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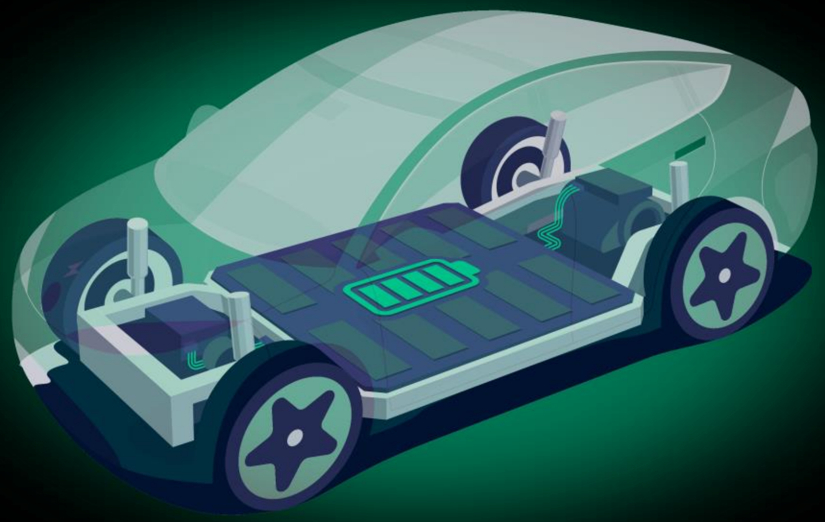

# Navigating the unknowns:
# drivers and projections for EV battery recycling

November 2024

# Preface

## About Deloitte

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## About the Global Battery Alliance

The Global Battery Alliance (GBA) is a public-private platform founded in 2017 to promote a sustainable and responsible global battery value chain by 2030. It brings together over 170 organisations, including industry leaders, NGOs, governments, and academia, to address environmental, social, and governance (ESG) risks associated with battery production. The GBA aims to drive circularity, reduce carbon emissions, protect human rights, and ensure sustainable energy access. Key initiatives include the Battery Passport and Circularity and Critical Minerals Advisory Group.

## Acknowledgement

This work is independent, reflects the views of the authors, and has not been commissioned by any business, government, or other institution. The authors from the Global Battery Alliance (GBA) include Inga Petersen and Pramoda Gode, while the Deloitte team comprises Aled Walker, Frederik Debrabander, Maarten Dubois, Nina Neubauer, Bianca Melodia, and Sjoerd De Jager. The authors wish to thank the Global Battery Alliance and its members whose input helped inform this report (see the full list in the annex). Our gratitude especially goes to: Ilai Bendavid and Bin Wu (Botree), Erle Lamothe (Natural Resources Canada), Alina Racu (Transport & Environment), Lewis Fulton and Alissa Kendall (UCDavis), and Paul Anderson (ReLib) who provided deep insights into the market.

### Disclaimer

This document is (co-)published by the Global Battery Alliance. The findings, interpretations and conclusions expressed herein are a result of a collaborative process facilitated and endorsed by the Global Battery Alliance but whose results do not necessarily represent the views of the entirety of its members, partners or other stakeholders.

# Executive summary

As the global transition toward electric vehicles (EVs) accelerates, concerns are growing over the substantial demand for **minerals required for battery production.** As the adoption of EVs surges globally, the demand for lithium has skyrocketed. In 2022, approximately 60% of the global lithium demand was attributed to EV batteries, a significant increase from the 15% recorded in 2017*.

**Recycling** or other circular economy practices, for example repurposing, are a way to address these concerns. Regulations such as the European Battery Regulation therefore mandate the use of recycled minerals in the production of new batteries. However, current recycling volumes are low and uncertainties around future markets, battery chemistries and recycling technologies are high, which constrains urgently needed investments. Well-informed policy makers and business leaders would be able to better navigate this evolving landscape and proactively optimise resource utilisation, minimise environmental impacts, and seize emerging business opportunities.

This **paper** informs policy makers and market actors across the battery value chain by identifying the main variables that influence the demand for EV battery recycling. The research methodology combines semi-structured interviews, literature review, expert knowledge, and proprietary data models. The analysis focused on lithium-ion (Li-ion) batteries due to their dominance in the EV battery sector. The European Union (EU), where the regulatory environment is most mature, was set as the scope to evaluate if recycled content targets for lithium, nickel and cobalt in batteries can be met by processing the batteries that reach end-of-life locally in the EU.

Our **modelling** shows that supply may fall short of demand around the year 2036 when legal targets are set to increase, unless demand is met through imported recycled content, or recycled content from other applications. Our sensitivity analysis shows that the most impactful drivers for the availability of recycled content relate to the lifespan of batteries, the weight and chemistry of future batteries, and trade in batteries as well as in second-hand cars. The outcomes of the model stress that accompanying policies and further investments will be required to achieve the circularity ambitions.

Source: (*) IEA (2024)

# Table of contents

## Study

## Annexes

# 1

# Introduction

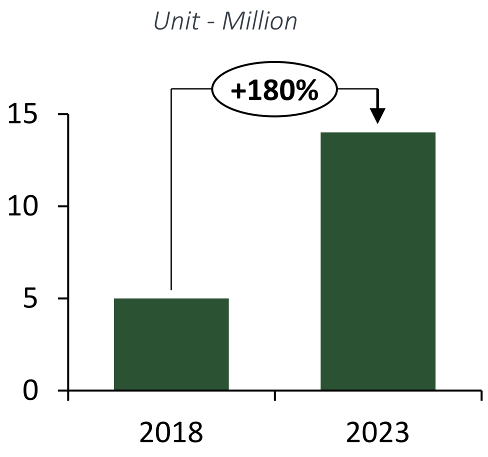
# Introduction

## In recent years, the use of batteries has surged in the market for passenger cars*

### Global transition

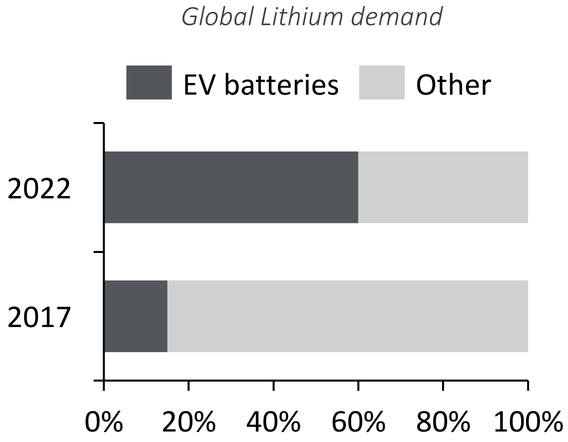
- With the **global shift toward a low-carbon economy**, batteries have become an essential component to support the green transition in various sectors, with batteries for electric vehicles (EVs) as a flagship application.
- EVs are generally fitted with **lithium-ion batteries** due to their exceptional properties, including high energy density, thermal stability, and low self-discharge rate. As the adoption of EVs surges globally, the demand for lithium has skyrocketed.

### EV sales



Source: IEA (2024)

### Minerals demand



### Boosting circularity: Opportunities and challenges

- The surge in demand for lithium and other minerals used in EV batteries, such as nickel, cobalt, copper and manganese, raises concerns about **scarcity, as well as the environmental and social impact** at the extraction and end-of-life stages.
- **Recycling and repurposing** present opportunities to address these concerns. Indeed, materials contained in batteries have the potential to be recycled at a high efficiency rate, as is already the case with lead acid batteries. Regulations such as the European Battery Regulation aim to accelerate this activity by mandating the use of recycled minerals in the production of new batteries.
- However, **availability of recycled battery minerals is currently low** and uncertainties around future battery market conditions, battery chemistries, as well as innovation and efficiencies in the recycling industry are high, which constrains urgently needed investments.

Note: (*) EVs can be PHEVs (Plug-in Hybrid Electric Vehicles) using both electricity and petrol, or BEVs (Battery Electric Vehicles) using only electricity. In this report, ‘EV’ should be understood as encompassing both PHEVs and BEVs.

# Introduction

## Current uncertainties are impacting the development of the EV End-of-Life market

### Key uncertainties

Certain market features will define the circular battery value chain of the future.
These include:

- The **number of EVs and EV batteries** that will come on the market
- The **proportion of batteries** that will be **reused or repurposed** before being recycled
- The **weight** and **chemistry of batteries** entering the recycling market
- The **geographic distribution** of retired EV batteries and the associated **capacity of recycling facilities** available in that region
- The **trade flows** of minerals, new EVs, second-hand EVs and recycling streams
- The **demand for recycled minerals** for new batteries and other applications

These factors will vary depending on **technological**, **policy**, **market**, **and geopolitical** factors.

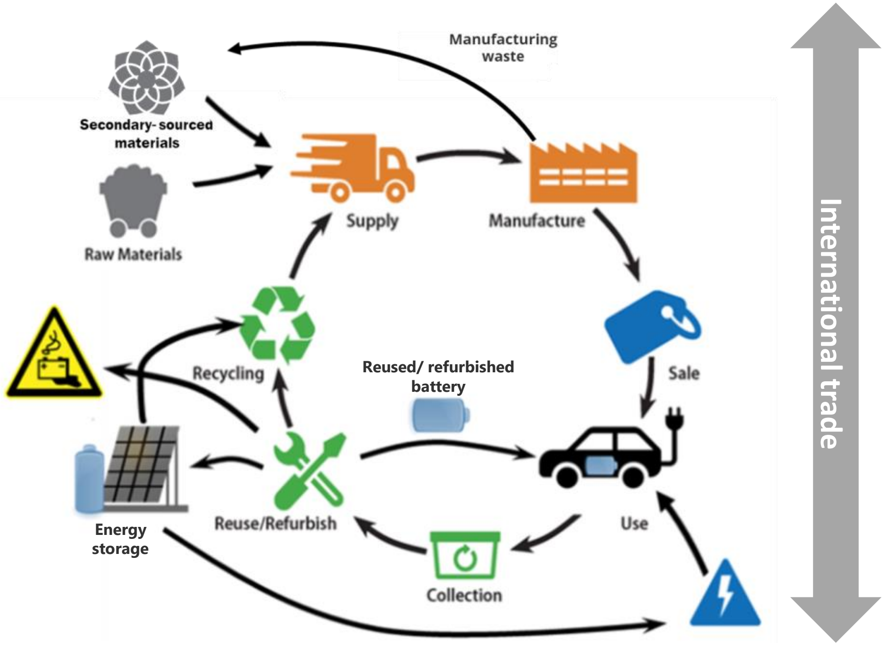


Figure: Circular battery value chain*

In this paper, we project future trends and scenarios within the EU market (only modelling cathode active materials for EV batteries). The EU has been chosen as a case study as it has legislated recycled content targets for key minerals, which can be used as an indication of future demand.

Note: (*) Adapted from End of Life EV Battery Policy Simulator: A dynamic systems, mixed-methods approach

# 2

# Projections for EV battery recycling in the EU

# Projections for EV battery recycling in the EU

The model for future EV battery recycling in the EU is based on several key drivers

**More details on assumptions are provided in the annex**

## 1. Annual availability of end-of-life EV battery minerals

In our model, we first multiply the following factors on an annual basis to calculate the number of end-of-life batteries from EVs that are available for treatment in the EU.

**11 mil**

**EV put on market forecast**

A linear increase of annual EV sales is expected, reaching 11 million by 2035. The number of annual sales is expected to stabilize thereafter.

**10-14**

**Average lifespan (in years)**

The average lifetime of an EV battery is estimated to increase from 10 to 14 years.

**55 - 74**

**Battery capacity & weight**

The average size of an EV battery is estimated to linearly increase from 55 kWh (2020) to 74 kWh (2040). It is also assumed that the cathode accounts for approximately 30% of the total EV battery weight.

**30%**

**Export of used EVs**

30% of EVs sold in the EU are estimated to be exported as used vehicles.

# Projections for EV battery recycling in the EU

The model for future EV battery recycling in the EU is based on several key drivers

**More details on assumptions are provided in the annex**

## 2. Manufacturing waste

Secondly, we calculate the availability of end-of-life batteries from EU battery manufacturing waste.

**50%**

**Battery manufacturing in the EU**

50% of battery cathodes for the EU market is to manufactured.

**10%**

**Manufacturing waste (scrap)**

10% of EV batteries produced are estimated to be discarded before reaching the market.

# Projections for EV battery recycling in the EU

The model for future EV battery recycling in the EU is based on several key drivers

**More details on assumptions are provided in the annex**

## 3. EoL treatment and applications

Thirdly, we estimate the availability of batteries for recycling by applying the following assumptions regarding end-of-life treatment.

**95%**

**Collection rate**

95% of end-of-life EV batteries are estimated to be collected for recycling or repurposing.

**30%**

**Battery repurposing**

30% of batteries are estimated to be repurposed after their first life in vehicles.

**10%**

**EoL battery replacement**

10% of EVs are estimated to need battery replacements during their lifespan.

# Projections for EV battery recycling in the EU

The model for future EV battery recycling in the EU is based on several key drivers

**More details on assumptions are provided in the annex**

## 4. Mineral mix

Finally, we estimate the availability of key minerals, by applying assumptions regarding the current and future mineral mix of EV battery cathodes.

We use projections for the **future mineral mix of EV battery cathodes** (based on IEA projections*) that predict a shift to nickel-rich chemistries, the adoption of solid-state batteries by 2030, and increased use of lithium-rich materials).

|  | 2020** | 2040 |
|---|---|---|
| **Mineral** | **%** | **%** |
| **Nickel** | 31,6% | 42,1% |
| **Cobalt** | 10,8% | 7,2% |
| **Lithium** | 7,0% | 9,3% |

***Note:*** *we model a LFP-dominant scenario on page 20.*

We assume a **fixed recovery rate** for each mineral until 2040, noting the challenges to reach 100% recovery. The recovery rates used are in line with the recovery targets from the new EU Battery Regulation***.

| Mineral | Recovery rate |
|---|---|
| **Nickel** | 95% |
| **Cobalt** | 95% |
| **Lithium** | 80% |

Sources: (*) IEA STEPS Policy scenario, (**) Data provided by Botree, (***) The New EU Battery Regulation

# Projections for EV battery recycling in the EU

By projecting changes to the chemistry of battery cathodes, we assess whether OEMs will be able to rely on secondary materials from recycled batteries placed on the EU market to meet future EU recycled content targets

*Projected availability of minerals in end-of-life batteries (nickel, cobalt, lithium)*

## Required recycled content

Bringing these factors together, we can project the extent to which EOL EV batteries in the EU will be able to meet the recycled content targets set for these three minerals in **the new EU Battery Regulation*****.

| Mineral | Target 2031 | Target 2036 |
|---|---|---|
| **Nickel** | 6% | 15% |
| **Cobalt** | 16% | 26% |
| **Lithium** | 6% | 12% |

These assumptions allow us to project and compare the future supply and demand for recycled content.

!

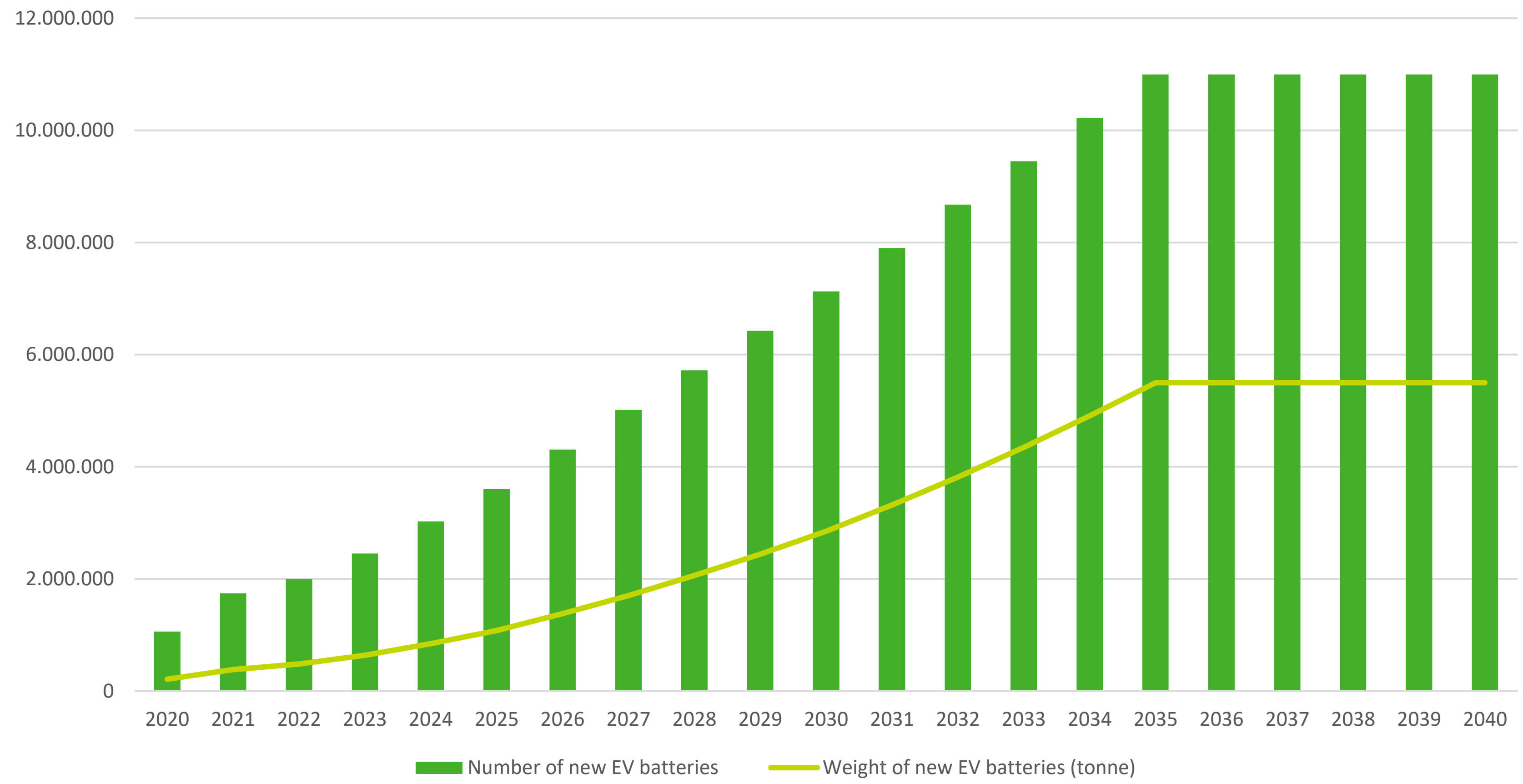
The **analysis focuses solely on minerals from Li-ion EV batteries that reach their end-of-life in the EU**, excluding imported/exported batteries and recycled content from other sources such as waste from electrical and electronic equipment (WEEE) and ceramics. It also assumes that there is not a significant impact from the "downcycling" of minerals no longer suitable for battery use. These estimates are highly dependent on the model's assumptions and carry significant uncertainty.

Sources: (*) IEA STEPS Policy scenario, (**) Data provided by Botree, (***) The New EU Battery Regulation

# Projections for EV battery recycling in the EU

In line with the EU requirements to shift towards full electric models by 2035, the model takes into account a steady increase of the number of EV batteries put on the market and the average battery weight

**Projected EV batteries placed on the EU market (2020-2040)**



### Modelling approach

To model the **future availability of end-of-life Li-ion EV batteries**, we first project **the battery capacity placed on the market**. As explained on page 9, this is calculated by multiplying the following forecasted parameters:

**Annual EV passenger car sales in the EU** **X** **Average EV battery weight**

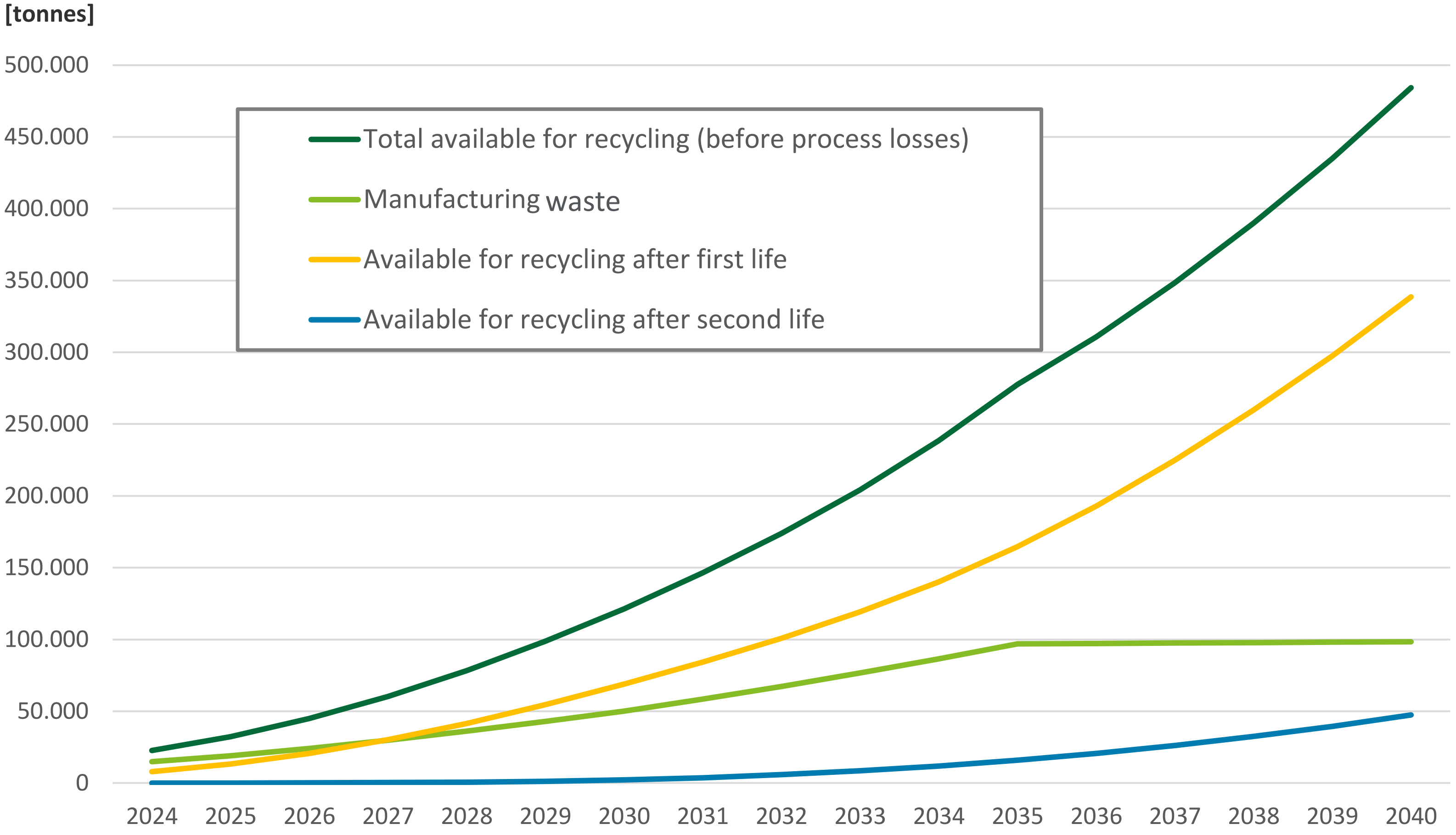
The annual number of EVs placed on the market is expected to increase each year until 2035, after which point **all new cars and vans placed on the EU market are set to be EV cars**. From 2035, the market is therefore projected to stabilise.

Sources: (*) IEA STEPS Policy scenario (2024), (**) IEA STEPS Policy scenario (2024) and Deloitte market research (see annex)

# Projections for EV battery recycling in the EU

Manufacturing waste will be the main feedstock of recycled content until 2028, beyond which materials from retired EV batteries will replace waste as the main feedstock

**Projected end-of-life Li-ion EV battery cathode materials available for recycling in the EU (2024-2040)**



### Key takeaways

The **total weight of EV battery cathodes available for recycling will grow by a factor of 20 from 2024 to 2040, reaching 500.000 tonnes**.

By looking at the underlying three key streams (waste, end-of-first-life, and end-of-second-life), we find:

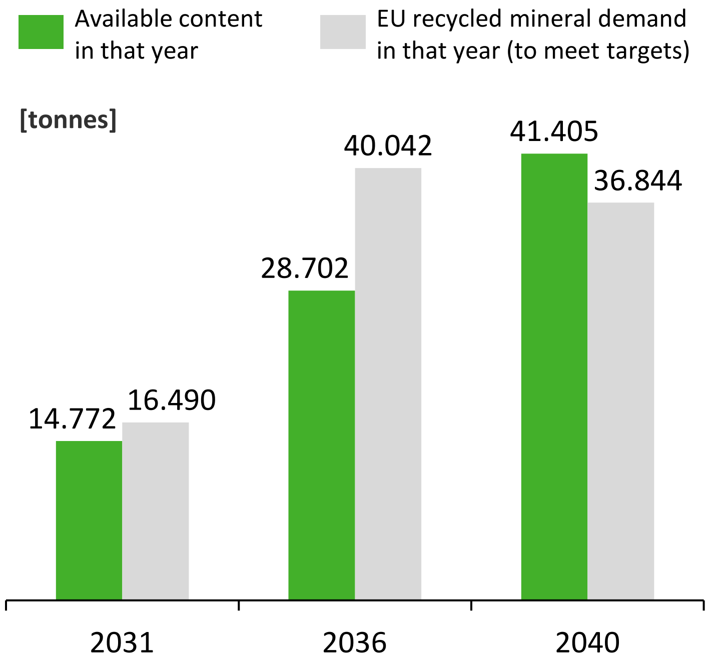
- **Manufacturing waste currently is the main feedstock** for EV battery recycling.
- **After 2028 end of 'first life' batteries will become the largest source.** [Note: For regions like China, which produces and exports many EV batteries, the tipping point may come later]
- **Starting in 2035, second-life batteries will begin to significantly contribute to the recycling feedstock**.

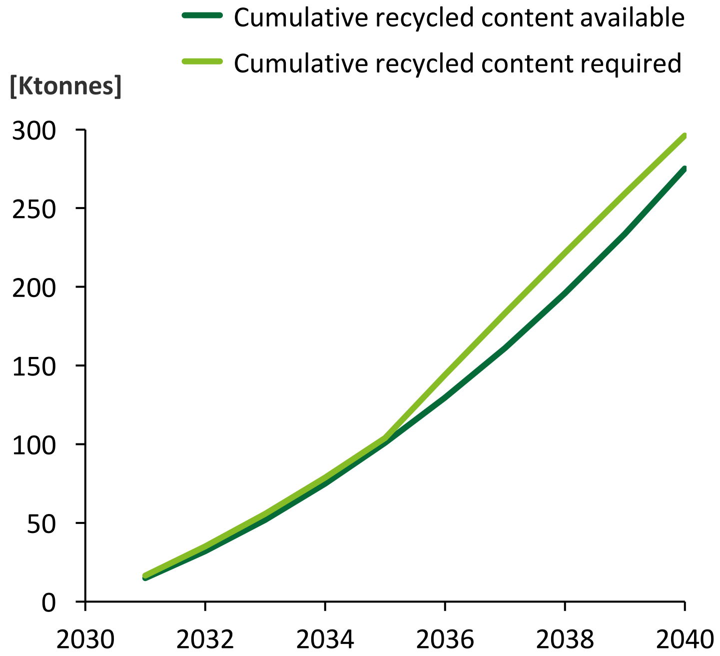
Source: (*) Data provided by Botree, Visual Capitalist [Visualizing the Key Minerals in an EV Battery (visualcapitalist.com)]

# Projections for EV battery recycling in the EU

A shortage of recycled content may occur for key minerals following increased targets in 2036. However, as demand for EVs stabilises and end-of-first-life batteries increasingly become available for recycling, the risk of shortages diminishes by 2040

## Cobalt





### Key takeaways

- Comparing yearly snapshots on the availability of **cobalt** from end-of-life batteries versus the demand from EU targets, our modelling shows a **projected deficit in 2031.** This deficit is **projected to increase in 2036 when EU targets will increase.**
- **In the year 2040, there is expected to be more cobalt available for recycling from end-of-life batteries than demanded to meet targets.** This is due to the projected decrease in the share of cobalt in **future batteries,** as well as the **levelling off in the demand for new EVs.**
- The chart on the right shows that a policy of **'stockpiling' could reduce some of the projected deficit.**

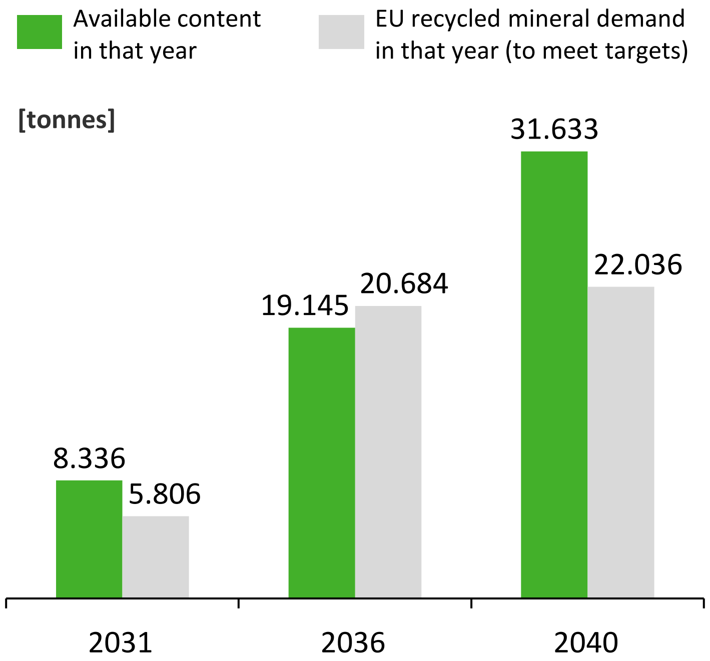
EU targets require cobalt in new EV batteries to comprise 16% recycled content from 2031 and 26% from 2036.

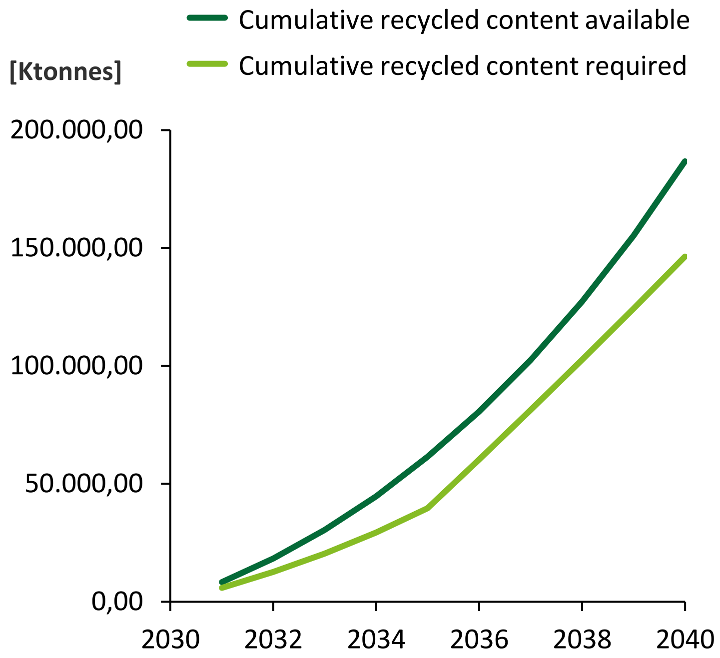
!

The **analysis focuses solely on minerals from Li-ion EV batteries that reach their end-of-life in the EU**, excluding imported/exported batteries and recycled content from other sources such as waste from electrical and electronic equipment (WEEE) and ceramics. It also assumes that there is not a significant impact from the "downcycling" of minerals no longer suitable for battery use. These estimates are highly dependent on the model's assumptions and carry significant uncertainty.

# Projections for EV battery recycling in the EU

## Lithium





### Key takeaways

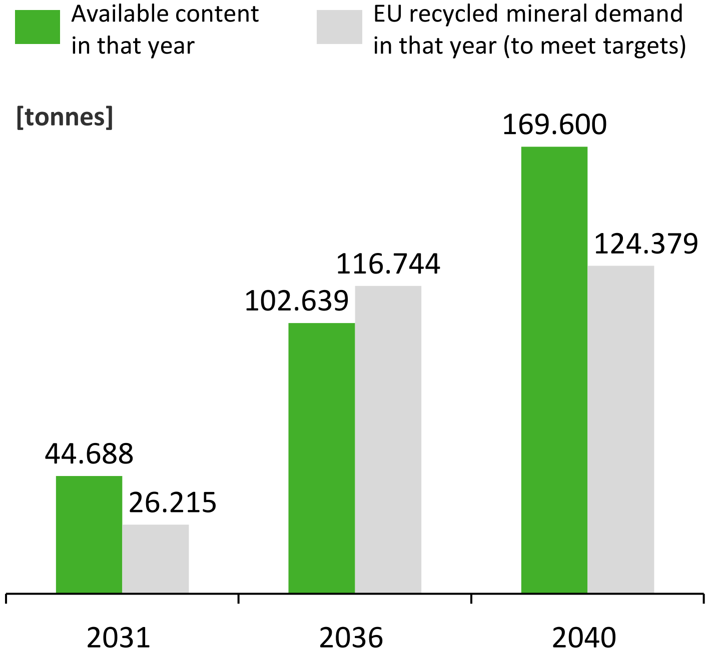
- Comparing yearly snapshots on the availability of **lithium** from end-of-life batteries versus the demand from EU targets, our modelling shows a **projected surplus in the year 2031**. However, this is projected to **shift to a deficit in 2036 when EU targets will increase.**
- **The projected available content in 2040 is substantially higher than the projected demand.** This is due in part to the **levelling off in demand for new EVs,** which counteracts the projected slight increase in the share of lithium in future batteries.
- The chart on the right shows that a policy of **'stockpiling' could completely remove the risk of deficits.**

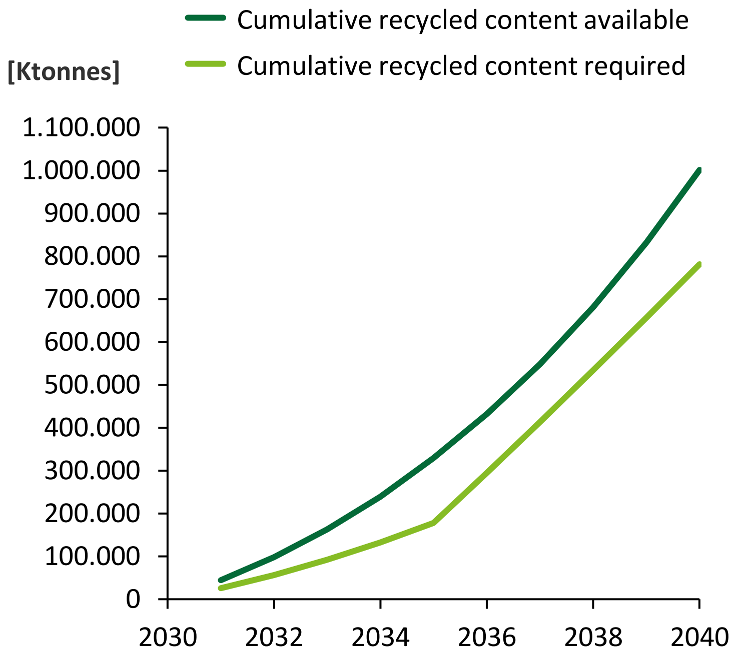
EU targets require lithium in new EV batteries to comprise 6% recycled content from 2031 and 12% from 2036.

! The **analysis focuses solely on minerals from Li-ion EV batteries that reach their end-of-life in the EU**, excluding imported/exported batteries and recycled content from other sources such as waste from electrical and electronic equipment (WEEE) and ceramics. It also assumes that there is not a significant impact from the "downcycling" of minerals no longer suitable for battery use. These estimates are highly dependent on the model's assumptions and carry significant uncertainty.

# Projections for EV battery recycling in the EU

## Nickel





### Key takeaways

- The projections for nickel show the **same trends as for lithium, with an in-year deficit projected for 2036 when the EU targets increase.**
- As with lithium, **a policy of 'stockpiling' could completely remove the risk of deficits.**

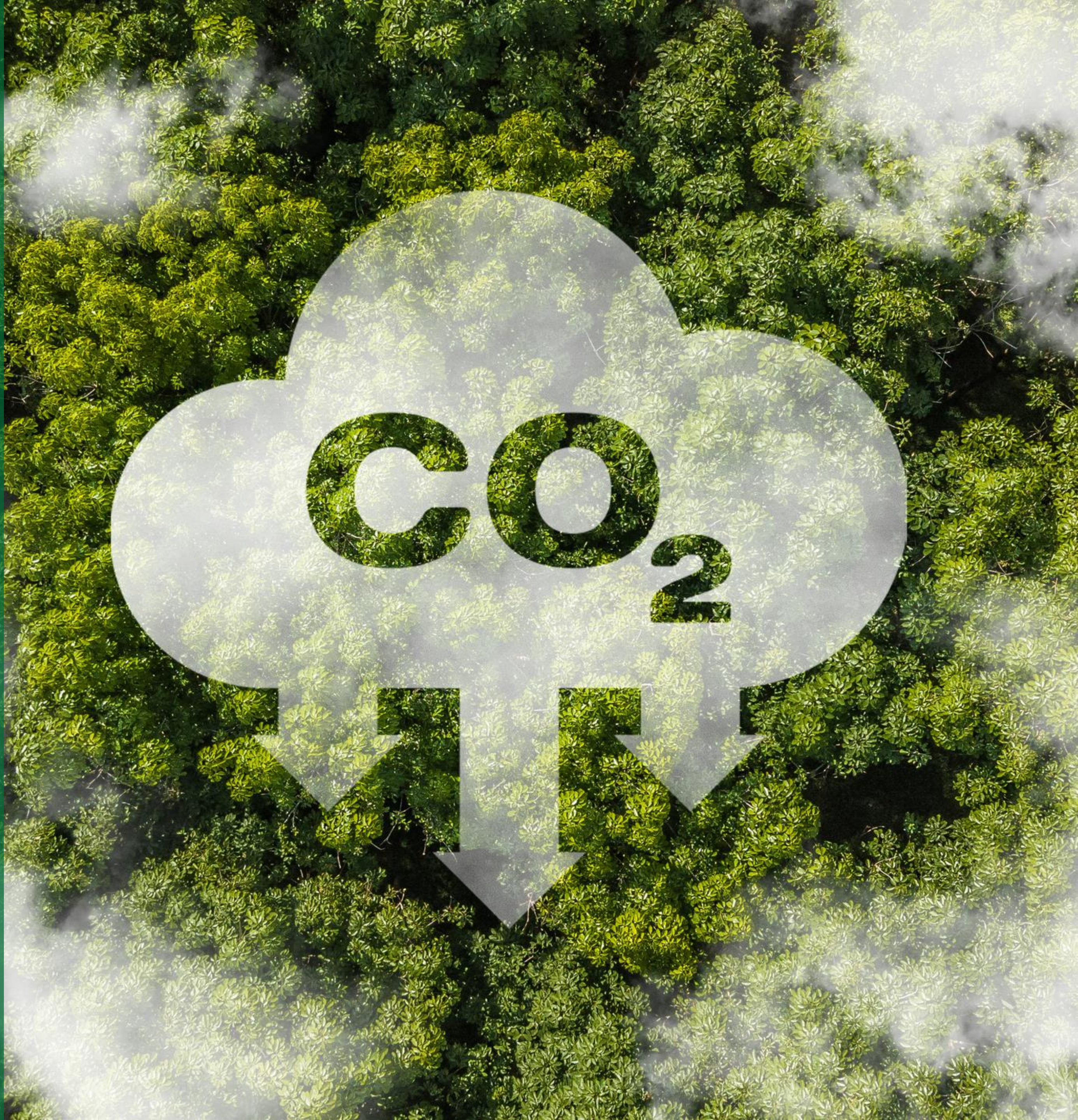
EU targets require nickel in new EV batteries to comprise 6% recycled content from 2031 and 15% from 2036.

!

The **analysis focuses solely on minerals from Li-ion EV batteries that reach their end-of-life in the EU**, excluding imported/exported batteries and recycled content from other sources such as waste from electrical and electronic equipment (WEEE) and ceramics. It also assumes that there is not a significant impact from the "downcycling" of minerals no longer suitable for battery use. These estimates are highly dependent on the model's assumptions and carry significant uncertainty.

# 3

# Key drivers and sensitivity analysis



# Key drivers and sensitivity

Sensitivity analysis on the key baseline assumptions provides a better understanding of the uncertainty and market drivers for the future availability of recycled content

## *Sensitivity analysis and tipping points for projected availability of recycled critical minerals (EU, 2036)*

| | |
|---|---|
| **Year** | Sensitivity analysis was conducted for the year **2036**, the year with the highest risk of recycled content shortages. |
| **Sensitivity** | A **30% variation** (up and down) from the baseline was applied for a set of key drivers *(except for collection rate, for which a 5% variation was tested owing to a 95% baseline rate).* |
| **Surplus** | Results of the sensitivity analysis are expressed in terms of the **"surplus" (recycled content available - recycled content needed to meet EU target).** Negative numbers represent a shortage in available recycled content, positive numbers represent sufficient recycled content. As stated in the previous section, this is based on the scenario whereby no stockpiling takes place from one year to the next, and all battery recycled content demand is met through EOL EV batteries processed in the EU. |
| **Tipping points** | This sensitivity analysis highlights the **tipping points**, in which a change in the value of a model parameter leads to a shift from a projected deficit in recycled content availability to a surplus (or vice versa). |

| Parameter in model | Input parameter values for the year 2036 (baseline, upper- and lower-bound) | Cobalt surplus in the year 2036 (tonnes) | Lithium surplus in the year 2036 (tonnes) | Nickel surplus in the year 2036 (tonnes) |
|---|---|---|---|---|
| **EV sales** | Upper-bound (+30%): 14.300.000 | -15.577 | -2.560 | -21.332 |
| | Baseline: 11.000.000 | -11.340 | -1.539 | -14.104 |
| | Lower-bound (-30%): 7.700.000 | -5.360 | 654 | -600 |
| **Manufacturing waste** | Upper-bound (+30%): 13% | -9.625 | -188 | -7.059 |
| | Baseline: 10% | -11.340 | -1.539 | -14.104 |
| | Lower-bound (-30%): 7% | -12.945 | -2.804 | -20.695 |
| **Production in the EU** | Upper-bound (+30%): 65% | -9.625 | -188 | -7.059 |
| | Baseline: 50% | -11.340 | -1.539 | -14.104 |
| | Lower-bound (-30%): 35% | -12.945 | -2.804 | 20.695 |
| **Export of used EVs** | Upper-bound (+30%): 39% | -13.832 | -3.214 | -23.070 |
| | Baseline: 30% | -11.340 | -1.539 | -14.104 |
| | Lower-bound (-30%): 21% | -8.843 | 139 | -5.117 |
| **Reuse** | Upper-bound (+30%): 39% | -13.032 | -2.667 | -20.153 |
| | Baseline: 30% | -11.340 | -1.539 | -14.104 |
| | Lower-bound (-30%): 21% | -9.649 | -411 | -8.056 |
| **Collection rate** | Upper-bound (+5%): 100% | -10.315 | -856 | -10.439 |
| | Baseline: 95% | -11.340 | -1.539 | -14.104 |
| | Lower-bound (-5%): 90% | -12.365 | -2.222 | -17.770 |
| **Average lifespan (year)** | Upper-bound (+30%): 13 – 18,2 | -18.998 | -6.683 | -41.645 |
| | Baseline: 10 – 14 | -11.340 | -1.539 | -14.104 |
| | Lower-bound (-30%): 7 - 9.8 | 3.367 | 8.331 | 38.752 |
| **Average weight (kg)** | Upper-bound (+30%): 213 - 650 | -14.134 | -2.696 | -20.944 |
| | Baseline: 240 – 500 | -11.340 | -1.539 | -14.104 |
| | Lower-bound (-30%): 169 - 350 | -4.757 | 760 | 255 |

# Key drivers and sensitivity

In the coming years, other battery chemistries could prevail in the EV battery market. One of the scenarios is that lithium-iron-phosphate (LFP) batteries become the dominant chemistry*

The model can assess the impact of a shift to an **LFP-dominant scenario in which the share of LFP in the EU increases from about 6% in 2023 to 50% in 2040**, with the other 50% being nickel-rich chemistries (NMC622 and NMC811**).

*Assumptions for an alternative scenario with a structural shift in battery chemistry from NMC to LFP:*

| | 2020 | 2040 (baseline) | 2040 (LFP dominant) |
|---|---|---|---|
| **Mineral** | % | % | % |
| **Nickel** | 31.6% | 42.1% | 21.3% |
| **Cobalt** | 10.8% | 7.2% | 4.6% |
| **Lithium** | 7.0% | 9.3% | 5.8% |

As LFP-batteries require less nickel, cobalt and lithium, **it is easier to fulfil the demand for recycled content in an LFP-dominant scenario**, especially because many mineral-rich NMC batteries will come end-of-life around 2036 when the shortage of supply is highest in the baseline scenario. This LFP scenario has three tipping points compared to the baseline (highlighted in green): in 2031 supply of recycled cobalt can meet demand. Same for lithium and nickel in 2036. Nonetheless, in 2036, there is still a (limited) recycled cobalt shortage.

*In an LFP-dominant scenario, some of the deficits projected within a given year (pages 14-16) would shift to surpluses:*

| | |
|---|---|
| Cobalt | Surplus projected in **2031** (instead of deficit) |
| Lithium | Surplus projected in **2036** (instead of deficit) |
| Nickel | Surplus projected in **2036** (instead of deficit) |

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Note: (*) This technological innovation is driven particularly by China, but there are also investments to secure supply in phosphate-rich countries such as Morocco. **Types of NMC battery chemistries. NMC622 contains 60% nickel, 20% manganese, 20% cobalt. NMC811 contains 80% nickel, 10% manganese, 10% cobalt. See here for more information. ***Positive numbers refer to more surplus of available recycled content, or less shortage. ***Trends in batteries – Global EV Outlook 2023 – Analysis - IEA

# 4

# Conclusion

# Analysis of results

Despite the many uncertainties, the projections highlight that the EU targets are ambitious, but can be achieved if policy makers create the right framework and companies accelerate their investment in recycling capacity

## There are many uncertainties around the drivers of the recycling market.

**Focus on: Batteries lifetime**

The average lifespan of batteries emerges by far as the **most sensitive driver** in terms of the availability of recycled content. Shorter lifespans lead to structurally more minerals that can be recycled (at least in the short run). This can cause tension between recycling and reuse objectives.

**Focus on: Exports**

The second most sensitive driver is the fraction of the EV batteries that are exported outside of the EU as part of a second-hand EV car trade. It is uncertain how the electrification of the vehicle fleet will affect trade of second-hand cars, but it seems plausible that the current export of older vehicles mainly from Europe to emerging economies will continue, even with the EV transition.

## Policies and economic incentives are required to accelerate investment.

Achieving the EU targets for recycled content in batteries will depend on a range of factors

- Innovation
- Market dynamics
- Imports and exports
- Political measures
- Degree of international cooperation

Some drivers of investment in recycling capacity can be tackled by targeted policy measures, for example, encouraging the imports into Europe of black mass from end-of-life batteries from outside of Europe, supporting innovation to minimise recycling process losses and setting up incentives to accelerate and maximise materials recovery. Altogether, the projections applied to the EU case study point out that recycled content targets are a good driver to activate the recycling market and create the business case for recyclers, but need to be accompanied by other targets and policies to overcome uncertainties and accelerate investments for a circular economy.

# Get in touch

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# 5

# Annex

## Model assumptions

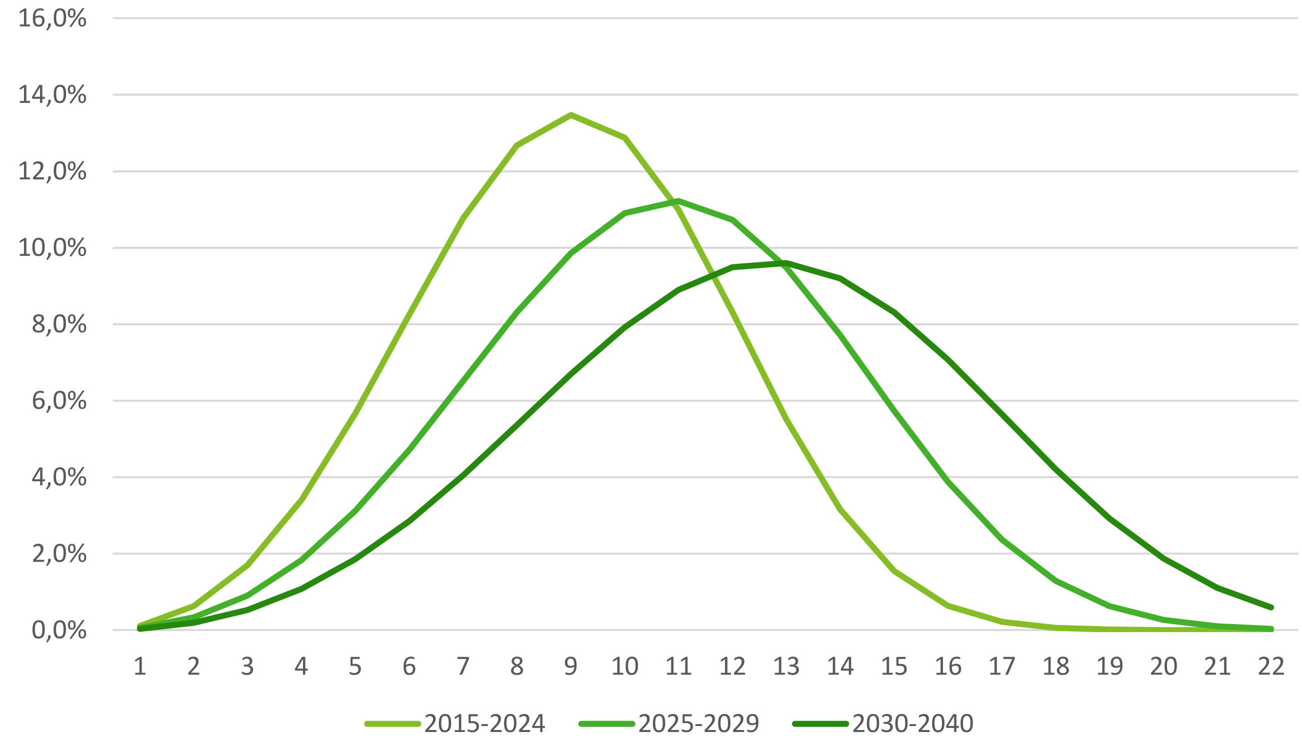
# Assumptions – EV battery lifespan

The model leverages a dynamic lifespan assumption for EV batteries placed on the market

The distribution lifespan of batteries is essential as it offers valuable insights into when batteries are likely to reach the end of their useful life. This information is critical for projecting both the timing and volume of batteries that will enter the recycling stream.

## Battery lifespan curves based on assumptions, with α(t) = 3.5*

**Percentage of batteries reaching end of life based on their average lifespan**



## Design principles

- The model is built using **a dynamic lifespan assumption** with continuous innovation expected to prolong the average lifespan of an EV battery. The following lifespans are used for first-life:
  - Batteries placed on the market **before 2024**: **10 years**
  - Batteries placed on the market **between 2025-2029**: **12 years**
  - Batteries placed on the market **after 2030**: **14 years**
- The average **second-life battery lifespan** is assumed to be **10 years.**
- **This study adopts the Weibull distribution function**, which accounts for diverse product life behaviours, enabling the modelling of realistic product lifespan distributions**. **The Weibull probability density function is characterised by two parameters**:
  - The **shape parameter** α(t) reflects the technical failure rates of the batteries and defines the shape of the probability density function.
  - The **scale parameter** β(t) represents the average lifespan of EV batteries.

Note: (*) α(t) is assumed to be constant throughout the study period, as its observed variation over time is minimal. **The Weibull distribution is widely employed in e-waste analysis and the examination of EOL EV batteries

Sources: U.S. end-of-life electric vehicle batteries: Dynamic inventory modeling and spatial analysis for regional solutions – ScienceDirect ; Lithium-ion cell-to-cell variation during battery electric vehicle operation – ScienceDirect .Temporal and spatial analysis for end-of-life power batteries from electric vehicles in China – ScienceDirect ; U.S. end-of-life electric vehicle batteries: Dynamic inventory modeling and spatial analysis for regional solutions – ScienceDirect ; Temporal and spatial analysis for end-of-life power batteries from electric vehicles in China – ScienceDirect ; eurobat_emobility_roadmap_lores_1.pdf

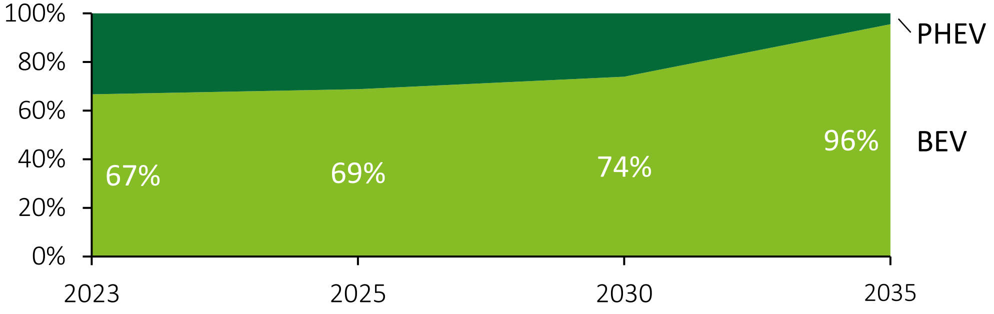
# Assumptions – Battery number, capacity and weight

A linear increase of annual EV sales is expected, reaching **11 million by 2035**. The number of annual sales is expected to stabilise thereafter. The main driver of the increase in battery weight will be the shift from PHEVs to BEVs

## Li-ion battery capacity projections

- To translate EV projections into future demand for Li-ion batteries, we take into account the **future shift from plug-in-hybrid vehicles (PHEVs) to battery electric vehicles (BEVs).**
- **BEVs rely solely on battery power and therefore require larger batteries,** whereas PHEVs have relatively smaller batteries since they also have an internal combustion powertrain.
- Based on the IEA STEPS scenario (pictured below), we project that the **average size of an EV battery will linearly increase from 55 kWh in 2020 to 74 kWh in 2040.**

**EV sales in Europe by powertrain**



**Note on energy density**

› Our literature review suggest that **PHEV batteries typically weigh between 50 and 120 kg**, while **BEV batteries generally weigh between 400 and 500 kg***. For instance, the battery of the second-generation Toyota Prius (PHEV) weighs approximately 50 kg, the Nissan LEAF (BEV) battery weighs around 300 kg, and Tesla Model 3 (BEV) batteries can weigh over 500 kg.

› **Given the gradual shift toward BEVs, it is forecasted that the average battery weight will increase from 240 kg in 2022 to 500 kg by 2035.** Any efficiency gains from more energy dense batteries may be counterbalanced by the need for bigger batteries that can provide more driving range on a single charge.

› Larger batteries mean more materials needed to manufacture them, but also that proportionally more battery cells will become available for recycling and repurposing down the line.

Note: (*) The IEA does not provide a separate forecast for the EU. However, based on the stated policies scenario, it can be expected that the percentage of BEV penetration in the EU will be above the European average.

# Assumptions – Availability of EOL batteries

Manufacturing waste and end-of-life batteries are key sources for recycling, but additional assumptions are needed to determine the actual available quantities

**50%**

### Battery manufacturing in the EU

The **EU aims to boost self-sufficiency in EV cell manufacturing**, including producing mineral-intensive cathode active material (CAM). However, as of August 2024, **only two plants are operational, and over half of the planned cathode plants for 2030 face delays or cancellations** without further government support*. Therefore, **we conservatively assume that 50% of required battery cathodes will be manufactured locally**, still reflecting significant growth.

**10%**

### Manufacturing waste (scrap)

**Manufacturing waste in EV battery production**, mainly from failed quality checks, **can reach 30% in new factories but usually stabilises at 10%**.** This waste is currently the primary source of recycled materials as EV batteries last longer than expected. Future waste will depend on advances in production technology, but forecasts, including the IEA's STEPS scenario, predict relatively high waste levels will continue in the near term due to production challenges.

**30%**

### Export of used EVs

We assume **a constant 30% export rate of used EVs from the EU to emerging economies*****, based on UNEP and OECD reports, following existing trade patterns for used fossil-fuel cars. While EV exports may be lower due to limited charging infrastructure—especially in Sub-Saharan Africa—UNEP research shows that many countries are promoting used EV imports to support sustainability goals. **Batteries in exported EVs are assumed not to return to the EU for recycling.**

**95%**

### Collection rate

Based on academic research, we assume a 95% collection rate for retired EV batteries****. Unlike smaller lithium-ion batteries, EV battery collection varies across the EU, ranging from 90% to nearly 100%, depending on infrastructure maturity. This is supported by data from producer responsibility organisations. While **the new Battery Regulation may increase collection rates**, its targets and assessment methods were not available at the time of writing.

**Total manufacturing waste available for recycling in the EU =** Total EV battery demand × Percentage of EU production × Average manufacturing waste percentage

**Batteries available in the EU after their first life** = Total batteries placed on market × (1 - Export rate) × Collection rate. These batteries can either by recycled or repurposed

Note: (*) https://www.transportenvironment.org/articles/european-made-batteries-could-be-60-less-carbon-intensive-than-chinese-analysis **https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-recycling-takes-the-drivers-seat and European battery recycling: An emerging cross-industry convergence | Arthur D. Little (adlittle.com) *** https://www.unep.org/resources/report/global-trade-used-vehicles-report and https://www.itf-oecd.org/sites/default/files/docs/new-but-used-electric-vehicle-global-second-hand-car-trade_0.pdf ****Prospects on end-of-life electric vehicle batteries through 2050 in Catalonia – ScienceDirect

# Assumptions – Availability of EOL batteries

Additionally, battery repurposing and replacement directly affect the total end-of-life volumes each year

## 30%

### Battery repurposing

For this study, we assume that **30% of EV batteries at the end of their first life will transition into a second life**, primarily for stationary energy storage. **The use phase of such batteries is prolonged for almost another decade, thus postponing their availability for recycling**. This assumption aligns with research conducted by Bloomberg and is reinforced by insights from Deloitte, particularly from the Belgian market*. It is noteworthy that the implementation of the recycled content targets in the EU could potentially impact the economics of repurposing as the demand for recycled minerals may make recycling more attractive than repurposing.

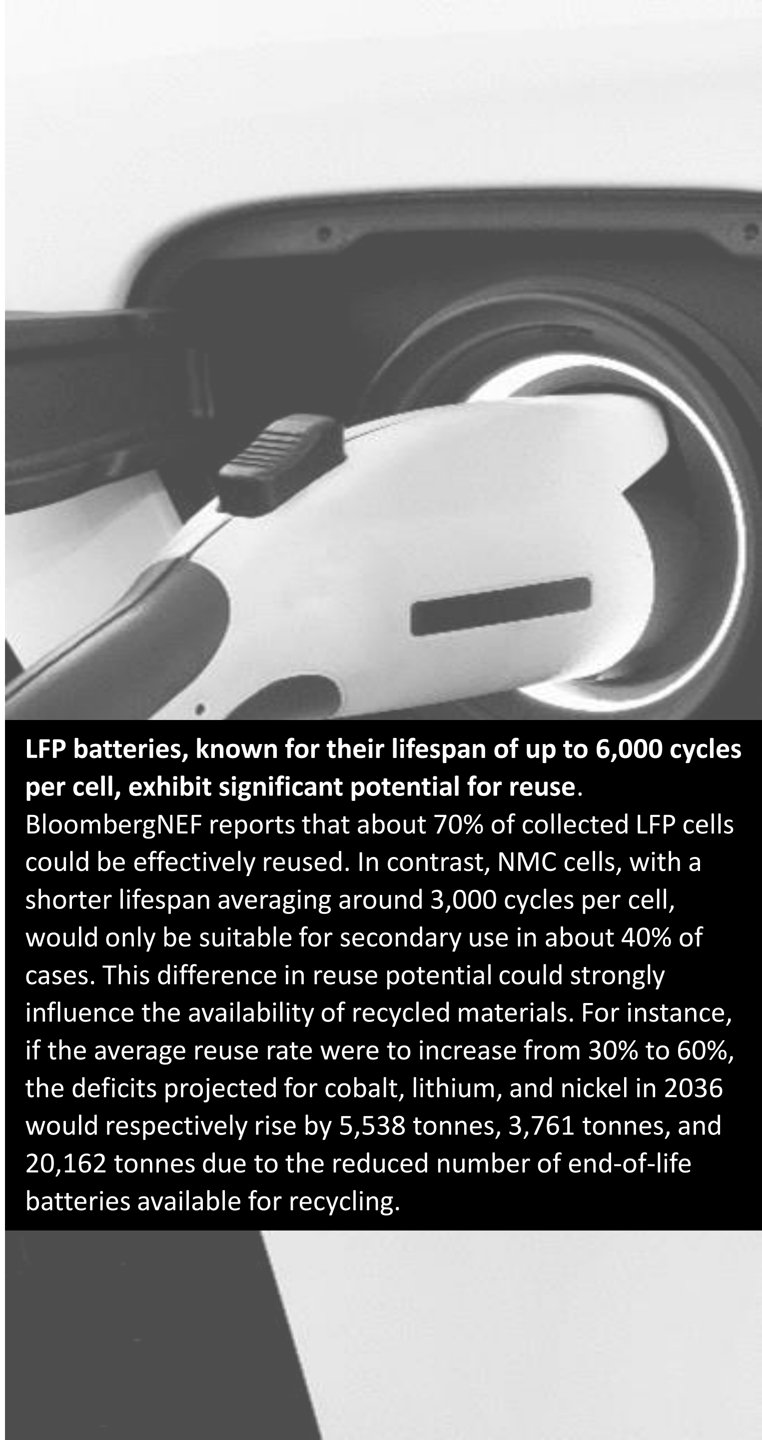
**Repurposed batteries will eventually be available for recycling, but this will be delayed due to their extended lifespan.**

## 10%

### EOL battery replacement

The study posits that **10% of EVs will need battery replacements during their lifespan**, which will increase demand for EV batteries and minerals. **Due to their high cost, replacements are economical only for new EVs that experience early battery failures.** For most EVs, replacing the battery is not cost-effective relative to the vehicle's overall value. These replacement batteries are expected to last around 10 years. After this period, 50% are anticipated to be suitable for a second life, while the remaining 50% will be recycled. Given the reduced export value of older EVs, only 10% of these replacement batteries are projected to be exported.

**Replacement batteries add to the total EV battery demand, in addition to the demand from new EV sales.**



**LFP batteries, known for their lifespan of up to 6,000 cycles per cell, exhibit significant potential for reuse.** BloombergNEF reports that about 70% of collected LFP cells could be effectively reused. In contrast, NMC cells, with a shorter lifespan averaging around 3,000 cycles per cell, would only be suitable for secondary use in about 40% of cases. This difference in reuse potential could strongly influence the availability of recycled materials. For instance, if the average reuse rate were to increase from 30% to 60%, the deficits projected for cobalt, lithium, and nickel in 2036 would respectively rise by 5,538 tonnes, 3,761 tonnes, and 20,162 tonnes due to the reduced number of end-of-life batteries available for recycling.

Note: (*) EVO Report 2024 | BloombergNEF | Bloomberg Finance LP (bnef.com)

# 6

# Annex

## Global Battery Alliance members

# List of GBA members and partners

Below are listed the members and partners of the Global Battery Alliance, as of October 15, 2024:

- African Development Bank (AFDB)
- Anglo American
- Battery Associates
- Battery Council International
- Botree Recycling
- CALB
- Calstart
- CATL
- Chemie Cluster Bayern
- Cirularise
- Cobalt Institute
- Critical Minerals Association (UK)
- Denso
- ECGA
- EITI
- Eucobat
- Eurasian Resources Group (ERG)
- Euro Manganese
- Euromot
- European Bank for Reconstruction and Development (ERBD)
- Exencell
- Federation of international Mining and Mineral Activities (FAB)
- Finnish Minerals Group
- Gaea
- GIZ
- Glassdome
- Government of British Columbia
- Huayou Recycling
- IndustriAll Global Union
- International Labour Organization
- Infyos
- International Lithium Association (ILiA)
- International Manganese Institute (IMnI)
- LG Chem
- LG Energy Sol.
- Minviro
- Natural Resources Canada
- Next Source
- Nickel Institute
- Panasonic
- RCS Global
- Renault
- REPT BATTERO
- Resolve/Regeneration
- Responsible Business Alliance (RBA)
- Resource Capital Funds
- Responsible Mica Initiative
- Rio Tinto
- RMI (Rocky Mountain Institute)
- Sabancı University Nanotechnology Research and Application Center
- Samsung SDI
- SAP
- SGS-CEC New Energy Technology
- Shenzhen Precise Testing Technology
- Siro Energy
- SQM
- TES
- Tesla
- Tethys: Trans-Eurasian Gateway
- The Faraday Institution
- The International Institute for Sustainable Development (IISD)
- Transport & Environment
- UC Davis
- UL Research Institute
- Umicore
- VeCarbon
- World Resources Institute (WRI)

*The views of the above-mentioned correspondents do not necessarily align with the statements in this paper. They have not reviewed or validated this paper.*

# 7

# Annex

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