COBALT INSTITUTE
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Responsible Secondary Cobalt

PUBLIC REPORT

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LGi sustainable innovation

LGI Sustainable Innovation was commissioned by the Cobalt Institute to prepare the Responsible Secondary Cobalt Report. LGI is a Paris-based mission-driven enterprise that delivers innovative strategies and solutions for sustainability. It focuses on the international challenges of climate, natural resources, and biodiversity.

The report was drafted based on analysis of key public policies affecting the market for secondary cobalt around the globe, and draws upon LGI's experience designing circular value chains for critical minerals

EXECUTIVE SUMMARY

The cobalt Institute's *Responsible Secondary Cobalt* report aims to support the development of a global circular economy of cobalt. Most recycled cobalt currently on the global market comes from **battery manufacturing scrap**, however this feedstock presents relatively few risks of improper disposal. Thus, the report focuses on secondary cobalt feedstocks that are currently not recycled, or at risk of being lost for recycling.

In the immediate term, spent **lithium-ion batteries (LIBs)** in portable electronics represent the greatest source of wasted cobalt globally, due to inadequate collection systems, and an unequal global distribution of battery recycling plants meaning that most regions of the world lack the capacity to recycle cobalt from spent batteries. Globally, upwards of 34,000 tonnes of cobalt become e-waste annually, with the majority of this material **disposed outside of formal collection** systems.

Meanwhile, in the coming decade **spent electric vehicle (EV) batteries** will become the largest source of secondary cobalt globally, as increasing numbers of vehicles reach their end of life. It remains to be seen whether most EVs will be scrapped within developed economies, or if global **trade in used EVs** will result in a significant portion of EVs being disposed of in middle- and low-income countries that currently lack LIB recycling capacity.

Recycling cobalt from spent LIBs is a highly capital-intensive process, that therefore necessitates significant **economies of scale** to profitably produce battery grade material. This means that **global trade** in secondary feedstocks (e.g. spent LIBs and black mass) will be necessary for an economically viable market for cobalt recycling, since large recycling hubs will need to receive shipments of feedstock that are collected across wide regions. Thus, this report explores the status of cobalt recycling and its relevant ESG risks in four different regions, as well as the key policies in each geography impacting the market for secondary cobalt.

INTERNATIONAL TRADE IN SECONDARY COBALT FEEDSTOCKS

The first geography of focus in the report is international trade in secondary cobalt. This section presents an overview of global secondary cobalt flows, showing that **China is the preeminent region in the global market for secondary cobalt.** The country is the world's largest producer and consumer of LIBs. It also has the largest share of global battery recycling capacity, and is the largest net importer of black mass.

The international section of the report also presents an overview of the environmental, social and governance risks that have been identified around the world in association with recycling of spent LIBs. These risks are summarised in Figure 1 below. Proper **due diligence** efforts by recycling companies and downstream cobalt consumers can help them to identify and mitigate these risks in their supply chains. Independent **standards for electronic waste** recycling can also provide quality assurance and reinforce trust across the LIB recycling value chain.

Figure 1: ESG risks summary

Environmental	Social	Governance
Pollution from LIBs in thermal runaway releasing toxic substances	Precarious employment and lack of collective bargaining power	Laundering illicit primary cobalt falsely reported as recycled material
Landfilling or illegal dumping of LIBs leaching toxic elements and heavy metals into surrounding environment	Exposure of workers and communities to hazardous substances in spent LIBs and black mass	Corruption, bribery and clientelism
Improper disposal of electrolyte causing soil, water and air pollution	Child labour in the informal e-waste sector	Illegal trade of spent batteries and e-waste
Greenhouse gas emissions associated with processing secondary feedstocks	Discrimination towards vulnerable communities working in the informal waste sector	Ambiguity over the legal classification of black mass as a commodity and waste product
		Lack of proper due diligence for secondary cobalt

Currently, trade in spent LIBs and black mass is made challenging due to the **hazardous** nature of these materials, and the restrictions that the **Basel Convention** places on their movement. In practice, the Basel Convention is unequally implemented by jurisdictions around the world, which apply **differing waste and trade classifications** for spent LIBs and black mass. Yet the emergence of **battery passports** globally presents an opportunity to support harmonised global standards for safe and fluid movement of secondary feedstocks destined for recycling.

BATTERY RECYCLING IN THE EU

The report then focuses on the EU, as is at the forefront of global legislative efforts aimed at fostering a responsible circular economy of cobalt. A series of new policies rolled out by the EU throughout 2023 and early 2024 are poised to significantly impact not just the battery recycling sector within the EU, but also the broader global cobalt recycling value chain.

Foremost among these policies is the **EU Battery Regulation**, which among the most exhaustive regulatory undertakings worldwide aimed at mandating circularity and traceability in battery materials and sustainable management of LIBs across the entire lifecycle. Complementing this effort is the **Critical Raw Materials Act,** which specifically targets the recycling of battery materials, including cobalt. Furthermore, the EU's trade in spent batteries and black mass is now subject to more stringent oversite under the recently updated **Waste Shipment Regulation.**

BATTERY RECYCLING IN THE UNITED STATES

Meanwhile, governance of portable and EV battery recycling in the U.S. is less comprehensive than in other developed economies. The country has no federal mandates or requirements for LIB recycling and is the only major country to have not ratified the Basel Convention.

Nevertheless, cobalt recycling capacity is rapidly expanding in the United States, as part of a broader growth of the country's battery industry. The recently passed **Bipartisan Infrastructure Law (BIL)** and the **Inflation Reduction Act (IRA)** have allocated generous public subsidies to complement private investment into recycling, and aim to onshore battery supply chains within the U.S., as part of the country's ambitions to achieve secure access to critical minerals.

BATTERY RECYCLING IN GHANA

The final region of focus in the report is Ghana, which is emblematic of the challenges and opportunities typical of managing spent LIBs in lower income countries. West Africa has emerged as a center for global electronic waste exports, and the Agbogbloshie site in Accra has gained considerable media attention as a symbol of the risks associated with **informal e-waste collection and processing**. However, collaboration between public, private, and informal actors to develop battery recycling in Ghana could unlock sustainable development, as exemplified by the work of **Mountain Research Institute**. The country passed legislation in 2016 for e-waste management that holds lessons for other countries in the region and around the world.

KEY CONCLUSIONS AND RECOMMENDATIONS FOR THE COBALT INDUSTRY

Cobalt losses at end of life are primarily due to inadequate spent battery collection systems

- To improve collection rates globally, industry could consider advocating for policymakers to implement **extended producer responsibility** covering portables and EVs in high income economies.
- To help boost secondary cobalt supply from low-income regions, and mitigate ESG risks associated with spent LIBs, industry could **facilitate collaborative dialogue** between informal battery collectors, the public sector, and industrial cobalt recyclers.

Global battery recycling capacity remains highly concentrated

- To address this, industry can leverage geopolitical concerns about critical mineral sovereignty to support members in building out regional cobalt recycling hubs across the globe. Monitoring the funds made available in the U.S. and EU by legislation studied in this report, as well as continuing dialogue with multilateral organisations providing funding in Africa, can help members access public funding options in support of new recycling facilities.

International trade in secondary cobalt feedstocks faces major obstacles

- Industry can help streamline international flows of secondary feedstock by advocating for **harmonised global waste classifications** for spent LIBs and black mass, and support efforts by other global thinktanks (e.g. StEP, PREVENT, etc.) to **improve the Prior Informed Consent** procedure in the Basel Convention. Industry could also consider outreach to the World Customs Organisation in support of developing a **Harmonised System (HS) trade code for black mass.**

1. INTRODUCTION

AMBITION

Cobalt is an essential element in numerous technologies that are ubiquitous to modern life. It is also an enabler of a decarbonised future, as a key component of the cathodes of the lithium- ion batteries (LIBs) within electric vehicles and portable electronic devices that will power the digital and energy transitions. The principles of circular economy can help drive the transition towards net zero, by ensuring that the materials underpinning new energy technologies are produced and consumed sustainably within planetary boundaries.

In the near term, the rapid rate of demand growth for batteries, particularly in Electric Vehicles (EV), means that primary supply will be needed in the near term to meet global demand. However, recycled (e.g. secondary) cobalt currently represents around 5% of global supply, and this share is expected to grow in coming decades as batteries put on the market reach their end of life and become available for recycling (Cobalt Institute, 2023).

This report seeks to support the transition towards a circular economy of cobalt by **providing guidance to both policymakers and industrial stakeholders** to help structure a responsible and economically competitive global battery recycling value chain.

The impetus for this report is based on several observations:

- **Cobalt is (in theory) infinitely recyclable**, and upon entering the global economy can be reprocessed into consumer products countless times without losing its unique material properties
- **Cobalt is also the key driver of profitability for the LIB recycling industry**, since it is the most valuable material in conventional battery chemistries. Numerous studies have demonstrated that the higher the cobalt content in battery cathodes, the more economically viable recycling becomes (Lima, Pontes, Vasconcelos, Junior, & Wu, 2022).[1]
- Nevertheless, **vast quantities of cobalt are currently lost at the end of product life**, primarily from **batteries within post-consumer electronics** being either abandoned or disposed of in landfills and incinerators.
- As demand for cobalt in LIBs continues to rapidly grow in the near future, driven primarily by demand for EVs globally, there is a heightened risk of substantial cobalt losses when batteries reach their end of life in geographies with **insufficient battery collection and recycling systems.**

Adopting a **just transition** perspective with respect to the emerging market for LIB recycling can support the cobalt sector in tackling the complex socio-political challenges that may limit secondary cobalt supply. This entails addressing both environmental and human rights while interrogating the relationship

[1] This research also calls into question the potential for profitably recycling non-cobalt LIBs (e.g. LFP, LMO).

between developing and developed countries along the entire value chain. It requires addressing questions around the collection, sorting, export and import of consumer appliances containing cobalt (for secondary use) and of black mass.

Within this approach, this report aims to:

1. Provide an overview of **current and future global stocks of spent LIBs containing cobalt**, and the impact of global trade on the availability of this feedstock for recycling.
2. Map the **environmental, social, and governance (ESG) risks** associated with the value chain of secondary cobalt to support responsible sourcing of this material and prevent its loss into landfills or the environment.
3. Assess the **policy landscape** that structures the global secondary cobalt value chain and international trade of cobalt containing products (e.g. consumer electronics and EVs destined for secondary use) and black mass, in order to identify policy barriers and opportunities to enable a responsible circular economy of cobalt.
4. Build industry momentum and support for addressing the ESG risks associated with recycling cobalt through an assessment of existing **due diligence protocols and recycling standards.**
5. Provide targeted **recommendations to the cobalt industry** to support circularity, in line with the Cobalt Institute's mission of promoting the safe, sustainable and responsible production of cobalt globally.

Battery recycling is a rapidly growing and evolving market for cobalt sourcing. Adopting a proactive approach to risk mitigation in this sector now can help the cobalt industry avoid repercussions in coming decades as the market for secondary cobalt develops at scale.

Fortunately, cobalt has been at the forefront of discussions around responsible material sourcing for numerous years. Many of the policies and frameworks adopted to promote responsible sourcing of primary cobalt have lessons that can be transposed onto secondary material, and this report seeks to advance that discussion.

SCOPE AND METHODOLOGY

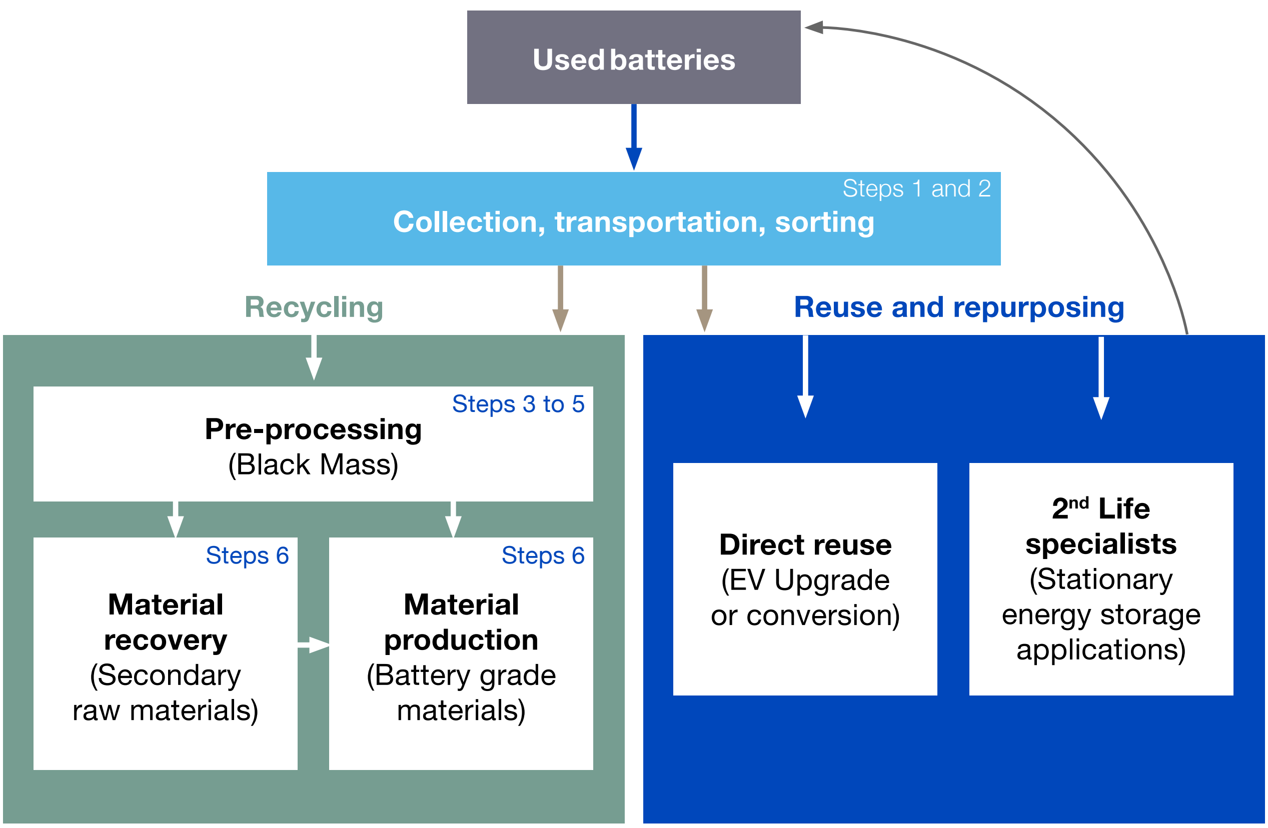
This report builds upon the 2023 study commissioned by the Cobalt Institute "Towards a Circular Value Chain of Cobalt" which presented a holistic approach to the circular economy of cobalt, from responsible mining, through to prolonged use of the material in batteries, and eventual recycling. A key finding of that study was that direct reuse and repurposing of LIBs can produce significant economic, social and environmental benefits.

While the focus of this report remains on recycling cobalt, it is important to note that recycling is not fully synonymous with the circular economy and is only environmentally optimal after reduction and reuse strategies have been developed. This new report concentrates on LIB recycling, as the rapid growth of the LIB market is the key driver of demand for secondary cobalt and spent batteries are also currently the largest source of end-of-life (EOL) cobalt losses from the global economy.

Studying the entire recycling value chain

Battery recycling is a complex process, which involves multiple actors and often deploys a diverse range of processing technologies for cobalt recovery. This report adopts a simplified schema developed by the OECD to describe a circular approach to managing spent LIBs and recovering the cobalt they contain, which is presented in Figure 2 below.

Figure 2: Overview of the stages in the battery recycling value chain



Source: OECD, 2023

Upon reaching the end of their life cycle, batteries within a circular economy process will first undergo (1) **collection and transportation** to facilities, where (2) **sorting** takes place. These initial steps are essential regardless of whether the aim is recycling, direct reuse, or repurposing. Sorting LIBs poses a challenge due to the absence of design standardisation and their diverse array of material chemistries.

For recycling purposes, the subsequent step often involves **pre-processing** in order to prepare spent batteries for hydrometallurgical systems that are often applied by Chinese and South Korean recyclers. Mechanical pre-processing is common, and encompasses (3) **discharging** and **dismantling**, (4) removing combustible materials to **clean the cell**, and (5) executing processes like **crushing, solvent removal, and mechanical separation**. These mechanical processes yield aluminium, copper, and a powdered substance known as **"black mass"**, containing valuable cathode and anode materials. Discharging and dismantling typically necessitate skilled operators and significant manual labour. Alternatively, some recyclers apply **thermal pretreatment methods**, pyrolysis and combustion, to safely deactivate the combustible components of LIB electrolytes (Neumann, et al., 2022).

The final stage of the recycling process involves (6) material recovery and production, facilitating the **obtention of secondary cobalt**, as well as other battery materials including lithium, manganese, and nickel, which can then be reintegrated into battery cell production. Numerous material recovery methods exist, typically involving some combination of pyrometallurgy and/or hydrometallurgy. Some pyrometallurgical systems also entirely bypass the need for pre- processing (steps 3-5), and directly smelt spent batteries. All these recycling processes require substantial capital investments and thus need to operate at scale.

A diversity of stakeholders acts along the recycling value chain, which may be more or less vertically integrated depending on the context. For the purposes of the analyses conducted throughout this report, the recycling value chain is broken into four high level stages: collection (with transportation and sorting), obtention of black mass through pre-processing, cobalt recovery, and procurement of secondary cobalt.

Selecting the geography

The report seeks to provide an overview of the global challenges that currently risk preventing the recovery of secondary cobalt feedstocks, as well as the opportunities that may enable the growth of a vibrant and responsible secondary cobalt market. Accordingly, the report focuses on four geographies across its main chapters:

- **Chapter 2 provides an overview of the international status of cobalt recycling** and the ESG risks that may accompany it. The focus in this geography is on international trade in used LIBs, spent LIBs and black mass, which structure the availability of secondary cobalt around the world. Two global initiatives, the Basel Convention and Battery Passports were selected since they represent the most significant frameworks structuring flows of used LIBs and secondary feedstocks. This chapter also includes a case study on the traceability service provider Circulor, who is developing a software solution to support Battery Passport implementation.

- **Chapter 3 studies the European Union (EU)**, which was selected because its Battery Regulation is a key driver of the global shift towards responsible battery supply chains. The EU is also at the centre of ongoing debates about the export of electronic goods (and their batteries), particularly due to its recent amendments to the Waste Shipment Regulation.
- **Chapter 4 looks at the United States (US)**, which was likewise selected because it is a major market for batteries that will reach their end of life. It faces challenges related to the export of EOL consumer electronics to developing countries, which are exacerbated since it is not party to the Basel Convention. The US is also rapidly expanding its LIB recycling capacity following major public investments in support of onshoring the LIB value chain.
- **Chapter 5 then describes the situation in Ghana**, which was chosen as the final geography because it embodies many of the challenges and opportunities that developing countries face in handling LIBs. West Africa has become a major hub for global electronic waste exports in recent years. The Agbogbloshie site in Accra in particular became highly mediatised and emblematic of the challenge of informal e-waste collection and processing. Yet Ghana also has a major potential to leverage battery recycling for sustainable development.

Assessing ESG risks along the secondary cobalt value chain

In each target geography, an assessment of observed and potential negative environmental, social and governance impacts was conducted along the four high level stages of the secondary cobalt value chain. The macro-categories inspiring the risk assessment were inspired by the Environmental and Social Risk Categories that require due diligence in the EU Battery Regulation, included in the annex. Governance risks were assessed according to the risk of a lack of regulatory compliance, as well as corruption and bribery.

Policy analysis to promote responsible cobalt recycling

For each of the four geographies within this study, selected policy measures influencing the value chain of cobalt recycling are analysed according to the following criteria:

- **Relevance to secondary cobalt** explores why the particular law was chosen, and what its relevance is to cobalt recycling
- **Policy Mechanisms** describes the specific content of the policy that impacts the secondary cobalt value chain, for instance through regulatory mandates or public subsidies
- **Governance Framework** identifies the specific actors tasked with implementing the policy and the relations between them
- **Capacity to enable responsible recycling of cobalt** provides an assessment of the extent to which the policy has effectively supported the development of a circular cobalt economy

- **Challenges and recommendations to improve the policy** engages critically with the policy in question to understand gaps in its effectiveness and opportunities to amend the policy to improve the responsible production of secondary cobalt and drive the global transition to net zero

Recommendations to Improve Cobalt Recycling

The report also works to support Cobalt Institute members by developing guidance based on relevant **due diligence guidance** and **recycling standards** that can mitigate risks in cobalt recycling, and offers recommendations for their continued improvement. These findings are presented in Chapter 5. Finally, Chapter 6 works to chart a path forward for the cobalt industry to build upon the findings of this report, by presenting **recommendations for policymakers** and members aimed at increasing the responsible recycling of cobalt.

2. INTERNATIONAL TRADE OF SECOND-HAND AND SPENT BATTERIES, AND BLACK MASS

This chapter of the report provides an overview of the current and emerging international market for secondary cobalt, along with the key international frameworks governing the global cobalt recycling value chain.

It begins by presenting an overview of current and future cobalt demand and its implications on secondary cobalt feedstocks. Figures for global battery recycling capacity, and international trade in secondary cobalt are also detailed. This is followed by an overview of the current and emerging ESG risks along the cobalt recycling value chain. Two prominent governance frameworks seeking to mitigate ESG risks in secondary cobalt at the international level are then assessed, the Basel Convention and multi-stakeholder battery passports (GBA and Battery Pass).

2.1. OVERVIEW OF THE CONTEXT OF SECONDARY COBALT

2.1.1. RATE OF BATTERY CONSUMPTION, DISPOSAL, AND RECYCLING

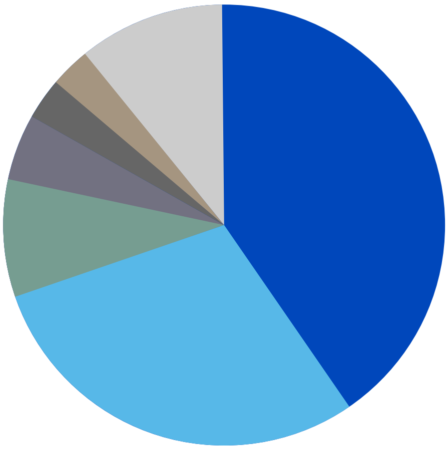
In 2022, 9.3 tonnes of secondary cobalt were produced globally, with 74% of this coming from process scrap generated during battery manufacturing (Cobalt Institute, 2023). The fact that only around 2.4 tonnes of cobalt were recycled in 2022 from spent batteries demonstrates the lost opportunity represented by the relative lack of spent batteries being recovered and recycled, compared to the available amount in spent devices around the world.

This section presents an overview of current and emerging available feedstocks of secondary cobalt, as well as the current distribution of global LIB recycling capacity.

Evolving global cobalt demand and implications for secondary supply

To understand the potential sources of secondary cobalt, it is essential to comprehend the demand for cobalt applications in the global economy, in order to determine the locations and forms in which cobalt products will ultimately reach their end of life. Total cobalt demand reached 187 ktonnes in 2022, representing a 21k tonne increase from the previous year. Notably, **battery applications accounted for 70% of cobalt demand, with EV batteries taking up 40% of demand and portables 30%.**

Figure 3: Demand share of cobalt end use sectors in 2022



Source: Cobalt Institute, 2023

LIBs will thus continue to be the leading available feedstock of secondary cobalt in the foreseeable future and are therefore the focus of this report. In the near term, the **spent LIB batteries available for recycling will predominantly come from portable electronics.** This is because prior to 2022, consumer electronics were the primary driver of cobalt demand for batteries. They also have much shorter life spans than EVs, and thus become available more quickly for recycling. The largest drivers of cobalt demand within consumer electronics are smartphones, followed by laptops, tablets, and other portable devices.

Portable electronics predominantly utilise **lithium cobalt oxide (LCO) cathodes** in their batteries. These cathodes are known for their high cobalt content, which is typically 60% of the cathode. With LCO technology expected to remain prevalent in electronics for the foreseeable future, it serves as a substantial source of cobalt. An overview of the estimated cobalt content in different consumer products and LIB cathode chemistries is presented in Figure 4 below. It also shows cobalt content for cathodes primarily used in EVs, which are NMC cathodes predominantly used in higher end EVs for their high energy density, and LFP cathodes, which are cobalt free and primarily used in low cost EVs particularly in China.

Figure 4: Estimated cobalt content in consumer products and cathode chemistries

Product	Cobalt content
Smartphone	5-20 g
Tablet or laptop	20-50 g
Plug-in hybrid electric vehicle (PHEV)	1-4 kg
Electric vehicle (EV)	4.5 - 15 kg

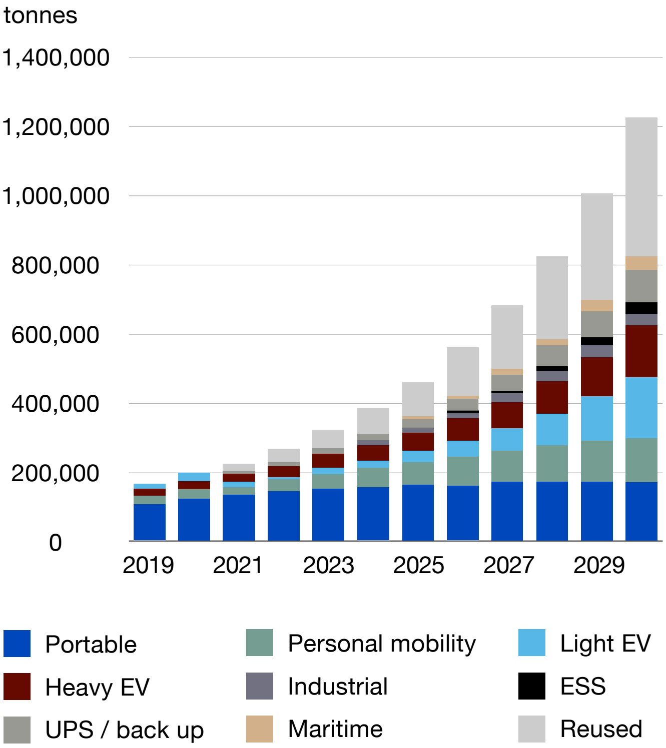
Cathode type	Cobalt content
Lithium cobalt oxides (LCO; electronics)	60%
Lithium nickel manganese cobalt oxides (NMC; passenger electric vehicles)	6-20%
Lithium iron phosphate (LFP; electric vehicles, e.g. Chinese buses)	0%

Source: BGR, 2021

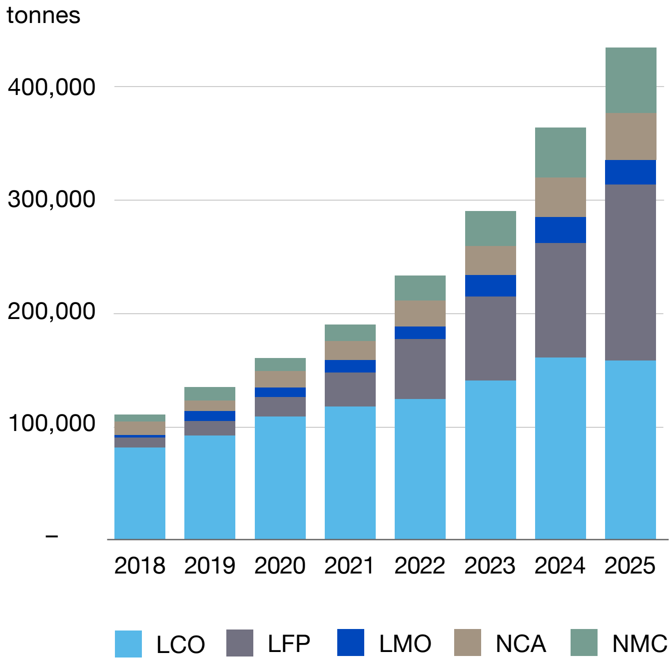
The evolving chemistry of LIB cathodes is also reflected in the chemistry of global LIBs available for recycling. Data from Circular Energy Storage (Figure 5) confirms the fact that LIB demand was historically primarily for portable electronics with LCO cathodes, but that increasingly EV batteries (with LFP or NMC cathodes) will become available for recycling globally as EVs reach their end of life.

Figure 5: LIBs available for recycling worldwide by application (left) and cathode chemistry (right)

Lithium-ion batteries available for recycling, worldwide,



Lithium-ion batteris available for recycling by chemistry,



Source: Circular Energy Storage, 2022

In the long term, the quantities of available cobalt from EOL electric vehicle (EV) batteries are expected to overshadow those from consumer electronics. Yet the substantial volumes of electronic waste generated annually highlight the immediate and tangible impact that improving rates of cobalt recycling from consumer electronics could have in bridging the gap between recycling capacity and recyclable material supply.

The recently published Global E-waste Monitor highlights the important quantities of cobalt that are currently not collected from portable electronics, estimating that globally **34 000 tonnes of cobalt was contained in the e-waste generated in 2022** (Baldé C. P., et al., 2024). The total amount of global e-waste has risen 82% between 2010 and 2022 and is on track to rise another 32% by 2030. Despite the significant amount of economic value represented by the materials in this waste, **only 22.3% of the world's e-waste was documented as being formally collected and recycled.**

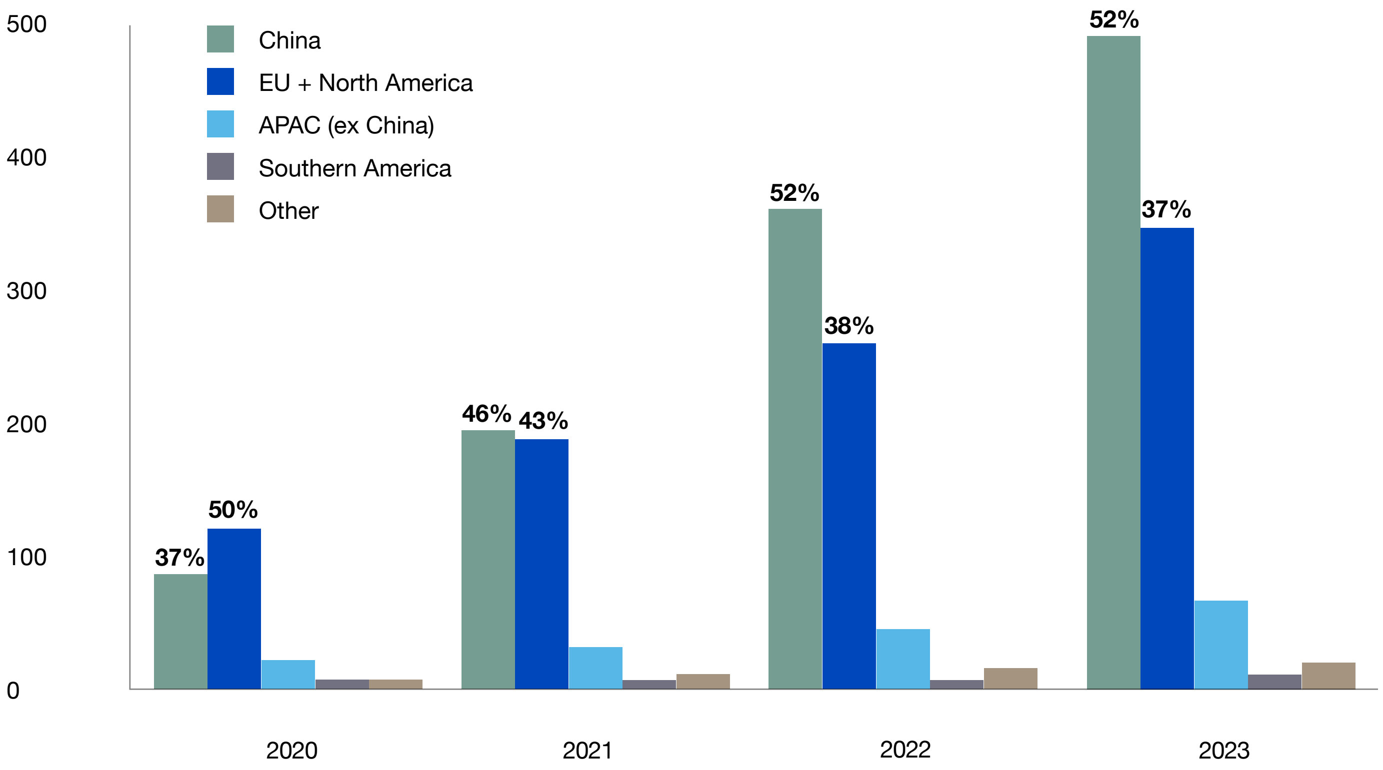
In the near future, as EV adoption continues to soar, **the volume of EOL EV batteries is also set to escalate dramatically.** In 2020, 250,000 tonnes of EV batteries reached their end of life. However, this figure is expected to surge to 1,850 ktonnes by 2030, 7,850 ktonnes by 2035, and reach a monumental 20,500 ktonnes by 2040 (McKinsey & Company, 2023).

Given that cobalt is a critical component of many EV batteries, effective recycling of these batteries is crucial for securing a sustainable supply chain for cobalt. Optimising recycling processes for both e-waste and EV batteries can play a crucial role in meeting future cobalt demand while reducing reliance on primary extraction and minimising environmental impact.

Europe and North America have historically been the world's leading consumers of cobalt in batteries, but increasingly China is the primary consumer of cobalt containing batteries and will thus also remain the predominant global source of secondary cobalt feedstocks in the near future.

Figure 6: EV battery demand by region and share of Cobalt demand by sector

GWh (regional market share as %)

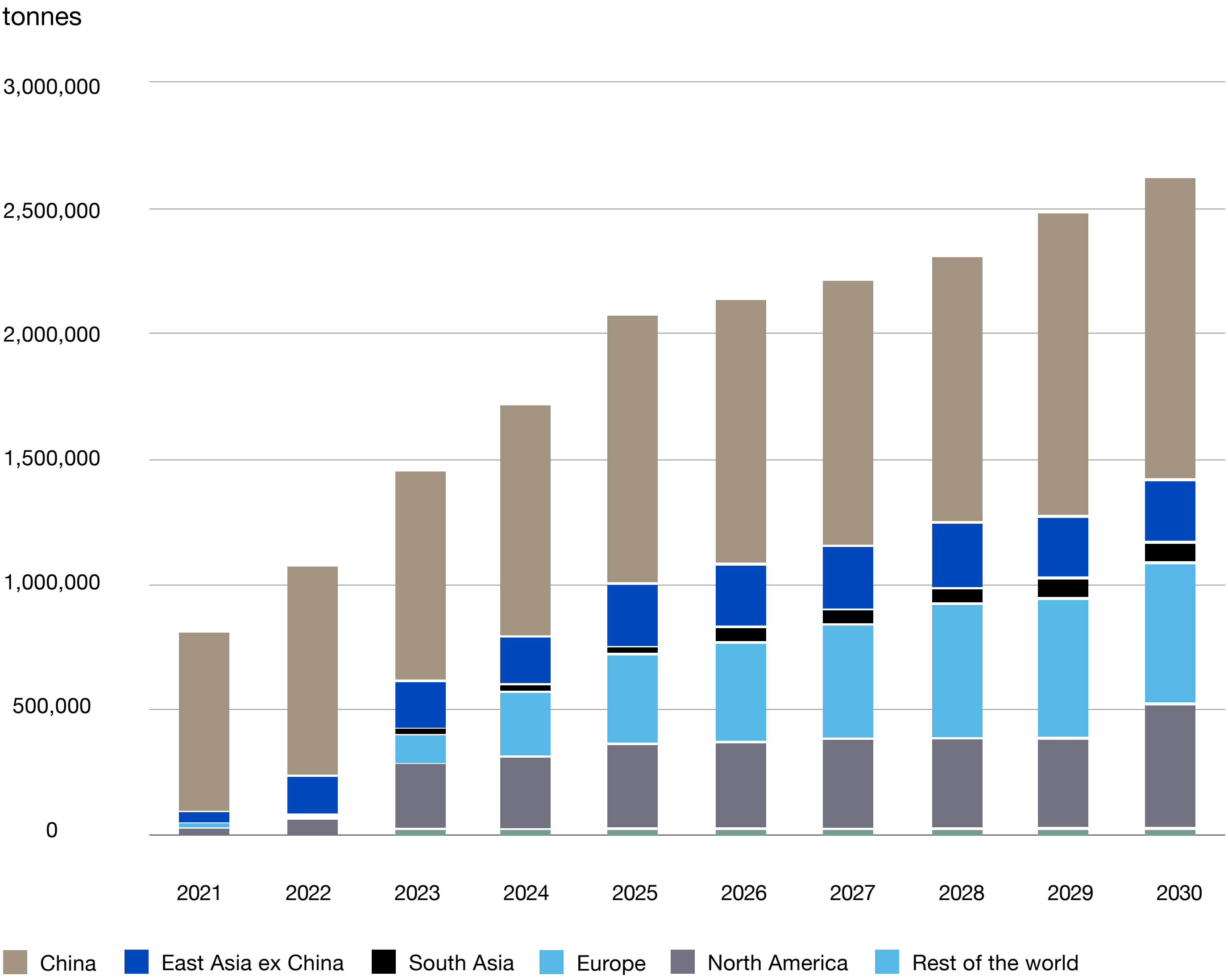


Source: Cobalt Institute, 2023

Global LIB recycling capacity highly concentrated in China

According to recent data from Circular Energy Storage, it is projected that by 2030, over 1.2 million tonnes of spent LIBs will undergo recycling globally. As a result, the amount of recycled cobalt available for use in the global battery supply chain is anticipated to reach approximately a quarter of the current market demand by that time. Moreover, as shown in Figure 7 below, China is expected to dominate global recycling capacity until 2030, followed by North American and the EU.

Figure 7: Global LIB material recovery capacity



Source: Circular Energy Storage, 2022

Battery recycling is dominated by China, which is more generally the dominant geography in the global battery value chain. Since currently most recycled cobalt on the global market is produced from production scrap rather than spent LIBs, Chinese recyclers benefit from the economies of scale available thanks to their close proximity to battery gigafactories. Global battery manufacturing scrap is projected to grow from 450,000 tonnes in 2023 to 911,655 tonnes in 2030 (Circular Energy Storage, 2022).

As gigafactories scale up in China and globally, they are projected to produce less manufacturing waste due to process improvements. This, coupled with the increasing amount of spent EV LIBs becoming available for recycling will make spent LIBs the main feedstock for secondary cobalt globally in the coming decade. Spent LIBs also represent the highest potential for the circular economy to capture value that is currently lost, or at risk of being lost, since production scrap faces fewer barriers to recycling and reintegration into new products. Thus, this report has focused its scope on spent portable and EV batteries due to the need for a comprehensive framework to maximise the potential value of the cobalt they contain.

2.1.2. GLOBAL TRADE IN SPENT BATTERIES AND USED EVS

The concentration of global cobalt recycling capacity in a few geographies makes international trade a key element in the secondary cobalt market. Trade in used batteries can notably empower developing countries on their path to decarbonisation, but may face trade-offs if these countries are unable to safely handle spent LIBs at end of life. Mapping international flows of spent LIBs and cobalt in battery scrap is made challenging by the lack of granularity in international trade statistics. The most detailed Harmonised System (HS) category aggregates various types of batteries, including single-use and rechargeable ones, spanning across different battery chemistries. As a result, the observed trade flows probably encompass the life cycles of batteries other than LIBs, such as lead-acid car batteries.

According to the OECD, citing Circular Energy Storage's data, a considerable portion of LIBs reaching the end of their primary lifespan in the European Union or the United States are exported. Typically, European batteries are shipped to pre-processing facilities in Malaysia, Indonesia, or the Philippines, while those from the United States have most often undergone pre-processing in Korea. Currently, pre-processing and cobalt recovery are often conducted in separate facilities, with material recovery operations closer to battery material producers, mainly situated in China (OECD, 2023).

The OECD cites Circular Energy Storage's estimates indicating that in 2019, **Europe and the United States were net exporters of LIB waste and scrap for pre-processing**, with 16,888 tons and 27,420 tons net exports, respectively. In contrast, **China was a net importer** of 56,559 tons of LIB waste and scrap. **China has a legal ban on importing waste batteries**, however these figures are plausible due to the legal import of LIBs for reuse, with some eventually entering the recycling stream due to quality concerns (OECD, 2023).

The future landscape of spent LIB and secondary cobalt feedstocks will largely depend on the global trade in used EVs, which will determine where batteries reach their end of life. Currently, only a minor share of used vehicles globally are EVs. However, the global passenger vehicle market generally involves new vehicles being built and sold primarily in developed countries, with middle and low-income countries in East Europe, Latin America, Africa, and South Asia relying primarily on imported second-hand vehicles to meet passenger demand. In the coming decades, **China is also expected to become a major global exporter** of second-hand vehicles (ITF, 2023).

Numerous economic and policy uncertainties currently exist about the emerging trade in used EVs, which make it challenging to determine if global trade in used EVs will mirror patterns in the trade of internal combustion engine vehicles (ICEV). Developed countries may place additional restrictions on EV exports, which currently are not placed on ICEV, out of a desire to maintain control over cobalt and other battery materials. Moreover, developing countries currently lack expansive charging infrastructure and often also stable electricity supply, which may inhibit demand for second-hand EVs. The emergence of a market for reuse of EV batteries in stationary storage may also limit used EV exports to developing countries (ITF, 2023).

Developing new economic models and policies to facilitate the emergence of a **global and circular EV economy** will be key to supporting global decarbonisation efforts. The alternative presented by

a business-as-usual scenario would risk merely displacing transportation emissions from the developed to the developing world, by locking in their dependence on ICEV. Alternatively, used EVs risk being disposed of in geographies that lack the proper infrastructure to safely recycle them at their end of life.

2.2. CURRENT AND EMERGING ESG RISKS IN THE SECONDARY COBALT SUPPLY CHAIN

Unlocking the market potential of secondary cobalt requires identifying and addressing the potential negative impacts across the battery recycling value chain. Adopting a proactive approach to tackling the ESG risks of secondary cobalt is a requirement for cobalt recyclers and consumers to comply with various regulatory requirements around the globe and avoid reputational risks. As the number of LIBs reaching their EOL increases in the near future, an awareness of ESG considerations for secondary material will become increasingly important for the cobalt industry.

A comprehensive assessment of ESG risks across the international value chain of secondary cobalt is presented below.

2.2.1. END-OF-LIFE BATTERY COLLECTION, TRANSPORT, AND SORTING

Environmental risks

Improper collection, transport, and disposal of LIBs carries severe environmental risks. Key among these is the risk of LIBs **combustion**. This occurs when spent batteries are not fully discharged and the contained energy is rapidly discharged when the battery is damaged, leading to a chemical reaction known as thermal runaway that ignites the flammable electrolytes within LIBs (Christensen, et al., 2021).

LIBs in thermal runaway release gases, often in the form of a white cloud, that are a mixture of toxic substances including carbon monoxide, carbon dioxide, hydrogen fluoride, short-chain alkanes and alkenes, hydrogen cyanide, nitrogen oxides and droplets of solvent (Mrozik, Rajaeifar, Heidrichab, & Christensen, 2021). The environmental risks posed by LIB fires are particularly acute in landfills, where batteries can be crushed during burial and their ensuing thermal runaway can ignite methane trapped within rubbish heaps.

Landfilling, or illegal dumping of LIBs in the environment, also carries serious risks of soil and water pollution. The leachate from LIB can carry with it toxic and heavy metals (Co, Cu, Mn, Ni) into the surrounding environment and groundwater supplies. Numerous studies have found that cobalt compounds found in LIB cathodes have ecotoxic effects on microorganisms as well as freshwater species.

Spent LIB can also degrade over time, with researchers documenting that over the course of 20 months spent LIB released traces of phosphoric acids from electrolytes, along with $LiPF_6$, other additives (i.e. cyclohexylbenzene) and solvents – DMC, EC, EMC and their degradation products. Researchers also identified several alkyl fluorophosphates with similar structures to chemical warfare agents within the degraded batteries, including dimethyl fluorophosphate (DMFP) and diethyl fluorophosphate (DEFP). (Grützke, et al., 2015).

Social risks

The primary social risks associated with LIB collection, transport, and sorting involve workers and communities being exposed to the hazardous substances within the batteries, as well as LIB fires, and suffering from serious, and potentially deadly health consequences as a result.

In developed economies, workplace health and safety regulations (such as OSHA in the US and REACH in the EU) typically require waste management companies handling spent LIB to follow stringent risk mitigation measures. Companies transporting spent LIBs must also ensure that their drivers are ADR licensed and prepared to deal with fire risks. Disposal of hazardous substances within LIBs is also stringently regulated, and only permitted within licensed facilities in the US and EU.

The health and safety of LIB collectors, and of communities living near disposal sites, are particularly at risk in developing economies where the informal sector plays a significant role in waste management. According to the United Nations Development Programme (UNDP), up to 20 million people work in the informal waste sector (Chen, 2023). These workers face precarious working conditions, and work in unregulated environments where they are exposed to toxic substances without personal protective equipment.

These health consequences of exposure to hazardous elements in spent LIB are particularly serious for children, and tens of thousands of children are estimated to work in informal e-waste management across the globe, with documented evidence of in India, Mexico, Nigeria, Ghana, and China (Abalansa, Mahrad, Icely, & Newton, 2021).

Informal e-waste collectors often struggle to earn a living as they earn variable incomes that fluctuate according to prices offered by scrap dealers. Significant inequalities exist within the informal waste system and collectors often lack bargaining power to negotiate prices for the materials they scavenge (Abalansa, Mahrad, Icely, & Newton, 2021).

In both formal and informal waste collection systems, workers face risks of precarious employment, and are more likely to come from historically marginalised communities. There is documented evidence that migrant communities are disproportionately likely to work in e-waste collection both in Europe and West Africa (Rendon, Espluga-Trenc, & Verd, 2021). As these communities are often excluded from other employment opportunities, e-waste collection and sorting may represent a survival strategy despite its visible risks.

Governance risks

At a global scale, there are numerous governance risks related to collecting, transporting and sorting spent LIB, which can be considered as responsible for the emergence of environmental and social hazards related to this feedstock. Due to the low rates of EVs presently reaching their end of life, these risks are primarily apparent for portable batteries, however may also become increasingly relevant for spent EV batteries in coming years.

The failure to implement an effective international governance system for collecting and disposing of end of life electronics (and the spent LIB they contain) is evidenced by the fact that **only 22% of the 62 billion kg of e-waste produced in 2022 was documented as being formally collected and recycled** in a manner the United Nations Environment Program qualifies as environmentally sound (Baldé C. P., et al., 2024). Meanwhile, 26% of global e-waste is estimated to be collected in high income countries outside of formal systems, 29% is handled by the informal sector in developing countries with no developed waste management systems, and the remaining 23% is estimated to be disposed of as residual waste, and typically landfilled (Baldé C. P., et al., 2024).

The low rates of collection and environmentally sound recycling of EOL electronics, and in turn their portable batteries, points to an **inadequate global framework for battery collection**. Improving battery collection at end of life, and separation of spent LIB batteries from household waste, requires improved coordination between consumers, electronic producers, the formal recycling sector and public authorities at multiple levels (most typically municipal).

The fact that most EOL electronics are collected globally by the informal sector also points to a serious global governance issue, which is the **lack of effective engagement with the informal sector** to improve responsible spent LIB collection. The lack of regulatory oversite over informal e-waste collection can enable egregious social and environmental damages to occur from improperly handled spent LIBs. The lack of effective governance of illegal or hazardous LIB disposal also serves to undercut the emergence of a formal and responsible LIB collection system, as informal collection systems are more cost competitive since they are not required to cover the costs of safe disposal of hazardous material.

When the public sector does engage with informal e-waste collectors, it is often done in a sporadic and punitive manner, by framing their work as illegal without regards to the importance of this work in supporting livelihoods. Police and regulatory authorities may use environmental non-compliance as a pretext for **extorting vulnerable workers** by threatening them with arrest (Salvaire, 2023). Public sector **corruption, bribery, and clientelism** are well documented globally in waste governance and scrap collection.

These challenges add to the difficulty of tackling the illegal trade in spent batteries across countries, which have been documented to be falsely labelled as used appliances and shipped to low-income countries with inadequate waste management facilities. These challenges are exacerbated by the lack of an HS customs code specific to spent LIBs, which inhibits oversight over flows of these feedstocks. While new HS codes were added by the World Customs Organization in 2022 to address specific flows of e-waste, the code for spent batteries (8549) does not specify LIBs from other battery chemistries.

2.2.2. PRE-PROCESSING

Environmental risks

The environmental risks associated with pre-processing of spent LIB are similar to the risks of collection, transport and sorting. Notably, **improper handling and disposal of the hazardous substances in spent LIBs (particularly the electrolyte) can cause soil, water and air pollution.**

The risk of **combustion** and thermal runaway, which then releases harmful particle matter into the surrounding environment, is particularly acute when degraded batteries are stored at waste treatment facilities and during battery dismantling. Between 2020 and 2023, over 40 “utility scale” fires were reported globally due to LIBs (Kamateros & Abdoli, 2023). Improper sorting of batteries can exacerbate these risks, with widely documented evidence of LIBs being mistakenly stored and mishandled alongside lead acid batteries.

After discharge, dismantling, removal of combustible materials, and shredding, the intermediate black mass produced still carries environmental risks. **Black mass may contain hazardous substances** alongside the cobalt and other cathode materials, including alkyl fluorophosphates which are ecotoxic (Mrozik, Rajaeifar, Heidrichab, & Christensen, 2021).

Social risks

The social risks associated with LIB pre-processing are primarily related to **worker and community exposure to the hazardous substances contained in spent LIBs**. Battery dismantling is typically done manually, and if done without proper PPE and health and safety protocols, risks exposing workers to unsafe conditions. Workers may be exposed to cobalt compounds (e.g. LiCoO2) during battery shredding if black mass dust is not prevented from entering the air in the workplace, which poses a risk as a carcinogen if inhaled at harmful doses.

Governance risks

Governance risks in LIB preprocessing are similar to those related to battery collection, transport, and sorting. Notably, **lack of integration between battery preprocessors and the informal sector collectors amplifies the global risk of improper storage of spent LIBs**, since informal actors remain unable to produce black mass without capital intensive equipment.

The governance of black mass is also challenged due to ambiguity over the legal classification of this feedstock. The **absence of a standardised HS code** for black mass results in the use of multiple HS codes (ex. 7504 nickel flake, 8105 cobalt scrap), leading to inconsistencies that can create challenges when exporting and importing black mass, thereby restricting potential new market avenues. Categorizing black mass as hazardous material results in increased transportation expenses and limited transport alternatives, as carriers must obtain hazardous transport certification. The risks associated with transporting black mass differ from those of end-of-life batteries, yet both are currently classified under the same category.

2.2.3. COBALT RECOVERY

Environmental risks

While Life Cycle Assessment studies consistently show that LIB **recycling reduces the environmental impact of cobalt** as compared to producing primary material (Kallitsis, Korre, & Kelsall, 2022), recovering secondary cobalt does also produce environmental externalities.

The environmental risks associated with cobalt recovery from pre-processed black mass will vary according to the recycling process applied by a given company, as well as the energy mix used to power the process. These risks primarily relate to the potential for hazardous chemicals within the black mass to enter into the environment, as well as the associated environment footprint and global warming impact of the chemicals and energy used within the process.

Optimising the combination of pre-processing and processing techniques to maximise the recovery of cobalt and other finite resources present within black mass will be an essential task in developing a fully circular cobalt economy under the transition towards a net-zero economy.

Social risks

The social risks related to cobalt recovery from black mass relate to both worker and community health and safety. If inadequate safety measures are put in place during recycling, workers may be exposed to inhalation of cobalt or other materials present in black mass which are carcinogenic or otherwise harmful to their health. Likewise, improper handling of residual wastes or runoff from recycling facilities poses a risk to surrounding communities.

Governance risks

Experts interviewed during the preparation of this report indicated that there is evidence of primary cobalt sourced from ASM or other high-risk sources being falsely reported by suppliers as recycled material (anonymous). This has the potential to undermine claims of recycled content within batteries, leading to greenwashing. It also carries the risk of allowing the laundering of illicit primary material, and the associated negative social and environmental impacts that this material may produce.

2.2.4. PROCUREMENT OF RECYCLED COBALT FOR LIB MANUFACTURING

Environmental and social risks

Demand for secondary cobalt could drive the emergence of environmental and social risks in several ways. Most directly, if proper due diligence is not conducted on secondary cobalt, recyclers sourcing feedstocks through harmful practices could be enabled or encouraged. This would also entail a reputational risk for battery producers and OEMs sourcing unsustainable secondary cobalt.

High demand for secondary cobalt could also create indirect environmental and social risks. If demand for recycled material is sufficiently high, or if price premiums emerge for secondary cobalt over primary, this could limit the market for battery reuse and the associated environmental and social benefits of prolonging battery lifespans. This demonstrates the potential for trade-offs to emerge at times between environmental and social ambitions, which must be addressed holistically. In particular, the emergence of closed loop battery recycling, in which OEMs maintain battery ownership after first life and developed countries limit outflows of secondary feedstock, also risks having the unintended consequence of undermining the benefits of prolonging appliance lifespans and enabling low-income consumer access to LIB powered appliances and vehicles.

Conversely, if recycled cobalt is not able to be produced in a cost competitive manner to primary cobalt, there is a risk of low demand for secondary material. This would hinder the positive environmental and social benefits offered by the circular economy.

Governance risks

The procurement of secondary cobalt without proper due diligence carries both regulatory and reputational risks for downstream industries, exposing them to the risks described across the cobalt recycling value chain. To uphold human rights and mitigate reputational risks, efforts are needed to improve transparency and traceability in the supply chains of all battery recycling processes.

2.3. RELEVANT INTERNATIONAL POLICIES AND INITIATIVES

A fully circular economy of cobalt will require transnational movement of used and spent LIBs, as well as black mass. As shown above in section 2.1.2, the market for second-hand EVs and consumer appliances containing cobalt is global, with large rates of export from developed to developing countries.

Moreover, the capital intensity of recovering cobalt and other materials from spent batteries means that the economic viability of cobalt recycling depends on achieving economies of scale. Available spent batteries for recycling are unlikely to provide sufficient feedstocks for profitable recycling if they remain within the confines of individual countries. To achieve profitability, large scale, regional, cobalt recycling hubs are required. Providing recycling facilities with adequate feedstock thus requires an effective international policy framework to allow for responsible and effective global trade in spent batteries and black mass.

The following subsection presents an overview of the implications for cobalt recyclers of the most significant international policy governing transboundary shipments of e-waste and spent LIBs, the Basel Convention. This is followed by an analysis of the GBA Battery Passport, which represents an emerging international framework for reporting sustainability performance of batteries with the potential to improve the transparency of international markets for secondary cobalt.

2.3.1. BASEL CONVENTION

The Basel Convention governs shipments of hazardous waste between all countries which have ratified it. The Convention came into effect in 1992, in response to global concerns about exports of dangerous material from developed countries to the developing nations that lacked regulatory oversite to ensure safe disposal. Currently 191 countries around the globe are party to the Basel Convention, including all major economies except the United States.

Relevance to secondary cobalt

While the Convention does not specifically reference cobalt content within spent batteries and black mass, several categories of waste covered by the Convention are relevant to spent LIB shipments[2]. The potential for combustion of spent LIBs also qualifies them as hazardous under Annex III of the Basel Convention. A new amendment will also enter into effect in 2025, which expands the scope of the

Convention and will require **most e-waste to follow Convention protocols**[3]. However, effectively sorted, and handled spent batteries containing cobalt may be exempt from consideration as hazardous under the Basel Convention (article IX)[4], provided they can demonstrate they do not contain any other hazardous materials or represent a fire hazard.

The applicability to the Convention to international trade in spent LIBs is made more frequent, and complex, by the fact that all wastes categorised by *national* governments party to the Convention are also subject to the restrictions of the Convention. Spent LIBs are subject to differing national classifications, and many countries have **ambiguous classifications for battery wastes** that do not distinguish according to material composition or battery type.

Policy Mechanisms

The definition of spent cobalt batteries as hazardous is significant because it creates major **barriers and regulatory hurdles to their international trade** under the Basel Convention. The Convention prohibits OECD and EU countries and Liechtenstein from exporting any hazardous wastes destined for recycling, direct re-use, or alternative uses to other countries (OECD, 2023).

In all other cases, exporting waste under the Basel Convention necessitates securing **prior informed consent (PIC)** from the importing nation and any transit nations. It also entails establishing a contract between the exporter and the disposal facility to ensure the environmentally responsible management of the waste (World Economic Forum, 2020), along with proper notification of the shipment.

Governance Framework

The Basel Convention is coordinated by its Secretariat, within the **UN Environment Programme**, however its **implementation is fully reliant on national governments** translating the provisions of the treaty into national law and enforcing its procedures.

This has resulted in a very **disparate implementation of the Convention between countries**. Nigeria for instance currently lacks national legislation to enforce the Basel Convention (STEP; Prevent Waste

[2] Annex I: (i) Y32: Inorganic fluorine compounds excluding calcium fluoride; (ii) Y34: Acidic solutions or acids in solid form. Annex II: Y46: Wastes collected from households.

Annex VIII: (i) A1170: Unsorted waste batteries excluding mixtures of only list B batteries. Waste batteries not specified on list B containing Annex I constituents to an extent to render them hazardous; (ii) A1180: Waste electrical and electronic assemblies or scrap containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB capacitors, or contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note the related entry on list B B1110). https://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

[3] BC-15/18: Amendments to Annexes II, VIII and IX to the Basel Convention

[4] Annex IX: B1090: Waste batteries conforming to a specification, excluding those made with lead, cadmium or mercury.

Alliance, 2022), while China formally banned imports of spent LIBs in 2019, but continues to import secondary cobalt within batteries classified as intended for re-use (OECD, 2023). Even in countries that have translated the Basel Convention into national legislation, multiple public authorities may be involved in enforcing the PIC procedure, and in many countries public officials have **limited capabilities** to follow its protocols.

Capacity to enable responsible recycling of cobalt

The Basel Convention emerged with the intention of prohibiting the disposal of hazardous waste in countries that lacked the proper capabilities to effectively handle and dispose of these materials. This de jure ambition is in line with the goal of preventing the environmental and social risks related to improperly handling, transporting, and disposal of cobalt batteries.

De facto however, the Convention has served to hinder the emergence of a globalised circular economy of cobalt, by prohibiting or disincentivising international trade in secondary feedstocks. The disposal of e-waste in developing countries with insufficient recycling capabilities has also not been eradicated since the introduction of the Basel Convention, due to challenges with illegal shipments of waste and exports of used electronic devices.

Several key barriers posed by the Basel Convention to increasing cobalt recycling are summarised below, along with opportunities for their improvement.

Challenges and recommendations to improve the Basel convention

The lack of harmonised definitions and national regulations of battery waste containing cobalt between countries poses challenges to tracking secondary cobalt, and to integrating international business operations across the recycling value chain. The Secretariat of the Convention has begun to address these challenges in several ways. It has produced a draft guidance on gathering data within member countries in order to produce a harmonised inventory of Li-ion waste produced globally (UNEP, 2020).

The Secretariat has also convened a “Small Intersessional Working Group on the development of technical guidelines on waste batteries” which offers a potential platform for advocating on harmonising and improving the granularity of trade and waste classification codes for cobalt containing battery waste. This could also inform battery labelling requirements, with the intention of removing ambiguity surrounding the hazardous nature of secondary cobalt feedstocks. The working group could also address safety standards to enable uninterrupted transportation of secondary cobalt across borders, and **approval standards for facilities** involved in pre-treatment and recycling of used and spent batteries.

Another major barrier within the Basel Convention relates to **the lack of effective capacity within competent national authorities to apply the PIC process.** This has resulted in long delays in approval time and inhibited international shipments of spent batteries and other e-waste, which have been reported to last up to several years to reach their destination. The challenges posed by the PIC process were detailed at length by StEP and the Prevent Waste Alliance in their recent discussion paper (STEP; Prevent Waste Alliance, 2022).

The paper proposed **seven possible improvements to the PIC process**, which are all relevant to enabling global flows of secondary cobalt:

1. Harmonise codes, approval processes and accountability within competent authorities
2. Simplify and standardise the concept of financial guarantees
3. A digital platform with fixed time frames and built-in explanatory elements
4. Streamlined processes for PIC procedures to qualified recyclers
5. An automatic tacit consent if the transit countries do not respond
6. Support the establishment of local or regional treatment facilities to reduce need to export
7. Improve understanding of the Basel Convention and its provisions amongst authorities and exporting companies through process-linked capacity building

The Basel Secretariat has several small intersessional working groups, including on improving the PIC procedure and on electronic approaches to notification for the transport of waste, in which these suggestions for improvement are being considered. The results of the working groups may be translated into amendments to the Convention at the upcoming Conference of Parties in May 2025. This will depend upon the support of national governments putting forward working group outputs into amendments, and their **effective implementation will ultimately depend upon the good will of implementing parties** to effectively harmonise their national regulations, digitise public services, and develop their national PIC approval capacities.

2.3.2. BATTERY PASSPORTS (GLOBAL BATTERY ALLIANCE AND BATTERY PASS)

Relevance to secondary cobalt

Two initiatives developing digital battery passports have emerged in recent years, the **Global Battery Alliance (GBA)**, and **Battery Pass**. These initiatives have brought together stakeholders with expertise from across the LIB value chain in an effort to improve the sustainability and circularity of global energy storage, particularly in EVs. Both initiatives have focused extensively on cobalt, and worked to develop frameworks that support circularity.

The **GBA is intended to be global in scope**, and has embarked upon a multistakeholder process to produce rulebooks for harmonised reporting on the Ghg footprint embedded within batteries, as well as reporting on child labour and human rights indices. Meanwhile, the **Battery Pass has to date focused on the EU**, in order to produce harmonised guidance for companies to achieve compliance with the EU Battery Regulation, which is detailed in section 3.3.1 of this report. The guidance produced by the Batter Pass covers a wider range of indicators than the GBA, with specific metrics related to the management of LIBs across their entire lifespan.

Mechanisms and governance framework for battery passports

A battery passport creates a **digital counterpart** of the physical battery, containing details regarding a holistic range of relevant sustainability and lifecycle criteria. Its objective is to enhance transparency in the global battery value chain by gathering, exchanging, organising, and reporting reliable data among all stakeholders involved across the LIB lifecycle.

Both initiatives can support the LIB industry to ensure **regulatory compliance**, notably with the EU Battery Regulation (analysed in section 3.3.1), which mandates battery passports be adopted in 2027 for all EVs sold in the bloc. However, while they have different scopes and ambitions, both battery passport initiatives go beyond the requirements of any specific legislation, and participation in the initiatives has been voluntary to date.

A wide array of data proposed is for inclusion within the battery passport guidance (Battery Pass, 2023). Several specific indicators are directly relevant for sustainable and responsible cobalt recycling and are included in both the GBA and Battery Pass guidance to be made publicly available to battery consumers including:

- The percentage of recycled cobalt content within the battery
- GhG footprint of the battery
- ESG indicators ensuring proper due diligence of cobalt within the battery against human rights and child labour risks

Beyond the publicly available data, under the Battery Pass guidance stakeholders involved in managing the battery throughout its lifespan will also have access to a wider array of data included in the battery passports that can enable sustainable and responsible cobalt recycling. This includes:

- The chemical composition of the battery
- The presence of hazardous substances within the battery
- Information relevant to battery repair and remanufacture
- Instructions for safe battery dismantling
- Numerous indicators related to the health of the battery during its lifetime

The GBA launched the world's first battery passport pilot in 2023 (Global Battery Alliance, 2023), yet no battery passport system has been adopted at commercial scale to date. The role of different stakeholders in deploying battery passports operationally are thus still being defined in practice. Much of the responsibility for creating and updating the information stored on the battery passport is planned to be borne by the OEM placing the battery onto the market. The OEM also is responsible for ensuring the accuracy of data related to the cobalt in their batteries, and compliance of cobalt recyclers with the rulebooks put forward by the GBA and Battery Pass (reflecting EU legislation).

It is important to note as well that neither the GBA nor Battery Pass seek to develop the digital infrastructure underpinning their battery passports and material traceability requirements. These initiatives have worked to provide a harmonised framework and guidance on the reporting standards within the passports. Meanwhile numerous service providers have developed digital platforms based on blockchain technologies that allow OEMs to comply with battery passport requirements. Examples of these companies include Minespider, Ipoint, Re|Source, and Circulor (presented further below).

Capacity to enable responsible recycling of cobalt

The development of global battery passports can a significantly contribute towards creating a responsible circular economy of cobalt that **comprehensively addresses ESG risks across the LIB recycling value chain.** Currently, actors involved in collecting, transporting, sorting, dismantling and pre-processing used and spent LIBs, lack crucial information which battery passports seek to provide.

For instance, **information on the battery chemistry provided under Battery Pass guidance could facilitate sorting**, reducing the mixture of LIBs with other harmful battery types and helping enable more tailored and sustainable pre-processing and recycling technologies tailored to precise battery chemistries. Including information about the hazardous substances present within the LIB could also streamline the process of qualifying spent LIBs as hazardous and enhance the health and safety of workers along the recycling value chain. Likewise, information on battery history and dismantling instructions are promising tools included within Battery Pass guidance to support workplace safety.

By granting access to essential information for assessing the battery's **State of Health (SOH)**, battery passports can also facilitate the decision to repurpose, remanufacture, or recycle a given battery. This has the potential to facilitate second-life applications, whose successful execution necessitates evaluating the condition of the battery and its cells.

Yet deploying battery passports commercially will not be without challenges. Gathering harmonised and reliable data to enable cobalt circularity (such as battery chemistry) is challenging due to the complexity of global supply chains, which include numerous actors. Battery manufacturers have been reported to be **reluctant to share intellectual property** about their battery composition with other stakeholders including recyclers.

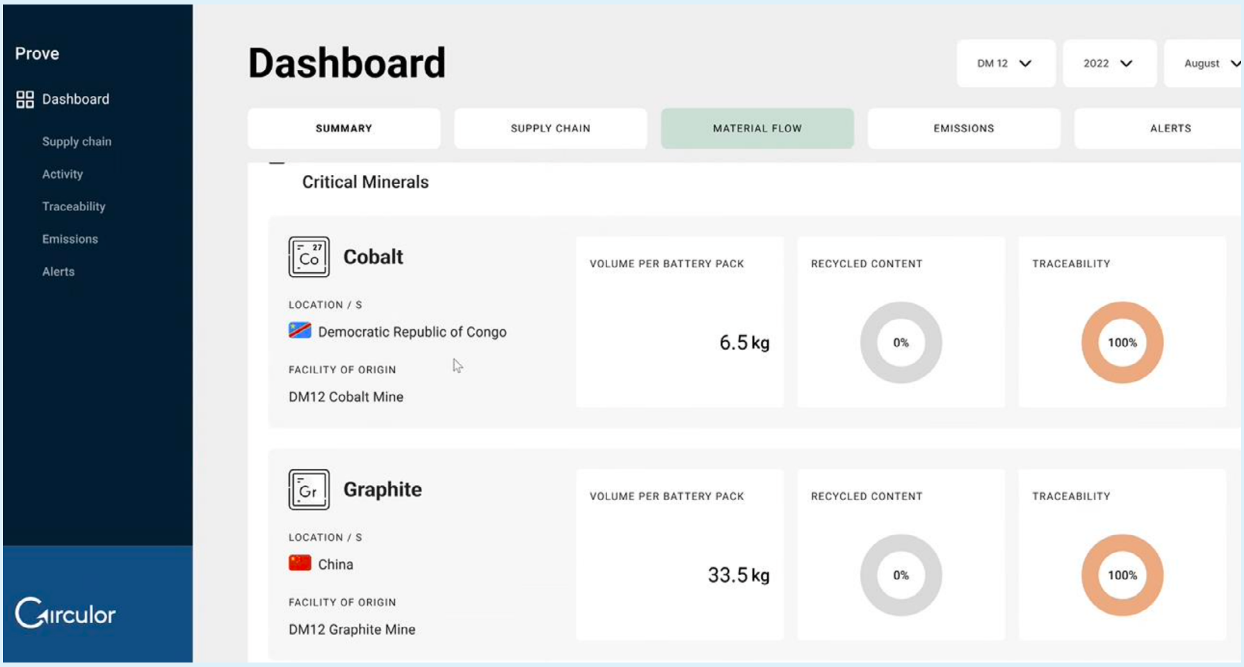
Moreover, **gathering data about the in-use phase of LIBs** (as proposed by Battery Pass), to determine their health and viability for second-life applications, may prove challenging as it will require **collaboration between battery manufacturers, OEMs, consumers, and independent operators** working to repair or dismantle EV batteries. Given the current predominance of the informal sector in global LIB collection and disposal, questions persist about the viability of battery passports on a global scale, particularly if second-hand EVs are widely exported to developing countries without a framework and resources in place to continue updating their passports.

CASE STUDY: CIRCULOR'S BATTERY PASSPORT

OVERVIEW OF THEIR WORK

Circulor offers digital solutions that provide traceability across global supply chains, with a particular focus on battery minerals. Their digital product passports (DPPs) enable customers end-to-end visibility of their supply chains by collecting data and insights across a large and growing network of extractors, refiners and manufacturers. This information is collated and connected to a unique battery passport, each with a unique QR code identifier, which presents product information for each battery to producers, customers, auditors, and regulators (figure 8). Circulor's initial focus has been on supporting the responsible and sustainable sourcing of primary raw materials, including cobalt, through traceability which provides a secure chain of custody and utilises blockchain to ensure data is tamper-proof. Their traceability solution also includes second-life and recycling stages of the battery lifecycle, offering their customers proof of the procurement of secondary materials, like cobalt, and proof of the recycled content in final products.

Figure 8: Screenshot of Circulor's platform dashboard indicating the volume, recycled content and origin of critical minerals inside a battery



By providing the digital infrastructure for a full lifecycle battery passport described in section 2.3.2, Circulor provides roles-based access to battery information including the provenance of the cobalt, the percentage of recycled cobalt in the battery, the embedded carbon footprint and ESG performance to provide transparency to consumers and meet regulatory requirements. This information is primarily gathered automatically via APIs that connect directly with the client's existing systems and applications. Once the battery enters the market, Circulor's platform collects regular updates on the information included within the passport, including state of health data, by connecting to the batteries Battery Management System (BMS). For scenarios where automation is not feasible, such as in remote locations where the infrastructure and internet connectivity is low, manual data uploads can be facilitated via spreadsheets, ensuring inclusivity across all stages of the value chain, including artisanal and small-scale mining (ASM) or informal e-waste sectors.

IMPACT

By providing a digital battery passport solution, with traceability proving the provenance of materials in each battery and digitally identifying recycled materials, Circulor enables manufacturers to comply with regulatory and tax requirements, like the EU Battery Regulation and U.S. Clean Vehicle Tax Credit, while proactively navigating evolving global sustainability regulations. The technology provides their customers, including as Volvo Cars, Polestar, Volkswagen, Daimler, and BMW—as well as midstream producers, miners, and recyclers, with the ability to benchmark and improve operations while fostering awareness to mitigate risks. Already used at scale by globally recognised brands, Circulor's platform has the largest battery traceability network on the market, with over 145 customer facilities connected globally and actively contributing traceability and sustainability data.

Circulor works with 52% of global cell manufacturing capacity (by production volume) and have provided supply chain visibility for over 157 million battery cells in 670,000 EVs by collecting over 2.5 billion traceability data points. Ultimately, this solution serves as a proof of sustainability for both customers and investors, and can unlock the potential benefits of battery passports detailed in section 2.3.2.

SCALABILITY

The challenge of implementing battery passports, such as Circulor's, to the recycling industry lies in its relative newness. While recyclers are making strides in scaling their operations, the current feedstock and therefore volumes of secondary materials remain limited.

However, projections indicate a significant uptick in material flow and availability over the next three years as more batteries reach end of life. This anticipated surge underscores the need for robust traceability measures and digital identifier services to ensure responsible, sustainable and efficient recycling activities to address the need for using secondary materials and increasing the circular economy.

Circulor offers their customers the possibility to tailor their DPPs to align with specific regulatory requirements, or customise it to show only relevant information for their stakeholders through roles-based access, thus avoiding challenges that battery passports may face related to confidentiality and intellectual property across the value chain. Harmonising reporting practices, even when reporting slightly varied information for different geographical regions (e.g., U.S. Inflation Reduction Act, ACCII, EU Battery Regulation, EU Ecodesign for Sustainable Products Regulation and the EU Critical Raw Materials Act), is crucial to minimising complexity. By providing different subsets of the same information, Circulor ensures consistency while accommodating regulatory nuances across regions. The battery passport solution developed by Circulor is also interoperable, meaning collaboration with other providers and existing operating systems is facilitated.

Circulor’s solutions extend beyond the automotive sector to encompass consumer electronics, giving access to battery information for Li-ion batteries in smartphones, laptops and tablets as well as other energy transition products such as wind turbines. However, it's worth noting that the sheer volume of data in the consumer electronics realm is considerably larger, with billions of portable batteries on the market, compared to the more concentrated EV market. Additionally, the content of valuable materials in consumer electronics batteries is less significant, necessitating careful consideration of economic factors that may pose challenges in implementation.

3. BATTERY RECYCLING IN EUROPE

3.1. OVERVIEW OF THE CURRENT CONTEXT

3.1.1. RATE OF BATTERY CONSUMPTION, DISPOSAL, AND RECYCLING

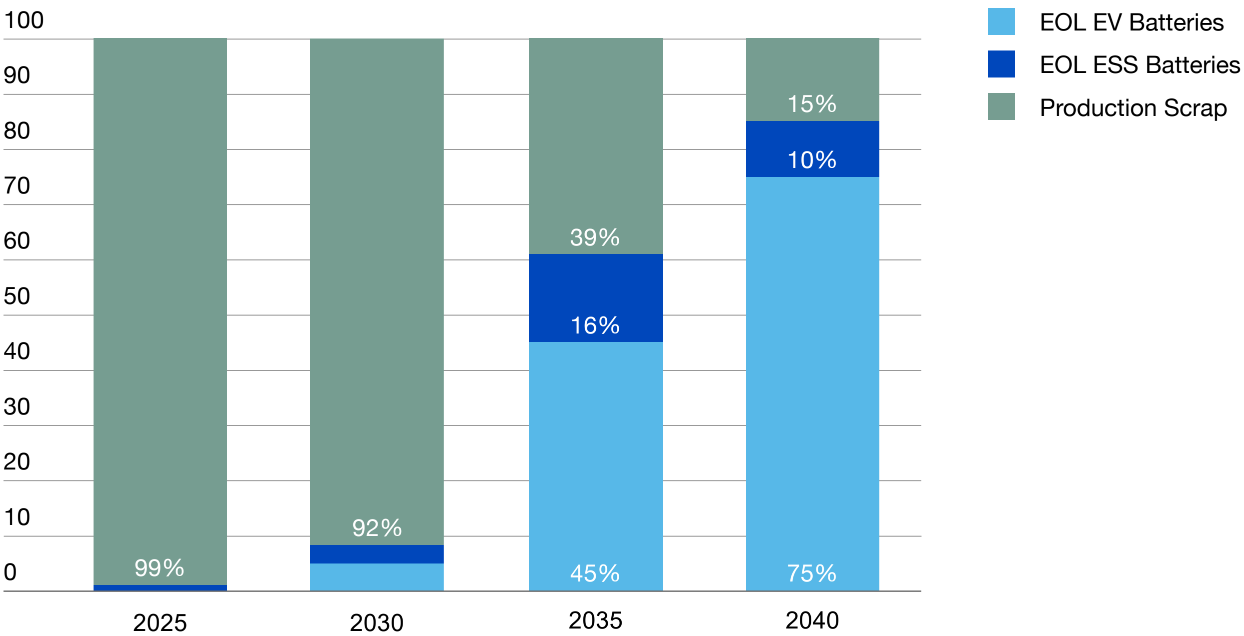
Availability of secondary cobalt in Europe

The current and future availability of secondary cobalt within Europe very much reflects the global tendencies that were presented in the international overview section of this report, in chapter 2.1. Currently, **the largest feedstock for cobalt recyclers in Europe remains production scrap** from European gigafactories.

As new European gigafactories are scaling up their production processes, they can be expected to have high scrap rates (~25%), which will be sent to recycling. Meanwhile, few EVs have currently reached their end of life in Europe, meaning their LIBs will not be available for recycling for years to come. With time, gigafactories are expected to hone in on their production practices, bringing down scrap rates (~5%), and spent EV batteries will make up an increasing share of available secondary cobalt in the EU (Transport and Environment, 2023).

T&E modelled this transition of available secondary cobalt feedstocks, which is presented in Figure 9 below. However, these figures are only focused on EV and ESS battery storage, and do not account for available cobalt from portable batteries.

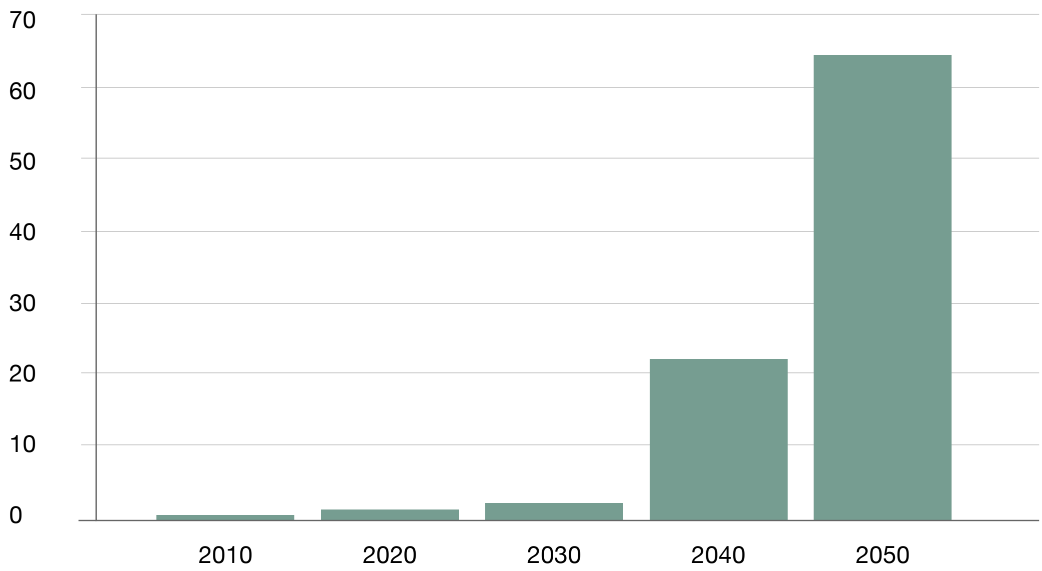
Figure 9: Sources of feedstock for European battery recycling



Note: EOL EV batteries including second life applications
Source:Transport and Environment, 2023

According to their models, T&E estimates that secondary feedstocks from the European EV and ESS markets (including production scrap) can satisfy ~5.7 ktonnes of cobalt by 2030, which they expect to be 10% of total EU demand. They estimate that this figure will rapidly rise to 14.6 ktonnes of secondary cobalt by 2035, which could constitute 20% of total EU demand (Transport and Environment, 2023). These figures are roughly in line with estimates made by KU Leuven, that **secondary cobalt could supply Europe with around 20 ktonnes by 2040** (KU Leuven, 2022).

Figure 10: Available supplies of secondary cobalt in Europe
ktonnes



Source: KU Leuven, 2022

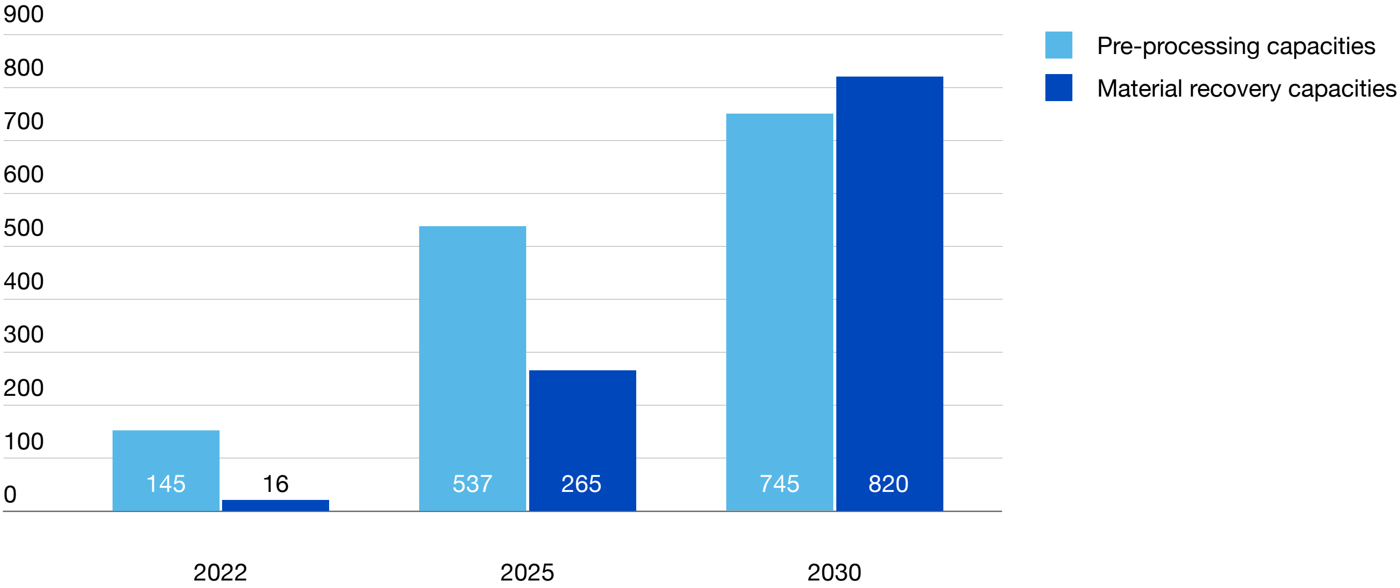
Accurate figures for the amount of cobalt available for recovery from spent portable LIBs in Europe are challenging to estimate because the EU currently amalgamates LIBs with other (non- cobalt) chemistries of portable batteries in their statistics. In 2021, the **EU collected 48% of the portable batteries sold on the EU market** (averaged between 2018-2021) (Eurostat, 2023).

European recycling capacity

Europe is rapidly scaling investments into the production of LIBs, in line with efforts to decarbonise its transportation system. This is planned to be accompanied by a **significant buildout in European recycling capacity**, as numerous integrated recycling projects have been announced to coincide with new gigafactories. Currently much of the LIB recycling capacity in Europe relates to pre-processing, with black mass often shipped to East Asia where it is used as a feedstock for cathode precursor production.

As announced recycling plants come online in coming years, this is expected to shift as Europe looks to increasingly recover cobalt and other battery materials from spent LIBs domestically. Figure 11 below presents an overview of current and emerging EU LIB recycling capacity (Transport and Environment, 2023).

Figure 11: Recycling capacities by processing stage in Europe
kt battery cells



Source: Transport and Environment, 2023, Circular Energy Storage Research and Consulting

A more detailed overview of all existing and announced LIB recycling plants in Europe in 2022 is also available in the annex.

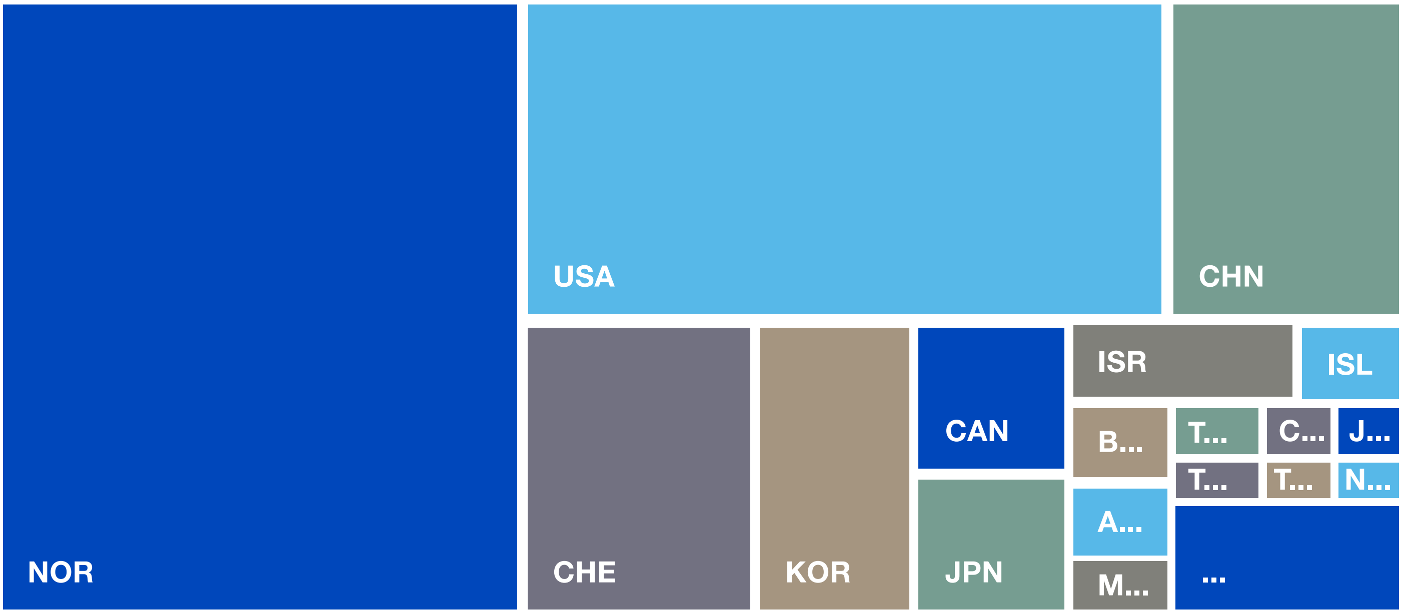
3.1.2. EU TRADE IN USED EVS AND SPENT BATTERIES

Exploring European trade in new, used, and spent LIBs can also provide insights into the current and future availability of secondary cobalt within the EU market. Currently, Europe remains dependent on imports to satisfy domestic demand for LIBs. In 2019, 63% of LIBs sold in Europe were imported (OECD, 2023), but **by 2022 more than half of LIBs sold in the EU were domestically produced** (Transport and Environment, 2023).

Despite a lack of clarity in international trade data, **Europe is also estimated to be a net exporter of spent LIB and black mass**. Spent LIBs from Europe are often shipped to pre- processors in Malaysia, Indonesia or the Philippines. The OECD cites data from Circular Energy Storage claiming that in 2019 Europe was a net exporter of 16 888 tonnes of LIB waste and scrap for pre-processing (OECD, 2023), though these trade patterns may evolve in coming years as new EU recycling capacity comes online.

Significant amounts of cobalt also leave the EU in the form of new and used EV exports. Between 2017 and 2020 the EU exported 559 862 new EVs and 42 634 used EVs (including both plug in hybrids and battery EVs). **Norway is the largest market for both new and used EV exports from the EU**, in keeping with the country's status as a global leader in EV adoption rates. Beyond Norway, new EVs are typically exported from the EU to China or developed markets such as the US, Switzerland, Korea, and Canada. Meanwhile **used EVs are more frequently exported to lower income countries** in East Europe or the MENA region such as Ukraine, Jordan, Moldova or Egypt (OECD, 2023).

Figure 12:
EU exports of new electric vehicles 2017-2020



EU exports of used electric vehicles 2017-2020

Source: OECD, 2023

As the EV market matures both in Europe and globally, the total number of EV exports out of the bloc is expected to increase as is the relative share of used EV exports.

Flows of secondary cobalt also leave the EU in the form of used electronics and e-waste. The primary destination of used electronics exported from Europe is Africa, with major flows from West to East Europe as well. The global e-waste monitor estimated that European countries (covering the whole region beyond just the EU) exported 1.9 million tonnes of e-waste in 2022, with only **32%** of this being controlled. This highlights the challenge of illegal e-waste exports facing the bloc, which only recovered between 2 – 17 ktonnes of e-waste in 2019, despite actual exports likely being much higher (Baldé C. P., et al., 2024).

3.2. ESG RISKS ALONG THE LIB RECYCLING VALUE CHAIN IN THE EU

The EU is considered a global leader with respect to the responsible handling of waste. The region has a well-developed formal waste sector, and a robust regulatory environment seeking to mitigate the risks related to hazardous waste management. Despite not being the most at risk geography, several of the ESG risks along the cobalt recycling value chain detailed in chapter 2.2 have been observed in Europe. This section provides a summary of observed and probable risks related to recycling cobalt from spent LIBs in Europe.

3.2.1. END-OF-LIFE BATTERY COLLECTION, TRANSPORT, AND SORTING

Environmental risks

Environmental risks related to the first stage in the cobalt recycling value chain are highest when no proper collection system is in place, as improperly disposed spent LIBs contain hazardous materials that pose a risk of soil and water pollution. In the EU, this risk is higher for portable batteries, since EV batteries have a high value for recyclers and the bloc aims to ensure 100% collection of spent EV batteries via EPR obligations.

Spent LIBs from portable electronics may continue to be mixed with household waste streams and disposed of in landfills or incinerators in the EU, where the pose a risk of releasing pollutants into the surrounding environment. In 2020, 16% of total EU waste was landfilled, with incineration being the most common disposal method for unsorted spent LIBs in the bloc (EEA, 2024).

Battery fires remain a common risk within the EU, despite the relative prevalence of formal collection and sorting systems. The French recycling association FEDEREC claims that between 2014-2019 the number of fires associated with LIBs in the member facilities increased 150%, with upwards of 150 incidents reported per year in France alone (Libert, 2022). Two recent LIB fires in particular have caused serious environmental degradation in France, with 12 000 EV batteries stored in Normandy causing an industrial fire in 2023 (Carré, 2024), and 900 tonnes of spent LIBs burning in Aveyron in 2024 (Reporterre, 2024). The German steel recyclers confederation (BDSV) has also claimed that 90% of fires at their associated sites in the last years were caused by LIBs. (Mrozik, Rajaeifar, Heidrichab, & Christensen, 2021)

Social risks

The direct social risks associated with LIB collection, transport and sorting in Europe involve the exposure of waste workers and surrounding communities to the hazardous materials contained in batteries, and the damages from the fires they provoke. For instance, members of the communities living near the above-mentioned large-scale battery fires in France have begun legal proceedings against the companies involved in storing the batteries, seeking retribution for the health damages they suffered from associated pollution. Each fire caused by LIBs in the EU is estimated to cost €190,000 in damages (GRINNER, 2023).

Moreover, while EU members have in place formal regulations governing working conditions related to waste collection (e.g., REACH), the informal sector is also active in waste collection in the EU and may be involved in collecting spent LIBs from e-waste. Only 42% of e-waste in the EU is documented as formally collected and recycled, with informal actors expected to account for much of the remaining feedstock.

Research indicates that in Europe informal waste pickers are likely to have one or several of the following demographic characteristics:

- Individuals belonging to ethnic minorities, who possess notably low levels of education and are subject to various social exclusion initiatives.
- Internal and cross-border migrants as well as refugees lacking legal status or formal identity documentation; and
- Various segments of the population marginalised from the labour market, including young individuals, seniors, female household heads, individuals experiencing homelessness, and others (Porras, Rendon, & Espluga, 2021).

The lack of formal frameworks to integrate informal waste collectors into European collection and sorting systems places these individuals at a heightened risk of precarious, dangerous and exploitative employment.

Governance risks

Fraudulent and illegal shipment and disposal of spent LIBs is a tangible risk in the EU. Providing specific figures on illicit flows of secondary material is challenging given the lack of oversite of this activity, but the Global E-Waste monitor estimates the illegal exports of e-waste from Europe remain common. Numerous recent incidents of illegal trafficking of scrap have been uncovered by European authorities in recent years, typically involving illegal exports of hazardous material from Europe to Africa that, while not specific to spent LIBs alone, demonstrate the feasibility of this risk (Nova News, 2023) (L'express de Madagascar, 2018).

3.2.2. PRE-PROCESSING AND COBALT RECOVERY

The ESG risks associated with LIB pre-processing to produce black mass, and cobalt recovery during recycling largely mirror the risks described in section 2.2 of this report. There is reported evidence of hazardous working conditions at battery preprocessing facilities in Europe. In particular, two preprocessing facilities operated in Hungary have been reported to have exposed workers to carcinogenic heavy metals when dust generated during LIB shredding was spewed from machinery across the facility. Workers in the facility were found by national regulatory authorities to have been exposed to nickel concentrations in the air over 2,000 times above the regulatory limit (BODNÁR, 2024)

The European energy mix has a lower carbon intensity than other leading battery recycling geographies globally, meaning that Ghg emissions from battery recycling in the EU are likely to be lower than elsewhere. The EU also has stringent regulations in place governing environmental standards and hazardous waste management, which control the use of solvents during hydrometallurgical recycling processes (Renault). However, the status of black mass as hazardous waste remains subject to ambiguity in the EU, depending on how member state governments interpret and apply national waste classification schemes, this topic is further explored in section 3.3.3.

3.2.3. PROCUREMENT OF RECYCLED COBALT

With the passage of the new EU Battery Regulation, which is detailed further in section 3.3.1, the EU has established the world's most stringent regulatory oversite on the procurement of recycled cobalt. The regulation places new obligations on OEMs to source recycled cobalt within their batteries, and to conduct thorough due diligence into their secondary cobalt supplies.

This new regulation is a promising development aimed at mitigating risks across the global value chain of secondary cobalt. It will be important to monitor the impact that the stringent regulation has on European procurement of secondary cobalt in practice. Research indicates that European automotive OEMs currently lag behind their global competitors in securing long term offtake agreements for the cobalt they require to meet their electrification ambitions by 2030 (Transport and Environment, 2023).

European ambitions to tackle the ESG risks of secondary cobalt through responsible procurement frameworks may thus struggle to have their intended effect if they inadvertently cap the capacity of European manufacturers to procure cobalt in a globally competitive market.

3.3. KEY POLICIES IMPACTING THE MARKET FOR SECONDARY COBALT

Choice of policies for analysis

The EU is at the global forefront of legislative efforts to develop a responsible circular economy of cobalt. A wave of new policies has been enacted by the EU in 2023 and early 2024 that will have major implications not only for the battery recycling industry within the EU, but also for the entire global value chain of recycled cobalt.

Chief among these policies is the **EU Battery Regulation**, which represents perhaps the most comprehensive regulatory endeavour globally to manage battery value chains and management over the entire battery lifecycle. The **Critical Raw Materials Act** also has a specific focus on the circular of battery materials including cobalt and will support EU efforts to implement a circular LIB economy within the bloc. Meanwhile, EU trade in spent batteries and black mass is regulated by the newly updated **Waste Shipment Regulation.**

Each of these policies has been codified within the twelve months prior to the writing of this report, thus it is not yet possible to assess their tangible implementation. However, understanding the mechanisms and governance of these policies can provide insights into the expected impact of these policies for the EU and global secondary cobalt market, as well as their possible barriers and opportunities to enable a vibrant and responsible global circular economy.

3.3.1. EU BATTERY REGULATION

Relevance to secondary cobalt

The new EU Battery Regulation has applied within the bloc since February 18th, 2024. This new regulation aims at reducing the environmental and social impacts of the entire LIB value chain, promoting a circular economy, and strengthening the functioning of the EU market (EU, 2023). All stakeholders involved in the EU LIB market, such as global LIB manufacturers, producers, importers, distributors, will be impacted under the scope of this new legislation. While the law covers portable batteries within its scope, its most stringent requirements are placed on batteries with a capacity greater than 2kWh, primarily destined for EVs.

The legislation contains a myriad of specific measures, which will structure the market for secondary cobalt in the EU. Four key themes within the legislation are directly related to responsible recycling of cobalt. The regulation:

1. Contains specific actions and targets related to the **circularity of cobalt in LIBs**
2. Includes requirements related to the **in-life management of batteries and their health**, which have implications for second-life applications of LIBs
3. Seeks to enable **transparency and traceability of materials** throughout their value chains and across the entire LIB life cycle
4. And has a specific focus on quantifying and reducing the **carbon footprint** of battery materials

Policy Mechanisms

The regulation contains several direct requirements covering cobalt circularity. Firstly, it mandates the incorporation of **recycled cobalt** within all batteries over 2kWh sold in the bloc (article 8).

- By 2028 **recycled cobalt content must be reported within batteries placed on the market**
- From **2031 16% of the cobalt** in newly sold batteries must be recycled
- This is raised to **26% recycled cobalt from 2036**

The law does however contain a provision allowing for the commission to revise these targets prior to their taking effect based on availability and demand of cobalt.

The law also mandates **collection targets** for spent LIBs from Light-Medium Transport (LMT) (typically used in two-wheel transport) (article 60) and portable batteries (article 59), as well as targets for cobalt recovery within all EU recycling facilities (article 71)

- **By 2029 51% of LMT batteries** placed on the market must be collected at their end of life and **61% by 2032.**
- **By 2024 45% of portable** waste batteries are targeted for collection, **63% by 2028 and 73% by 2031.**
- And **by 2028 90% of cobalt must be recovered during recycling, and 95% recovered by 2032.**

The law also contains specific provisions seeking to facilitate the sharing of information to enable the repurposing of batteries for second-life applications (article 73) and the safe dismantling and recycling of spent batteries (article 74). Specifically, this relates to sharing of **information on battery health** from the battery management system to enable businesses to assess the viability of repurposing used batteries (for instance for use in stationary energy storage) (article 14).

Information on the collection systems in place for batteries at their end of life, as well as safe handling and **dismantling** of batteries and the **hazardous substances** they contain must also be provided by battery producers to end users. By February 2027, the design of their portable electronics sold in the EU must also be readapted to allow for their simple removal and replacement.

The regulation also mandates that companies placing batteries on the market to **conduct due diligence** on their supply chains (Chapter VII), in line with the OECD Guidelines for Multinational Enterprises and the United Nations Guiding Principles on Business and Human Rights. Cobalt is listed as a material of focused due diligence within the law.

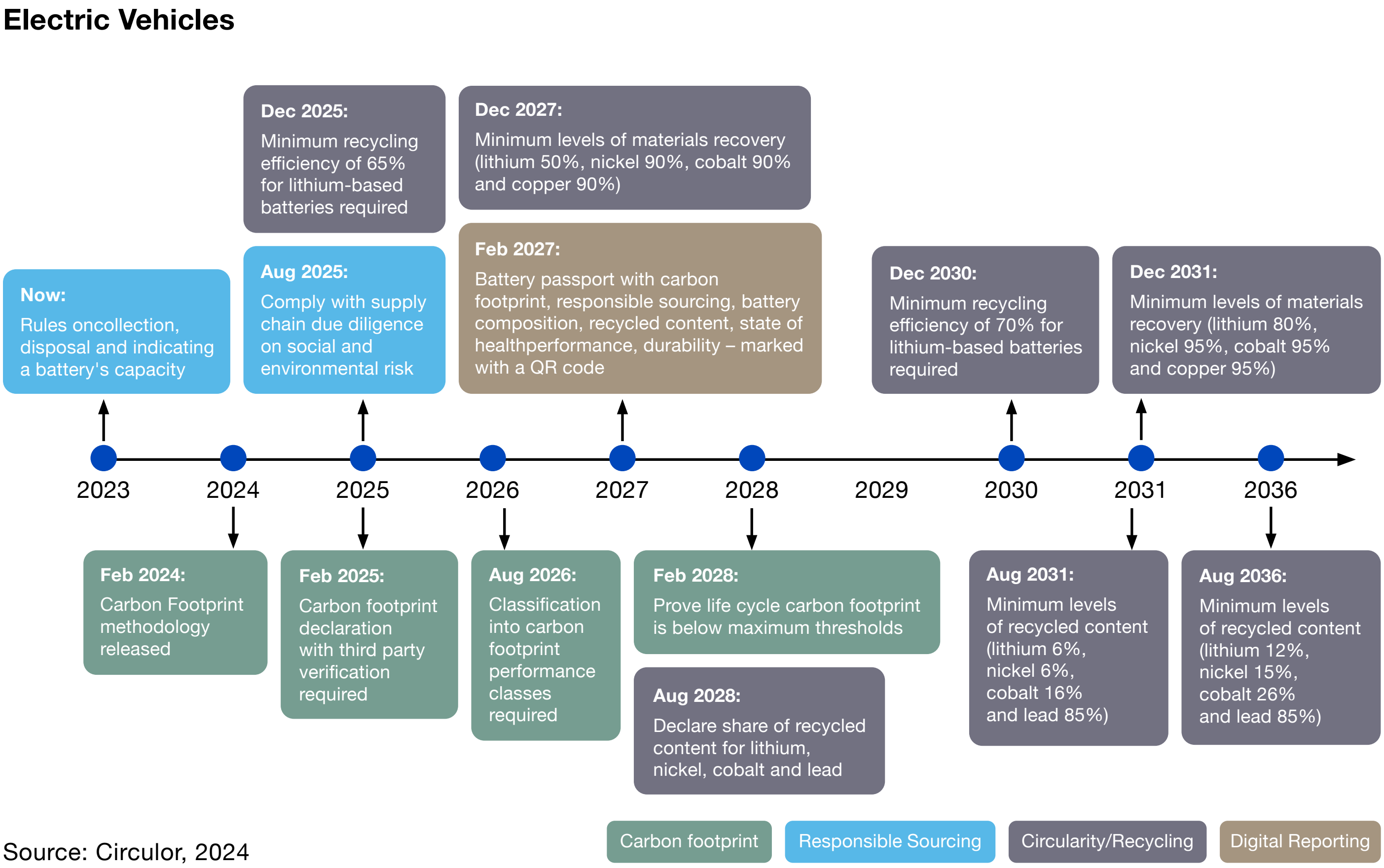
The regulation requires that, beginning in August 2025, OEMs placing batteries onto the market have management systems in place to identify and manage environmental and social risks in their raw material supply chains. It also mandates the adoption of **traceability** solutions detailing the chain of custody of cobalt entering into batteries on the EU market (article 49). This will have direct implications for the procurement of secondary cobalt into batteries sold in the EU.

The regulation also seeks to reduce the **carbon footprint** of batteries placed on the EU market. By February 2025, a declaration of the carbon footprint of EV batteries will be required, and in August 2026 batteries will need to be classified according to their relative associated GhG emissions compared to the industry. In February 2028, producers will need to demonstrate their batteries are below a maximum emissions threshold set by the EU. This will have direct implications related to the choice of recycling technologies used to recover cobalt, according to their emissions intensity.

Compliance with the various reporting requirements for batteries sold in the EU will be monitored via the deployment of a unique electronic **battery passport** for all EV batteries. This is mandated by February 2027 (Chapter IX), and presents the legal impetus for the development of the Battery Pass framework, which was presented in section 2.3.2.

A summary of the key mechanisms for EV batteries within the EU Battery Regulation and their timeline is presented in Figure 13 below.

Figure 13: Timeline of EU Battery Regulation for EV Batteries



Source: Circulor, 2024

Governance Framework

Compliance with the targets and requirements of the EU battery regulation is intended to be monitored by member states within the bloc, who will each appoint a competent authority to ensure the law is applied and report back to the European Commission on their progress. However, the majority of the burden to concretely implement the provisions in the law falls on businesses that place batteries onto the market in Europe, which in the case of EV and portable LIBs means automotive and electronic OEMs.

OEMs have the legal obligation to demonstrate their compliance with the due diligence requirements of the law. The business placing a battery on the EU market is also tasked with ensuring the accuracy of information in the associated battery passport (article 77). In the case that a battery is transferred to another business for repurposing and reuse, this new business then also assumes the responsibility for the information in the battery passport, until the battery is recycled, and the passport will cease to exist by law.

OEMs are also the key stakeholders tasked with managing the collection of spent LIBs, via provisions for **extended producer responsibility (EPR)** that are detailed in the law (article 56). Under these provisions they must put in place facilities for the safe and separated collection of spent batteries from consumers at no charge to customers and ensure that these batteries are safely transported to authorised recycling facilities. OEMs can however designate an authorised “producer responsibility organisation” to take on their responsibilities related to spent batter management under the law (article 57).

Capacity to enable responsible recycling of cobalt

The EU Battery Regulation represents an ambitious effort to increase both the supply and demand of secondary cobalt within Europe. It contains robust measures to improve the lifespan of LIBs, their collection rates, rates of recovery of recycled cobalt, and the procurement of secondary cobalt for battery manufacturing.

The requirements within the law to related to the provision of transparent, interoperable, and robust data on LIBs promise to help identify and quantify risks related to the secondary cobalt value chain. The EU legislation is also the primary driver of the push for global battery passports and traceability solutions, which as detailed in section 2.3.2, are a promising tool in tackling barriers to a responsible global market for secondary cobalt. The purchasing power of the EU as a major market for EVs also means that these regulatory requirements are likely to impact the global market for secondary cobalt and raise ESG and recycling standards for battery producers around the world.

Challenges and recommendations related to the EU Battery Regulation

The EU Battery Regulation has only recently gone into effect, and many of its provisions will not take effect for several years, making it impossible to assess its effectiveness as of yet at effectively promoting responsible cobalt recycling. Nevertheless, several potential challenges are unintended consequences can still be foreseen as possible risks during the implementation of the law. These are presented below, along with recommendations for EU policymakers to consider in order to address these potential pitfalls.

One potential challenge that may emerge during the implementation of the regulation involves **the risk of stifling the growth of the EU EV market** due to certain regulatory requirements. The LIB industry is highly dynamic and innovative, regulating it carries with it the risk that certain provisions in the law become less relevant or fully outdated before they can ever take effect (Melin & al., 2023).

This is particularly the case with respect to the list of raw materials with due diligence and recycling requirements within the law, which may become quickly dated due to the rapid change in battery chemistries on the market. Setting fixed requirements for recycled cobalt within new batteries for instance may effectively limit the total amount of new LIBs with cobalt cathodes that can be placed on the market in 2031, due to a **scarcity in secondary feedstocks**. It also risks creating price distortions in the market for used LIBs and the raw materials they contain. Fortunately, the EU has included provisions in the law allowing for recycled content targets to be adapted prior to 2031 based on market conditions, and for new battery materials to become subject to similar regulatory requirements.

The other risks for the EU in achieving its objectives under the law relate to the challenge of creating a fully circular economy within a **highly globalised LIB value chain**. Several experts have pointed out that the recycled content targets within the EU legislation risk actually disadvantaging EU battery recyclers and manufacturers, in favour of East Asian producers who have access to higher feedstocks of battery scrap and spent LIBs and thus a greater ease of meeting the 16% threshold (Melin & al., 2023).

The legislation also risks failing to meet its ambitious collection requirements due to global trade in used EVs, electronics, and LIBs. The EPR requirements and custody of battery passports effectively end at the EU's borders under the current legislation. However, as was detailed in section 2.1.2, it is a common occurrence for cars and electronics purchased in Europe to end up having second life applications in developing countries, where they risk reaching their end of life without adequate systems in place for battery collection and recycling.

Researchers highlighting the limits of EU EPR schemes within a global economy have proposed an alternative model they dub **"ultimate producer responsibility (UPR)"** that could potentially help achieve the ambitions of a just transition where low income populations benefit from electrification, while also supporting Europe's ambitions for material sovereignty and sustainability (Thapa, Vermeulen, Deutz, & Olayide, 2023).

Under a UPR framework, the responsibility that producers have to ensure effective collection of spent LIBs would not end when these batteries are exported in used products. Rather, the costs borne by producers under the EU EPR framework would be transferred to other global actors working to ensure responsible collection and management of spent LIBs. This could provide a much-needed funding source for efforts in developing countries to formalise e-waste collection, invest in infrastructure for spent LIB management, and could also increase flows secondary feedstocks back to recyclers in the EU.

3.3.2. CRITICAL RAW MATERIALS ACT

Relevance to secondary cobalt

The Critical Raw Materials Act (CRMA) is the EU's flagship legislation aimed at securing European access to the CRMs necessary for Europe's industrial and climate ambitions. **Cobalt is listed by the EU as both a critical and strategic raw material** and is thus directly within the scope of the law. Much of the law focuses on primary supply, however it also contains provisions relating to boosting European recycling capacity and access to secondary supply. On the 18th of March 2024, the EU member states gave their final approval of the law, which is now in effect (European Commission, 2023).

Policy Mechanisms

The most direct policy mechanism influencing European cobalt recycling is the target set by the CRMA for Europe to have **domestic recycling capacity capable of meeting at least 15% of total European demand** for all critical and strategic materials (article 1). This is roughly in line with the target in the EU Battery Regulation for 16% of cobalt in EU batteries to be sourced from recycled materials by 2031. The act also sets a target of diversifying material supply and having no more than 65% of any critical or strategic material sourced from a single third country.

The primary mechanism proposed by the EU to meet these targets is by designating certain **"strategic projects"** (article 5), which will include recycling facilities. These projects are guaranteed an expedited approval process for permitting, which will be streamlined under a single regulatory body and should take no longer than 12 months for recycling projects. They will also benefit from support in administrative procedures, securing access to finance (from the EIB or other available sources), and in securing offtake agreements.

The acts ambition of boosting EU secondary supply of cobalt and other CRM also has an international component, via the establishment of **strategic partnerships** (article 33) with non- EU countries that could benefit from EU investments under the Global Gateway program to boost battery collection and recycling, provided this was determined beneficial to both the partner country and the EU.

The CRMA also includes specific **measures to promote the circularity of CRM** and strategic materials in the EU (article 25), which are complementary to the EU Battery Regulation. This includes mandating member states to develop strategies to improve the recovery and reuse of CRM within their economies.

Governance Framework

The CRMA will be governed by a newly established **CRM Board**, composed of representatives from each member state and the EU Commission. The Board will meet regularly to determine the selection of strategic projects and carry out monitoring activities on the progress of the act (Chapter 7).

Capacity to enable responsible recycling of cobalt

The CRMA could act to support EU ambitions for domestic recycling capacity by providing a stable environment for the private sector to invest along the battery recycling value chain.

The example of the delays and uncertainty in securing permitting for Glencore and Li-cycle's planned battery recycling facility in Portovesme Italy demonstrates the challenges that the private sector faces in supporting Europe's ambitious battery recycling targets (Allen, 2023). Should this project (or similar recently announced endeavours) receive the status of strategic projects, this may help expedite the development of European LIB recycling capacity.

Challenges and recommendations to improve the CRMA

In a context of geopolitical competition for CRM, where many countries around the world are intent on expanding their position in the LIB value chain, Europe may face challenges to meet its ambitions in cobalt sovereignty. While the CRM act sets ambitious targets in terms of recycling, and provides a harmonised framework for governing the approval of strategic projects, it does not include additional public subsidies to incentivise the buildout of battery recycling infrastructure in the way that recent US policies have (see section 4.3).

Without additional public subsidies, it remains to be seen if European battery recyclers will be able to compete economically with East Asian competitors, given the higher operating costs associated with recycling in Europe and the potential for a global overcapacity of cobalt recycling capacity. Several industry associations have also pointed to the risk that Europe may struggle to meet its recycling targets if measures are not taken to stop the export of black mass out of the bloc (Transport and Environment, 2023)

(RECHARGE, 2022). The newly updated EU Waste Shipment Regulation has implications for the shipment of secondary feedstocks out of the bloc.

3.3.3. WASTE SHIPMENT REGULATION

Relevance to secondary cobalt

The revised EU Waste Shipment Regulation regulates the **transport of all waste products** within the EU as well as exports and imports of waste into the EU. As such it governs European trade in **spent LIBs**, and likely also **black mass**. The revised regulation was approved by the EU Council on March 25th, 2024, but has as of the time of this report not been published in the EU Official Journal. It will enter into force within two years of its adoption.

Policy Mechanisms

The waste shipment regulation represents **the transposition of the Basel convention** into European law. Notably, the regulation codifies the 2019 BAN amendment to the Basel convention within Europe, and as such prohibits the export of hazardous wastes (including spent LIBs) from Europe to non-OECD countries.

The new regulation also contains provisions to enforce more stringent monitoring of EU exports, with the intention of preventing illegal or fraudulent exports of e-waste. All EU companies that export waste outside the EU must now demonstrate that the facilities receiving their waste are subject to an independent audit showing that they manage this waste in an environmentally sound manner, in line with European regulatory standards.

To facilitate the shipment of waste to environmentally sound facilities the updated regulation supports a **"pre-approval"** process to expedite sending waste shipments to authorised recycling facilities. It also creates new digital procedures for the approval of waste shipments.

Governance Framework

Waste shipment controls are carried out by national competent authorities and inspection services, and custom offices. Every three years, member states must update the Commission on the progress in implementing the regulation.

Capacity to enable responsible recycling of cobalt

Improvements in the oversite of EU waste exports may help prevent the ESG risks related to the disposal of LIBs in geographies that lack proper recycling facilities. Likewise, provisions in the new regulation intended to facilitate shipment of spent LIBs to competent EU recycling facilities are an encouraging development in support of responsible cobalt recovery.

Challenges and recommendations to improve the Waste Shipment Regulation

A key challenge within the EU Waste Shipment Regulation relates to the ambiguity surrounding the definition and interpretation of secondary cobalt feedstocks as hazardous wastes. Several industry associations, including RECHARGE and Eurometaux, have issued a public statement calling on the European Commission to provide clarity on the legal status of spent LIBs and black mass as a waste material, by issuing new, more granular, waste codes specific to these secondary feedstocks (RECHARGE, Avere, Eurometaux, 2023).

Including black mass on the European list of hazardous wastes would effectively prevent its export from the bloc, thereby supporting European recyclers in their efforts to secure access to feedstocks. However, there is also a risk that the EU's geopolitical ambitions for critical material sovereignty conflicts with its sustainability agenda if additional restrictions on the free movement of black mass into and out of the EU limit global cobalt recycling rates. This could occur if new restrictions disrupt existing battery recycling supply chains between the EU member states, or between the EU and East Asia, and by preventing EU recyclers from importing new secondary feedstocks from geographies that lack recycling capacity.

Support by environmental authorities in EU member states to offer expedited approval for imports of secondary feedstocks by competent EU cobalt recyclers will thus be key in mitigating these risks. Harmonising waste codes between member states could also support intra-EU shipments of secondary feedstocks, removing procedural obstacles to the effective development of a cobalt recycling chain within the EU. Reports indicate that the EU Joint Research Centre is expected to soon announce updates to the waste classification codes of these secondary feedstocks (Batteries International, 2024).

4. BATTERY RECYCLING IN THE U.S.

4.1. OVERVIEW OF THE CURRENT CONTEXT

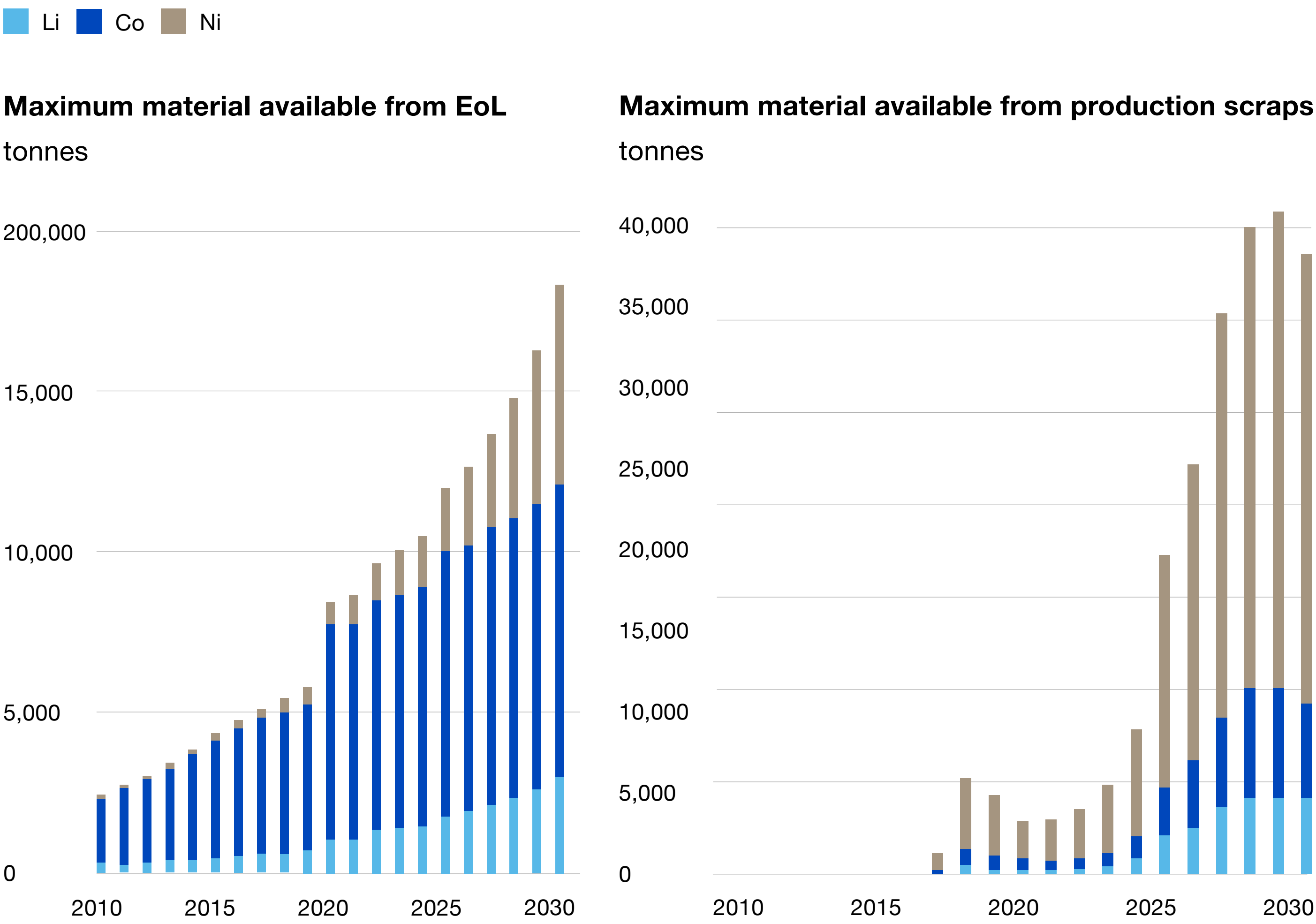
4.1.1. RATE OF BATTERY CONSUMPTION, DISPOSAL, AND RECYCLING

Availability of secondary cobalt in the U.S.

The U.S. recyclable cobalt availability scene mirrors International and European trends, with production scrap from domestic gigafactories currently being the primary source. However, a new wave of recyclable cobalt is emerging as consumer electronics and, increasingly, electric vehicle batteries reach their end-of-life.

A 2023 study estimates that 7-8 ktonnes of cobalt became available for recycling in the U.S. that year, with that number projected to hit 15 ktonnes by 2030 (Gaines, Zhang, He, Bouchard, & Melin, 2023).

Figure 14: Material expected to be available for recycling in the U.S. from end-of-life products and scrap



Source: Gaines, Zhang, He, Bouchard, & Melin, 2023

The study also suggested that in 2019, around 54% of spent LIBs generated in the U.S. were recycled, with nearly 10% processed domestically and the remaining 44% sent to China, reflecting China's dominance in the battery recycling sector.

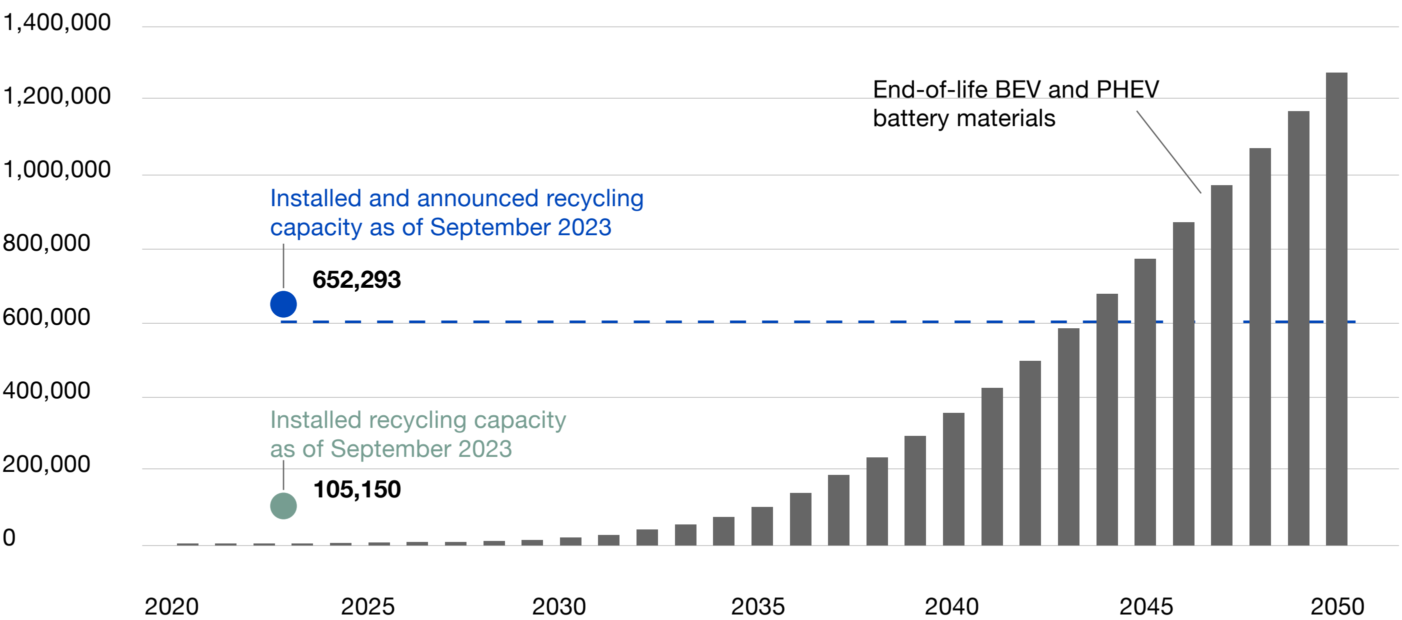
Applying this domestic recycling rate to 2023's available material suggests roughly 0.7-0.8 thousand tonnes of cobalt were recycled domestically. In an optimistic scenario envisioning a future prioritising environmental issues, widespread electric vehicle adoption, and robust recycling infrastructure, it is estimated that up to 20 ktonnes of cobalt will be recycled annually in 2040 (Miatto & Graedel, 2023).

U.S. recycling capacity

The installed LIB recycling capacity in the U.S. by 2023 significantly exceeded the amount of available spent batteries and production scrap in North America. As of September 2023, the International Council on Clean Transportation (ICCT) calculated total annual battery recycling capacity at around 105 ktonnes of material. With current available EV material estimated at 7-8 ktonnes, this indicates a clear surplus of installed recycling capacity that could already handle the expected material flux by the mid-2030s.

Figure 15: Recycling capacity vs projected end-of-life EV battery materials in the U.S.

Metric tons of end-of-life electric vehicle batteries



Source: ICCT, 2023

Furthermore, new U.S. legislation is spurring investment in domestic recycling facilities, extending the horizon even further. If these announced facilities are factored in, total recycling capacity would reach 650 ktonnes by 2030, enough to process around 1.3 million EOL electric car batteries annually (ICCT, 2023). With over half of today's battery recycling feedstock coming from production scrap, this lack will persist until more EVs reach their natural lifespan.

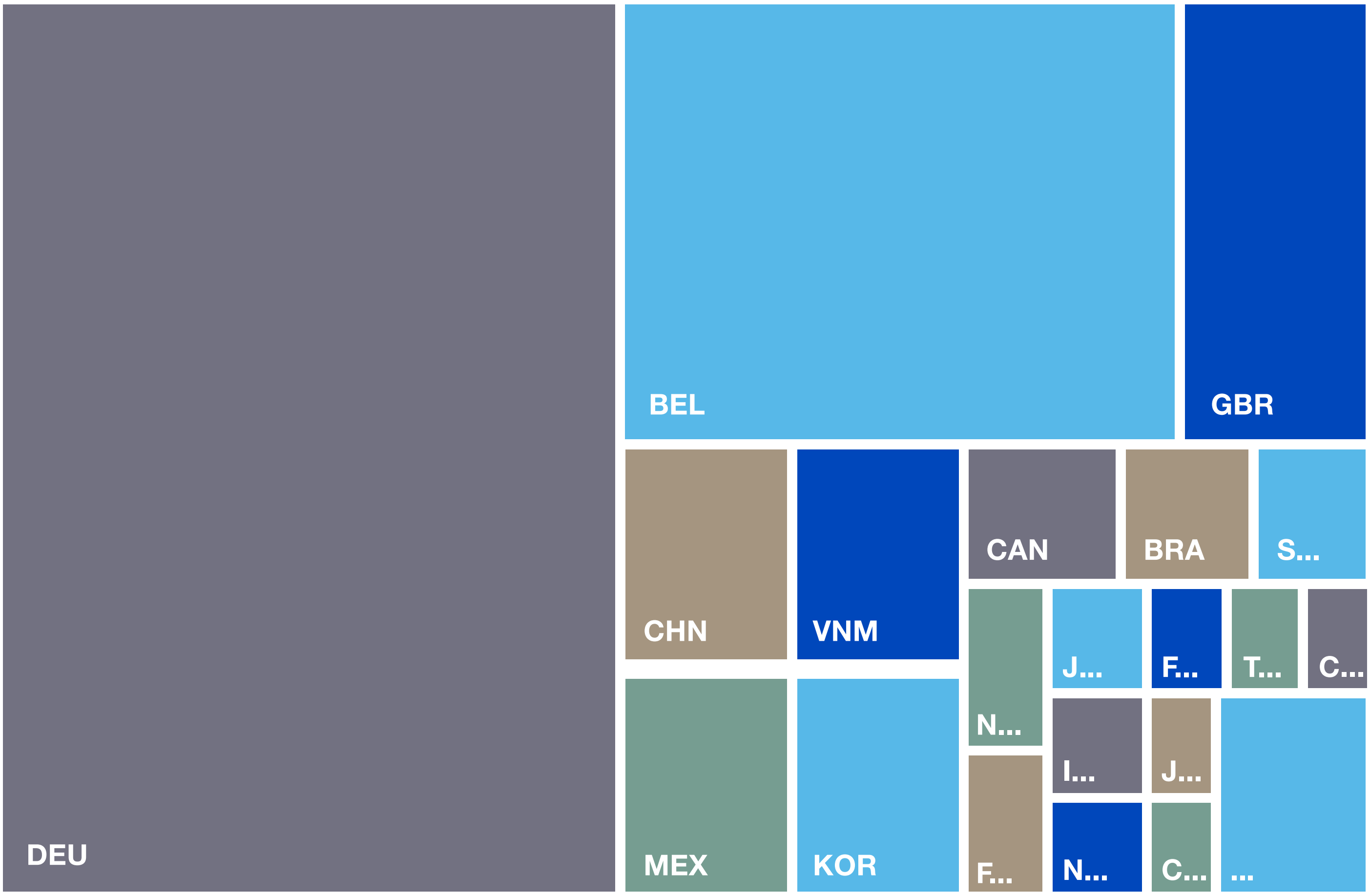
4.1.2. U.S. TRADE IN USED EVS AND SPENT BATTERIES

The current and future availability of secondary cobalt feedstocks in the US will also depend on the amounts of LIBs that are exported out of the US in the form of spent LIBs, used electronics and used EVs.

Like the EU, the US is a net exporter of spent LIBs. According to the OECD, citing Circular Energy Storage data, in 2019 the US exported 27 420 more tonnes of spent LIBs than it imported. Typically, this material is sent for pre-processing in South Korea (OECD, 2023).

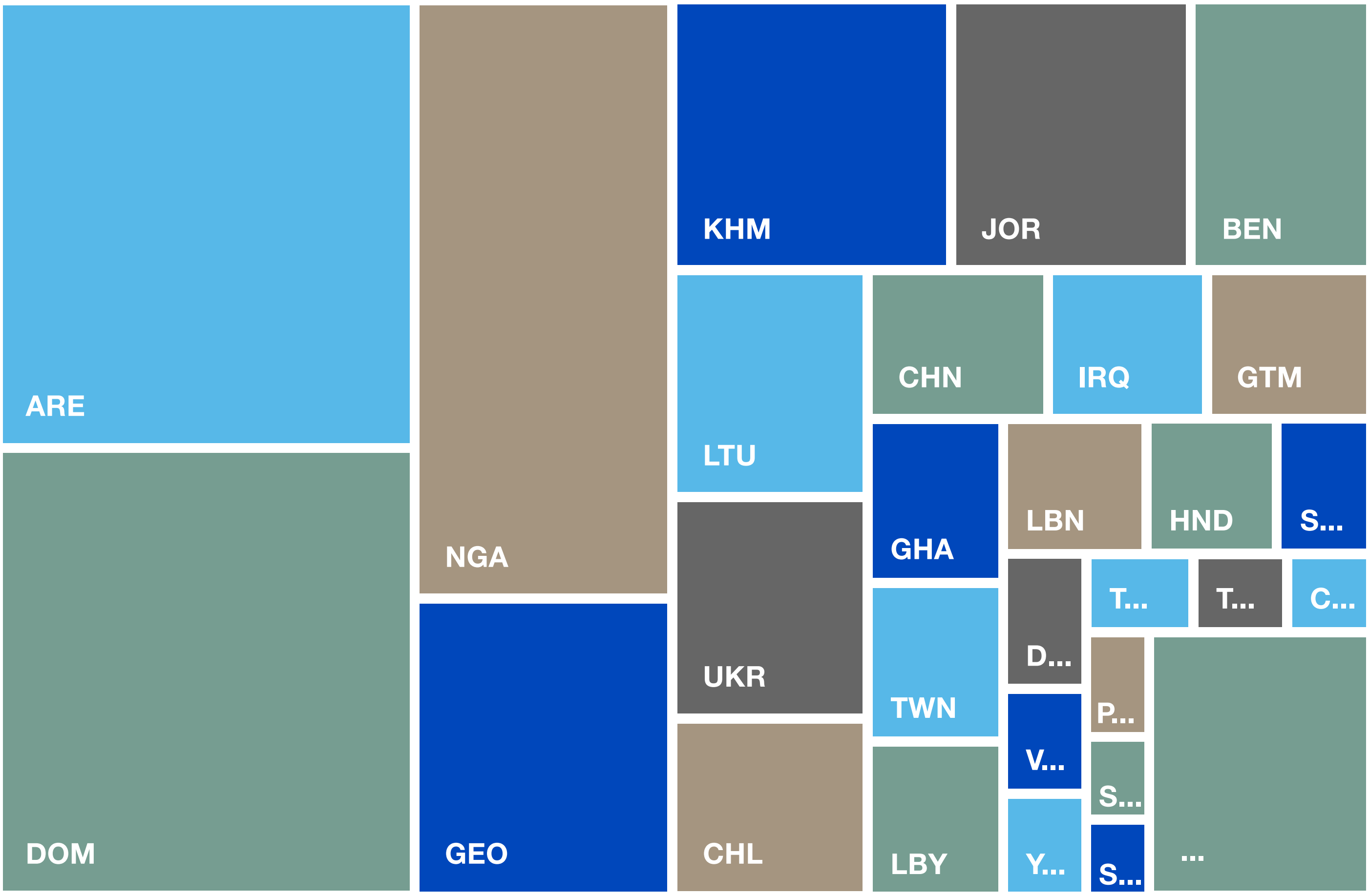
The US also exports significant amounts of cobalt in the form of new and used EVs and hybrid electric vehicles. Unlike other developed countries, the US actually exports more used hybrid vehicles than new, with most new vehicles produced in the US destined for domestic consumption. Between 2017 and 2020, the US exported 78 990 new vehicles with LIBs, and 294 758 used vehicles with LIBs. The destinations of these exports are shown in Figure 16 below.

Figure 16: US exports of new EVs 2017-2020



Source: OECD, 2023

US exports of used EVs 2017-2020



Source: OECD, 2023

As can be seen, the largest markets for new cars with LIBs from the US are mid to high income countries including Germany, Belgium, the United Kingdom, China and Mexico. Meanwhile, used electric vehicles from the US are sold to the United Arab Emirates, as well as developing economies including Dominican Republic, Nigeria, Georgia and Cambodia.

Meanwhile, a significant percentage of the spent LIBs present in portable electronics in the United States are also likely to be exported abroad via informal or illegal e-waste shipments. A 2016 study by the Basel Action Network using GPS observation to track shipments, found that 40% of the American e-waste recycling shipments they observed were exported outside of the nation. Moreover, 93% of the recipient countries for this e-waste were developing countries, primarily in Asia, whose reception of these shipments is illegal under the Basel convention (Basel Action Network, 2016).

4.2. CURRENT AND EMERGING ESG RISKS IN THE SECONDARY COBALT SUPPLY CHAIN

Similar to the case of the EU, several of the ESG risks along the cobalt recycling value chain detailed in chapter 2.2 have been observed in the U.S.

4.2.1. END-OF-LIFE BATTERY COLLECTION, TRANSPORT AND SORTING

Environmental risks

North America is one of the regions with the highest levels of e-waste generation globally (Baldé C. P., et al., 2024). The lack of a cohesive federal law has resulted in a regulatory patchwork of different state laws, creating EPR compliance challenges for producers. Consequently, a considerable portion of used electronics either accumulates in households or finds its way into landfills and incinerators. Furthermore, the export of collected e-waste from the U.S. to low- income countries with cheap labour raises another major concern. In these regions, informal dismantling poses environmental and health risks in the form of fire incidents, soil and water contamination and exposure to toxic materials.

Social risks

Beyond the social risks inherent in battery collection, one specific social risk in the U.S. recycling value chain relates to the use of prison labour in handling e-waste. In several states, inmates engage in dismantling, sorting, and processing electronic waste as part of their work duties within correctional facilities. While these operations offer a potential avenue for providing valuable activity and job training for prisoners, they also present known risks for abuse.

These risks include allowing a subsidy effect, which undermine the private sector recyclers from a competitiveness standpoint, allowing high-risk individuals to manage data security operations, and exposure of a marginalised labour force to hazardous materials or emissions. For Instance, in October 2005, the Arkansas Department of Environmental Quality announced the project GREEN-FED, a unique partnership with Federal Prison Industries, Inc., using captive prison labour to recycle e-waste in recycling facilities. These facilities typically rely on low-tech methods and manual labour to accommodate the greatest number of prison workers. With very low wages paid to inmates, it becomes increasingly difficult for responsible e-waste recycling to compete with the low-cost option of prison labour (Dayaneni & Shuman, 2007).

Governance risks

As outlined in the Global E-waste Monitor 2024, there is a concerning trend of used electronics and e-waste being illicitly transported from the U.S. to regions including Central and South America, as well as West Africa. However, efforts to mitigate this issue are underway through recycling standards and certifications like R2 (Responsible Recycling) and e-Stewards. These standards are designed to limit improper handling practices and prevent illegal exportation of e-waste containing hazardous chemicals, thus promoting more responsible and sustainable management of electronic waste.

4.2.2. PRE-PROCESSING AND COBALT RECOVERY

In the United States, the environmental hazards linked with pre-processing of spent lithium-ion batteries (LIBs) mirror those mentioned in chapters 2.2 and 3.2. Improper handling of hazardous substances in LIBs, such as the electrolyte, can lead to soil, water, and air pollution, exacerbated by the potential for combustion during storage or dismantling. Improper sorting increases these risks, as evidenced by instances of LIBs being mishandled alongside lead acid batteries. Moreover, manual dismantling without proper safety measures exposes workers to hazardous substances, including carcinogenic cobalt compounds like lithium cobalt oxide ($LiCoO_2$).

4.3. KEY POLICIES IMPACTING THE MARKET FOR SECONDARY COBALT

The U.S. political strategy regarding e-waste management and EV battery recycling is not as comprehensive as in other developed economies, with strict policies regarding LIB recycling yet to be put in place at the federal level. Today, the U.S. has no federal recycling mandates or requirements for LIBs. In addition, despite signing the Basel Convention in 1990, the U.S. did not implement legislation for its ratification.

However, there is a growing political consensus in the U.S. that the government needs to play a role in supporting these industries. In this frame of mind, the U.S. Government has passed legislation in recent years encouraging investments in the American battery industry to improve its resilience and supplementing private investment with generous public subsidies. Through legislation such as the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA), the U.S. is making available hundreds of billions of dollars of subsidies to 're-shore' or strengthen the U.S. battery supply chains.

4.3.1. BIPARTISAN INFRASTRUCTURE LAW

The $1.2 trillion Bipartisan infrastructure Law (BIL), passed in 2021, provides funding over 10 years for a wide range of infrastructure projects, including roads, bridges, public transit, broadband internet, and clean energy.

Relevance to secondary cobalt

A significant portion of BIL funds is directed towards supporting EV battery recycling and e- waste recycling research and development, as part of broader ambitions to develop a domestic supply chain for EV batteries. As EV adoption rises in the U.S., demand for cobalt, a key battery material, will too. This could incentivise investments in responsible cobalt recycling to meet future demand while lowering reliance on imports.

While the law does not mandate battery recycling, in sections 40207 and 40208, it provides $60 million for research into battery recycling and $50 million for local governments and $15 million to retailers to fund battery recycling programs (Bird, Baum, Yu, & Ma, 2022). It also provides a process for research into reuse of electric vehicle batteries and proposes a task force to develop an extended producer responsibility framework and provides funding to the Environmental Protection Agency (EPA) to develop best practices for battery recycling and guidelines for voluntary battery labelling.

Policy Mechanisms

The BIL authorises the creation of grant and loan programs administered by federal agencies. In total, the BIL is investing more than $7 billion in LIB supply chains over the next five years. The legislation provides funding for both the EPA and the Department of Energy (DOE). An overview of relevant provisions in the BIL loan program is presented in Table 1 below.

Table 1: BIL authorised loans relevant for battery recycling

BIL Section	Program Name	Agency Name	Funding mechanism	Time Period	Available Fund
Sec. 40207(B). Battery processing and manufacturing	Battery Material Processing Grants	DOE	Grant	FY22-26	$3 billion
Sec. 40207(C). Battery processing and manufacturing	Battery Manufacturing and Recycling Grants	DOE	Grant	FY22-26	$3 billion
Sec. 40207(E). Battery processing and manufacturing	Li-ion Battery Recycling Prize	DOE	Grant	FY22	$10 billion
Sec. 40207(F). Battery processing and manufacturing	Battery and Critical Mineral Recycling[5]	DOE	Grant	FY22-26	$125 billion
Sec. 40208. Electric drive vehicle battery recycling and second-life applications program	Electric Drive Vehicle Battery Recycling and Second-Life Applications	DOE	Grant	FY22-26	$200 billion

The DOE already started providing grants to projects. In November 2022, they announced a total of $73.9 million in funding to support research and development projects on recycling and repurposing of EV batteries under the Electric Drive Vehicle Battery Recycling and Second-Life Applications program (Vehicle Technologies Office, 2022). These projects could be key contributors to scaling up technological innovation to increase domestic recycling and make second-life stationary storage more accessible.

During the same period, the DOE announced awarding $2.8 billion in grants from the BIL to 20 manufacturing and processing companies for projects which support new, retrofitted, and expanded commercial-scale domestic facilities to produce battery materials, processing, and battery recycling and manufacturing demonstrations.

[5] The Battery and Critical Mineral Recycling program includes:

– Battery Recycling Research, Development, and Demonstration Grants ($60M, FY22-26)

– State and Local Programs ($50M, FY22-26)

– Retailers as Collection Points Program for Consumer Electronics Battery Collection and Transport ($15M, FY22-26)

Governance Framework

The BIL relies on a collaborative approach involving multiple entities for implementation and oversight. The DOE oversees funding for clean energy projects. The BIL authorises or funds the federal government to make loans for a variety of purposes. Loans would be administered by the DOE through their Loan Programs Office (LPO), which operates programs to provide financing for clean and advanced energy, industrial, and clean vehicle manufacturing projects. The benefit of working with the LPO for a project is that these loans are lower cost, the LPO is able to offer more flexible financing options, and the office remains involved in the project for its lifetime, offering access to DOE's team of experts to help ensure the success of the project.

The EPA is required to develop **battery recycling best practices** and **battery labelling guidelines** as part of BIL funding (SEC. 70401). Congress allocated $10 million and $15 million respectively to the Agency to complete these two initiatives by September 30, 2026.

Capacity to enable responsible recycling of cobalt

The Bipartisan Infrastructure Law doesn't directly mandate or establish specific policies for responsible cobalt recycling. However, it does create opportunities that could indirectly encourage it. By supporting projects in battery recycling and second-life applications, the BIL aims to advance technologies and processes that can improve the efficiency, cost-effectiveness, and environmental sustainability of battery recycling and repurposing.

4.3.2. INFLATION REDUCTION ACT

The Inflation Reduction Act (IRA), passed in 2022, is a 10-year bill that seeks to invest in domestic manufacturing of renewable energy and EVs, by facilitating the growth of domestic supply chains. The IRA is the signature piece of climate legislation developed by the Biden administration, and aims to contribute to cutting the carbon footprint of the U.S. by roughly 40% by 2030 (from 1990).

Relevance to secondary cobalt

The IRA package includes $369 billion in climate and energy provisions, making it the largest clean energy tax credit package in U.S. history. The aim is to reduce greenhouse gas emissions, lower energy prices, speed up the deployment of clean energy technology, and build a more reliable energy infrastructure among other things (Transport and Environment, 2023).

Through the introduction of tax credits, the IRA provides substantial incentives to boost EV production and domestic battery production and recycling. On the demand side, the IRA introduced a **Clean Vehicle credit**, providing subsidies for customers buying EVs equipped with batteries containing domestically produced or recycled critical minerals including cobalt.

On the supply side, the **Advanced Manufacturing Production** credit provision was introduced in the IRA to support battery component manufacturers and develop a domestic battery supply chain. U.S. battery recycling and subsequently secondary cobalt supply is getting a boost as this clause grants tax credits for the production of battery cells and modules as well as for the production of battery minerals notably through recycling.

Apart from tax credits, the IRA is also providing loans to support the EV and EV battery manufacturing and recycling industry through the Advanced Technology Vehicles Manufacturing Direct Loan Program (ATVM). This $25 billion direct loan program, overseen by the DOE, was funded in 2008 to provide dept capital to the U.S. automotive industry and support the manufacture of eligible advanced technology vehicles and components. The IRA removed the $25 billion cap on the program and appropriated $3 billion in funding, available through 2028 to support these loans. Since this legislative update, the loan program has announced financing commitments in excess of $14 billion. These fundings include a $2.5 billion loan in 2022 to Ultium Cells for the construction of three LIB cell manufacturing facilities, $2 billion loan to Redwood Materials as well as a $375 million loan to Li-Cycle, both announced in 2023 to help finance the construction of new U.S. battery resource recovery facilities (Loan Programs Office, 2023).

Policy Mechanisms

The IRA establishes a Clean Vehicle credit (section 13401 of the IRA) of up to $7,500 per new vehicle to incentivise and accelerate the adoption of electric vehicles. To be eligible, new EVs must undergo final assembly in North America, must not exceed a retail price of $55,000 for light vehicles ($80,000 for vans, SUVs and pick-up trucks) and should meet the **critical minerals requirement** ($3,750) and the **battery components requirement** ($3,750). The provision also includes up to $4,000 of credit per used vehicle, with a condition of having a sale price of less than $25,000 and having a model year at least 2 years.

Table 2: IRA's Clean Vehicle Credit requirements

	Description	Threshold
Critical mineral Requirement	A percentage of the value of the critical minerals contained in the battery must be extracted or processed in the United States or a country with which the United States has a free trade agreement [6], or be recycled in North America	40% in 2023, rising to 80% in 2027
Battery component requirement	A percentage of the value of the battery components must be manufactured or assembled in North America	50% in 2023, rising to 100% in 2029

[6] Countries the U.S. has a free trade agreement with: Australia, Bahrain, Canada, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Israel, Japan, Jordan, Korea, Mexico, Morocco, Nicaragua, Oman, Panama, Peru, and Singapore.

Starting 2025, EVs that contain minerals or battery component sourced from China and other foreign entities of concern will not be ineligible for the Clean Vehicle credit. In contrast, EV battery materials recycled in the U.S. are automatically qualified as American-made for subsidies, regardless of their origin. This clause in the IRA qualifies and incentivises automakers to source U.S.-recycled battery materials for EV production incentives.

Another provision that could help shape the domestic battery recycling supply chain in the U.S. is the Advanced Manufacturing Production credit (section 13502-45X of the IRA) which provides incentives for eligible components produced and sold in the nation. Eligible components include EV battery components such as battery cells and modules as well as electrode active materials **including cobalt.**

Table 3: IRA's Advanced Manufacturing Production Credit Eligible components

Eligible component	Credit Amount
Electrode active materials (including cathode materials such as cobalt)	10% of the cost of production
Battery cell	\$35 per kWh of capacity
Battery module	\$10 per kWh of capacity

In short, a battery manufacturing factory in the U.S. will get \$45/kwh for each battery pack sold. Knowing that on average the battery cost was around \$130/kwh in 2021, this tax can cut by a third the price of making a battery pack (Voelcker, 2023). As the price of battery packs is decreasing, the tax can be more significant. In addition, battery recyclers will get a 10% credit of the cost of producing their recycled materials.

Governance framework

The Internal Revenue Service (IRS) is responsible of implementing the IRA's tax credits by creating and updating tax forms, instructions, and publications to reflect these credits. In addition, the U.S. Treasury Department, working together with the IRS, plays a key role in developing tax regulations and guidance to implement the tax credits. In March 2023, they released the Notice of Proposed Rulemaking (NPRM), a proposed guidance on the new clean vehicle provisions explaining how manufacturers may satisfy the critical mineral and battery component requirements under the IRA (U.S. Department of Treasury, 2023).

Capacity to enable responsible recycling of cobalt

As most of the cobalt used today in EV batteries is mined in the DRC and processed in China, meeting the critical mineral requirement through procurement of minerals from North America or FTA countries will be challenging (ICCT, 2023). However, the domestic critical material requirement can alternatively be met by procuring the minerals from **domestically recycled battery material**. The OEMs desire to make their EVs eligible for their customers for the tax credit will **increase the demand** for recycled minerals, notably recycled cobalt.

Domestic recycled cobalt is also being enabled by the advanced manufacturing production credit included in the IRA as it provides an opportunity for producers recycled cobalt to cut 10% in production cost and make their product **more competitive** compared to primary cobalt. This provision is already encouraging U.S. companies to move faster on recycling efforts, especially compared with their counterparts in the EU, where the focus has been more on mandates, including minimum amounts of recycled materials in future EV batteries. While several European recycling plants remain planned for the future, in the U.S. recycling firms are already building plants thanks to the speed of access to funding and the made-in-America incentive provided by the IRA.

Challenges and recommendations related to the Inflation Reduction Act

The critical mineral requirements in the IRA, while essential to achieving a secure supply of materials needed to decarbonise the U.S. transportation sector, are viewed as largely unachievable. The current-decade timeline and percentage of applicable critical minerals requirements (80% by 2027) are indeed ambitious (the metals company, 2022). The lack of clarity on how to meet the critical mineral requirement is a risk for manufacturers to be unable to meet them and hence a risk for consumers to be unable to obtain the proposed Clean Vehicle Credit.

Reducing the requirements or extending the timeline might be necessary to take full advantage of this tax credit. The U.S. might also need to explore negotiating an agreement with the EU on critical minerals, which would count the same as a free trade agreement, so that minerals that are produced or processed in the EU can count as part of the requirements for the IRA.

The issue of securing sufficient amounts of secondary feedstocks for recycling also remains under addressed by the IRA. This is concerning as significant recycling capacity was announced by automakers and recyclers as a response to IRA's funding and subsidies. To enable procurement of spent LIBs, a robust collection system is essential, allowing safe collection and cost-effective transportation of these batteries.

Currently, transporting of LIBs to recycling and refurbishment centres remains a major hurdle. Classified as Class 9 hazardous materials under the U.S. Department of Transportation's Hazardous Materials Regulations, used LIBs require special handling, significantly driving up the costs of packaging, logistics and transportation of batteries, and directly impacting the economics of battery recycling and reuse (CalEPA, 2022).

Extended Producer Responsibility (EPR) programs offer another solution for securing a steady stream of used LIBs. Implementing these programs at the federal level would be ideal, but considering the current political climate, establishing consistent EPR laws across states is a more feasible initial step. Today, EPR laws have been enacted in a couple of states such as California, but the specifics of these laws vary significantly from state to state. Therefore, consistent state- level EPR regulations targeting LIBs are likely necessary to make battery recycling effective and economical, while ensuring the throughput necessary for recycling facilities (Bird, Baum, Yu, & Ma, 2022).

Another challenge related to the IRA is failing to comprehensively address key environmental and social concerns around secondary production of critical battery materials like cobalt. The IRA aims to stimulate the U.S. lithium-ion economy, but while domestic battery recycling and the use of secondary cobalt can significantly reduce the environmental and social risks associated with primary cobalt mining, current legislation often fails to address ESG concerns surrounding secondary cobalt production itself.

4.3.3. ADVANCED CALIFORNIA

In addition to federal initiatives, there are a number of state and local governments that are also taking steps to support EV battery recycling and e-waste management. Several states have passed laws that require the collection and recycling of e-waste, while others offer financial incentives to businesses that recycle EV batteries.

California was the first state in the nation to introduce EPR schemes for batteries in the mid- 2000s. Those programs, operated under the Cell Phone Recycling Act of 2004 and the Rechargeable Battery Act of 2006, covered most rechargeable batteries sold in the state. Since then, the use of batteries in the state has grown dramatically, leading to growing concerns of batteries of all types being improperly disposed of into the state's waste systems.

In 2018, California established the Lithium-Ion Car Battery Advisory Group, composed of automakers, dismantling companies, battery companies, state agencies, and non-profit and environmental justice groups. The group worked to develop policy recommendations aimed at ensuring that as close to 100 percent as possible of electric vehicle traction batteries in the state are reused or recycled at EOL in a safe and cost-effective manner.

This advisory group, who met between 2019 and 2022, developed policy recommendations specific to end-of-life LIB management and highlighted the need to clearly define end-of-life management responsibility for out-of-warranty batteries as well as develop producer take-back policy. Significant barriers were also identified, pertaining to the high cost of spent LIBs transportation. The advisory group mentioned the lack of basic battery information for proper handling, suggesting the need for increased access to information via standardised physical battery labels or digital identifiers (CalEPA, 2022).

In 2022, a new EPR regulation was then enacted in California under the **Responsible Battery Recycling Act 2022 (AB 2440)**. The law replaces the Cell Phone Recycling Act of 2004 and the Rechargeable Battery Act of 2006, and created a singular EPR program for batteries within the state. AB 2240 requires producers to establish, fund, and operate a stewardship program to manage collection, transportation and recycling of covered batteries and battery-containing products, including primary, rechargeable, and lithium-ion batteries, which can explode or cause fires (Product Stewardship Institute, 2022).

Despite being one of the most advanced states in producer responsibility, California still faces challenges in developing a cost-effective value chain for cobalt recycling from collection to recycling. Both the business potential and challenges of recycling Californian cobalt were recently seen by Redwood Materials. In February 2022, the company launched a comprehensive electric vehicle battery recycling program in California to establish efficient, safe and effective recovery pathways for end-of-life hybrid and electric vehicle battery packs. In one year, they were able to safely package, collect and transport around 225 tonnes of battery material to their facility in Nevada, where they recovered crucial battery materials such as lithium, cobalt and nickel at a recovery rate exceeding 95%. Their experience so far shows that the most significant cost of battery pack collection and recycling is logistics, and achieving economies of scale through increased collection can be key to reducing these costs (Redwood Materials, 2023).

Despite the challenges in building out a comprehensive infrastructure for LIB collection, transport, and recycling, California demonstrates a potential model for other states in the U.S. to follow thanks to its ambitious EPR scheme.

5. BATTERY RECYCLING IN GHANA

5.1. OVERVIEW OF THE CURRENT CONTEXT

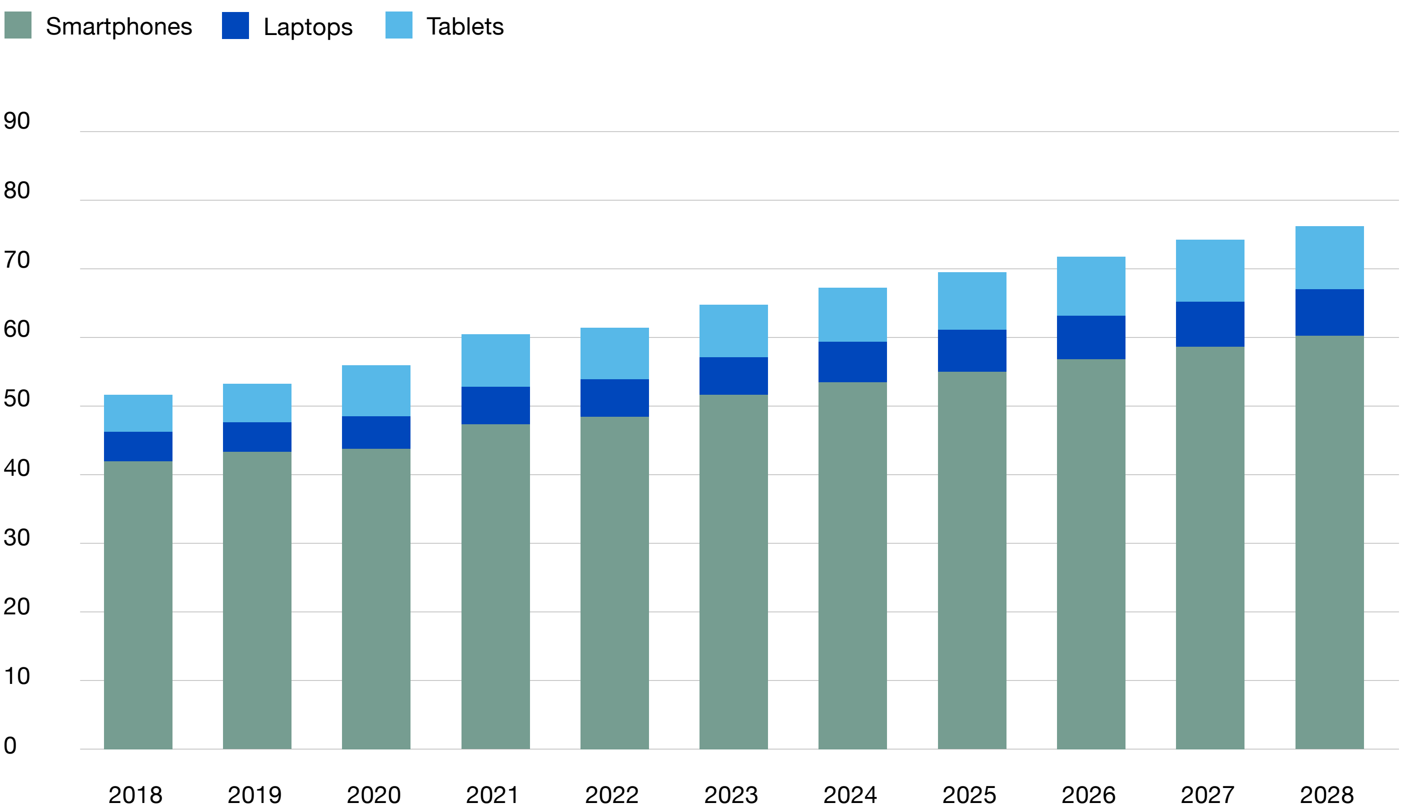
This section of the report focuses on the example of Ghana, to highlight the challenges and opportunities facing Sub-Saharan Africa more generally with respect to recovering secondary cobalt that is currently lost in spent batteries. The county has received significant publicity as a global e-waste hub but has also been at the forefront of legislative efforts to remedy the situation and improve the conditions of the informal e-waste sector.

5.1.1. RATE OF BATTERY CONSUMPTION, DISPOSAL, AND RECYCLING

The market and value chain for EVs remains limited in West Africa, and thus the majority of secondary cobalt feedstocks in the region are in portable LIBs. West Africa's demand for portable electronics is increasing. By 2023, the market for cell phones, laptops and tablets boasted 65 million units, and this number is projected to steadily increase in the next few years, reaching 76.5 million units by 2028 (Statista Market Insights, 2024).

Figure 17: Total volume of smartphones, laptops and tablets in use in West Africa

Million units



Source: Statista Market Insights, 2024

The growth in demand for electronics in West Africa coupled with the inherently short lifespan of second-hand electronics, has resulted in a massive e-waste problem with vast amounts of e-waste generated and imported into the region each year. In 2022, 750 million kg of e-waste were generated in West Africa, with less than 1% documented as formally collected and recycled (Baldé C. P., et al., 2024).

The vast amount of e-waste generated and imported in West Africa presents an opportunity for cobalt recovery, as it comprises electronics with significant cobalt content, such as smartphones, laptops, and tablets containing around 5-20g, 20-50g and 20-50g of cobalt, respectively. Based on the 2024 Global E-waste Monitor and on Figure 17, e-waste generated in West Africa in 2022 is estimated to contain between 0.5-1.5 ktonnes of cobalt.

However, as of today, Africa lacks formal facilities to recycle LIBs and recover cobalt. Most cobalt containing products end up unaccounted for, either discarded or handled through informal means. This represents a significant loss of potential value. By establishing proper e-waste recycling infrastructure, Africa can tap into this valuable resource and avoid losing the potential it holds.

Ghanaian e-waste management context

The surge in information and communication technologies in Ghana during the 1990s, alongside population and economic growth, has spurred increased consumption of electrical and electronic devices. Consequently, there has been a corresponding rise in the generation of e-waste with around 53,000 tonnes of e-waste generated in Ghana in 2019 (Forti et al, 2020). This waste encompasses various electronic devices, such as laptops, cell phones, and power tools, many of which contain used or end-of-life lithium-ion batteries. As a result, hundreds of tonnes of lithium-ion batteries are annually disposed of in landfills, either separately or embedded within consumer electronics. (GIZ, 2022).

Ghana receives electrical and electronic devices with limited remaining useful lifespans from developed countries as second-hand goods. Around 15% of these imports are considered e- waste on arrival. This is mainly attributed to violations of the Basel Convention, making it possible for e-waste to be illegally imported to Ghana, frequently disguised as wrongly declared second-hand goods and ending up as e-waste (GIZ, 2022). However, imports from developed countries do not constitute the primary source of e-waste as according to the United Nations Environment Programme, 85% of the e-waste dumped in Ghana originates from within the country and West Africa.

Regardless of the origin of the e-waste, Ghana, particularly Accra, has become a central hub for its accumulation and unfortunately, the country lacks an effective and environmentally sound recycling sector and rely instead on the informal sector to manage this growing issue.

Organisation of the informal sector

In Ghana, several registered companies are engaged in e-waste management and recycling. However, they encounter challenging legal and market conditions due to the informal recycling sector's advantage. Informal recyclers do not have to cover the costs of disposing hazardous e-waste and operate under lower environmental and social standards. This makes unsound recycling more profitable than responsible practices.

Consequently, e-waste management and recycling in Ghana are primarily conducted through informal channels, with approximately 95% of e-waste being informally collected (GIZ). This system typically operates in three stages:

- **Collection:** collectors set out in the early mornings and walk through the streets of Accra to collect/buy e-waste from households, warehouses, and second-hand shops and then deliver/sell the scrap to scrap dealers in scrapyards for processing in the evening.
- **Repairing, dismantling, sorting and processing:** informal recyclers commonly focus on recovering valuable materials, while non-valuable and polluting fractions are disposed uncontrolled or burned.
- **Trade:** after undergoing primary dismantling and processing, the e-waste is typically sold to domestic and/or foreign refineries for further processing.

The informal sector is associated with several critical environmental and social risks. Yet it holds key benefits. Despite its informal nature, e-waste collection activities in Ghana are highly effective, as the informal sector contributes to high collection rates. In addition, the informal sector provides a livelihood for many Ghanaians. As of 2017, the informal e-waste sector in Ghana generates $105–268 million annually and sustains the livelihoods of at least 200,000 people nationwide (GIZ, 2019).

THE CASE OF THE AGBOGBLOSHIE SITE

Established in the early 1990s and located in the centre of the Greater Accra Region, the Agbogbloshie site became infamous as one of the world's largest scrapyards for e-waste with informal and unsound recycling practices accompanied by severe environmental and health impacts. Situated strategically near the port and the Central Business District of Accra, the Agbogbloshie site had inexpensive access to both international and domestic e-waste, offering favourable logistics for e-waste brokers to profit from facilitating the transfer of discarded materials. With the increased consumption of electrical and electronic gadgets and importation of second-hand devices, e-waste became a key waste stream, and the site quickly became Ghana's market for e-waste, processing an estimated 40–60% of the country's total e-waste (Davis, Akese, & Garb, 2018).

Hosting more than 200 small business operations, the Agbogbloshie site directly employed between 4,500–6,500 workers (collectors and dismantlers), and indirectly supported a dependent population estimated at 20,300–33,600 (Davis, Akese, & Garb, 2018; GIZ, 2022).

Predominantly, these workers were migrants from the northern part of Ghana who migrated to urban areas in search of better opportunities through informal waged labour in the capital (GIZ, 2022).

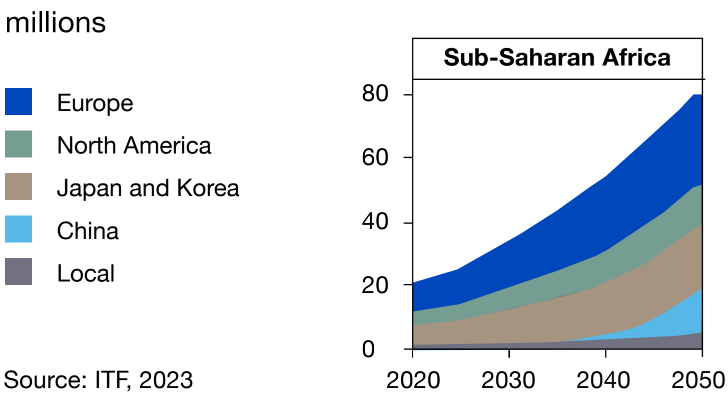
In July 2021, in an attempt to reduce environmental and health risks, the Agbogbloshie scrapyard was demolished by the government without prior warning, evicting its residents and depriving many from their jobs and their livelihoods. However, this event did not stop the e-waste work, but instead pushed the practices underground to the inside of homes and closer to where people live. Consequently, instead of one Agbogbloshie plant, many new informal e-waste recycling sites emerged throughout Accra and nearby cities.

5.1.2. WEST AFRICAN TRADE IN USED EVS AND SPENT BATTERIES

As mentioned, the majority of secondary cobalt feedstocks available in Ghana, and in Sub Saharran Africa more generally, are currently present in the form of spent LIBs from portable electronics. However, the electrification of the mobility sector will also have major implications for African countries. Policy and trade decisions taken in the coming years will have lasting effects on African access to e-mobility, and on the eventual availability of spent EV batteries in the region.

EV uptake in Sub-Saharran Africa is currently quite low, however understanding patterns in ICEV trade in the region can offer insights into the potential for an EV market to emerge on the continent. Currently, over 85% of the vehicles in circulation in Africa are second-hand cars (Ayetor, Mbonigaba, Sackey, & Andoh, 2021). In 2019, Nigeria was the continents leading importer with over 170,000 used vehicles imported. Ghana meanwhile imported over 76,000 used vehicles. Passenger cars in the region typically originate from North America, Europe, Japan and Korea. However, according to the International Transportation Forum (ITF) in coming decades China is expected to become a major exporter of used vehicles to Sub-Saharan Africa, as seen in Figure 18.

Figure 18: Estimated passenger car stock for Sub-Saharan Africa by import source



Source: ITF, 2023

As passenger fleets in high income, exporting, countries become electrified, it is likely that increasing amounts of used EVs will become available for export to Africa. Several factors could limit the extent to which global trade in second-hand EVs mirrors the used ICEV market including:

- **Export restrictions** may be imposed by developed countries on EVs, out of a possible desire for material security or concerns about the lack of battery recycling capacity in developing countries
- The lack of **charging infrastructure** and reliable grid infrastructure present in Sub- Saharan Africa may limit demand for EVs
- The market **demand for battery reuse applications and recycling** may make used EVs prohibitively expensive consumers in low-income countries
- Policies encouraging EV adoption in developed countries may lead to a surplus of **cheap used ICEVs** available for export to low-income countries

Depending on the occurrence of these different factors, used EV exports to Sub-Saharran Africa will vary dramatically in coming decades. According to the ITF, if EVs remain equally as likely to be exported to Africa as ICEV, then around half of all African passenger cars can be expected to be electric by 2050. However, if a restricted scenario emerges where EVs are only 20% as likely to be exported as ICEV, only around 10% of Sub-Saharan passenger vehicles will be electric by 2050 (ITF, 2023).

The future of trade in electric vehicles between developed economies and Sub-Saharan Africa illustrates the complex potential trade-offs that can emerge between different aspects of the global sustainable development agenda. The export of used EVs to developing nations can help reduce air pollution locally, create positive socio-economic impacts, and contribute significantly to reducing global Ghg emissions. However, material security concerns from OEMs and governments in high income countries may result in circular economy policies that limit exports of used batteries in EVs in order to collect and recycle cobalt and other battery materials within high income countries. As highlighted by the ITF (ITF, 2023), international collaboration between public and private stakeholders in both high and low income countries will be key to balance these competing interests and enable global decarbonization alongside effective material recovery from spent EV batteries.

5.2. CURRENT AND EMERGING ESG RISKS IN THE SECONDARY COBALT SUPPLY CHAIN

5.2.1. END-OF-LIFE BATTERY COLLECTION, TRANSPORT AND SORTING

Environmental risks

Ghana's e-waste management sector faces significant environmental risks stemming from informal practices. Over the years, the country's existing e-waste economies have borne the brunt of environmental degradation.

Informal actors often manage the recycling and reuse of electronic waste by resorting to burning or improper disposal of remaining materials that hold no value to collectors and processors. This burning releases copious amounts of toxic smoke containing a variety of harmful chemicals, contributing to soil and water pollution. Mismanagement of e-waste significantly impacts the health of nearby rivers and soil, releasing toxins and posing a substantial environmental challenge for the broader population, particularly in larger urban centres like Accra.

Social risks

Informal e-waste management in Ghana not only poses environmental risks but also significant social challenges. Despite the economic benefits of e-waste, low-income earners, settlers, children, and people with minimal education are disproportionately exposed to its health effects due to poverty, lack of education, and lax regulations.

Children are especially vulnerable to health risks because they are closer to the ground and ingest a relatively high amount of chemicals in relation to their body size (Njoku, et al., 2024). Within this informal sector, scrapyard owners and collectors engage in informal practices, and might perpetuate inequality among collectors, underscoring broader social disparities within the country. In addition, fires, accidental or deliberate, release toxic fumes and pose health risks such as respiratory diseases due to exposure to toxic elements (Sampson, 2023).

However, the informal sector provides vital livelihoods for many Ghanaians. Simply removing it, as seen with the 2021 demolition of the Agbogbloshie scrapyard, is not a sustainable solution. Moreover, the exclusion of the informal sector from waste management decisions and planning hinders efforts toward formalisation and sustainable management practices.

Governance risks

Governance challenges loom large over Ghana's informal e-waste management sector, complicating efforts to address environmental and social risks. Import of falsely labelled appliances and instances of public sector corruption further marginalise workers, exacerbating existing governance challenges and environmental risks. Organised crime adds another layer of complexity, as evidenced by the recent discovery in January 2023 of an organised crime group caught smuggling over 5 million kg of e-waste from the Canary Islands to West African countries including Ghana and Nigeria (Baldé C. P., et al., 2024).

The sector's informal nature, influenced by divisions along ethnic lines, further hampers effective governance and contributes to ongoing environmental degradation. Establishing inclusive policies and decision-making processes is essential to account for the diverse needs of all stakeholders involved in e-waste management. This approach is crucial to prevent straining the trust between informal workers and the state, as seen with the eviction of Agbogbloshie residents in 2019.

5.2.2. PRE-PROCESSING, COBALT RECOVERY, AND PROCUREMENT OF RECYCLED COBALT

As of today, Ghana and Africa lack facilities to recycle lithium-ion batteries (LIBs) and recover cobalt. This absence of pre-processing and recycling infrastructure eliminates any environmental, social, and governance (ESG) risks associated with these processes. However, due to the lack of proper e-waste management facilities, discarded materials often end up in landfills or open dumps, creating associated environmental and social hazards (Bimpong, Asibey, & Inkoom, 2023).

5.3. KEY POLICIES IMPACTING THE MARKET FOR SECONDARY COBALT

The Government of Ghana has recognised the challenge of e-waste management and since 2016, has started addressing it. On an international level, Ghana has ratified several waste related International and Multilateral Environment Agreements including The Basel Convention, The Vienna Convention and The Stockholm Convention. These mostly determine control and regulations of hazardous substances (GIZ, 2022).

5.3.1. ACT 917

In 2016, the Parliament of Ghana passed ACT 917 “The Hazardous and Electronic Waste Control and Management ACT, 2016”, to specifically deal with e-waste management, supported by a Legislative Instrument (L.I.) 2250 on Hazardous, electronic and other wastes (classification) control and management regulations.

Relevance to secondary cobalt

Act 917 introduced measures regarding e-waste management, including import and export of electrical and electronic waste, the establishment of an advanced eco-levy and an Electrical and Electronic Waste Management Fund and the establishment of recycling facilities. Act 917 also prescribes requirements for the disposal of e-waste, including lithium-ion batteries and regulates the roles of producers of e-waste, repairers, dismantlers, recyclers and operators of collection centres.

While the policy doesn’t focus directly on secondary cobalt recovery, it does address the EOL of cobalt products. Tackling Ghana’s e-waste problem can unlock a major source of secondary cobalt while also mitigating the environmental and social issues linked with current informal handling methods.

Policy Mechanisms

The law seeks to formalise the activities of the informal recyclers by ensuring the registration of all value chain actors for permits. The Act also requires producers of electronic and electrical equipment to **take back used electronic equipment**. Furthermore, the principle of polluter- pays is established, as an **advanced eco-levy** is to be collected from importers and manufacturers on different electronic and electrical equipment including lithium primary cells and batteries ($0.15), laptops ($1.5) and mobile phones ($1.5).

The eco-levy, along with other funding sources such as grants and donations, finances an **Electrical and Electronic Waste Management Fund**. The object of the fund is to cover activities such as providing support for construction and management of e-waste recycling or treatment facilities. The fund also aims to offer incentives for collection, transportation and disposal of electrical waste, and promote public education and awareness on the safe disposal of electrical and electronic waste and negative effects of electronic waste (GIZ, 2019).

Governance framework

After several years of initiating efforts to develop legislation on hazardous and electronic waste, the Ghana **Environmental Protection Agency** achieved the passage of Act 917 in 2016. An important consideration in designing the policy was bringing onboard relevant stakeholders who are in one way or the other affected by the programme, or those whose expertise in the field of discussion can be sought to serve as an input for the design and even implementation of the programme. Apart from the representatives of the EPA and the Ministry of Environment Science Technology and Innovation, institutions from public and private sectors were solicited for consultations such as labour and finance ministries as well as scrap dealers' associations and trade associations.

The Ghana EPA also **ensures the registration** of all recycling value chain actors for permits. This includes importers and exporters of e-waste or used electronics, who must also register with the EPA, and acquire an import or export permit; allowing the EPA to keep track of all electrical and electronic products, regardless of whether they are made locally or imported into Ghana (Bimpong, Asibey, & Inkoom, 2023).

As for the eco-levy, an **External Service Provider** is designated by the Government to collect the eco-levy and to carry out physical inspection and verification at the country of export of any used electrical and electronic products.

In 2018, the Ministry of Environment, Science, Technology (MESTI) and the EPA introduced the **Technical Guidelines on Environmentally Sound E-waste Management**, providing essential insight on how to develop the required Environment, Health and Safety working standards for all aspects of e-waste management (Environmental Protection Agency & Sustainable Recycling Industries, 2018). The guidelines mention the importance of separating lithium batteries from e-waste and handling them with special precautions and safety measures to prevent damage or exposure to heat and water during handling sorting and storage. However, they lack detailed information on reuse and recycling of LIBs.

This legal framework was adopted to regulate the classification of waste, prescribe requirements for take-back systems, prescribe requirements and timeframes for the management of listed wastes, prescribe general duties of waste generators, waste transporters and waste managers, in an attempt to ensure safe and environmentally sound treatment of e-waste in Ghana.

Capacity to enable responsible recycling of cobalt

The passing of ACT 917 by Ghana signifies a commitment to enabling responsible EOL management of e-waste including cobalt products. This legislation intends to improve battery collection and enhance health and safety standards within the informal sector while granting legal status and permits to informal businesses. Moreover, it intends to protect the environment surrounding e-waste disposal sites, thereby benefiting impacted communities. The legislation encourages the adoption of the Basel Convention and the monitoring of electronic goods shipments to prevent spent batteries from entering Ghana. Furthermore, the act seeks to compensate suppliers above local material value for cobalt products, bringing economic benefits and potentially improving livelihoods for scrap collectors.

However, Ghana has struggled to adequately fund its e-waste management efforts, primarily due to shortcomings in the eco-levy system. Originally designed to provide substantial funding, the eco-levy faced criticism from OEMs and importers during the design phase for its perceived high fees, leading the government to significantly reduce the amounts paid. As a result, the flow of funds has been slow, with only roughly $1 million collected since 2018 (Sampson, 2023). Consequently, the National E-waste Fund struggles to meet its ambitious targets, and waste management departments lack adequate resources, rendering monitoring and supervision challenging and ineffective.

Challenges and recommendations

International and national policies that seek to eliminate this industry would deprive vulnerable populations of a much-needed source of livelihood. While closing e-waste scrapyards and restricting e-waste imports from these hubs might reduce pollution and health risks going forward, less often considered are the unintended negative consequences to e-waste- dependent economies: a return to high unemployment, squandered sunk costs in equipment, and underutilised expert knowledge. These consequences all emerge while leaving e-waste hubs with an enduring toxic legacy.

It becomes important then to **recognise the importance of the informal sector and engage with it to build on existing networks**. The significance of established players and structures in scrap collection and management cannot be overlooked. Collaboration between formal and informal actors is essential, ensuring that each party's strengths are leveraged in waste management strategies. Examining the potential benefits and challenges of such partnerships is crucial for promoting integrated solutions.

These solutions can provide social, financial, and health advantages, ensuring a sustainable e- waste management system throughout the recycling value chain (STEP, 2020). For instance, as observed in the GIZ pilot project, engaging with the Greater Accra Scrap Dealers Association (GASDA), which represents the scrap workers in scrapyards, was a key factor in the steady increase of collection volume over time. Involving the GASDA in planning and implementing any future efforts to formalise the sector is essential (GIZ, 2020).

A redesigned interface between informal and formal recycling economies could leverage the informal sector's efficient collection networks for LIBs. Trained informal workers, equipped to safely sort and

and disassemble LIBs at designated collection centres, could separate them from lead-acid batteries and other materials. This pre-sorted stream of LIBs could then be directed to local, certified recycling facilities for proper processing. This approach optimises existing collection infrastructure while ensuring safe and effective recycling of spent LIBs.

Reform strategies solely based on training and technology provision have limited measurable impact as **unsound recycling still holds economic advantages compared to sound recycling** which comprises the costly management of hazardous fractions. The informal sector is driven by economic opportunity, with workers adopting the cheapest and simplest way to disassemble.

To promote responsible practices, incentives are demonstrably more effective than punishments, as pushing away and penalising the informal sector is counterproductive (Minere, 2023; Sampson, 2023). **Incentive-based collection systems can instead be developed**, by setting up handover centres and offering monetary incentives to informal collectors for e-waste upon delivery, compensating them above the local value for delivered e-waste. The collected materials would then be directed to certified recycling facilities, ensuring sound recycling. This system capitalises on the informal sector's high collection efficiency, which generally do not pose significant ESG risks. The system then replaces environmentally harmful informal processing practices with certified recycling, significantly reducing overall ESG risks.

Successful initiatives have already been undertaken, such as the GIZ pilot for copper cables and the Fairphone pilot for waste mobile phones. The concept of incentive-based collection however is not meant to replace other approaches to reform informal collection and recycling activities such as registration/formalisation, training and provision with appropriate handling and treatment technologies and regulatory enforcement.

There is a **struggle with policy enforcement in the e-waste management sector in Ghana** hindering the ability to collect enough funding. Ensuring constant financing for incentive-based collection and other sound e-waste management approaches is crucial. Ghana already has the legal pre-condition to provide constant financing for sound e-waste collection with the establishment of the National E-waste Fund, mandated by ACT 917, and funded by e-waste levies on imported equipment (GIZ, 2020).

Regulatory enforcement is essential, with the EPA and municipalities needing increased capacity to enforce environmental regulations, particularly in e-waste management where they currently have low capacity (Sampson, 2023). Once regulations are effectively enforced, the E- waste Fund can be properly funded and utilised as intended. This includes establishing e-waste recycling facilities, providing incentives for collection, promoting public awareness on safe disposal practices for e-waste, and highlighting the negative effects of improper disposal.

Another way to secure proper management of e-waste in Ghana is to **drive investments for formal e-waste recycling**. As of today, few private recycling facilities exist to undertake some form of separation of the items and then export some of the fractions to recyclers outside the country performing end-to-end recycling. Funding and investment in formal e-waste recycling systems at the local level in Ghana are not sufficient. To attract investment, the government of Ghana should focus on raising awareness about the benefits of investing in developing countries, such as job creation, adherence to ESG standards, and pollution reduction. Additionally, there is an opportunity for companies in Europe to obtain black mass from Ghana instead of China, which could further incentivise investment.

Industry stakeholders should also join efforts in collaborating and investing in sorting and recycling facilities in Ghana, as e-waste should be recycled locally. Targeting investors from Europe, the U.S., Ghana, and other and other African countries is essential. European investors, in particular, need reassurance regarding ESG risks, such as bribery and corruption, but are encouraged to adapt to the local context via a constructive engagement approach.

Increasing the involvement of stakeholders is necessary to scale up the current initiatives and further reduce the negative impacts of e-waste. Adequate funding from partners in developed countries is essential for implementing projects. Establishing facilities, which could cost a few million dollars (around 3-4), has the potential to significantly decrease scrap. These investments can enable the construction of facilities, the employment of local workers at competitive wages compared to standards in developed countries, and the provision of education and awareness programs on the responsible management of e-waste and its environmental and health implications. Subsidies can also be offered for e-waste recycling facilities in an attempt to make those more competitive when pitched against any informal sector operations since the informal sector has an unfair financial advantage (GIZ, 2019).

Another challenge the Government of Ghana faces is a lack of or unreliable data on both e- waste importation and those generated domestically, posing a challenge for developing strategies and interventions to tackle e-waste (Bimpong, Asibey, & Inkoom, 2023). Currently, there is a lack of clarity regarding the quantity of lithium-ion batteries present in e-waste in Ghana, as well as the flow of these batteries throughout the system.

A fully **transparent and accountable system should be developed, providing all necessary information and documentation on mass-flows**, financial flows and individual transactions (GIZ, 2020). Establishing this system, implementable at repair shops, collection centres, and recycling facilities, would facilitate the mapping of battery flows and provide a clearer understanding of the extent of material loss opportunities.

CASE STUDY – MOUNTAIN RESEARCH INSTITUTE PROMOTING RESPONSIBLE LIB COLLECTION IN GHANA

The Mountain Research Institute (MRI) is a research and consultancy firm that specialises in education, training, research and development. MRI specialises in bold environmental and circular economy consultancies within the domain of sustainable cycles of resources to promote sound economic development. With its highly qualified and competent human expertise, MRI brings cutting-edge solution for environmental, social and economic development. They co-develop solutions between the informal, formal and public sectors to tackle the e-waste challenge in Ghana and responsibly manage spent LIBs from EVs and portable devices.

OVERVIEW OF THEIR WORK

Over the years, MRI has been actively engaged in various projects and initiatives. One notable involvement includes the Sustainable Recycling Industries (SRI) project, which is funded by the Swiss government. This project aims to facilitate the integration of informal scrap dealers into the formal economy by providing training opportunities. Additionally, MRI played a crucial role in supporting the EPA in developing Technical Guidelines on sound e-waste management.

MRI has also been a key player in the E-Waste Programme (2016-2023), implemented by the GIZ, aiming to improve conditions for sustainable electronic waste management in Ghana. Through collaboration with relevant public and private stakeholders, MRI worked to improve policy frameworks at the national and municipal levels, introduce viable business models, and offer capacity building.

CAPACITY BUILDING

One of MRI's primary endeavours revolves around providing capacity building to various stakeholders within the e-waste management sector, including training of Metropolitan Municipal District Assemblies (MMDAs) and informal workers. Out of Ghana's 261 MMDAs, over 50 have been trained by MRI, with ongoing efforts to expand training to another 70 in the upcoming year. Training covers regulatory players and extends to informal workers, ensuring knowledge of the regulatory system for e-waste management in Ghana. Efforts are underway to develop curricula for institutions (Schools of Hygiene) training municipal staff, ensuring the sustainability of these initiatives and promoting sustainable e-waste management practices.

Another significant aspect of MRI's work lies in its engagement with diverse stakeholders involved in e-waste management, including government entities, the informal sector, and the private sector. It emphasises inclusive discussions and decisions. MRI aims to change perceptions of the informal sector in Ghana, showcasing its vital role in the recycling ecosystem, and potential as a driver of social development.

INCENTIVE BASED COLLECTION OF LI-ION BATTERIES

MRI, together with its partners, KFW, Ministry of Environment Science and Technology, Fund Administration, GOPA Infra, Green Advocacy and Black Forest participates in various initiatives promoting incentive-based e-waste collection and the development of economically viable business models.

One such initiative involves collaborating with the German Development Bank KFW to implement an incentive-based collection scheme for spent LIBs. At their collection centre in Accra, incentives are offered to informal actors who collect batteries, which are then safely stored in sand in the national battery storage facility. This pilot program has resulted in the accumulation of over 1.4 tonnes of spent LIBs within 3 years.

However, the program faces some challenges. The monetary incentive for spent LIBs is too low to cover the cost of transporting them long distances, and therefore only batteries from the Accra region are currently collected. Moreover, the low incentive rate also means that informal collectors prefer to sell batteries from laptops and other appliances to informal businesses specialised in repurposing these batteries for re-use in energy storage for solar systems. Some also sell to Nigerians who export to Nigeria, aggregate to larger volumes and export to other countries. MRI is also in need of downstream solutions to dispose of batteries once they have been collected.

As Africa lacks domestic LIB recycling capacity, there is a need for external off-takers to purchase and recycle collected batteries. Developing LIB pre-processing in Ghana could also support safe storage of the secondary cobalt (as black mass) and facilitate its export.

IMPACT

MRI plays a significant role in Ghana's e-waste management sector, with impactful activities aimed at mitigating environmental and social risks associated with unsound practices in the informal sector. Environmentally, MRI prevents the improper disposal of LIBs by collecting and storing them, thereby reducing fire risks and minimising environmental contamination.

Socially, the organisation provides capacity building in health and safety for workers, enhancing their ability to handle e-waste safely and improving overall working conditions. Economically, through their involvement in the development and piloting of various business models, MRI contributes to creating economic opportunities within the sector.

SCALABILITY (FUTURE OPPORTUNITIES)

In Ghanaian legislation, LIBs hold strategic importance, necessitating the development of a comprehensive strategy to manage the increasing volume of these spent batteries. While government funding for recycling is limited, the hope lies in private sector investment.

Initiatives should commence with enhancing collection incentives to broaden program outreach. As a medium-term solution, investment in dismantling facilities is proposed to facilitate material transportation to regions with recycling capacity, like Europe. Long-term strategies entail investing in cobalt recovery within West Africa.

6. INITIATIVES SUPPORTING RESPONSIBLE COBALT RECYCLING

The emergence of a vibrant and sustainable market for secondary cobalt will require action on the part of industries across the cobalt value chain. This chapter provides an overview of the mechanisms available to industries involved in recycling and procuring cobalt to directly address ESG risks related to cobalt recycling. Addressing these risks is essential to ensuring consumer confidence as well as compliance with regulatory requirements in the world's largest cobalt markets (e.g. IRA in the U.S., Battery Regulation in the EU, and Requirements of the Industry Standards for the Comprehensive Utilization of Waste Power Storage Batteries of New Energy Vehicles in China).

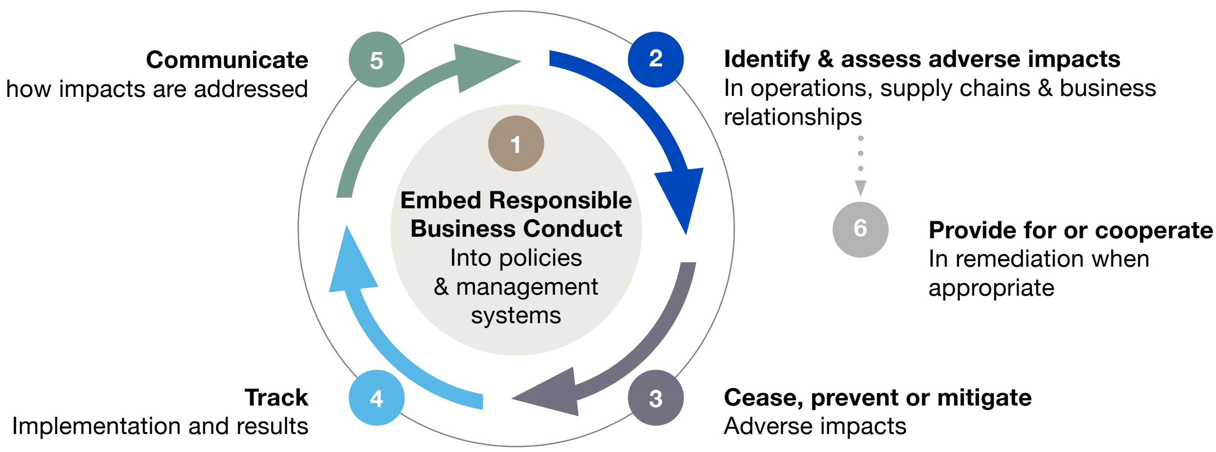
Due diligence guidance and **recycling facility certification** schemes offer a direct way for the cobalt sector to address risks across the recycling value chain, and to build social and regulatory trust through improved transparency. This chapter provides an overview of relevant due diligence guidance and assurance mechanisms, as well as recycling standards that can mitigate risks in cobalt recycling, and offers recommendations for their continued improvement.

6.1. DUE DILIGENCE GUIDANCE

To date, much of the work related to responsible sourcing of cobalt has been focused on developing due diligence guidance related to the risks related to sourcing primary cobalt from conflict affected and high-risk countries. The due diligence processes already put in place by cobalt refiners and consumers can also be a powerful tool for tackling ESG risks in the secondary cobalt market.

The OECD Due Diligence Guidance for Responsible Business Conduct, presented in Figure 19 below, serves as the global standard for corporate due diligence, and is the foundation of regulatory requirements around the world.

Figure 19: OECD Due diligence process and supporting measures



Source: OECD, 2018

The existing guidelines for due diligence in cobalt sourcing applying these steps, including the OECD Due Diligence Guidance for Responsible Mineral Supply Chains, and the Cobalt Refiner Due Diligence Standard developed by the RMI, provide a strong foundation for addressing the ESG risks related to cobalt recycling detailed in Chapter 2.2. An overview of several relevant due diligence initiatives, and the scope of ESG risks they address for secondary cobalt is presented in Table 4 below.

Table 4: Scope of existing due diligence initiatives to mitigating risks in secondary cobalt

Initiative	Section(s) of the recycling value chain directly addressed	Scope of initiative for mitigating risks related to sourcing recycled cobalt
OECD Handbook on Environmental Due Diligence in Mineral Supply Chains (OECD, 2023)	Cobalt recovery and Procurement of secondary cobalt	**Comprehensive ESG** – Expands upon the work within the OECD Due Diligence Guidance for Responsible Mineral Supply Chains from Conflict Affected and High-Risk Areas, and includes specific guidance related to the unique ESG risks associated with metal recycling (chapter 2.4).
RMI - Cobalt Refiner Supply Chain Due Diligence Standard (RMI, 2021)	Cobalt recovery and Procurement of secondary cobalt	**Governance** – In line with the OECD Due Diligence Guidance for Responsible Mineral Supply Chains from Conflict Affected and High-Risk Areas, the standard supports actors with due diligence when sourcing from cobalt refiners, including cobalt recyclers. The Standard primarily seeks to mitigate the potential for recycling to enable the laundering of illicit primary cobalt.
RMI – Risk Readiness Assessment (RRA) (RMI, 2023)	Cobalt recovery and Procurement of secondary cobalt	**Comprehensive ESG** – A tool developed to promote a common understanding of due diligence practices and a means to consistently assess ESG risks. It provides a general checklist addressing most salient ESG risks related to cobalt recycling, and includes specific recommendation on integration of circularity at facilities (topic 30). The tool itself is not assured by third party audits.

RMI – Responsible Minerals Assurance Process (RMAP): Environmental, Social & Governance (ESG) Standard for Mineral Supply Chains (RMI, 2023)	Cobalt recovery and Procurement of secondary cobalt	**Comprehensive ESG** – The criteria in this standard are in line with the RMI RRA Criteria, and are used in audits to provide assurance of responsible workplace and other ESG matters at mineral processors (including recycling facilities). Conformance with RMAP substantially addresses identified ESG risks in LIB pre-processing and cobalt recycling facilities, thereby supporting downstream companies in demonstrating they source responsible secondary cobalt.
Coppermark – Risk Readiness Assessment Criteria Guide V3.0 (Coppermark; RMI, 2023)	Cobalt recovery (when jointly recovered with copper and/or nickel)	**Comprehensive ESG for Nickel and Copper Processors** – Provides expanded guidance on the 33 RMI RRA Criteria, in order to support their implementation at facilities, including recycling sites. The criteria are auditable, and form the basis of the assurance provided by the Coppermark for downstream companies seeking to responsibly source copper and nickel. Criterion 30 includes comprehensive and ambitious guidance for companies to improve the recovery of pre- and post-consumer scrap, to set actionable circularity targets, and to conduct due diligence on secondary feedstocks.

Existing guidelines can thus contribute significantly to risk reduction in cobalt recycling. In particular, existing protocols can support cobalt recyclers, and downstream companies sourcing recycled cobalt in demonstrating the validity of **claims to recycled content**, preventing **laundering of illicit primary material**, and improving **environmental and workplace conditions at battery recycling facilities.**

However, this report has also shown that many of the risks associated with secondary cobalt relate to the **improper or total lack of collection of spent LIBs**. Notably most spent LIBs are currently found in portable electronic devices, and only 28% of global e-waste is documented as properly collected for recycling within formal systems (Baldé C. P., et al., 2024). The social and environmental risks associated with spent LIBs are most salient when batteries are improperly disposed of, or collected by the informal sector. Existing guidelines could thus further support companies in mitigating collection related risks by developing additional guidance for **stakeholder engagement with the informal waste sector.**

Stakeholder engagement with the informal waste sector

Further work in line with RMI and OECD due diligence guidelines could support engagement with the informal waste sector and **draw inspiration from** provisions within the guidelines for engagement with the **ASM** sector (criteria 21 of the RMI RRA). Notably, this could catalyse multistakeholder dialogues between the formal cobalt sector, informal actors involved in battery collection and pre-preprocessing, the public sector, and civil society around addressing risks in informal battery collection. Just as existing due diligence initiatives related to ASM have supported formalization and professionalization, similar efforts could be undertaken to enable responsible sourcing and risk mitigation when sourcing secondary material collected by the informal sector.

ISO Guidance Principles for the Sustainable Management of Secondary Metals (ISO, 2017), provide a foundational direction for discussions related to formalizing global battery collection. These principles are currently being updated as part of **ISO Standard 59014** on "sustainability and traceability of secondary materials recovery". The **Fair Circularity Principles**, while initially developed to respond to informal plastic recycling, also provide a notable example of collective industry action to address informality that identifies risks which are also directly related to informal collection of portable electronics.

6.2. BENCHMARK OF RECYCLING CERTIFICATIONS

Established guidelines and requirements for the handling of e-waste and EV batteries in appropriate facilities can help support cobalt recyclers in mitigating ESG risks, and demonstrating their compliance with due diligence guidance. To be effective, these standards should address proper management and recycling of cobalt-containing products across all stages of the recycling value chain.

Today, three main standards have emerged for responsible recycling globally: **R2, e-Stewards** and **WEEELabex**. Originating within a similar timeframe (2008-2012), these standards have gained significant traction. R2 has the broadest reach of the three standards, and has certified 1148 facilities across 41 countries. While both R2 and e-Stewards are U.S.-based standards, their applicability also extends globally. Conversely, WEEELabex specifically targets recyclers in Europe. Each of these standards places a primary emphasis on the proper management and handling of e-waste, including aspects such as collection, transportation, storage, treatment, and recovery of materials.

Table 5: Overview of three WEEE recycling standards

	WEEELabex	R2	e-Stewards
Governance	WEEELabex organisation	Sustainable Electronics Recycling International (SERI)	Basel Action Network (BAN)
Year developed	2009-2012	2008	2009
Most recent version (year)	10.0 (2012)	3.1 (2024)	4.1 (2022)
Geographical Scope	EU	Global	Global
Number of certified operators	340	1148	68[7]
Number of countries	18	41	3

Source: WEEELabex, R2, e-Stewards

Key battery recycling risks covered by the standards

Standards currently lack well-developed sections specifically addressing LIBs. Although EVs, a primary source of spent LIBs, are not currently within the scope of recycling standards, there's a possibility of future inclusion (Grieve, 2023). Nevertheless, these standards do encompass some risks associated with LIB management as part of a broader focus on responsible e-waste management. A detailed comparison outlining how each of the three standards addresses these risks is provided in the Annex.

All standards include measures concerning both upstream and downstream due diligence. Notably, e-Stewards **imposes strict due diligence** and monitoring requirements, extending responsibility for equipment reuse even when passed to third parties. Regarding illegal transboundary movement, all standards enforce control over e-waste movement, albeit with varying degrees of stringency. E-waste exports to countries not authorised to receive it, and movement of e-waste from formal to informal actors are prohibited.

In terms of final disposal, all standards **prohibit the incineration and burying in landfills** of hazardous waste such as LIBs. Instead, safe storage, detailing protection against weather conditions (WEEELabex) or maximum storage quantity and duration allowed (e-Stewards), and subsequent proper recycling are favoured. When facilities are equipped for material recovery processes, standards require safe and effective battery removal through mechanical processing or manual dismantling, then separation from the remaining e-waste.

[7] Sustainable Recycling Industry, 2015

Training requirements vary among standards. While R2 hardly includes any related directives, e-Stewards includes some general requirements, and WEEELabex requires operators to **ensure personnel competency**, including informing workers about the environmental, health and safety risks and training them to mitigate and fight these risks such as lithium battery fires.

Ethical and social risks are not thoroughly addressed in recycling standards, with WEEELabex and e-Stewards lacking explicit mention of human rights concerns. However, R2 **forbids child and forced labour** and mandates that facilities adopt non-discrimination policies. Additionally, North American standards address prison labour. While this issue is not perceived as relevant in Europe, and therefore not part of the European standards, R2 and e-Stewards both warn about the potential exposure to health and safety risks as well as issues with data security, and allow it under conditions of proper health and safety considerations, fair compensation and training provision. One ethical concern addressed across all standards though is unintended data access and data theft. With the necessity for certified facilities to perform thorough sanitization of data storage devices to ensure data security, which could be relevant to the deployment of battery passports.

Relevance and future improvements

Certifications play a crucial role within the recycling value chain, encompassing various stakeholders like collectors, refurbishers, recyclers, and brokers. These standards can form the backbone of a **global network of certified facilities**, fostering **trust and cooperation** among the diverse actors involved. By obtaining certification, facilities can streamline processes, enabling straightforward collaboration and partnership **without the burden of exhaustive due diligence research.**

However, it's essential to underscore that certification doesn't absolve facilities of their due diligence responsibilities; rather, it reinforces them. Rigorous scrutiny of transboundary device movement remains paramount, necessitating compliance with export laws, import restrictions of receiving companies as well as any transport company in the middle. Establishing a network of certified facilities simplifies this diligence process, ensuring all actors within the battery recycling value chain adhere to uniform standards and obligations.

Yet, the evolution of standards must remain fluid to **adapt to the dynamic landscape**, particularly with the rise in demand of LIBs from electronic devices and, notably, EVs. Presently, these standards lack specific provisions addressing EV batteries. They should therefore be revisited to **incorporate detailed sections concerning LIB transportation, storage, handling, and recycling.** Emphasis should be placed on identifying associated risks such as fire hazards and hazardous materials within electrolytes, along with mitigation strategies.

In addition, similarly to WEEELabex, and in alignment with pertinent regulations such as the Battery Regulation, recycling standards should **consider incorporating specific targets for recycling rates and material recovery rates.** Notably, a key difference between the European and the American standards lies in the former's inclusion of recycling and recovery targets, a feature absent in the latter. This integration can

can ensure maximal efficiency and economic value extraction from recycled materials. Furthermore, guidance should be provided on reintegrating recycled materials back into their respective markets, ensuring sustainable resource utilisation.

7. RECOMMENDATIONS FOR THE COBALT INDUSTRY

7.1. IMPROVING INTERNATIONAL TRADE IN SECONDARY COBALT

RECOMMENDATIONS TO DEVELOP WITH INTERNATIONAL POLICY MAKERS AND STAKEHOLDERS

7.1.1. SUPPORT THE TRANSPARENCY AND FLUIDITY OF GLOBAL SECONDARY COBALT FLOWS BY ADVOCATING FOR THE DEVELOPMENT OF NEW HS CODES RELATED TO SECONDARY FEEDSTOCKS

Rationale: a major barrier to global trade in secondary feedstocks is the lack of harmonised customs declarations between different countries

- Consider engaging directly, or indirectly via relevant organisations, with the World Customs Organisation to highlight the challenges around tracing global trade in spent LIBs and black mass
- Advocate for more granular HS codes for LIBs and spent LIBs based on cobalt cathode chemistry
- Advocate for the development of an HS code for black mass. This could draw upon examples of black mass definitions emerging in cobalt trading, such as the standards Fastmarkets use to price black mass (e.g. NCA, NCM, LCO)

7.1.2. PROVIDE CLARITY ABOUT THE STATUS OF SECONDARY COBALT FEEDSTOCKS AS HAZARDOUS MATERIALS UNDER THE BASEL CONVENTION

Rationale: uneven national interpretation of waste codes in the Basel convention by competent authorities leads to major delays in international transport of used and spent LIBs and black mass

- Engage with the Secretariate of the Basel Convention to determine and disseminate the precise specifications for spent LIBs with cobalt chemistries to qualify as non-hazardous under Annex IX code B1090 of the Basel convention
- This would could be supported by the drafting of a science-based paper assessing whether black mass containing cobalt should be qualified as hazardous material, and consider submitting this study to the Environmental Agencies of large member states within the Basel Convention

7.1.3. SUPPORT MEMBERS IN NAVIGATING THE DIFFICULTIES OF THE PRIOR INFORMED CONSENT (PIC) PROCEDURE UNDER THE BASEL CONVENTION

Rationale: The PIC procedure is unequally implemented between countries, leading to delays in shipments of material that can last years or fully prevent shipments of material

- Add the voice of industry to other multilateral initiatives (including Eurometaux, Solving the E-Waste Problem (StEP), and Prevent Waste Alliance) calling for the Basel Convention to take up a pre-consent process for waste recovery facilities and black mass exporters, inspired by the OECD control system for waste recovery
- Provide technical guidance to members and competent authorities in Basel country signatories on the recycling protocols for cobalt feedstocks that should qualify a facility for (pre) approval
- Explore opportunities to present best practices in safe and efficient handling and transport of cobalt content within spent LIB and black mass to the Basel Convention's Small Intersessional Working Group on the technical guidelines on the environmentally sound management of waste batteries

7.1.4. ENCOURAGE DIALOGUE WITHIN THE GBA ON THE USE OF BATTERY PASSPORTS TO IMPROVE TRACEABILITY AND FLUIDITY OF SECONDARY COBALT FLOWS

Rationale: Battery passports have major potential to improve responsible trade in secondary cobalt, but this will require international collaboration to introduce harmonised passport frameworks

- Within the GBA advocate for improved traceability of black mass globally, and encourage demo projects by GBA members showing how pre-processing companies can provide full traceability over the identity of the spent batteries they transform into black mass, with an accompanying cobalt mass balance
- Explore the potential for battery passports to become interoperable with the digital PIC procedure under development by the Basel Convention Secretariat
- Advocate for battery passport data on battery health in life (such as that mandated by the EU Battery Regulation) along with technical guidance on its interpretation, to be made available by OEMs to national customs administrations, to support enforcement of national and international waste shipment laws and combat illegal shipments of falsely labelled spent batteries and EVs

RECOMMENDATIONS TO DEVELOP WITH MEMBERS

7.1.5. CAPITALISE ON EXISTING INITIATIVES DEVELOPING BATTERY PASSPORTS THAT CAN ENABLE MEMBERS TO IMPROVE SUSTAINABILITY ACROSS THE COBALT RECYCLING VALUE CHAIN

Rationale: harmonised and transparent indicators developed by the GBA and Battery Pass can help stakeholders assess and mitigate risks across the LIB recycling value chain

- Communicate about how providing chain of custody of batteries during collection, transport, and sorting can help members avoid sourcing secondary feedstock from illicit actors that do not respect human rights and child labour

- Support the GBA's efforts to produce harmonised data on GhG footprint (and other environmental impacts) for recycled cobalt that can support responsible sourcing, sustainable consumer choices, and future policy development (e.g. Carbon Border Adjustment Mechanisms)
- Endorse the Battery Pass metrics on spent battery safety and disassembly, which can improve recycling safety and logistics with specific alerts related to toxic and hazardous materials within the battery

7.1.6. ENCOURAGE MEMBERS AND INTER-GOVERNMENTAL ORGANISATIONS TO ENGAGE IN DIALOGUE ON ESTABLISHING REGIONAL COBALT RECYCLING FACILITIES THAT CAPTURE LOST COBALT FEEDSTOCKS

Rationale: Given that transportation is estimated to contribute between 40 and 60% of EOL costs, members could reduce cost of sourcing secondary feedstocks by avoiding the need to transport hazardous materials long distances, with lengthy PIC procedures. This could also be publicly supported due to policy maker interest to maintain critical mineral sovereignty. However, these initiatives should be undertaken regionally to provide for effective economies of scale

- Support exchanges between market intelligence firms and inter-governmental organisations (e.g. MSP, World Bank, AfDB, ADB, etc.) to encourage the development of market data on available and forecasted secondary cobalt feedstocks at a regional level in support of investments in regions that currently lack battery recycling capacity.
- Leverage this data to support the development of public-private, regional, partnerships based on both the business opportunity of developing new cobalt supply and the geopolitical desire for critical material sovereignty
- Encourage public and private collaboration to develop local pre-processing facilities that make them non-hazardous by disassembly/shredding and enable batteries to be more feasibly collected prior to transport, making shipment more cost-effective and reducing transport of spent batteries

7.2. IMPROVING COBALT RECYCLING IN THE EU

RECOMMENDATIONS TO DEVELOP WITH EU POLICY MAKERS AND STAKEHOLDERS

7.2.1. CAPITALISE ON THE MOMENTUM OF THE CRM ACT TO CREATE VALUE FOR MEMBERS

Rationale: The CRM intends to accelerate the growth of European recycling capacity, but its implementation is still to be determined

- Monitor progress on the selection of strategic cobalt recycling projects in the EU and globally, and the implementation of the new expedited approval process planned within the CRMA
- Advocate for the EU to streamline financial support to support the entire cobalt recycling value chain, as accessing funds from sources such as the Recovery and Resilience Facility, EIB, and IPCEI framework is currently complex and burdensome

7.2.2. ENCOURAGE HARMONISED INTERPRETATION OF WASTE CLASSIFICATIONS ACROSS THE EU FOR SPENT LIBS AND BLACK MASS IN ORDER TO FACILITATE FLOWS OF SECONDARY COBALT

Rationale: The EU currently lacks granular waste codes and different national authorities interpret shipments of spent LIBs and black mass differently, making it challenging to easily transport secondary feedstocks across the bloc

- Monitor the work of the JRC in defining new waste classifications for spent LIBs and black mass
- Work to ensure that members are supported in meeting new regulatory requirements once new waste codes are announced
- Advocate for the EU to allow imports of spent LIBs and black mass into pre-approved facilities from any country

7.2.3. ADVOCATE FOR IMPROVED MONITORING OF EXPORTS OF USED EVS AND ELECTRONICS, AND CONSIDER DEVELOPING UPON THE CONCEPT OF ULTIMATE PRODUCER RESPONSIBILITY

Rationale: The export of used electronics and EVs from Europe risks undermining the objectives of the EU battery regulation to monitor and recycle all LIBs batteries within the block

- Encourage EU regulators to establish minimum battery health and expected lifespans (enabled by the battery passport) on any batteries exported from the bloc
- Ask the EU commission for clarity on the interpretation of the EU battery regulation with respect to when a battery passport “ceases to exist” and encourage international collaboration around battery

passports exported out of the EU in used appliances, as well as maintaining passports after batteries die to certify black mass composition

- Consider advocating for an eco-levy paid by OEMs and exporters, covering the cost of responsibly recovering exported cobalt and other critical raw materials within used LIBs in developing countries that currently lack qualified recycling facilities
    - This could potentially work to both preserve access to affordable electric products in developing countries, while also covering the cost of collection, transport and recycling of these products at their end of life. Access to funds generated by the UPR levy could be made conditional upon the return of recovered cobalt to the EU. The example of Fairphone's engagement in West Africa to support battery recycling could inspire such initiatives.

7.2.4. ADVOCATE FOR FORMALISING BATTERY RECYCLING AND TECHNOLOGY TRANSFER AS PART OF RAW MATERIAL STRATEGIC PARTNERSHIPS

Rationale: The EU can play a supporting role in recovering cobalt that is currently landfilled globally, while building out win-win partnerships that help the EU to diversify cobalt supply by unlocking new black mass sources while also supporting local development in partner countries

- Encourage the replication of similar partnerships to the GIZ e-waste program in Ghana
- Advocate for financial support via the Global Gateway for infrastructure along the cobalt recycling value chain, starting with improved collection and pre-processing
- Encourage members in the EU to pursue offtake agreements for fair black mass and receive support as pre-qualified facilities

7.2.5. SUPPORT DIALOGUE WITH EU REGULATORS ON THE VIABILITY OF RECYCLED CONTENT TARGETS IN THE EU BATTERY REGULATION

Rationale: The EU Battery Regulation sets requirements for recycled cobalt content within new batteries (currently 16% in 2031) that are modifiable but risk limiting its electrification ambitions if set too high

- Consistently provide EU regulators with up-to-date data in the runup to 2031 on the amount of secondary cobalt available globally, and the expected share of EU cobalt demand for battery cathodes that this supply can cover
- Engage in regular dialogue with members along the LIB value chain to determine if the recycled content targets are causing unintended distortions in the global cobalt market

7.3. IMPROVING COBALT RECYCLING IN THE U.S.

RECOMMENDATIONS TO DEVELOP WITH U.S. POLICY MAKERS AND STAKEHOLDERS

7.3.1. ENCOURAGE THE PASSAGE STATE OR FEDERAL LAWS MANDATING EXTENDED PRODUCER RESPONSIBILITY FOR LIBS

Rationale: Losses of cobalt primarily occur due to a lack of effective battery collection and sorting, and US policymakers have a strategic interest in recovering secondary cobalt to support material sovereignty

- Advocate for harmonised state level EPR laws for EOL EVs and electronics, using California's Responsible Battery Recycling Act as a model
- Encourage government support to incentivise consumers to return EOL batteries, and for OEMs to safely deploy takeback schemes
- Advocate for making LIB landfilling illegal across all 50 states

7.3.2. ADVOCATE FOR NEW REGULATIONS TO DEVELOP THE U.S. MARKET FOR SECONDARY COBALT

Rationale: The U.S. lacks significant federal regulations on battery recycling, but is looking to maintain cobalt within its economy as a means to ensure security of supply within the scope of its strategic competition with China

- Promote targets for cobalt recycling via legislation mandating:
  - Recycled content within batteries
  - Material recovery rates at recycling facilities
  - This will help create a market for recycled cobalt, driving cost competitiveness of sustainable material recovery
- Improve the viability of receiving the clean vehicle credit
  - Consider including recycled content targets as an additional condition to access clean vehicle credit
  - Lower the 80% sourcing requirement for critical minerals by 2027, which is not viable given the current market for primary and secondary cobalt
- Encourage the U.S. government to improve oversite of the export of spent LIBs to countries that lack proper treatment facilities in line with OECD and Basel Convention protocols (for instance the Secure E-Waste Export and Recycling Act introduced in 2019)
- Capitalise on the momentum of the recently announced TRACE bill proposed in May 2024 to support the development of digital battery passports in the US to introduce this recommendation

7.3.3. MONITOR DEPARTMENT OF ENERGY FUNDING OPPORTUNITIES TO REGULARLY INFORM MEMBERS AND MEDIATE WITH THE PUBLIC SECTOR TO ENABLE MEMBERS TO CAPITALISE ON THE FUNDING OF THE BIL AND THE IRA

Rationale: Loans and subsidies can support members in developing new commercial and R&D opportunities that align with U.S. efforts to ensure security of cobalt supply

- Regularly check and disseminate information to members on funding opportunities within recently passed U.S. legislation, while also relaying concerns they may have about the speed of delivery of these funds to public stakeholders
  - Including the Clean Energy Infrastructure exchange (DOE)
  - Electric drive vehicle battery recycling and second-life apps (DOE)
  - California Energy Commission EPIC Program
  - Title 17 DOE loan programs office
- Support the use of funding from EPA and DOE within BIL to fund technical solutions for municipal and regulatory compliance related to packaging and handling safety mechanisms, such as preprocessing EOL batteries locally to make them easier and safer to transport
  - Encourage the EPA to provide education on safe collection and handling of lithium-ion batteries, for safety and quality of streams

7.4. IMPROVING COBALT RECYCLING IN WEST AFRICA

RECOMMENDATIONS TO DEVELOP WITH WEST AFRICAN POLICY MAKERS AND STAKEHOLDERS

7.4.1. RAISE AWARENESS ABOUT FAIR SOLUTIONS FOR THE INFORMAL COLLECTION OF LIBS

Rationale: The informal sector handles the majority of global e-waste, which contains an estimated 34,000 tonnes of cobalt and is challenging to recover

- Acknowledge the potential benefits of formalising e-waste collection, drawing lessons from the CI's position on ASM
- Highlight the ingenuity of the informal sector in supporting the circular economy of cobalt, by enabling high collection rates and battery reuse (e.g. second-life application of batteries for solar storage)
- Engage with efforts by STEP, WEEE Forum, African Circular Economy Network, RRRM and other multistakeholder platforms in their efforts to raise awareness around fair solutions for spent LIBs in e-waste

7.4.2. COOPERATE WITH LOCAL ACTORS WHO PROVIDE TRAINING FOR INFORMAL WORKERS

Rationale: Training of trainers can be an impactful way to improve safe and responsible collection of spent LIBs in West Africa

- Support the EPA of Ghana or partner organisations such as GIZ and Mountain Research Institute with science-based evidence on handling cobalt compounds in spent LIB and black mass
- Encourage these partners to then integrate CI and GBA feedback into their training material for identifying and sorting LIBs from other portable or car batteries. Training initiatives should focus on equipping informal collectors with the ability to identify lithium-ion batteries (LIBs) and LIB products, enabling efficient collection and sorting processes

7.4.3. SUPPORT A MULTI-STAKEHOLDER PROGRAMME TO DEVELOP A LIB RECYCLING VALUE CHAIN IN WEST AFRICA

Rationale: The governments of Ghana and Nigeria are both looking to create local value within LIB value chains, yet both countries currently lack the capacity to safely handle spent LIBs. Addressing this risk can create business opportunities by bolstering global secondary cobalt supply, while pre-processing material can reduce the cost of transporting it to global cobalt recycling facilities overseas

- Encourage public-private collaboration to fund LIB takeback schemes in Ghana to incentivise collection by informal workers to earn a decent livelihood

- In the short term, foster dialogue around public-private partnerships for battery pre- processing at the municipal level
  - Priority work should support lead acid battery recyclers in sorting LIBs, and disincentivise the unregulated draining of electrolytes
- In the medium to long term, encourage a public-private partnership to develop a regional recycling hub in West Africa
- Consider pursuing funding via the EU Global Gateway, the Mineral Security Partnership or under the framework of the AfDB's African Green Minerals Strategy
  - This would involve working with members and data providers to establish a business case for recycling in the region based on available feedstocks, and identifying the comparative advantage for the location of the facility
  - Dialogue on international movement of spent LIB and black mass could be facilitated at the ECOWAS level

7.4.4. ADVOCATE FOR THE GBA TO SUPPORT CUSTOMS AUTHORITIES IN WEST AFRICA WITH CRITERIA TO ASSESS BATTERY HEALTH OF EVS

Rationale: Improving monitoring of used LIBs into e-waste hubs can expedite trade in secondary cobalt and reduce losses of valuable cobalt in geographies incapable of recovering it

- Produce factsheets for customs authorities on the interpretation battery health indicators included within battery passports, and their implications for battery lifespan, and health and safety
- Encourage the adoption of interoperable digital traceability tools that allow for rapid inspection of cargo containing LIBs and black mass

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ABBREVIATIONS AND ACRONYMS

ACRONYM	DESCRIPTION
ATVM	Advanced Technology Vehicles Manufacturing Direct Loan Program
BIL	Bipartisan Infrastructure Law
DOL	Department of Labour
DOE	Department of Energy
DRC	Democratic Republic of the Congo
EOL	End-of-life
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
ESG	Environmental Social and Governance
EV	Electric Vehicle
FTA	Free Trade Agreement
GASDA	Greater Accra Scrap Dealers Association
GhG	Greenhous Gas
HS Code	Harmonised System Code
ICEV	Internal combustion engine vehicle
IRA	Inflation Reduction Act
IRS	Internal Revenue Service
LIB	Li-ion battery
LMT	Lightweight means of transport (e.g. electric scooters and bikes)
LPO	Loan Programs Office
MESTI	Ministry of Environment, Science, Technology and Innovation
NPRM	Notice of Proposed Rulemaking
OECD	Organisation for Economic Cooperation and Development
OEM	Original Equipment Manufacturer

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ANNEX

LIST OF INTERVIEWEES CONTRIBUTING TO THE REPORT

Name	Organisation	Geography	Expertise
Come Salvaire	Science Po	Nigeria	Informal sector in Nigeria
Kunal Sinha	Glencore	U.S., International	Recycling, International Policy
Anonymous	Anonymous	International	International Policy
Gilles Moreau	Verkor	Europe	ESG Risks, European Policy
Jean-Denis Curt, Sophie Schidtlin, Nadia Chibani	Renault	Europe	ESG Risks, European Policy
Jessica Young, Patrick Wise, Ellen Meyer, Andrew Taylor, Kimberly Cochran, Katty Lett	EPA	U.S.	ESG Risks, American Policy
Thierry VanKerckhoven	Umicore	Europe, International	International Policy
Anonymous	Agro360	Europe	ESG Risks, European Policy
Mattia Pelligrini	DG Environment	Europe	ESG Risks, European Policy
Lisa Minere	Fairphone	Ghana	Ghanian Policy, International Policy
Douglas Johnson-Poensgen, Rhys Mason	Circulor	International	Traceability of battery materials
Roger Greive	SERI	U.S.	International Policy, American Policy
Dr. Atiemo Sampson	Mountain Research Institute	Ghana	Ghanian Policy, International Policy

COMPARATIVE ANALYSIS OF RECYCLING STANDARDS IN ADDRESSING ESG RISKS IN LIB RECYCLING

Standards / Risks	WEEELabex	R2	e-Stewards
Lack of due diligence (origin and downstream)	Operator shall document the origin of the WEEE treated and the downstream treatment chain of WEEE. Responsibility of downstream monitoring remains in cases where handing over of WEEE to dealers or brokers, or when shipped across borders.	R2 operator has to perform "due diligence" by ensuring that its downstream vendors comply with some (but not all) sections of the standard. For equipment for reuse, the responsibility for compliance is passed from the original operator to third parties receiving the equipment.	Operator shall ensure that its materials are managed only by approved downstream operators throughout the Recycling Chain with audits required for these operators. e-Stewards is much stricter overall, containing detailed requirements to enforce due diligence and monitoring of all downstream parties until the end of the recycling chain is reached. For equipment for reuse, the responsibility for compliance fully stays with the original operator, even when the equipment for reuse is handed to third parties.
Improper disposal (landfilling or incineration)	Precautions should be taken before disposal. Landfill not prohibited but should be avoided. No mention of incineration.	Incineration or land disposal is prohibited for focus materials including batteries.	Solid waste disposal operations, incineration and melting in open fires are all prohibited. Smelting is prohibited unless effective controls to capture any hazardous emissions generated are taken.

Improper storage and handling	WEEELabex contains details with respect to the storage infrastructure and the protection of the storage areas against weather conditions. It also defines a maximum quantity of material that is allowed to be stored. In addition, WEEE shall be handled and stored with due care in order to avoid release of hazardous substances into air, water, or soil, as a result of damage and/or leakage.	North American standards only provide quite general/vague requirements.	North American standards only provide quite general/vague requirements. However, e- stewards provides a maximum duration of storage of 2 years for hazardous substances including LIBs.
Unintended access to data or data theft	All standards require that data is destroyed from data storage devices.	All standards require that data is destroyed from data storage devices.	All standards require that data is destroyed from data storage devices.
Prison Labour	Not mentioned as this issue is not perceived as relevant in Europe, and therefore not part of the European standards.	The use of prisoners is only acceptable if it is voluntary, compensated beyond room and board, and skills are taught for gainful employment after release.	Prison operations are not permitted by this Standard unless the e-Stewards Program Administrator agrees in writing that occupational health and safety protections are maintained.
Untrained workers	Standards require informing workers about the environmental, health and safety risks and train them to mitigate and fight these risks. All involved employees shall be informed about the risk and trained to fight a lithium battery fire	No explicit mention.	Operator shall ensure the necessary competency of personnel, including training on its Stewardship Management System (SMS) for all workers as relevant to their roles.

Material recovery	Special precautions and safety measures shall be in place for operations concerning used LIBs to minimise the risk of environmental, health or safety incidents during battery removal. Exposure to heat, humidity, sunlight, water, or physical damage to LIBs shall be avoided. Recycling and recovery targets are indicated.	If an R2 facility is not equipped to properly recycle batteries, it shall send removed batteries to treatment facilities that meet all applicable regulatory requirements, and that use appropriate technology to safely and effectively manage these batteries.	Batteries should be recycled in battery recycling facilities or steel mills that recover the metal value and have appropriate air pollution controls.
Child labour and discrimination	No explicit mention.	R2 shall not use child labour and shall document a non-discrimination policy for fair and equal treatment of all workers, regardless of age, gender, race, religion or sexual orientation.	No explicit mention.
Illegal transboundary movement	Movement of e-waste is controlled with all shipping documentation, labelling, and import/export declarations use accurate codes, descriptions, and required declarations consistent with regulatory requirements.	Prior to any international shipment, the R2 facility shall verify import/export compliance of each shipment in accordance with its legal compliance plan that affirms the international shipment is legal.	e-Stewards prohibits exports that do not comply with the BAN guidelines. Compliance obligations shall include a duty to not violate or abet the violation of any national laws, multilateral waste trade agreements, and/or treaty obligations relevant to the Transboundary Movement of waste, both within the organisation and throughout its downstream recycling chain. When exporting any EE (including components) to downstream actors for reuse or repair, the organisation shall ensure that each shipment is accompanied by a completed and signed label/declaration that meets requirements regarding description, testing and labelling.

OVERVIEW OF BATTERY RECYCLING CAPACITY IN THE U.S., ADAPTED FROM (ICCT, 2023)

Company name	Operational since	Location	Capacity (ton/yr)	EV equiv./yr*
Li-Cycle	2020	Rochester, New York	18,000	36,000
Li-Cycle	2022	Phoenix, Arizona	18,000	36,000
Li-Cycle	2022	Tuscaloosa, Alabama	10,000	20,000
International Metals Reclamation Company	Operational	Elwood City, Pennsylvania	6,000	12,000
Omega Harvested Metallurgical Omega Harvested Metallurgical	Operational	Winchester, Ohio	?	?
Cirba Solutions	Operational	Wixom, Michigan	23,000	46,000
Li Industries	Operational	Blacksburg, Virginia	?	?
Ascend Elements	Operational	Worcester, Massachusetts	150	300
Ascend Elements	Q4 2022	Covington, Georgia	30,000	70,000
Ascend Elements	2024	Hopkinsville, Kentucky	107,143	250,000
Ace Green Recycling	2025	Houston area, Texas	20,000	?
Ecobat	Late 2023	Casa Grande, Arizona	10,000	?
Redwood Materials*	2030	Near Reno, Nevada	?	?
Redwood Materials*	2030	Charleston, South Carolina	?	?
Li-Cycle	Early 2023	Warren, Ohio	15,000	30,000
SungEel HiTech	2024	Atlanta, Georgia	?	?
Cirba Solutions*	2024/2025	Lancaster, Ohio	100,000	200,000
Cirba Solutions*	Late 2024	Columbia, South Carolina	250,000	500,000
Cirba Solutions*	Mid-2023	Eloy, Arizona	25,000	50,000
American Battery Technology Company	Announced (permit granted)	Fernley, Nevada	20,000	40,0000
Total 2023 – operational recycling plants			105,150	220,300
Total 2023 – operational and announced recycling plants			652,293	1,290,300

* Explanations on how we addressed some of the missing data
Tons of material needed to produce one EV battery: 0.5
For the Ascend Elements plant based in Kentucky, recycling capacity was estimated based on the number of electric vehicles (the publicly reported EV equivalent per year) that could be manufactured with the battery-grade material recovered by the plant. We are assuming that about half a metric ton (roughly 500 kilograms) is needed to produce an EV battery.
For the Cirba Solutions plants, recycling capacity is not publicly reported so it was estimated based on the annual number of electric vehicles (the publicly reported EV equivalent per year) that could be manufactured with the battery-grade material recovered by the recycling plant. We are assuming that about half a metric ton (roughly 500 kilograms) is needed to produce an EV battery.
For Redwood Materials, the recycling capacity of different plants is not publicly reported. The company reports an EV equivalent per year (5 million electric vehicles by 2030), but the number includes the use of both virgin and recycled materials. For this reason, we cannot use a methodology similar to the one described above for Ascend Elements and Cirba Solutions. Read more on Redwood Materials here: https://www.redwoodmaterials.com/news/manufacturing-anode-copper-foil-and-cathode-active-materials/

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Contact us if you have any questions

Phone: +44 1483 578877

Email: ci@cobaltinstitute.org

Web: www.cobaltinstitute.org

Cobalt Institute

3rd Floor, 45 Albemarle Street, Mayfair, London W1S4JL UK