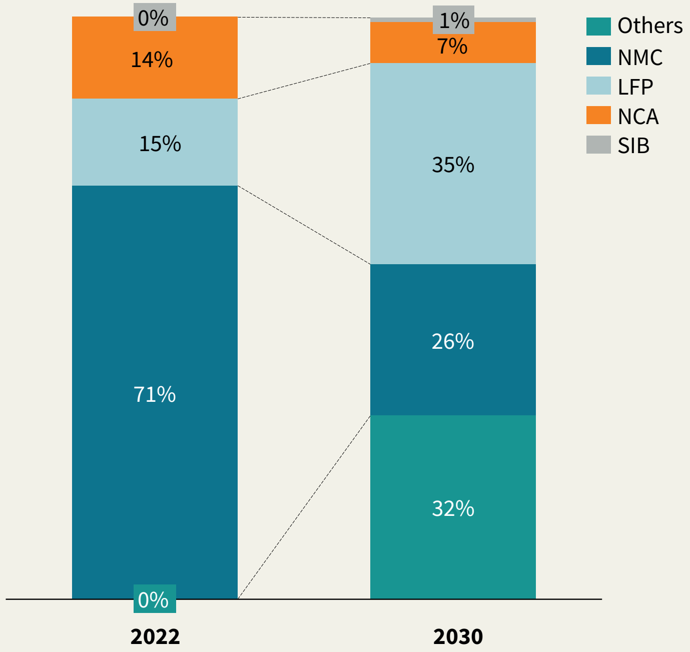


Fig. 2: Annual EU demand for Lithium-Ion Battery cathode chemistries (GWh). *Sources: Systemiq analysis, T&E (2023); Bloomberg NEF (2023), IEA (2021), Wood Mackenzie (2023)*

Figure 3: **Market share of different battery chemistries in 2022 and 2023 (in %)**



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[1] This capacity would surpass total EU demand for batteries, estimated around 1,050 GWh, see fig. 1.

LFP do not rely on cobalt and nickel, however there may be conflicting demands for phosphate, as they compete with fertilizer production. The shift in the market shares of the respective battery chemistries, is a result of their technical, economic, and environmental performance (see fig. 4).

Sodium Ion Batteries (SIB), a lithium- free energy storage solution, are promising to become a cost-effective and environmentally friendly alternative battery type. Raw materials for SIB production (namely sodium) cost less and avoid transition materials like lithium entirely. It is possible to avoid all transition materials like nickel and cobalt. It is depending on chosen cathode chemistry e.g. Prussian White chemistries can completely avoid the use of transition materials. However, they cannot yet be marked and mass production and incorporation into BEVs will likely only start towards the end of this decade or in the early 2030 (Wood Mackenzie 2023) (see fig. 3).

Figure 4: **Technical, economic and materials environmental performance of the different battery chemistries**

	NMC	NCA	LFP	SIB*1
Technical performance	▲ High energy density	▲ High energy density ▼ Safety	▼ Low energy density. Limited to lower range vehicle applications. ▲ Safety ▲ Lifespan	▼ Low energy density. Limited to lower range vehicles, or stationary storage.
Economic performance	▼ Exposure to volatility in prices (Li, Co, Ni).	▼ Exposure to volatility in prices (Li, Co, Ni).	▲ Reduced cost. Reliance on cheaper materials (Fe, P)(~15%-18% less than NMC).	▲ Reduced cost. Reliance on cheaper materials (Na)(~30% less than LFP battery)
Materials' environmental impact	▼ Reliance on Co, Ni. Mining of these materials creates large environmental burden.	▼ Reliance on Co, Ni. Mining of these materials creates large environmental burden.	▲ No reliance on Co, Ni. ▼ Conflicting demands for P may arise as it competes with fertilizer production.	▲ Complete avoidance of critical materials.*2
Overall trend	**Reduced share but continues to be a leading type of battery in the market** **Development of versions with reduced Co concentrations**	**Grows in terms of volume but reduces market share due to limited application (Tesla's proprietary technology)**	**Faster growth due to economic competitiveness** **Research and development to improve energy density performance**	**Technology reaches maturity (TRL 9)** **Mass production and incorporation into BEVs towards the end of the decade or beginning of 2030's**

▲ Strength
▼ Challenge

Fig. 3 & 4: Technical, economic, and environmental performance of different battery types, and projected changes in market shares. *Sources: Systemiq analysis; Bloomberg NEF (2023), IEA (2021); Miao et al. (2019); Zou (2021).*

*Note *1: SIB CAGR (Compound annual growth rate) from 2027 when first volume in demand is forecasted. Note *2: Prussian White chemistries can completely avoid the use of transition materials.)*

To meet the demand for increasing battery production in Europe, the supply of the five transition materials in cathode and anode production, namely lithium, nickel, cobalt, manganese and graphite, will have to increase between two and seven times by 2030. Demand for lithium, manganese, natural graphite and nickel will increase substantially. Cobalt will show a less marked rise (see fig. 5). **Thanks to the shift in battery chemistries, the growth in demand for nickel and cobalt will be less pronounced than it would be without such a shift. The estimated demand of nickel and cobalt can be met without the necessity of highly contentious developments such as mining the deep seabed (see also SINTEF 2022).**

Figure 5: Annual EU demand for battery materials for BEVs and ESS application (kt)

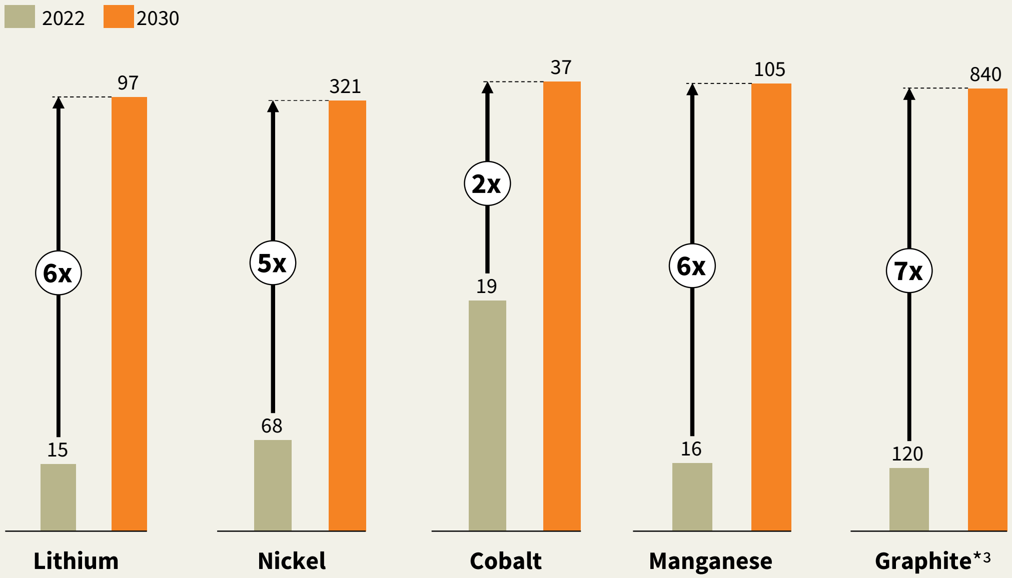
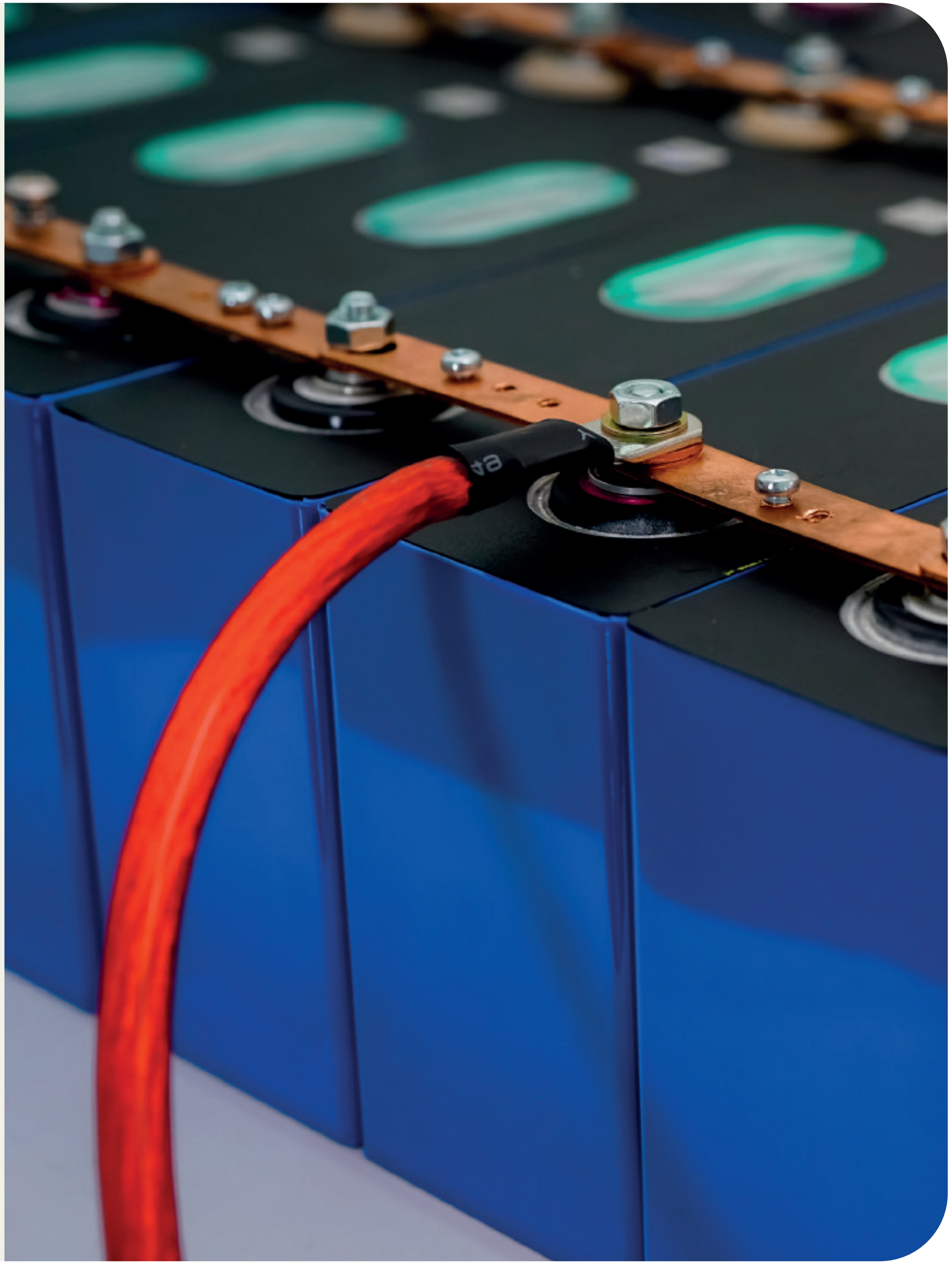


Fig. 5: Annual EU demand for battery materials for BEV and ESS application (kt). *Sources: Systemiq analysis; T&E (2023), Bloomberg NEF (2023), IEA (2021)*

*Note *3: All references to graphite in this study refer to natural graphite*



KEY RESULT 2: NECESSITY FOR RELOCATING REFINING AND PROCESSING CAPACITIES TO EUROPE

A large proportion of the battery value chain activities are located outside of the EU, particularly regarding upstream segments. This renders the EU battery market highly dependent on imports, and this dependency is set to intensify by 2030. By 2030, the EU's requirements for refined materials to meet its battery demand will amount to approximately 1,400 kt per year of lithium, nickel, cobalt, manganese, and natural graphite. However, the current refinery planning scenario will allow for only 180 kt per year, implying an annual shortfall of 1,220 kt.

With the exception of cobalt, currently the majority of refined materials for battery production has to be imported to the EU. There are no refining and processing capacities for lithium and natural graphite in Europe, resulting in a heavy reliance on imports from Chile, China and Mozambique (see fig. 6). There is some domestic supply of refined nickel and manganese, however most of this goes into other industries. **In this context, it is important to note that batteries are not the only drivers for transition materials demand, e.g., only 2% of nickel supply serves the battery sector. 49% of nickel in Europe is used for stainless steel, and 18% for alloy steel and casting** (European Commission 2023a). Cobalt is the material with the largest domestic refined material supply, due to high refining capacities in Finland and Belgium.

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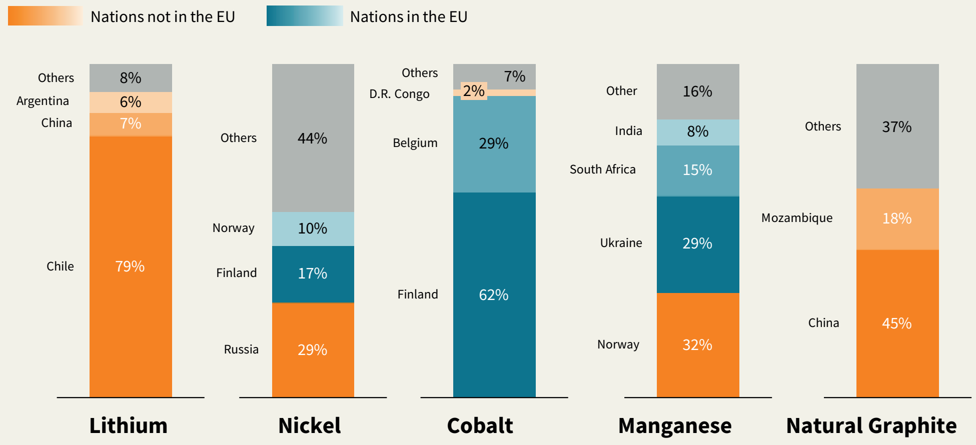
Figure 6: **Current EU refined material sourcing for all applications *4 (2021)**



EU import reliance:*5

	Lithium	Nickel	Cobalt	Manganese	Natural Graphite
Raw material	**81%**	**31%**	**81%**	**96%**	**99%**
Processed material	**100%**	**75%**	**1%**	**61%**	**100%**

Fig. 6: Current EU refined material sourcing for all applications (2021). Note *4: Refined material sourcing is for all applications, does not reflect EU sourcing for batteries only. Note *5: Import reliance is calculated as the ratio of net 2021 imports to apparent consumption. *Sources: Systemiq analysis; European Commission (2021a); European Commission (2023a)*

While mining is dependent on geographical resource availability, some key steps in the value chain could be expanded in the EU, such as refining and processing. To meet the projected demand in Europe in 2030, the capacity along the value chain needs to be ramped up accordingly.

In order to meet the CRMA benchmark of 40% for domestic processing and refining of battery materials, capacities for the transition materials nickel, cobalt, manganese, lithium and natural graphite would have to reach 560 kt per year by 2030.

Figure 7 illustrates the EU's current operational refining and processing capacity for the five crucial battery transition materials by 2030; **the projected base case capacity, which includes projects that are well advanced with a high likelihood of realisation; and the full potential capacity, which includes projects with a yet uncertain outcome**. Refining and processing capacities in Europe could potentially be increased by a factor of three from 101 kt in 2022 to 293 kt in 2030.

Assuming that the base case capacity is achieved, the EU is forecast to reach 180 kt of material refining capacity by 2030. This still implies a shortfall of 380 kt of battery material refining and processing that will require relocating to meet the CRMA benchmark of 40% (i.e., 560 kt per year).

For processed natural graphite and lithium, the EU currently relies entirely on imports. For lithium, this situation is anticipated to change if planned refinery projects materialise by 2030. **Only lithium and manganese have a projected refining capacity that meets the CRMA benchmark in 2030** (see. fig. 8)[2]. Three lithium refining projects in the EU are highly likely to become operational before 2030[3]. These would allow the EU to surpass the 40% benchmark for domestic production of battery grade lithium salts (Keliber in Finland, AMG and Rock Tech in Germany). There are no graphite projects with a high probability of becoming operational before 2030, and no announcements of new cobalt refining capacities in Europe. The nickel sulphate project pipeline suggests a potential 35 kt expansion of the Nornickel plant in Finland by 2030.

Figure 7: **EU battery materials processing supply and demand forecast (kt p.a.)**

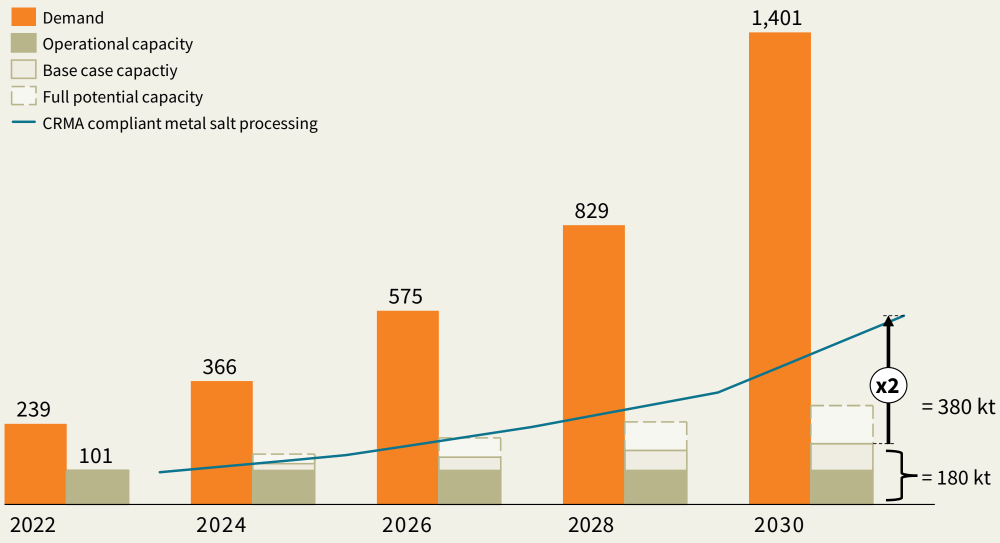


Fig. 7: EU battery material processing supply and demand forecast (kt/a). Note: Demand and supply are for battery application only, and do not reflect total EU refining capacity. Utilisation rate of facilities not accounted for in capacity forecast. Capacity to meet CRMA benchmark calculated to meet 40% of total battery demand. *Sources: Systemiq analysis, T&E (2023), Bloomberg NEF (2023), KU Leuven (2023), European Commission (2023a)*

Figure 8: **Annual 2030 EU battery material processing supply and demand (kt)**

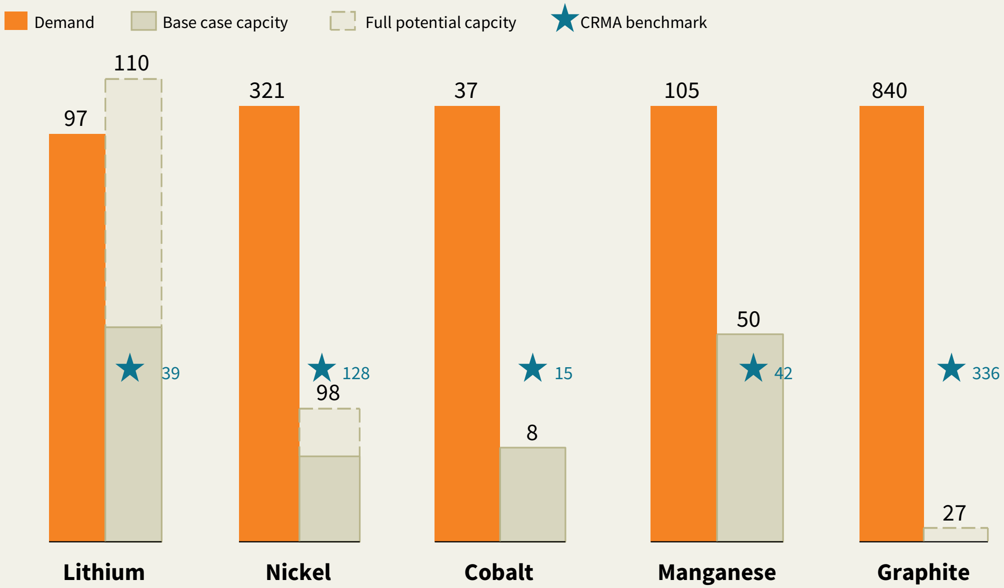


Fig. 8: Annual 2030 EU battery material processing supply and demand (kt). Note: Demand and supply are for battery application only and do not reflect total EU refining capacity. Utilisation rate of facilities not accounted for in capacity forecast. *Sources: Systemiq analysis; T&E (2023); Bloomberg NEF (2023); KU Leuven (2023 European Commission (2023a)*

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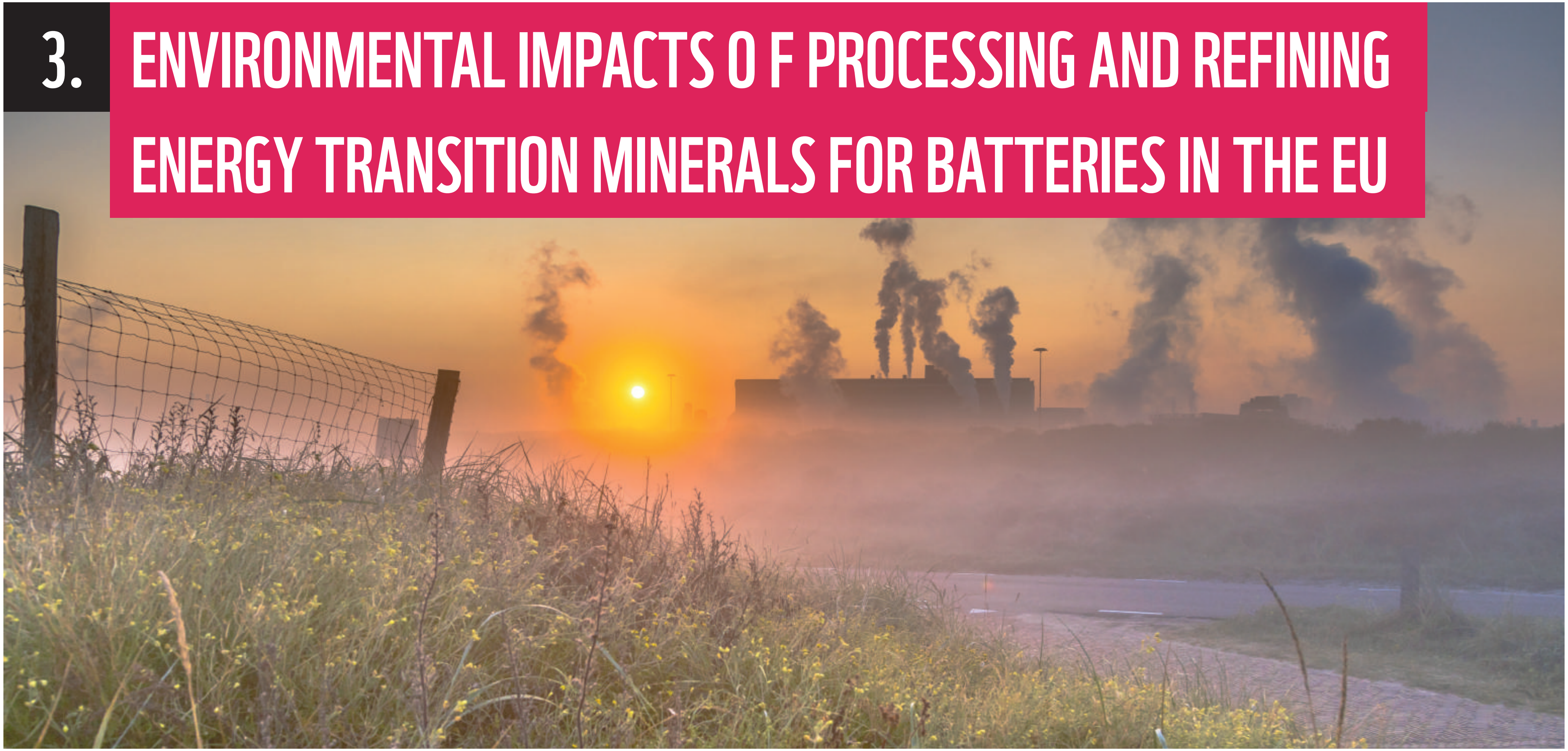
[2] Manganese pipeline projects are not mentioned distinctly in sources, therefore 2030 capacity is based on % of manganese used for batteries (~2%) applied to BNEF forecast of total announced manganese refining capacity.

[3] The lithium project pipeline is impacted by politics surrounding its mining in Portugal.

3. ENVIRONMENTAL IMPACTS O F PROCESSING AND REFINING ENERGY TRANSITION MINERALS FOR BATTERIES IN THE EU



This chapter presents the key outcomes of the analysis of the environmental impacts of processing and refining for battery production in Europe[4]. **A deep dive was performed for the 5 most relevant transition materials, across different battery chemistries, establishing the metal's uses, EU sourcing and high-level processing routes**. System boundaries were set by determining relevant inputs, intermediate products and outputs for the refining and processing stages of production (see fig. 9). **Eleven impact factors, such as CO_2-emissions, Global Warming Potential (GWP), Water and Land use, Eutrophication, Human Toxicity and Ecotoxicity, were assessed**. A definitive blanket assessment of the climate impact trade-offs of refining and processing in the EU compared to current international suppliers is not possible. This requires a case-by-case analysis, considering factors such as material type and the energy mix employed in each case.

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[4] Even though quantitative assessments such as the one made in this study are limited by data availability and quality, and data bases like Ecoinvent used here have been criticized for lack of transparency and comparability with other sources, they give an indication of the order of magnitude of effects.

Figure 9: Established process boundaries for the production of battery grade materials

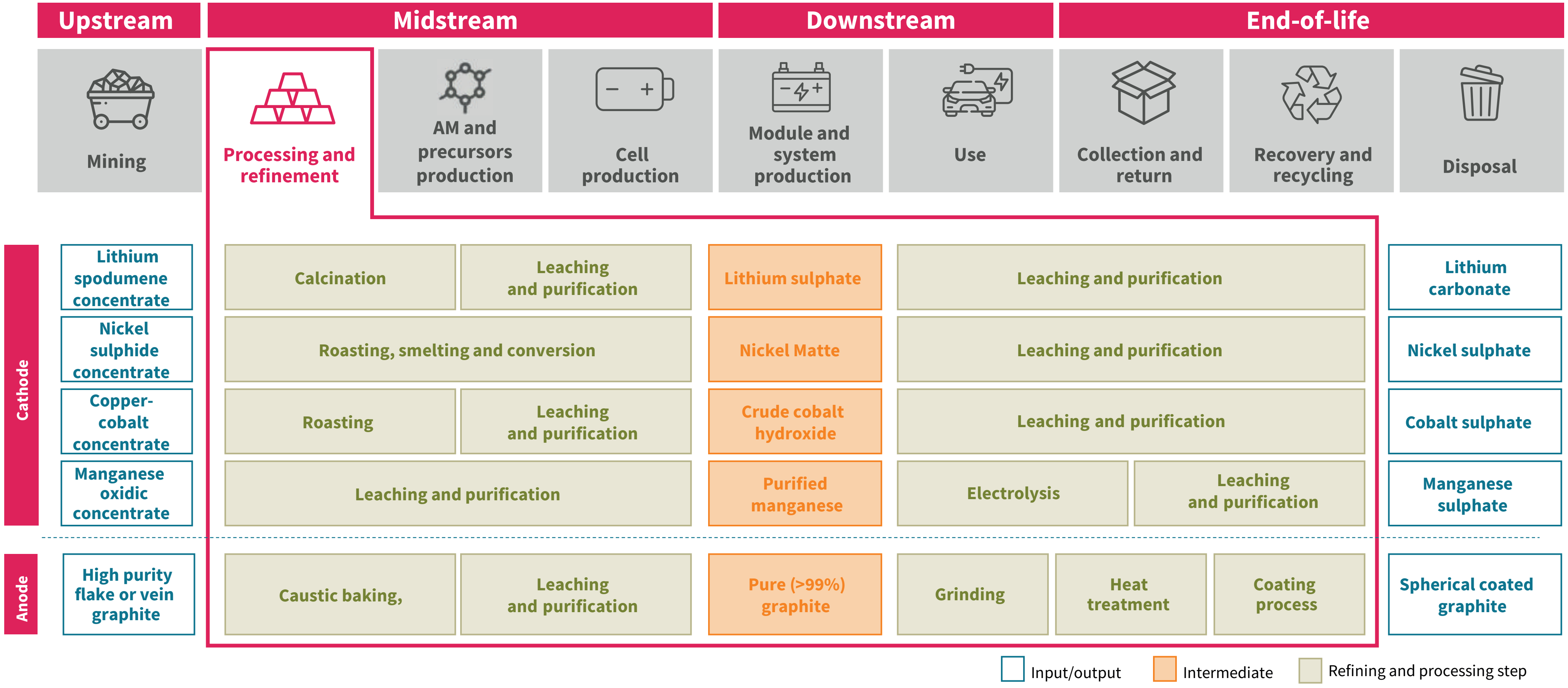


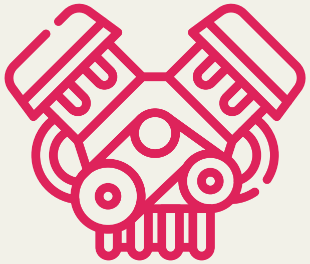
Fig. 9: Determination of system boundaries, relevant inputs, intermediate products and outputs for environmental impact assessment of five crucial raw materials for battery production. *Source: Global Battery Alliance (2023)*

Environmental impact data with equivalent boundaries were sourced from the Ecoinvent database. The Life Cycle Analysis (LCA) approach for each impact factor was chosen following the International Reference Life Cycle Data System (ILCD) (see Appendix for methodology). The compiled impact factors were used for assessing the total unmitigated environmental impact associated with meeting the CRMA objective. This calculation involved specific assumptions: (1) Impact factors are global averages and remain constant. Therefore, they do not account for potential technological advancements in refining facilities or energy production, or geographical variation. (2) The relocation volume was determined by reverse calculating the quantity of battery materials needed to meet the estimated demand for batteries in the EU. This assumes that subsequent production steps possess the necessary capacity to meet the 40% benchmark set by CRMA.

KEY RESULT 3: 9.5 MT CO_2 EQ PER YEAR FROM ICE VEHICLES COULD BE DISPLACED BY SECURING THE PRODUCTION OF 6.7 MILLION PASSENGER BEVS

The supply of the transition materials for 6.7 million BEVs required to meet the CRMA benchmark would generate 3.5 million tonnes CO_2 (Mt CO_2) per year by European refineries. It should be noted that emissions from the refining and processing sectors represent just one portion of overall battery production emissions. At the same time, the internal combustion engine (ICE) emissions displaced by the BEVs produced from this secured material would be four times higher than the emissions for refining and processing battery materials.

3.5 Mt CO_2 eq per year is equivalent to 0.8% of the annual emissions of EU passenger ICE vehicles (436 Mt CO_2 eq per year) and only 1.6% of the emissions of the steel industry. Even if emissions along battery supply chains are unavoidable, they do not belie the climate advantages of BEV. Total lifecycle greenhouse gas (GHG) emissions of BEV are on average half those of ICE cars, with a further potential reduction of 25% by using of low-carbon electricity (IEA 2021, see fig. 10).



9.5 MT CO_2

EQUIVALENT PER YEAR FROM INTERNAL COMBUSTION ENGINES (ICE) COULD BE AVOIDED IN THE EU IN 2030 IF THEY WERE REPLACED BY 6.7 MILLION PASSENGER BEVS.

Figure 10: **Life-cycle GHG emissions per powertrain**

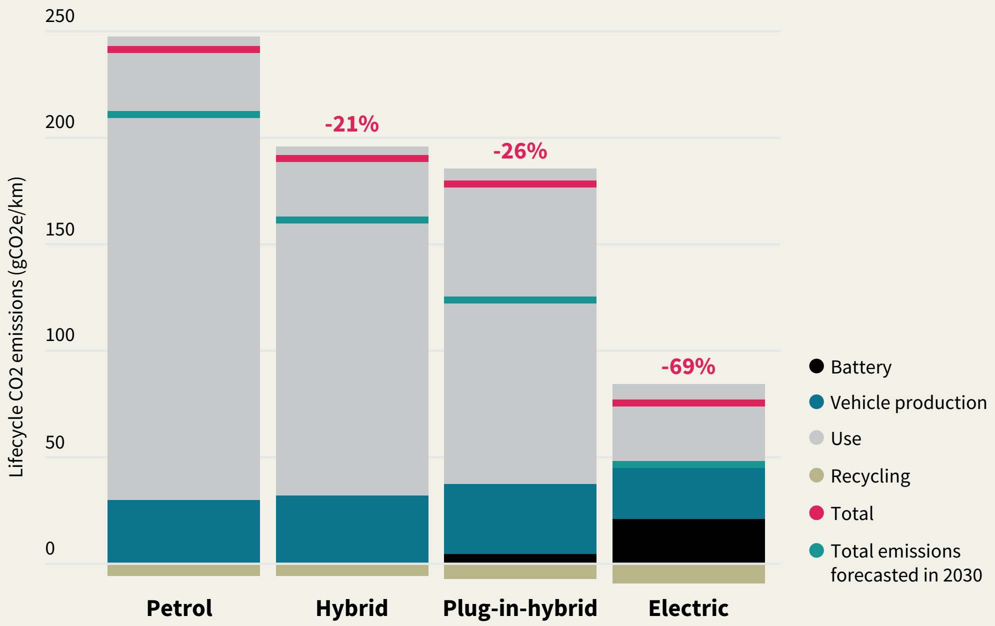
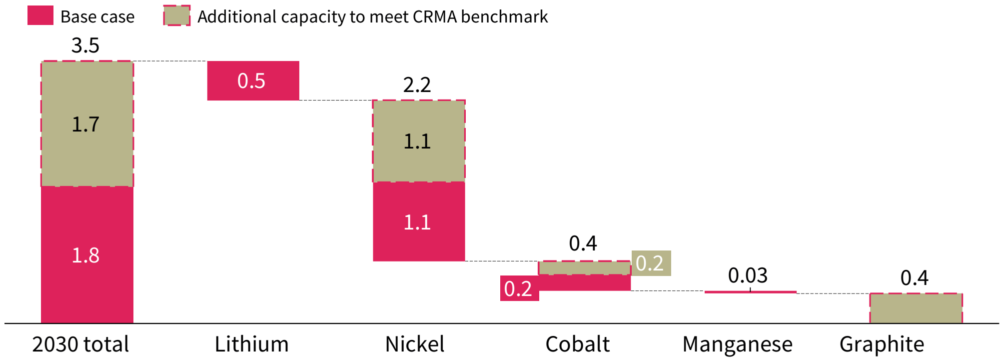


Fig. 10: Life-cycle GHG emissions per powertrain. Note: T&E analysis of a medium-sized car, battery assumed to be produced with the EU27 average grid, BEV/Plug- in hybrid charging with the EU27 average grid. *Source: T&E (2022)*

EMISSIONS BREAKDOWN BY MINERAL

Among the transition materials for BEVs, nickel is projected to produce the highest additional emissions from relocating refinery and processing (an additional 1.1 Mt CO_2 eq per year) to achieve the CRMA benchmark of 40% in 2030, followed by cobalt with 0.2 Mt CO_2 eq per year. This is driven by the large relocation volume for nickel, estimated at 65 kt, and the high emissions factors for processing these two metals (nickel 16.8 GWP and cobalt 26.5 GWP). The projected development of lithium and manganese refineries suggest that no additional relocation will be required beyond the base case capacity to meet the CRMA benchmark (see fig. 11).

Figure 11: EU GHG emissions, battery material midstream production (Mt CO2 eq p.a.)



	Lithium	Nickel	Cobalt	Manganese	Graphite
GWP [kg CO_2 eq per kg]	8.9	16.8	26.5	2.6	1.2
2030 gap from base case to 40% [kt]	Surpasses 40%	65	7	Surpasses 40%	336

Fig. 11: EU GHG emissions from battery materials production (Mt CO2 eq/a). Notes: "Additional capacity to meet CRMA benchmark" assumes each individual battery material achieves 40% target; "battery material" includes nickel, cobalt, manganese, lithium and graphite only; Base case capacity is forecast linearly; Emissions factors are held constant. *Sources: Sytemiq analysis; Ecoinvent 3.9 (2023)*

KEY RESULT 4:

DEPENDING ON THE ORIGIN OF RAW MATERIALS, GHG EMISSIONS FROM LITHIUM AND NICKEL REFINERY IN THE EU CAN VARY BY A FACTOR OF FIVE.

Figure 12: **EU GHG emissions, battery material midstream production of lithium and nickel (Mt CO2 eq p.a.)**

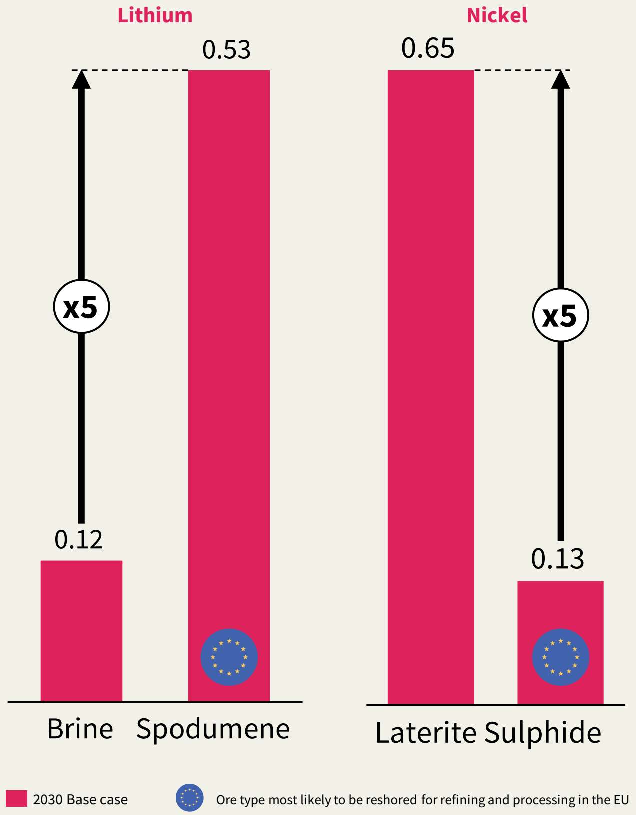


Fig. 12: GHG emissions of lithium and nickel refinery and processing in the EU, depending on raw material source (Mt CO2 eq/a) (non-exhaustive). Sources: Roberts, J. (2023), *Drive Sustainability Initiative (n.d.); Minviro, (2023); T&E (2023a)*

Lithium	**Potential suppliers**	**GWP** (kg CO$_2$ eq per kg)
Ore I: Brine	🇨🇱 🇨🇳	2.0
Ore II: Spodumene	🇦🇺 🇨🇦	8.9

Nickel	**Potential suppliers**	**GWP** (kg CO$_2$ eq per kg)
Ore I: Laterite ore	🇮🇩 🇵🇭	10.3
Ore II: Sulphide ore	🇨🇦 🇷🇺	2.0

Lithium: Relocating lithium midstream processing could increase emissions by a factor of five (see fig. 12). Spodumene sourced from Canada and Australia is viewed as the most promising raw material for EU refineries as its production is likely to meet EU Environmental, Social and Corporate Governance (ESG) standards, it is of high quality, and agreements are already in place with refineries in Europe. Brine processing is unlikely to be relocated as resources are largely located in Chile and China where refining is vertically integrated. Refining spodumene is more emissions-intensive than brine due to its lower lithium content and the use of high-temperature processing steps such as roasting or calcination.

Nickel: Canada is presently the primary external sulphide nickel supplier to EU refineries (24% of sourcing). Sulphide ores generally have lower refining and processing GHG intensity than laterite ore due to a higher nickel content and the sulphur content acting as a fuel source. This could translate to a 0.52 Mt CO$_2$ eq per year fewer emissions if refined nickel is produced from sourcing further sulphide or from Canada, as opposed to laterite ore refined elsewhere.

Electricity use contributes up to 73% of the GWP of lithium carbonate production and up to 18-40% of the GWP of nickel sulphate production. Should the EU grid align with the decarbonisation pathway forecast by the European Environment Agency (2023a), 0.18 Mt of GHG emissions in the refinery and processing of lithium could be avoided in 2030. For nickel, the Nickel Institute (2023) demonstrated that GHG emissions could be reduced by 0.75 Mt in 2030 if all on-site electricity is converted to renewable sources and the EU grid decarbonisation pathway is accounted for. The use of renewable energy sources in lithium and nickel refineries and EU grid decarbonisation could reduce potential GHG emissions by up to 35% (see fig. 13).

Figure 13: **GWP breakdown and 2030 EU GHG emissions from material refining and processing (% and Mt CO2 eq p.a.)**

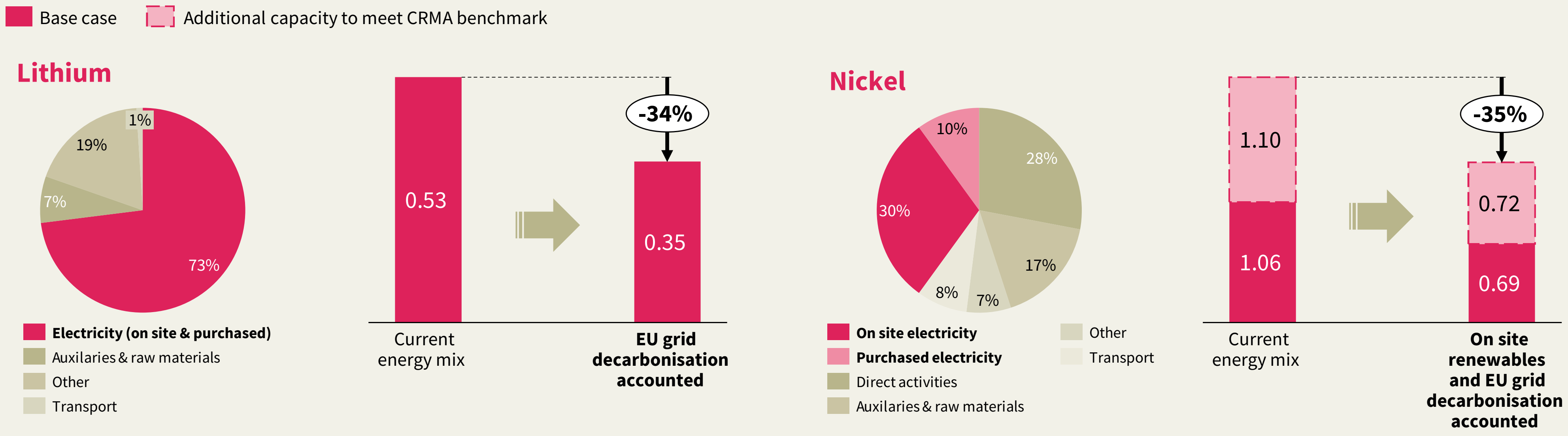


Fig. 13: GWP breakdown and 2030 GHG emissions for lithium and nickel refining and processing (% and Mt CO2 eq/a). *Sources: Kelly et al. (2021); Nickel Institute (2023); Mistry et al. (2016); European Environment Agency (2023a)*

THE USE OF RENEWABLE ENERGY SOURCES IN LITHIUM AND NICKEL REFINERIES AND EU GRID DECARBONISATION COULD REDUCE POTENTIAL GHG EMISSIONS BY UP TO

35%

KEY RESULT 5: ENVIRONMENTAL IMPACTS OF REFINING KEY MINERALS NEED TO BE MITIGATED

Midstream processes involve heavy industrial activities and environmental impacts requiring mitigation. Beside GHG emissions, battery metal refinery and processing pose additional environmental impact risks, such as freshwater and/or marine eutrophication from lithium, or acidification of water environments by manganese (see fig. 14).

Lithium - Marine & Freshwater Eutrophication

The primary contributors to eutrophication potential is the leaching step in the upstream production of sodium carbonate, with sodium hydroxide.

Cobalt - Human Toxicity & Water Use

Cobalt processing potentially emits heavy metal (Note 1: Heavy metals a group of metalic elements that can be toxic at relatively low concentrations due to their ability to accumulate in living organisms and interfere with normal biological functions.) dust or fumes, and their inhalation can cause respiratory and cardiovascular problems in humans.

Hydrometallurgical aqueous processing as well as purification and washing gives rises to high water consumption.

Nickel - Particulate Matter Formation & Ecotoxicity

Smelting of sulphide concentrates of nickel generates sulphur dioxide (SO2) gas, which can result in acid rain formation.

Potential heavy metal exposure and acid rain would seriously harming ecosystems.

Manganese - Acidification

Acidification impacts from manganese are primarily due to nitrogen oxides and phosphates accumulation in water environments.

Natural Graphite - Marine Ecotoxicity

Anode graphite refining wastes up to 70% of the initial graphite leading to large quantities of waste effluent.

Process chemicals and effluents could have negative impacts on aquatic biodiversity through the contamination of water resources.

Figure 14: Possible environmental impact of midstream production

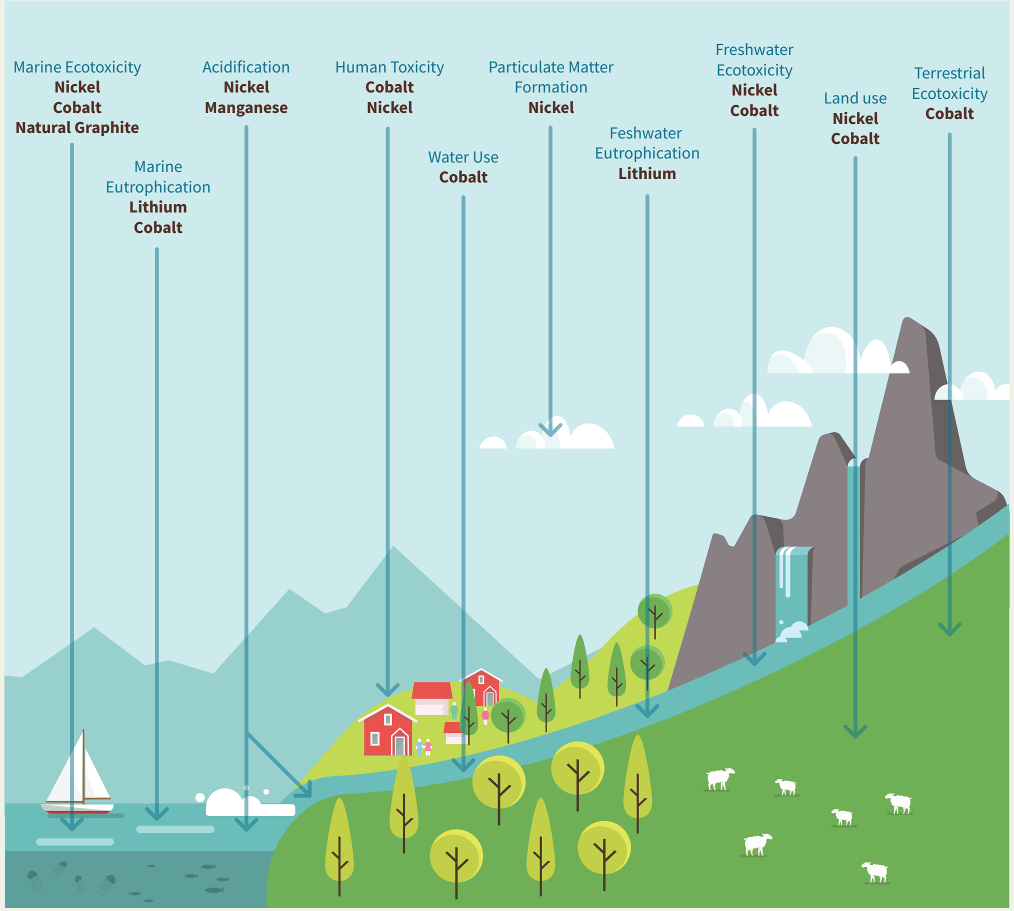


Fig. 14: Possible environmental impact of midstream production of battery material. *Sources: Systemiq analysis; Ecoinvent 3.9 – cut-off approach*

KEY EU LEGISLATIVE INSTRUMENTS FOR MITIGATING ENVIRONMENTAL IMPACT

At least eight policies in the EU regulate emissions and health and safety measures in midstream processing facilities (see table 1).

These policies have been developed or updated in the past 20 years and it is advisable to review and revise their details to ensure they adequately address all the impacts of the evolving industry.

Table 1: EU regulation associated with environmental impacts of battery materials

Legislative instrument	
Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (EC 1907/2006)	The main EU law to protect human health and the environment from the risks that can be posed by chemicals like nickel and cobalt
National Emission Reduction Commitments Directive (NECD) (2016/2284/EU)	Sets national emission reduction commitments for Member States and the EU for five key air pollutants1
Industrial Emissions EU Directive (IED) (2010/75/EU)	Main EU instrument regulating pollutant emissions from industrial installations
Occupational Exposure EU Directive (2004/37 & 2022/431)	Lists indicative occupational exposure limit values for chemical agents.
Carcinogens, Mutagens or Reprotoxic (CMR) Substances at Work EU Directive (2004/37/EC)	Minimum requirements for protecting workers against risks to their health and safety from CMR substances.
Major-Accident Hazards involving Dangerous Substances Directive (Seveso III) ((2012/18/EU)	Establishes rules and measures to prevent accidents involving dangerous materials
Water Framework Directive (WFD) (2000/60/EU)	Ensuring good qualitative and quantitative health, i.e. on reducing and removing pollution of groundwater and surface water
Classification, Labelling and Packaging of Products (CLP) Regulation (1272/2008/EC)	Establishes rules for communicating hazard levels of substances for employees and consumers

Table 1: Main EU legislation associated with environmental impacts of battery materials (non-exhaustive). Note1: Five key air pollutants included in NECD: nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO2), ammonia (NH3) and fine particular matter (PM2.5)

THE EU CARCINOGENS AND MUTAGENS DIRECTIVE ALONE COULD PREVENT UP TO

77%

OF POTENTIAL CANCER CASES IN 2030.

The EU Carcinogens and Mutagens Directive sets a limit to occupational exposure to nickel compounds and the commission is set to propose an occupational exposure limit to cobalt by the end of 2024. This regulation alone could prevent up to 77% of potential cancer cases in 2030 (Systemiq analysis).

Commitments set by EU member states in National Emission Reduction Commitments Directives (NECDs)[5] are predicted to reduce premature deaths from fine particulate matter (PM2.5) by 66% by 2030 compared to 2005 levels, overshooting the 55% target (Systemiq analysis)[6].

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5. Five key air pollutants are included in NECDs – nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO2), ammonia (NH3) and fine particulate matter (PM2.5)
6. Assumes deaths caused and PM2.5 emissions volume have a direct correlation.

4. GHG EMISSIONS FROM THE MANUFACTURE OF DIFFERENT BATTERY CHEMISTRIES IN THE EU

This section evaluates the GHG emissions from the projected battery production volume in Europe by 2030, taking into account different battery chemistries and predicted changes in respective market shares by 2030. Potential emissions avoidance through the use of renewable energy were also analysed. The analysis focuses on cradle-to-gate (production) emissions, as these have the highest relevance for the consequences of relocating production capacities to the EU (see fig. 15).

Figure 15: **Cradle to gate (production) emissions as focus area of this analysis**

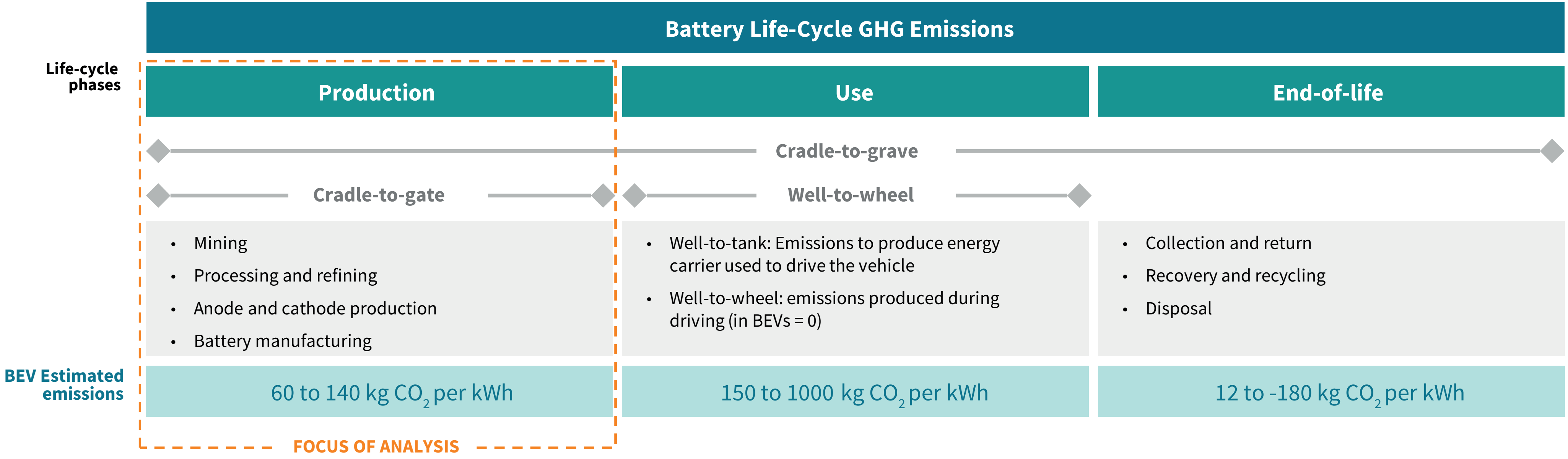


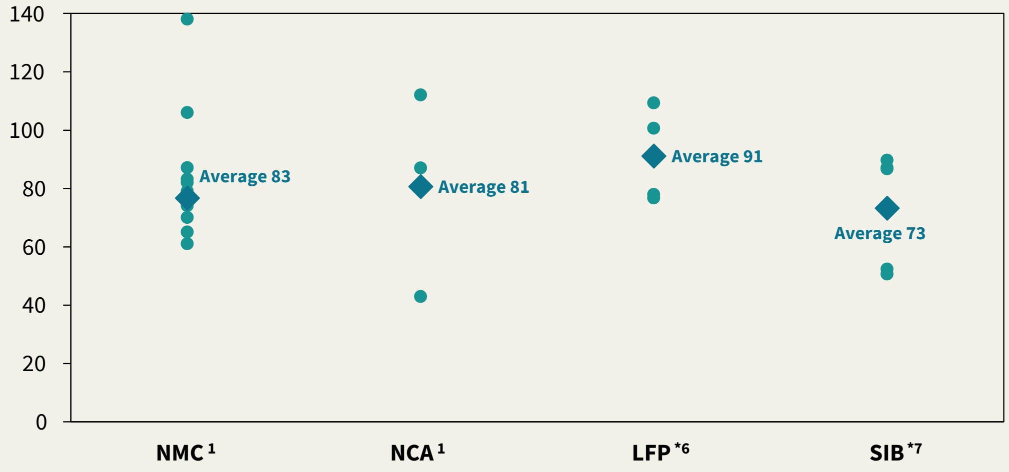
Fig. 15: Life cycle of batteries and focus of the analysis on cradle-to-gate emissions. Sources: Systemiq analysis; Peters et al. (2017), Peters et al. (2021), Schulz Mönninghof (2021); Chen et al. (2022), Wang et al. (2022); Bobba et al (2019); Dong et al (2023); Mohr et al (2020). Notes: Values represent approximations to batteries applied in electric vehicles. Inconsistent system boundaries from sources make it challenging to compare LCA data.

KEY RESULT 6: SHIFTS IN THE MIX OF BATTERY CHEMISTRIES WILL HAVE A LIMITED EFFECT ON OVERALL EMISSIONS TOWARDS 2030

LCA results suggest that emission factors for the manufacturing of LFP, NCA, NMC and SIB battery cells range at similar average values between 70-90 kg CO_2 per kWh. **Shifts in the mix of battery chemistries will therefore have a limited effect on overall GHG emissions towards 2030**. There would be no significant trade off in GHG emissions from switching between NMC or LFP chemistries, as both have similar emission factors.

LFP marked shares are expected to increase significantly over the next years. LFP batteries display the highest average emission factor at 91 kg CO_2 eq per kWh. Although composed of materials with lower environmental impact than NMC and NCA batteries, their lower energy density requires the assembly of larger batteries, leading to increased use of additional materials and energy. Looking closer, SIB batteries perform slightly better in terms of GHG emissions (see fig. 16).

Figure 16: Average GHG emissions from battery cell manufacturing (kg CO2 eq per kWh)



Different boundaries conditions and LCA methodologies produce variability in results and make data comparability difficult

Fig. 16: Average GHG emissions from battery cell manufacturing by battery chemistry (kg CO_2 eq/kWh). *Sources: Systemiq analysis; Hill et al. (2020), Pell & Lindsay (2022), Quan et al. (2022), Emilsson & Dahllöf (2019), Crenna et al (2021), Mohr et al. (2020), Hao et al. (2017), Kelly et al. (2020), Messagie (2017); Peters et al. (2021).* Note *6: 20 recently published LCA studies were assessed to extract emission factors of LIB and SIB battery production. The most comparable data were plotted (11 data points for NMC, 3 data points for NCA and 4 data points for LFP), and an average value was estimated per battery chemistry; Note *7: Data points correspond to 5 different Sodium Ion Batteries: NaMMC, NaMVP, NaMMO, NaMMT, NaBPA.

GHG emissions derived from the projected domestic battery production imply a close to five-fold increase in GHG emissions, reaching > 90 Mt CO_2 eq per year by 2030, driven by the two dominant battery chemistries NMC and LFP (see fig. 17). **Emissions from increased battery production will occur regardless of whether processing is domestic or international. However, the source of these emissions would be relocated to Europe, giving the EU more control over them within its borders**.

This supply of batteries would contribute to displacing the ~500 Mt CO_2 eq per year (19.3% of total 2022 EU emissions) currently emitted in road transportation by ICE vehicles in the EU (European Environment Agency 2023b and 2023c). Despite the displacement of road transport emissions, a substantial volume of emissions remains, almost equivalent to half of the current emissions from the steel industry in the EU. Necessary mitigation actions would be required for this expanding industry. **The next pages provides an insight into instruments available within the EU to minimise emissions and environmental impacts.**

Figure 17: EU battery production associated GHG emissions (Mt CO2 eq per year)

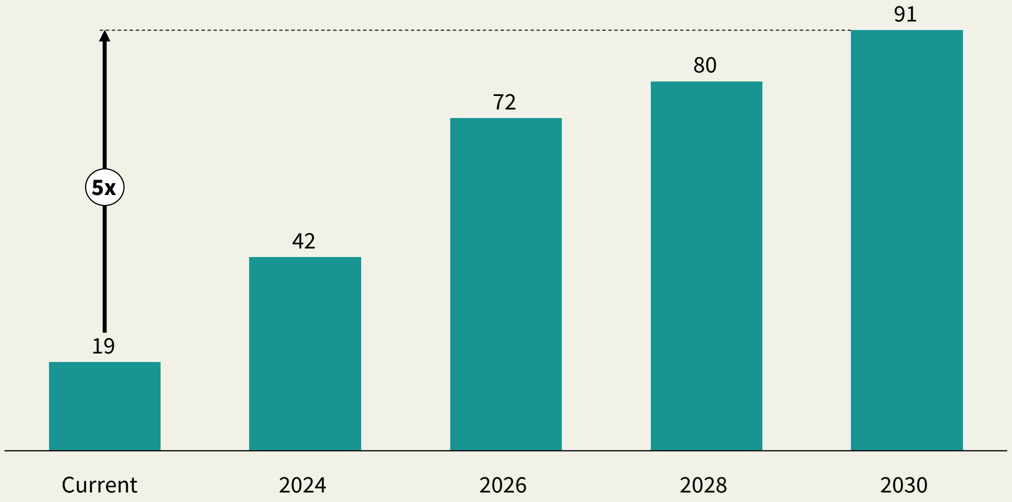


Fig. 17: GHG emissions associated with EU battery production until 2030 (Mt CO2 eq/a). *Sources: Systemiq analysis; BNEF (2023); Hill et al. (2020), Pell, R. & Lindsay, J. (2022), Quan et al. (2022), Emilsson & Dahllöf (2019), Crenna E. et al (2021), Mohr et al. (2020), Hao et al. (2017), Kelly et al. (2020), Messagie (2017).* Notes: Analysis takes installed and announced battery capacity from BNEF. 63% of data described the type of battery chemistry from the installed or announced capacity. For the remaining 37%, capacity is expected to show the same behaviour as the EU demand forecast. Batteries classified as 'others' (batteries other than NMC, NCA, LFP, SIB) were not included. Emission factors include the energy consumption improvements over time described in Hill et al. (2020) pp.357.

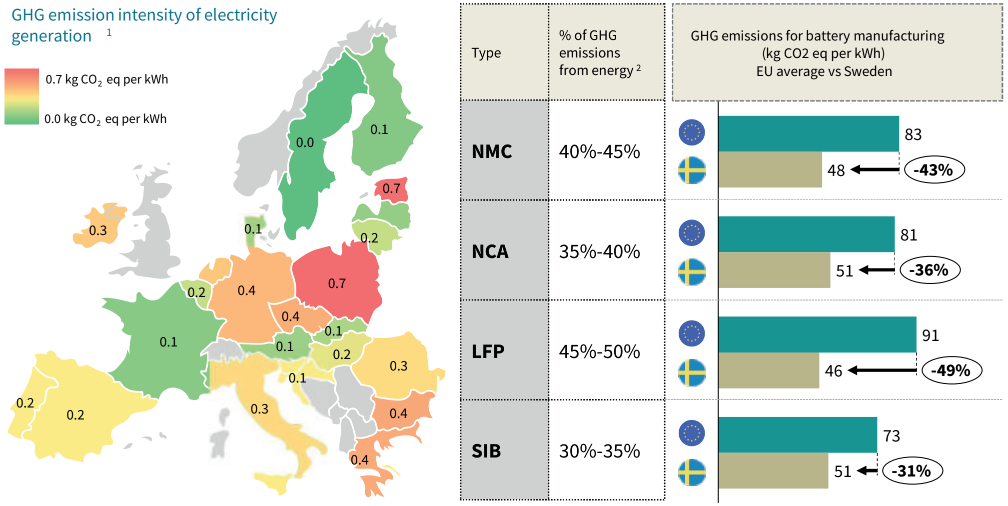
HOWEVER, COMPARED TO AN ICE, THE BULK OF GHG EMISSIONS IN THE LIFE CYCLE OF A BEV TAKE PLACE DURING THE MANUFACTURING PROCESS OF THE BATTERY AND THE CAR, WHILE AN ICE GENERATES GHG EMISSIONS DURING THE MANUFACTURING PROCESS AND DURING ITS USE BY BURNING FOSSIL FUELS THAT ARE SUBSEQUENTLY NOT AVAILABLE FOR OTHER PURPOSES THE WAY USED BATTERIES ARE, E.G. REUSE FOR LOCAL ENERGY STORAGE, OR RECYCLING AT THE END OF THEIR LIFE.

The average GHG emissions of producing a 40kWh EV battery generate approximately three tonnes of CO_2 eq. This represents around 50% of the total emissions from manufacturing a complete ICE. **However, compared to an ICE, the bulk of GHG emissions in the life cycle of a BEV take place during the manufacturing process of the battery and the car, while an ICE generates GHG emissions during the manufacturing process and during its use by burning fossil fuels that are subsequently not available for other purposes the way used batteries are, e.g. reuse for local energy storage, or recycling at the end of their life.**

POTENTIAL LEVERS FOR REDUCING SPECIFIC GREENHOUSE GAS EMISSIONS FROM BATTERY MANUFACTURING

For every battery chemistry, cell manufacturing energy (electricity and heat) causes the largest share of GHG emissions. The comparison of GHG emissions from battery production across EU countries, as a result of their respective energy mix, shows that by using renewable energy in battery production, emissions can be reduced by 30% to 50% (see fig. 18).

Figure 18: Share of GHG emissions from manufacturing energy (electricity and heat) in battery cell production (%) and impacts from emissivity of energy input (kg CO2 eq per kWh)



Type	% of GHG emissions from energy ²	GHG emissions for battery manufacturing (kg CO2 eq per kWh) EU average vs Sweden
NMC	40%-45%	83 48 ← -43%
NCA	35%-40%	81 51 ← -36%
LFP	45%-50%	91 46 ← -49%
SIB	30%-35%	73 51 ← -31%

Fig. 18: Share of GHG emissions from manufacturing energy (electricity and heat) in battery cell production (%) and GHG emissions from energy input (kg CO2 eq/kWh). Sources: *Systemiq analysis; European Environment Agency (2023a); Mohr et al. (2020)*

Decarbonisation of the EU electric grid needs to be underpinned by legislation supporting and incentivising the use of green energy for battery refining operations, while at the same time avoiding greenwashing. This section presents potential levers for reducing specific greenhouse gas emissions from battery manufacturing. EU regulatory instruments to pave the way for more renewable energy use in battery manufacturing include the Battery Regulation and the support of green Power Purchase Agreements (PPAs). Green PPAs are a technical approach to reducing GHG emissions, as are advances in production processes and an increase in the use of recycled materials. The potentials of the levers will be discussed in section 5.

THE EU BATTERIES REGULATION AND THE BATTERY PASSPORT

The new EU Battery Regulation came into force in August 2023, replacing the EU Battery Directive (European Parliament 2023b). The Regulation is binding in its entirety for all EU countries. Touching on a number of relevant environmental and social issues that are bound to intensify as this crucial technology gains importance within the next decade, the new Batteries Regulation provides a legal framework for promoting sustainability, circularity, ensuring safety and improving transparency relating to the environmental impacts of the entire life cycle of batteries sold on the EU market. It aims to ensure that batteries have a low carbon footprint, use minimal harmful substances, need less raw materials from non-EU countries, and are collected, reused and recycled to a high degree. The Batteries Regulation applies to the entire life cycle of batteries, thereby it includes the obligations under the Corporate Sustainability Due Diligence Directive (CSDDD).

Regarding GHG emissions, the Regulation will gradually introduce declaration requirements and limits for the carbon footprint of batteries for electric vehicles, light means of transport (such as e-bikes and scooters) and rechargeable industrial batteries, starting from 2025 (European Commission (2023b). The Regulation will very likely push battery producers in Europe towards the use of green energy.

The Batteries Regulation is also ground-breaking as it mandates the first digital product passport, which will become mandatory from February 2027 onwards. The Battery Passport will provide complete product information, including environmentally relevant content, such as labels and certifications, carbon footprint, supply chain due diligence, materials and composition, circularity and resource efficiency and performance and durability (Battery Pass 2023).

GREEN POWER PURCHASE AGREEMENTS

Green Power Purchase Agreements (green PPAs) are direct medium to long-term (5-20 year) contracts between companies and renewable electricity suppliers. They are expected to become a major driver for market-based expansion of renewable energies in the EU in the coming years.

Green PPAs can be used to finance new investments in renewable energy plants by guaranteeing price stability for electricity over a period of more than 10 years without the need for additional subsidies. In principle, a PPA can be applied to any type of power plant. However, their appeal lies primarily in their application to new plants, which is why they play an important role in the expansion of renewables as a financing instrument to accelerate the energy transition. The prerequisite is a price that can be calculated over a long period of time, which represents a reliable income for the investor and an acceptable and reliable price corridor for the buyer. The commitment to long-term purchase, often over 10 to 20 years, ensures the necessary creditworthiness of the investment (WWF Germany 2021). With the use of green PPAs companies have the possibility to reduce their environmental impact, to stabilise their energy cost (risk management) and to have energy cost savings due to lower cost renewable energy sources. The most important advantage of green PPAs could be the compliance with EU Regulations like the Battery regulation. The proposed reform of the EU's electricity market design is intended to boost renewable energies and explicitly recognises green PPAs as powerful market mechanisms to support the energy transition. The reform foresees amendments to four pieces of EU legislation, and it will be partly up to individual Member States to implement these revisions to their national legislation in an effective way. Member States are explicitly called upon to remove regulatory and administrative barriers to long term renewable PPAs and to formulate policies and measures facilitating the uptake of green PPAs (European Parliament 2023c).

ENHANCEMENT OF PRODUCTION PROCESSES

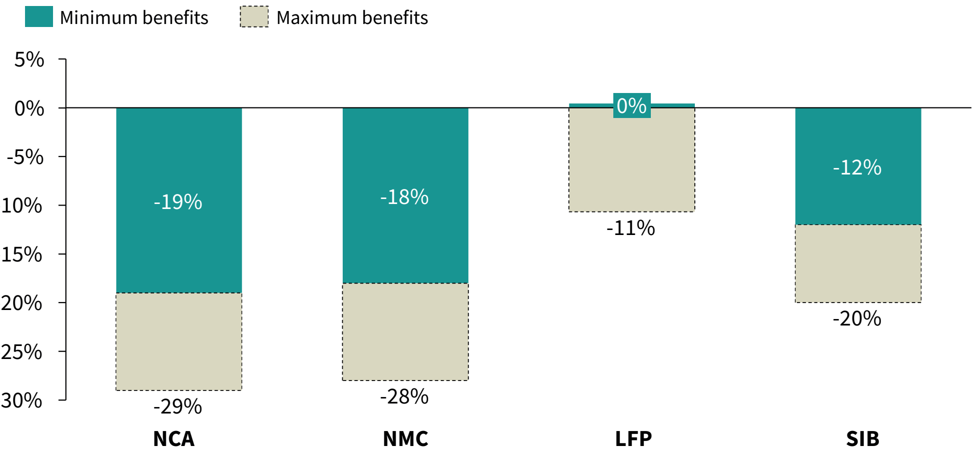
A promising technological advance in battery cell production processes is switching from wet to dry cathode coating technology, which can reduce the energy intensity of cathode production. Dry coating involves mixing a powder with a polymeric binder, applying it directly to the metal foil, and subjecting it to pressure and temperature changes for adhesion. This avoids the use of liquid slurries which require drying, thus reducing the energy required for this process step. It also eliminates solvent use and requires fewer preparation steps and equipment, lowering hazard risk and process expenses (Pell R. & Lindsay, J (2022), Groß, A. & Ernst, S. (2023)[7].

INCREASE BATTERY MATERIAL RECYCLING

Waste streams from EV batteries will only become significant after 2030, when the amount of spent EV batteries reaching the end of their first life is expected to surge (IEA 2021). At this time, the use of recycled material will hold large potential for reducing the environmental impacts of battery cell production; academic studies suggest that emissions can be reduced by up to 29% through the use of recycled minerals.

Particularly NCA and NMC production will benefit from the use of recycled materials, as this minimises emissions and other environmental impacts associated with the mining and refining of nickel and cobalt. The use of recycled materials in producing these chemistries will result in emission reductions -18% to -29% compared with non-recycled battery cell production. Recycling of LFP has the lowest impact. Recycling through pyrometallurgy would even add emissions, due to the amount of inputs needed to recover materials (see fig. 19). Other or maybe new battery recycling technologies will recover more materials from the recycling process or reduce emissions of battery recycling. (ICCT 2023)

Figure 19: Benefits from recycling process (as % of GHG emissions of non-recycled battery cell production



Results from academic study involving modelling. To accurately assess the recycling potential of various battery chemistries, an LCA analysis must be conducted within an industrial context and at scale

Fig. 19: % reduction in GHG emissions by using recycled materials instead of non-recycled materials in battery cell production. *Source: Systemiq analysis, Mohr et al. (2020).* Notes: Results are associated with major uncertainties, as is typical for prospective assessments of not yet established technologies.

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[7] Results are associated with major uncertainties, as is typical for prospective assessments of not yet established technologies.

5. CONCLUSIONS AND DISCUSSION

This analysis was conducted to examine the environmental and climate implications of achieving the benchmarks stipulated by the CRMA and NZIA, specifically of two elements: first the aim to refine 40% of the raw minerals within the EU, and second to increase battery manufacturing in Europe. Relocating parts of the battery supply chain, apart from supporting strategic autonomy goals, offers the **EU the possibility to control production parameters – including social and environmental – within its borders and to apply its ambitious environmental and climate policies to set the highest global standards for sustainable battery production**, compatible with the Paris Agreement and also with the Global Biodiversity Framework.

The EU, pushing forward with the implementation of the Green Deal, has proposed and is bringing into force an increasing number of legal instruments designed to ensure the sustainability of products and supply chains. From an environmental and global sustainable development perspective, to support the EU's aim to install capacity for refining at least 40% of its transition materials in an environmentally responsible way, WWF recommends the following:

The analysis shows the following results:

Shift from NMC and NCA batteries to LFP battery chemistries - with a less pronounced demand of cobalt and nickel.

Necessity to relocate refining and processing capacities to Europe only 180 kt of battery materials refining and processing could be reached by 2030 - a shortfall of 380 kt to fulfil the CRMA benchmark of 40%.

9.5 million tonnes of CO_2 eq per year from ICE vehicles could be displaced by securing the production of 6.7 million passenger s.

Depending on the origin of raw materials, GHG emissions from lithium and nickel refinery in the EU can vary by a factor of 5.

Environmental impacts of refining key minerals need to be mitigated by EU regulations - cobalt and nickel implicate the greatest potential of local environmental impact.

Shifts in the mix of battery chemistries will have a limited effect on overall emissions by 2030

1. THE INCREASED USE OF RENEWABLE ENERGY FOR BATTERY PRODUCTION MUST BE SUPPORTED BY INCENTIVES FOR GREEN POWER PURCHASE AGREEMENTS AND THE FURTHER DECARBONISATION OF THE EU ELECTRICITY GRID.

The supply of the transition materials for 6.7 million BEVs required to meet the CRMA benchmark would generate 3.5 million tonnes CO_2 per year by European refineries. It should be noted that emissions from the refining and processing sectors represent just one portion of overall battery production emissions. At the same time, the internal combustion engine (ICE) emissions displaced by the BEVs produced from this secured material would be four times higher than the emissions for refining and processing battery materials. Even if emissions along battery supply chains are unavoidable, they do not belie the climate advantages of BEV. Total lifecycle greenhouse gas (GHG) emissions of BEV are on average half those of ICE cars, with a further potential reduction of 25% by using of low-carbon electricity.

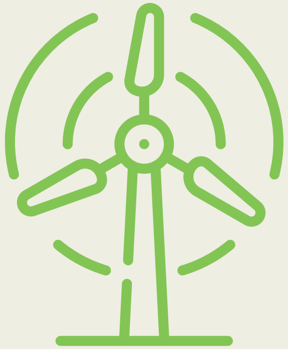
For every battery chemistry, cell manufacturing energy (electricity and heat) causes the largest portion of GHG emissions. Potential technical levers for reducing the CO_2 footprint of the battery production are the use of more secondary transition materials, enhanced recycling technologies and advanced technologies like dry coating.

The comparison of GHG emissions from battery production across EU countries, as a result of their respective energy mix, shows a potential 30-50% reduction in GHG emissions by using renewable energy in battery production. Decarbonisation of the EU electric grid needs to be underpinned by legislation supporting and incentivising the use of green energy for battery refining operations.

A potential lever to decarbonise the EU electric grid for reducing specific GHG emissions from battery manufacturing are green Power Purchase Agreements (green PPAs). Green PPAs are – direct medium to long-term (5-20 year) contracts between companies and renewable electricity suppliers. They can be used to finance new investments in renewable energy plants by guaranteeing price stability for electricity over a period of more than 10 years without the need for additional subsidies. Green PPAs are expected to become a major driver for market-based expansion of renewable energies in the EU in the coming years. For PPAs to realise their full potential to power the energy transition, the proposed reform of the EU's electricity market design needs to be implemented meticulously in Member States where this is required.

The Battery Regulation will be a good opportunity to reduce the CO_2 footprint of battery production, and through its due diligence provisions, it will also provide the opportunity to ensure that environmental protection and human rights are respected along the supply chains of lithium, nickel, graphite and cobalt. The upcoming guidelines the Commission will publish on this must ensure the highest of standards are adhered to and that the bar is not lowered. The Battery Regulation will be a starting point for reducing the CO_2 footprint of battery production. It will gradually introduce declaration requirements and limits on the carbon footprint of batteries for electric vehicles, light means of transport (such as e-bikes and scooters) and rechargeable industrial batteries, starting from 2025.

WWF RECOMMENDS DEFINING THE MAXIMUM CARBON THRESHOLD CATEGORIES OF THE PERFORMANCE CLASSES AS LOW AS POSSIBLE TO PUSH BATTERY PRODUCERS AND STAKEHOLDERS IN THE BATTERY VALUE CHAIN IN EUROPE TOWARDS THE USE OF GREEN ELECTRICITY.



2. AIMING FOR THE 40% DOMESTIC REFINING THRESHOLD OF THE CRMA IS NOT NECESSARILY PRACTICAL FOR ALL TRANSITION MATERIALS.

Contrary to popular belief, cobalt and nickel demand for battery production will rise less markedly than the current market situation suggests. In the short term (by 2030), cobalt and nickel-free battery chemistries – particularly lithium iron phosphate (LFP) and derivatives and, later, sodium ion batteries (SIB) – will be on the rise and replacing NMC and NCA batteries as market leader, thus contributing to a relatively reduced demand for these transition materials. This change in battery technology is resulting from the quest for cheaper, more environmentally friendly, and socially less questionable battery chemistries. Together with new technology, circular economy models and recycling, the demand for transition materials can be reduced to levels that can be met without necessitating such highly contentious developments as the mining of the deep seabed.

Additionally, relocating the refining of some materials may not result in environmental benefits depending on the ore type imported. A large proportion of the battery value chain activities are located outside of the EU, particularly regarding upstream segments. With the exception of cobalt, currently the majority of refined materials for battery production has to be imported to the EU. There are no refining and processing capacities for lithium and natural graphite in Europe, resulting in a heavy reliance on imports from Chile, China and Mozambique. There is some domestic supply of refined nickel and manganese, however, most of this goes into other industries. In order to meet the CRMA benchmark of 40% for domestic processing and refining of battery materials, capacities for the transition materials nickel, cobalt, manganese, lithium and natural graphite would have to reach 560 kt per year by 2030.The example of relocating midstream lithium processing to the EU illustrates this: the processing of lithium sulphate from brine is up to five times less emissions intensive than refining from spodumene. As brine processing is vertically integrated in its countries of origin (Chile & China), it is unlikely to be relocated to Europe. Without environmental considerations, the EU may opt for importing spodumene to reach the 40% benchmark, thereby increasing carbon emissions and undermining the objective of the Battery Regulation to reduce the GHG emissions of batteries.

INSTEAD OF PRESCRIBING BLANKET BENCHMARKS FOR RELOCATING PRODUCTION PROCESSES TO THE EU, WWF RECOMMENDS FOR POLICYMAKING TO CONSIDER FACT-BASED ASSESSMENTS OF THE POTENTIAL ENVIRONMENTAL IMPLICATIONS OF THE TYPES OF ORE IMPORTED FOR FURTHER PROCESSING.

3. RAW MATERIAL DEMAND REDUCTION AND CIRCULAR ECONOMY NEEDS TO BE IMPLEMENTED IN EU REGULATIONS AND SHOULD BE DISCUSSED WITH INDUSTRY STAKEHOLDERS.

From an environmental point of view, the CRMA has also been challenged for disregarding demand reduction scenarios, placing its strategic objectives of expanding mining and refining above other complementary options like reducing required materials, environmental concerns of the new industrial processes and for prioritising industry over citizen communities (e.g., European Environmental Bureau 2023, Friends of the Earth Europe 2023). Technical solutions alone will not suffice to stabilise global GHG emissions of the refining sector.

As a final note, it must be highlighted that consumers have the power to modulate demand for the goods our global economy revolves around. In 2023, WWF, together with three of the most renowned German research institutes, modelled circular economy scenarios for nine sectors, including transport (WWF Germany 2023). The results were clear: a change in consumer behaviour towards an increased use of public transport and car sharing, away from the use of private cars, has the greatest savings potential in terms of carbon emissions and resource utilisation.

When opting to own a car, consumer choices also have significant impact. In addition to choosing durable, reusable and recyclable product design, opting for smaller cars and keeping them in use for a longer time contribute to reducing the industry's resource intensity (WWF France 2023).

WWF RECOMMENDS THAT TECHNOLOGICAL ADVANCES NEED TO GO HAND IN HAND WITH DEMAND REDUCTION FOR TRANSITION MATERIALS. POLICIES NEED TO FOSTER INNOVATION BY ENCOURAGING THE DESIGN OF COMPONENTS AND GOODS THAT REQUIRE FEWER RESOURCES TO PROVIDE SIMILAR SERVICES.

4. AN IMPORTANT POINT FOR THE EU TO REALISE THE POTENTIAL FOR RESPONSIBLE BATTERIES IS TO ENSURE THAT EU LEGISLATION IS STRONG, STRINGENT AND ALIGNED WITH THE REQUIREMENTS OF THE CRMA.

Battery production is resource intensive, particularly regarding some transition materials such as nickel, cobalt, manganese, lithium and graphite. Of these, especially the mining of cobalt and nickel have been raising ethical and environmental concerns, and processing these minerals is energy intensive.

At the same time, it is **important to consider that the environmental impacts of extracting the transition materials required for a clean energy-mobility transition are far lower than those imposed by the extraction and use of fossil fuels.** Shifting from an energy system based on combusting fossil fuels which must be continuously extracted, to the use of durable metals which can be reused and recycled, is inherently more sustainable. **This development supports the push for decarbonising the global economy, seeing that by now it has been sufficiently demonstrated that over their entire life cycle, battery electric vehicles (BEV) are less carbon emissions intensive than internal combustion engine (ICE) vehicles.**

Proportionally to the growth of the battery market, however, both the demand for cumulative transition materials and GHG emissions associated with battery production will increase in the near future, highlighting the need for stringent environmental regulations to minimise negative environmental and climate effects of the green energy transition on a local and global level.

The CRMA has been criticised by some for risking replication of unjust economic relations between the EU and resource extracting countries, particularly in the Global South (Willems & Claes 2023). For this reason, it is imperative the strategic projects that are selected in third countries do not perpetuate harm by the mining industry but instead bring added value to the region.

As the Commission intends to use certification schemes as a tool to assess the sustainability of projects, the WWF recommendation is that only schemes that have been designed by civil society and industry together and that have true multistakeholder governance and decision-making structures are selected. The certification offered by the International Responsible Mining Assurance (IRMA) is a mining standard endorsed by WWF. Nonetheless, schemes should not be the sole criteria to assess a project, nor should they substitute effective due diligence.

With comparatively ambitious environmental and climate policies in place, the EU has strong foundations to develop a best-in-class battery value chain, compatible with the Paris Agreement and with the Global Biodiversity Framework.

WWF RECOMMENDS THAT THEY ARE KEPT UPDATED AND ALIGNED WITH THE REQUIREMENTS OF THE CRMA AND THAT THE CRMA DOES NOT PROVIDE ANY LEEWAY FOR OVERRIDING ENVIRONMENTAL LEGISLATION, OR FOR SIDESTEPPING ENVIRONMENTAL AND SOCIAL CORPORATE DUE DILIGENCE OBLIGATIONS, SUCH AS ENVIRONMENTAL IMPACT ASSESSMENTS.

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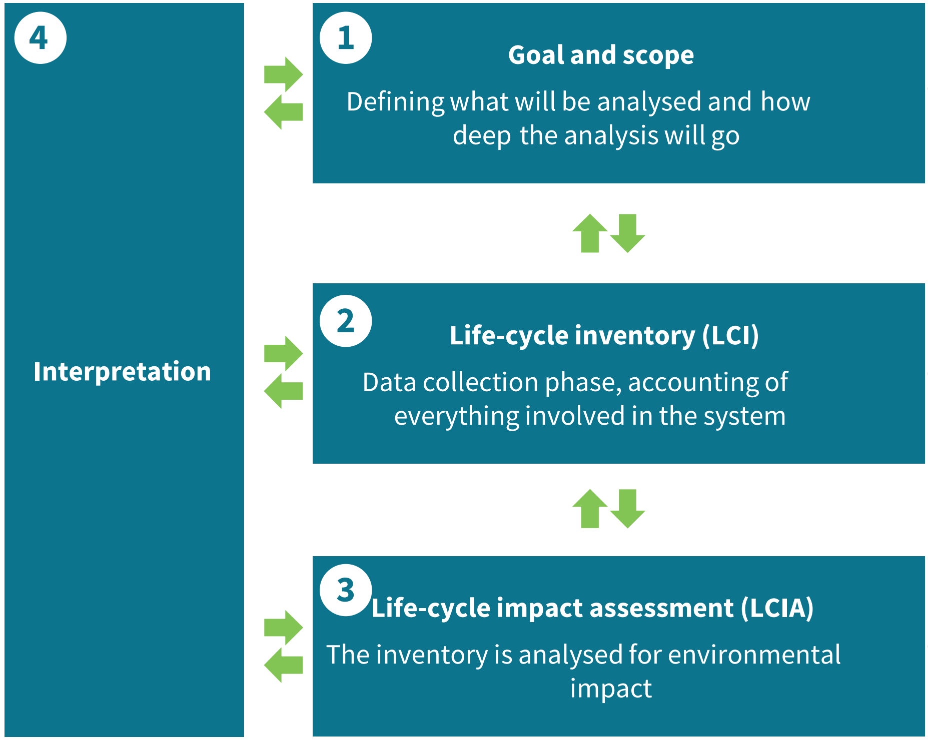
APPENDIX

LCAs have 4 fundamental phases and the different steps depend on each other

The 4 phase LCA procedure



4

Interpretation

1

Goal and scope

Defining what will be analysed and how deep the analysis will go

2

Life-cycle inventory (LCI)

Data collection phase, accounting of everything involved in the system

3

Life-cycle impact assessment (LCIA)

The inventory is analysed for environmental impact

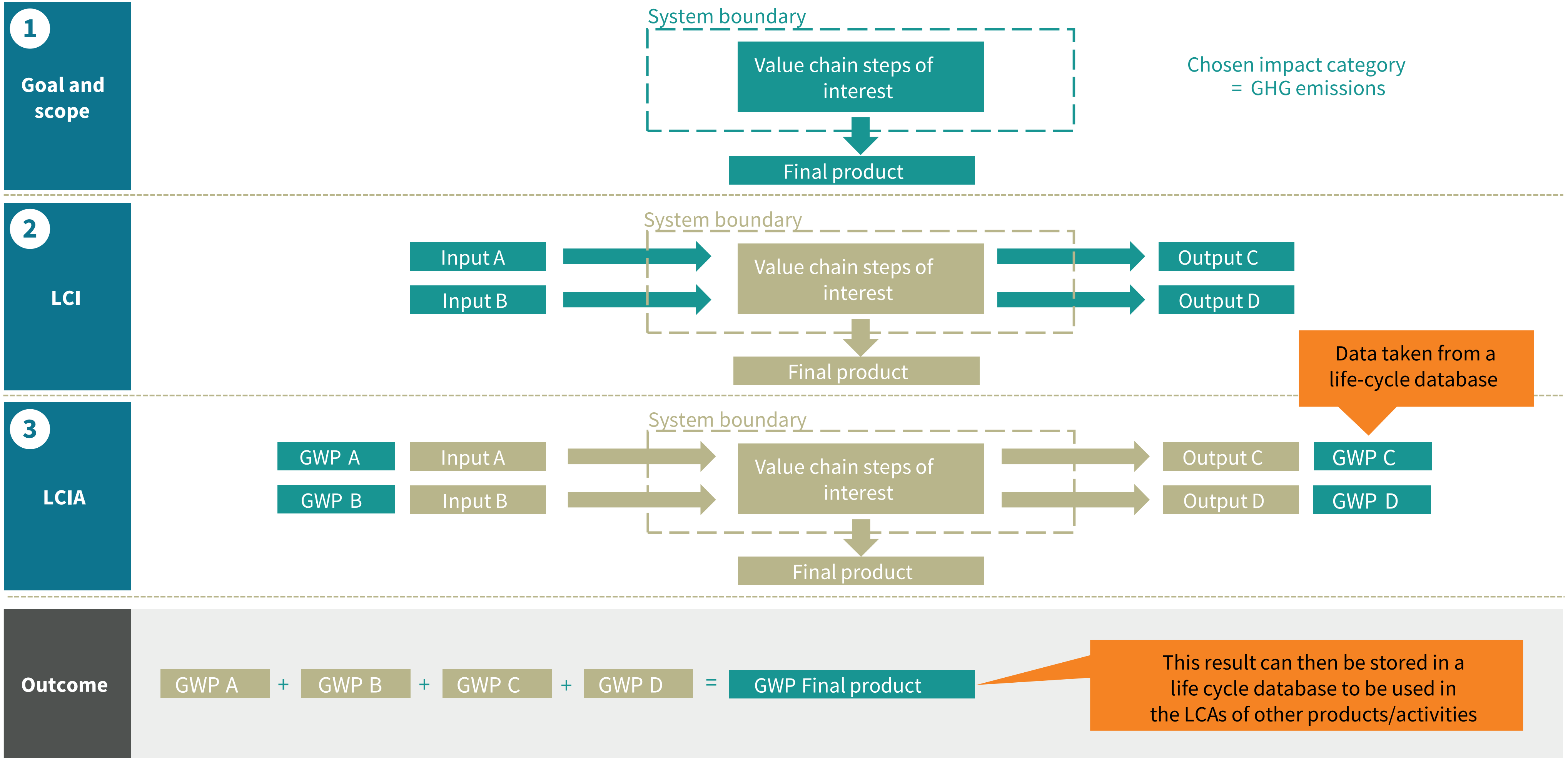
Description and relevance to our analysis

- In this first phase the following variables are defined:
  - Material/activity under assessment and functional unit
  - Product life-cycle model, system boundaries and division of value chain steps
  - Impact categories

- This step involves detailed tracking of inputs and outputs of the product system e.g. energy, water, materials, etc.
- A flow model is used to show what enters and leave the system boundaries

- In the final step the inventory is analysed for environmental impact
- Values from life-cycle inventory databases are extracted for each of the input and outputs to establish the overall impact of the process flow

Each phase of an LCA builds up the overall picture of a product's impact

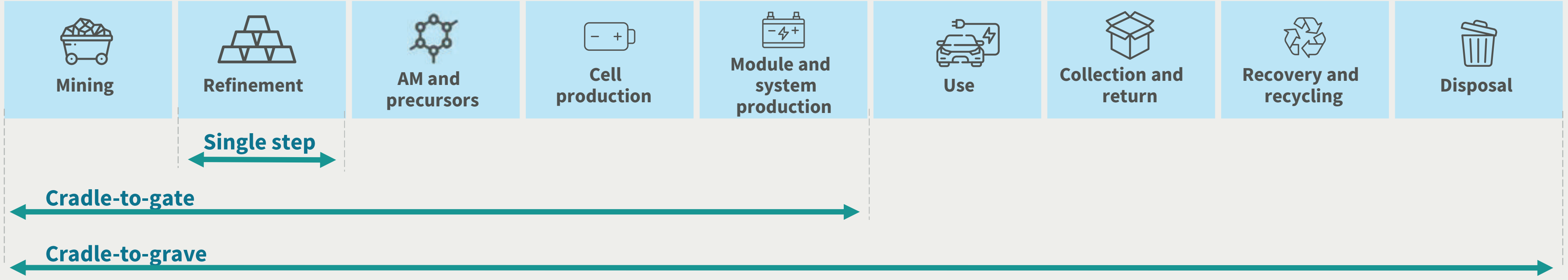


Data taken from a life-cycle database

This result can then be stored in a life cycle database to be used in the LCAs of other products/activities

LCA methodology and approach Is highly variable: 3 key examples

1. Assessed portion of the product life-cycle



2. LCIA method

Many different LCIA methods have been developed which use different:

- Underlying data and modelling approach
- Orientation of approach (see 3.)
- Impact categories
- EOL and co-product allocations

Well known examples include:

CML | EF | ReCiPe | USEtox

3. Approach

The data output from an LCA will either be a “midpoint” or “endpoint” depending on if the approach was:

- **Problem orientated approach** > quantifying what causes environmental harm
- **Damage oriented approach** > quantifying the effect of environmental harm

e.g. Acidification potential

MIDPOINT	0.003 **mol H+** / kg Ni
ENDPOINT	2.58 **species. yr** / kg Ni

OUR MISSION IS TO STOP THE DEGRADATION OF THE PLANET'S NATURAL ENVIRONMENT AND TO BUILD A FUTURE IN WHICH HUMANS LIVE IN HARMONY WITH NATURE.

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