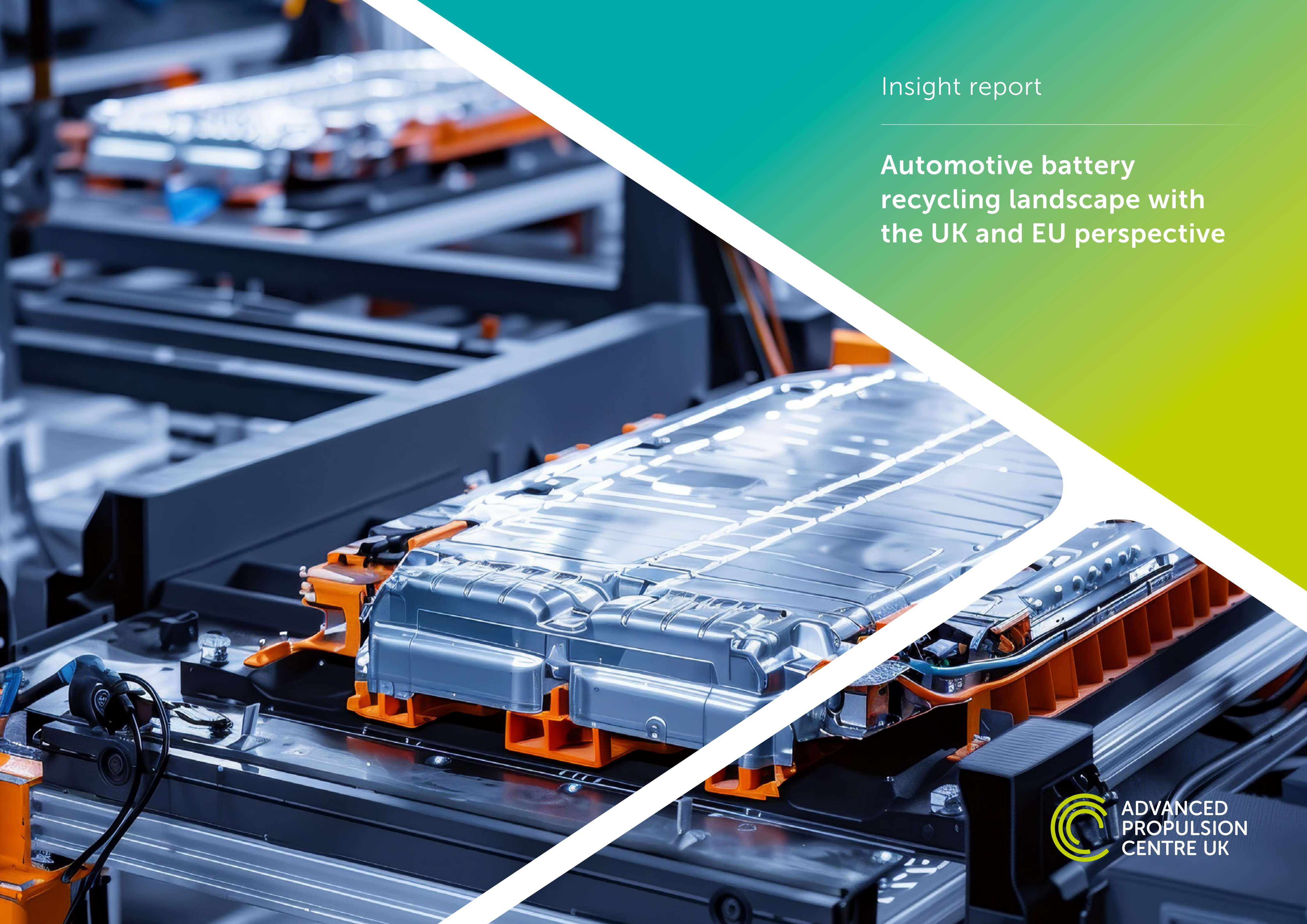


Insight report

Automotive battery recycling landscape with the UK and EU perspective

ADVANCED PROPULSION CENTRE UK

Contents

Department for
Business & Trade

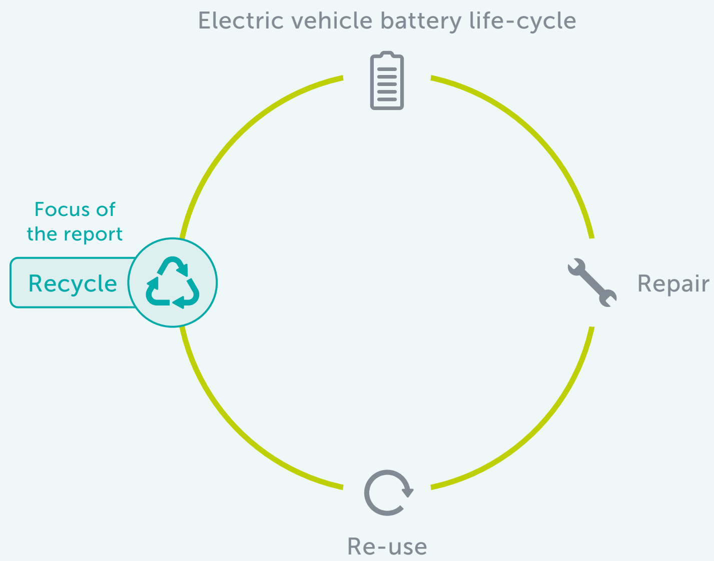
The Advanced Propulsion Centre UK (APC) operational costs are funded by the UK Government's Department for Business and Trade (DBT) and industry contributions. DBT is the ministerial department for economic growth, supporting businesses to invest, grow, and export, creating jobs and opportunities across the country. Our combined mission is to accelerate the development of advanced propulsion technologies to reduce greenhouse gas emissions, minimise embedded carbon, and improve air quality.

1. Introduction

As battery electrification becomes mainstream in automotive transportation, the focus will shift to the lifecycle impact of the energy storage systems used in vehicles. The batteries are made of key critical materials that are mined and refined from diverse regions of the world. They consume energy, water, and other valuable resources to build a battery system and are viewed as more than an energy storage solution; they must be seen as an enabler of a wider circular, closed-loop system. To enable this, the batteries need to be considered within the 3Rs of the closed-loop circular system: repair, re-use and recycle.

This report focuses specifically on the recycling phase of the battery lifecycle and provides an overview of the current state of battery recycling in the UK, as shown in Figure 1. It covers EU battery regulations, the recycling value chain, technology pathways, key challenges in meeting recycling targets, and profitability challenges. While repair and reuse are as vital to the overall circular economy, they fall outside the scope of this report.

Figure 1: Battery lifecycle and 3Rs



2. Executive Summary

The report has the following key observations:

UK secondary material status:
Up to 20% of the UK's automotive lithium-ion production demand in 2035 could be met by secondary materials—metals recovered from production waste and end-of-life batteries derived from UK sources. Over the next 5 years, however, gigafactory production scrap will make up much of the available secondary material. The ramp-up speed of the gigafactories will be key to the availability of secondary critical materials like lithium, nickel, and cobalt. The end-of-life retirement age of EVs will have a significant impact on the overall volume of battery waste. The average retirement age is 15 years.

Disassembly:
R&D investment is needed in automated, flexible disassembly platforms that can handle current and future variants of battery chemistries and battery packs. This will reduce the current operational costs associated with the labour-intensive discharging and dismantling of end-of-life batteries. Designing packs with the end-of-life dismantling and recycling could be encouraged.

Profitability of the recycling facilities:
Improving traction battery collection for shredding, and reducing the cost of refining black mass will increase recycling efficiency. Hydrometallurgy refining currently dominates the recycling landscape, but profitability remains challenging, with a minimum of 10,000 tonnes of recycling feedstock per annum needed for break-even point.

Alternative hydrometallurgy technologies:
Opportunities for innovation to reduce black mass refining costs in the UK, particularly by addressing the cost of handling aggressive chemical by-products such as sodium sulphate in hydrometallurgical refining. Alternatively, less corrosive processes, such as bio-inspired leaching and chromatography, hold promise for reducing the refining costs.

Scaling up facilities:
The UK must ramp up black mass refining facilities and consider integrating them closer to gigafactory plants to maximise scrap recovery and reduce transportation costs. Scaling up facilities can incentivise cathode active material (CAM) manufacturers to move to the UK, as pre-cursor cathode active material (pCAM) is synthesised from black mass refining.

Regulatory alignment:
Aligning the UK's battery waste classifications and the critical metal recovery targets with the EU's latest battery regulations (2023/1542) is important to advance cross-border trade in battery materials between the UK and Europe. This includes aligning battery passport frameworks. Good progress has been made in the recently published Vision 2035: critical minerals strategy from the UK government.

3. External drivers for recycling: Regulatory overview

Regulations are a key driver of battery recycling worldwide. Countries like India, China and the EU have updated their waste battery and recycling regulations this year.

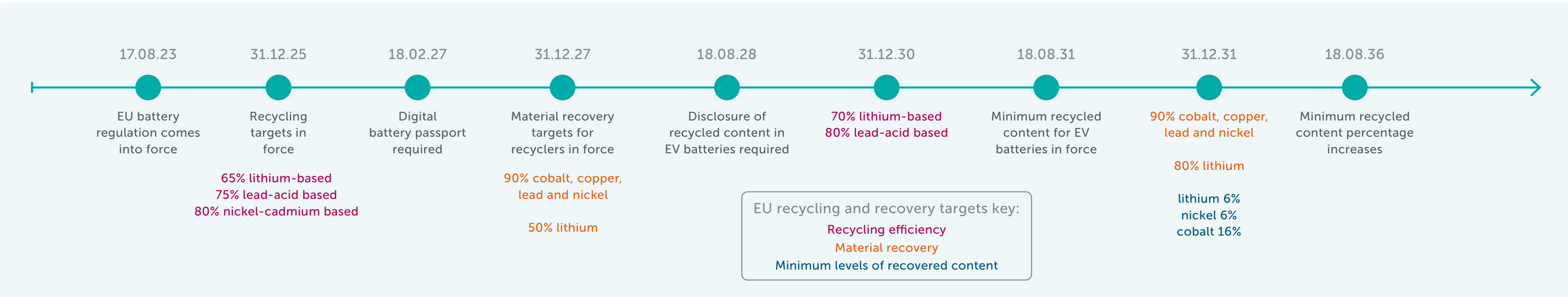
EU regulations:
In the EU, the new Batteries Regulation (EU) 2023/1542 came into effect in August 2023. Though the recycling targets will come into force only in 2025. It sets mandatory sustainability criteria across the entire battery lifecycle, including recycling. This regulation applies to portable, EV, and industrial batteries as well as those used in light means of transport (LMT) such as e-bikes or scooters. The regulation focuses on key areas such as traceability, sustainability, and battery design.

Key milestones in the EU battery waste legislation are shown in figure 2.

The digital battery passport framework, as well as recycling recovery targets for key battery minerals such as lithium, nickel, and cobalt, are set to shape the future of battery recycling and the innovations needed. A digital battery passport is an information system designed to add contextual information about the batteries. Each battery product will have a unique code, production facility, and business operator details. This can potentially add more clarity and information to recyclers.

The EU regulation sets clear recycling targets and efficiency rates, giving companies a clear mandate for recycling, as shown in Figure 2.

Figure 2: Key EU battery recycling regulation dates



To meet recycling targets and efficiency rates, it is vital to recover cathode and anode active materials. These components form most of the battery cell's weight content, as shown in Figure 3.

Recycling recovery rates determine the efficiency of recycling processes. Performance varies across regions as shown in Figure 4, due to differences in:

- Business models
- Technological maturity
- Operational capabilities

The EU is lagging behind countries like China in recycling efficiency for metals like lithium. To increase lithium recovery in the EU from the current 46% to 80%, as shown in Figure 4, innovation and process improvements are essential. The EU targets, though, provide a good framework for recovering valuable metals from nickel-rich batteries; they have not included manganese targets that would have accounted for LFP or LFMP batteries.

UK regulations:
The central regulation in the UK for battery waste is "The Waste Battery and Accumulator Regulations 2015," which stipulates that producers are responsible for collecting and delivering to an approved battery treatment operator or an approved battery exporter. Battery treatment operators are required to apply for approval for waste battery treatment, and record and report the recycling data. This includes information on the total amount of waste batteries accepted, recycled, exported outside the UK, etc. Operators are also required to achieve a recycling efficiency of at least 50% by the average weight of waste lithium-ion batteries. In November 2025, the UK government published the vision 2035: Critical Minerals strategy for the UK, that provides ambition of meeting 20% of total annual UK demand for critical minerals met through recycling.[1]

[1]https://www.gov.uk/government/publications/uk-critical-minerals-strategy/vision-2035-critical-minerals-strategy

Figure 3: Typical NMC cell weight
Source: APC research

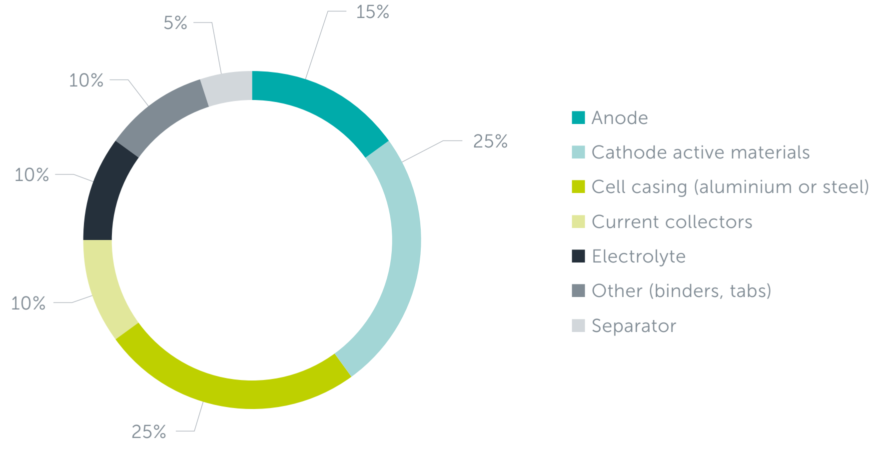
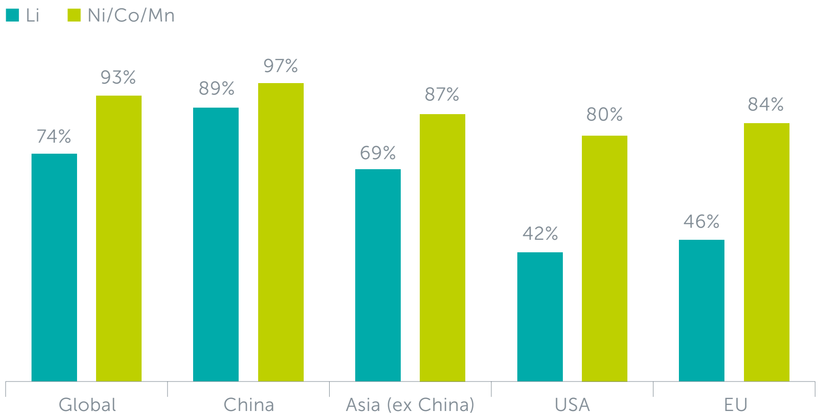


Figure 4. Global battery recycling efficiency rates as of 2025
Source: Benchmark analysis

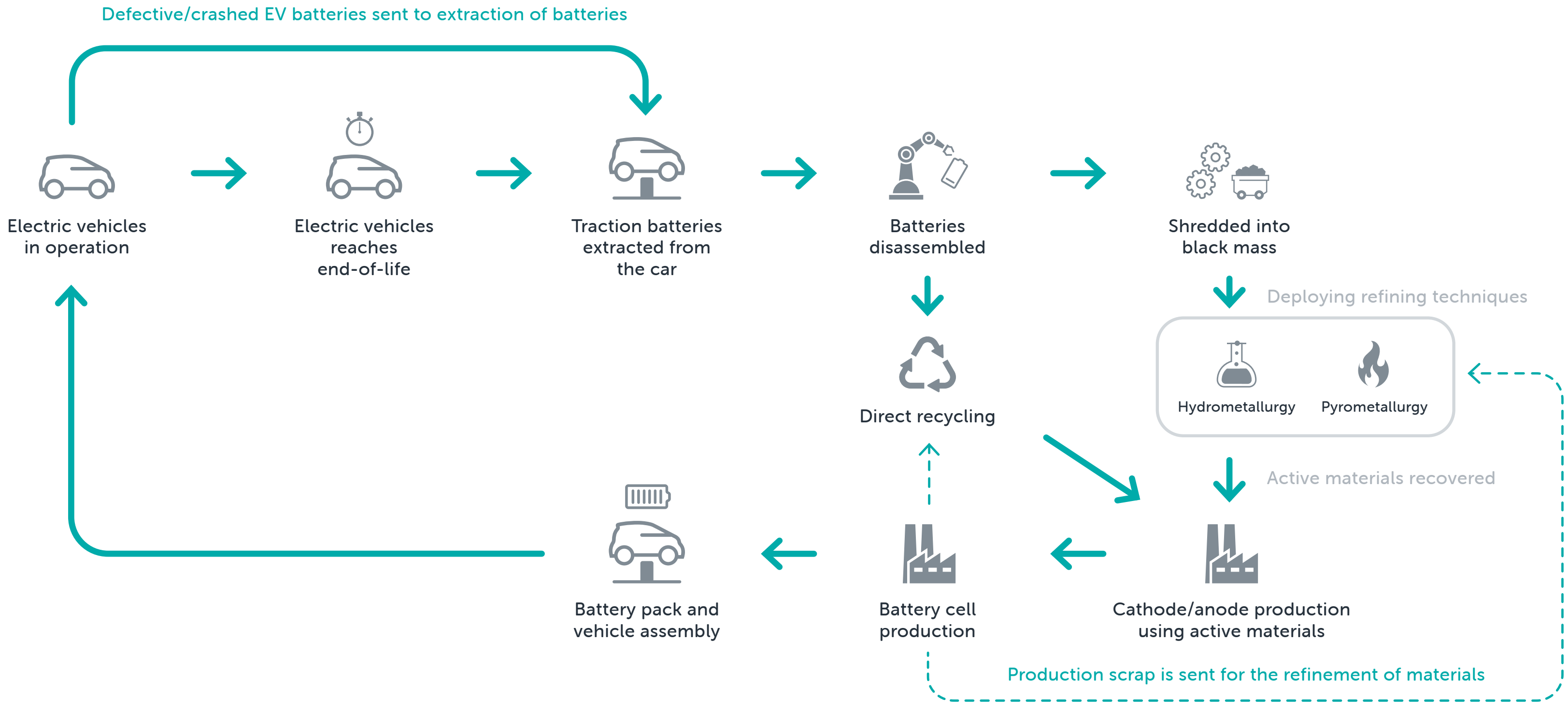


4. Battery recycling value chain and technology pathways

The automotive recycling value chain is shown in Figure 5 below, along with an overview of the end-of-life recycling value chain from the APC's 2023 *Automotive Battery End-of-life Value Chain report*.

Black mass is the material produced when battery cells are shredded, consisting of cathode, anode and some current collectors components. After further refining, black mass can be processed into cathode and anode active materials that are reused to manufacture new battery cells, as shown in Figure 5.

Figure 5: Battery recycling value chain



Recycling material can be sourced from two pathways:

1. Production scrap
2. End-of-life batteries.

Production scrap:

Arises from the losses within battery manufacturing plants, mainly from electrode trimmings and rejected cells within the manufacturing facility.

Gigafactory scrap and end-of-life battery scrap are recycled in similar ways through mechanical pre-treatment and shredding into black mass. The purity of the black mass composition dictates the value of the refined metals. Variations in purity and composition contribute to the different gradings and prices for both the black mass and the extracted metals.[2]

Production scrap potential in Battery cell manufacturing

Source: Adapted from APC battery value chain 2023

"The purity of the black mass composition dictates the value of the refined metals."

[2]Faraday insights

Different refining methods for black mass:

The Faraday Intuition's recycling insights report provides a detailed overview of the technologies and process methods used in battery recycling. Key highlights from the various refining processes observed in the industry are summarised in Table 1.

Table 1: Key black mass refining technologies with their challenges

Technology	Recovery rates	Environmental impact	Advantages	Challenges
Pyrometallurgical	Medium-high	Very high, due to intense energy operations	No battery pre-sorting needed	Not cost-effective to run Low recovery rates of lithium and aluminium
Hydrometallurgical	Very high	Moderate impact, affecting water usage	Highly economical when run at a large scale Higher profit margins, especially when integrated with pre-cathode active material (pCAM) processes	Chemical handling and requiring the disposal of sodium sulphate, an unwanted by-product Requires pre-treatment of the batteries before refining
Direct recycling	Very high	Low	Reduces the need for pre-treatment and battery shredding steps Preserves the structure and integrity of active materials	Low TRL levels for commercial use Requires sorting and organised dismantling of batteries before processing
Bio leaching process	At pilot stages and unproven at large scale	Very low	Low energy consumption Less toxic waste handling	Low commercial maturity
Chromatography	High recovery rates	Low	Can be applied to various chemistries Less toxic waste handling	Complex system and low throughput

5. Secondary material feedstock flow for recycling

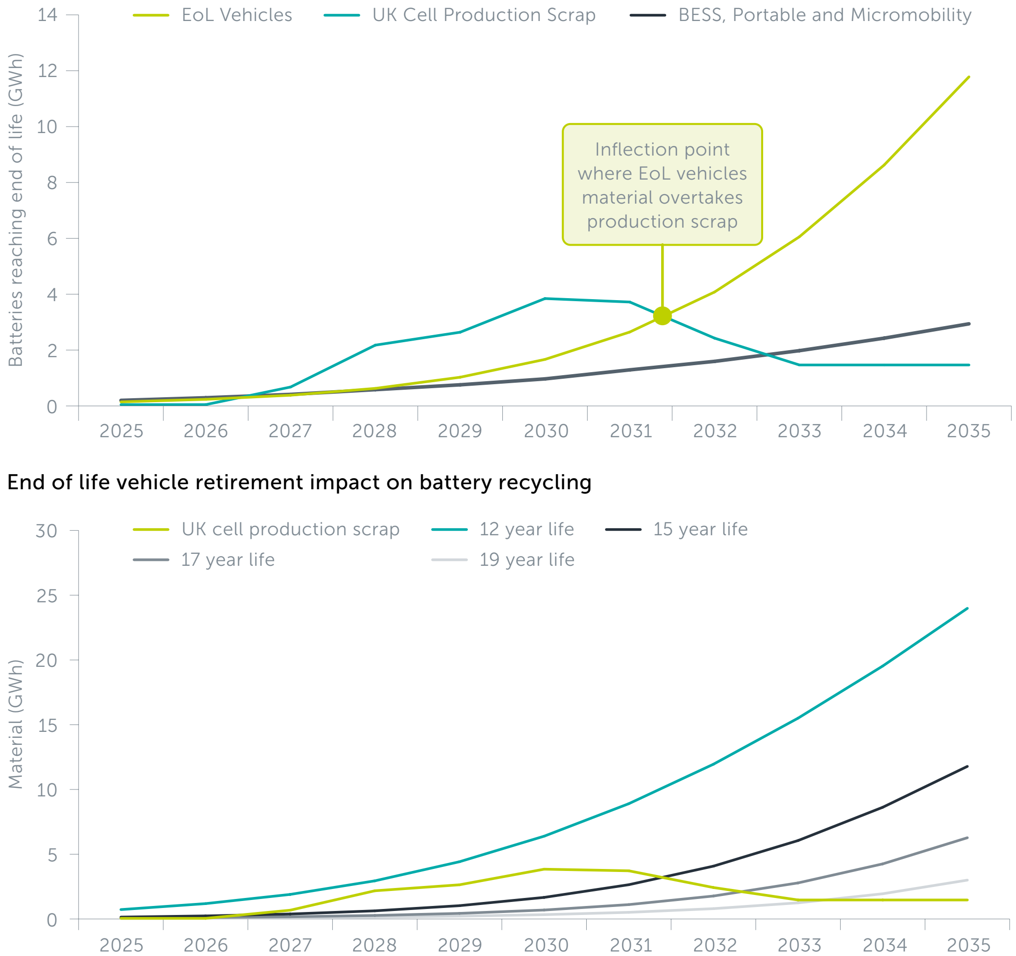
APC analysed UK vehicle production and sales forecasts for passenger cars, light-duty and heavy-duty vehicles, to estimate the potential UK supply of secondary battery material. The analysis considered other sources of battery materials, including battery production scrap, battery energy storage systems (BESS), portable batteries and micromobility traction battery sources.

Until 2031, most of the UK's secondary battery materials will come from gigafactory production scrap containing valuable critical materials for re-use. After that, end-of-life vehicle batteries will become the main source of recyclable battery material, as shown in Figure 6. The future of battery recycling feedstock will largely depend on when vehicles reach the end of their lifespans. However, there may be a future trade-off: technologies that extend vehicle lifespan could delay battery retirement, reducing the available feedstock for battery-recycling materials. Currently, the average retirement age for a vehicle is around 15 years.

"The future of battery recycling feedstock will largely depend on when vehicles reach the end of their lifespans."

Figure 6: Availability of secondary material in the UK and the influence of retirement age of EVs

Source: APC analysis

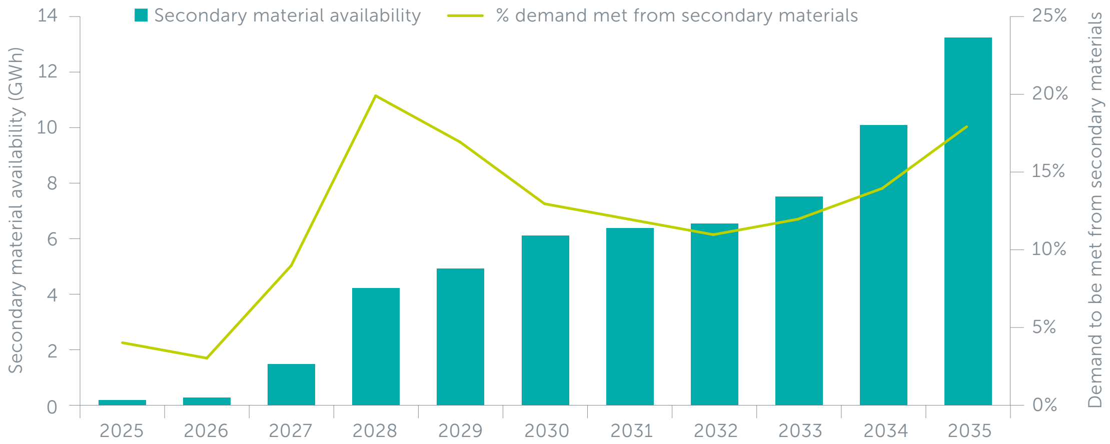


If all available gigafactory scrap and end-of-life battery material is recovered and refined, secondary battery materials could meet up to 20% of the UK's automotive battery demand by 2035 as shown in APC analysis in Figure 7. There are vital chemical elements within the battery cells that are tagged as critical to the mineral supply of the UK and the EU and should be recovered and reused. With the recent geopolitical constraints and mining sources of critical minerals like nickel and cobalt being outside the EU, it is essential to recover and process these metals from end-of-life batteries.

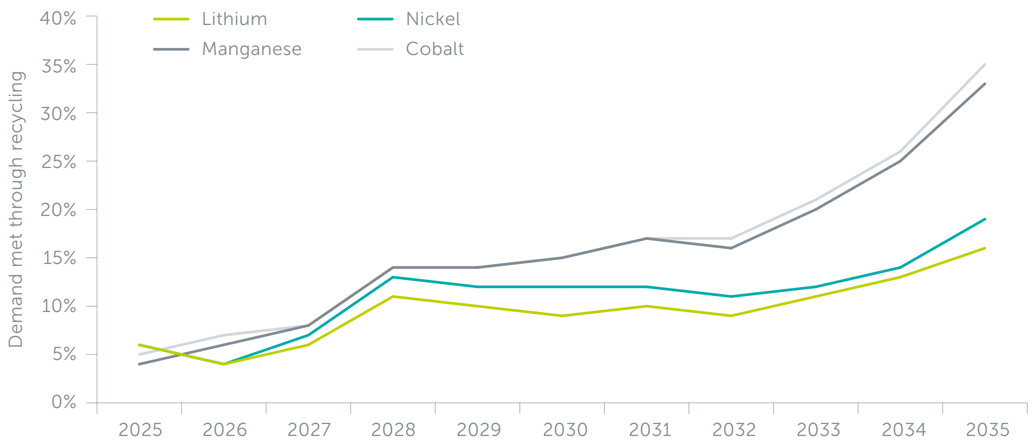
"With the recent geopolitical constraints and mining sources of critical minerals like nickel and cobalt being outside the EU, is essential to recover and process these metals from end-of-life batteries."

Figure 7: Production demand met by recycled materials in the UK

Source: APC analysis



Critical minerals potential in batteries as percentage of demand



Importance of the recovery of copper from battery recycling:

In addition to critical minerals like cobalt and nickel, battery packs also contain other important materials, such as aluminium and copper, as illustrated in Figure 8. By 2030, each battery electric vehicle (BEV) would require around 65-70 kg of copper, with copper demand from the vehicle and battery sectors rising by 177% by 2030. Data centre facilities for AI capabilities are expected to add significant pressure on demand, contributing an average of approximately 400,000 metric tons per year over the next decade.[3]

Initially, the volume of materials recovered will largely depend on gigafactory ramp-up rates, since early recovery efforts will primarily rely on production scrap, as shown in Figure 9.

Figure 8: Aluminium and copper content from batteries in the UK

Source: APC analysis

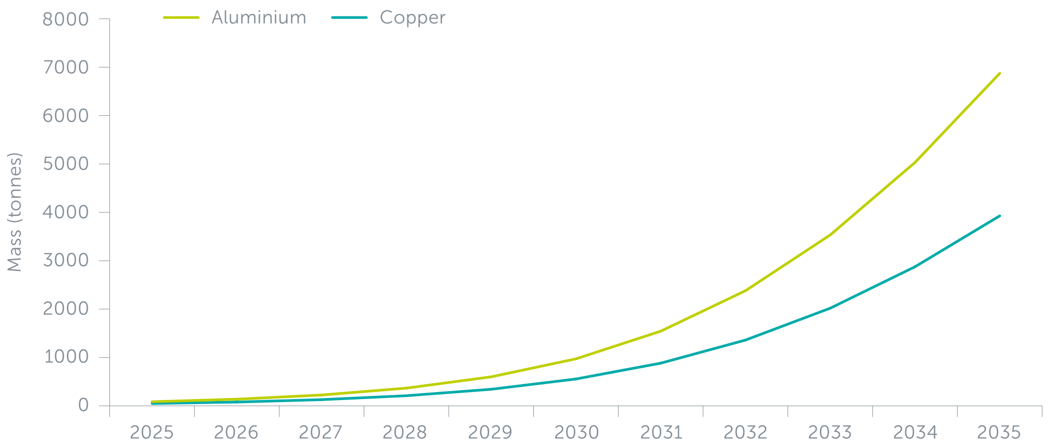
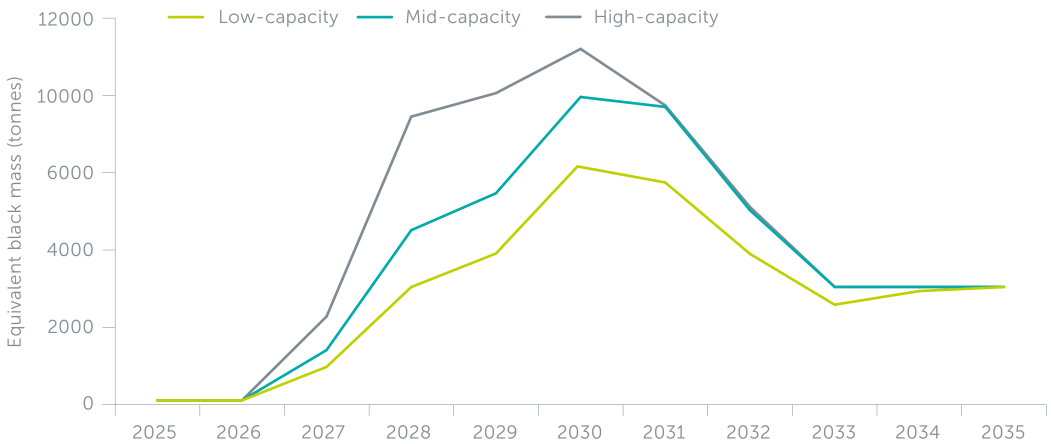


Figure 9: Influence of gigafactory ramp-up rate on battery materials

Source: APC analysis



It is important to note that the exact composition and percentage of black mass can vary significantly depending on the specific battery design (e.g., cell format, housing materials) and the efficiency of the initial shredding and separation process.

[3] Bloomberg

6. Current refining landscape and value chain players in the EU

Black mass regulations play a key role in ensuring the safe disposal of battery waste worldwide. The export restrictions on black mass may encourage the use of raw materials, such as lithium, cobalt, and nickel, within regional markets, supporting local recycling efforts and supplying future battery production. The key battery waste regulations across the world are shown in Table 2 opposite.

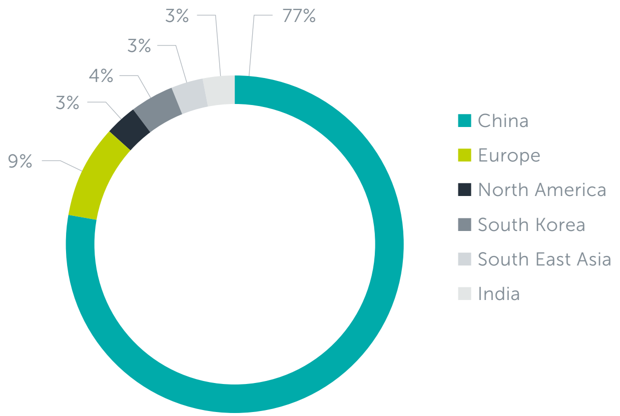
In March 2025, the European Commission classified waste batteries, including black mass, as hazardous waste. This classification restricts exports to non-OECD (Organisation for Economic Co-operation and Development) countries, aiming to keep valuable battery materials within the European economy. China dominates global pre-treatment capacity, as shown in the Figure 10 opposite, driven by its vertically integrated battery supply chain, which provides a consistent feedstock for recycling operations.

Table 2: Global waste regulations[4]

	Waste battery regulation	Shipment/transport regulation	End-of-life battery classification	Black mass clarification
	EU Battery Regulation (EU) 2023/1542	Basel Convention, regulation on Shipments of Waste (EU)	Hazardous Waste	Hazardous Waste
	Resource Conservation and Recovery ACT (RCRA)	Hazardous Materials Regulations (HMR)	Hazardous Waste	Product
	The Measures for the Comprehensive Utilisation of NEV Batteries (Draft)	Regulation on Road Transport. Road Transport of Dangerous Goods	Recyclable Waste	Recyclable Waste
	Battery Waste management Rules 2023	Guidelines for Transportation of Hazardous Waste	Hazardous Waste	Hazardous Waste

Figure 10: Pre-treatment capacity year-to-date (YTD) 2025

Source: Benchmark recycling capacity database 2025



"The export restrictions on black mass may encourage the use of raw materials, such as lithium, cobalt, and nickel, within regional markets, supporting local recycling efforts and supplying future battery production."

[4]Benchmark intelligence

While the EU's classification of black mass as hazardous waste may help to retain battery materials within the region, the lack of refining capacity to process the waste is a key bottleneck, as shown in Figure 11. According to T&E analysis, the refining capacities will need to increase 10 times to handle the anticipated volume of feedstock of spent batteries.

Hydrometallurgical processing is currently the predominant black-mass refining method, mainly due to its scalability and the economics of chemical refining. Currently, hydrometallurgy facilities are concentrated in China, India, and South Korea, as illustrated in Figure 12. This is due to the maturity of battery manufacturing capabilities in countries like China and South Korea. India, meanwhile, capitalised on previous black-mass-exporting regimes to establish its refining facilities. Recent changes to the EU's classification of black mass as hazardous waste may incentivise the future location of these refineries within Europe. However, there is a possibility that black mass could be rerouted to countries such as South Korea and Japan, which are eligible as part of the OECD block.

Figure 11: Europe's recycling refining capacity constraints[5]

Source: T&E analysis

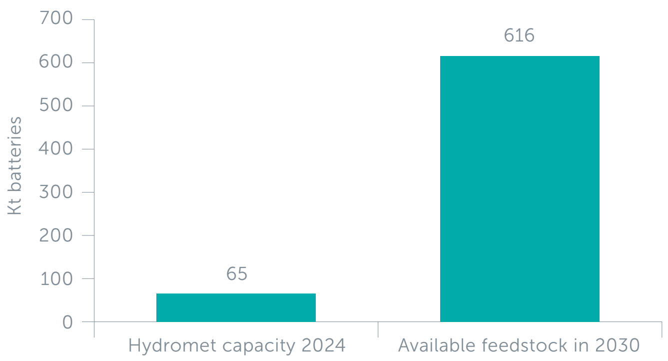
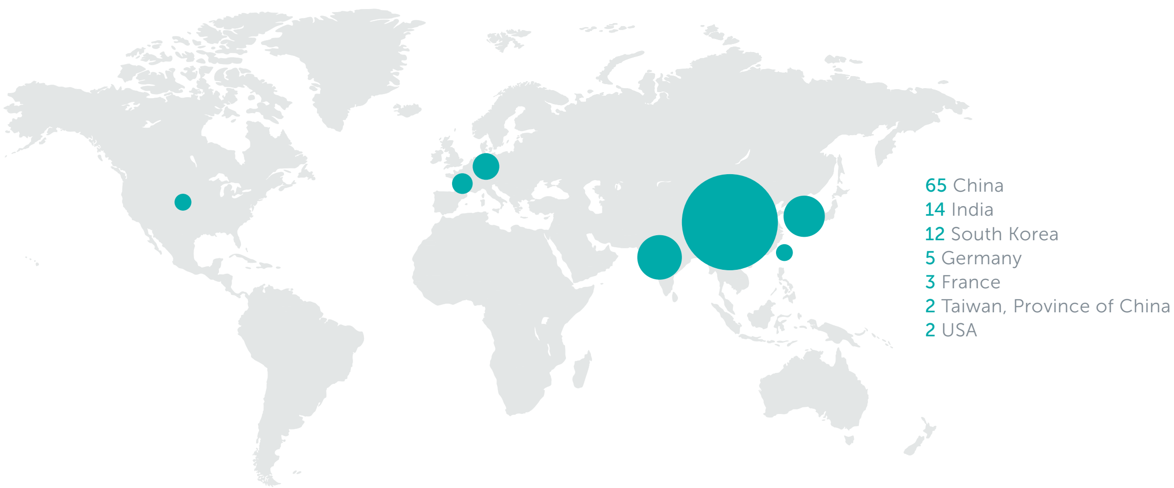


Figure 12: Current hydrometallurgy refining landscape

Source: Benchmark recycling capacity database



[5]T&E recycling insights

Figure 13 lists the current players across various parts of the EU battery recycling value chain. A growing number of smaller companies have entered the pre-treatment of spent batteries, shredding them into black mass.

The market for refining is challenging due to the competition from China and increasing OPEX (operating expenditure) in Europe. According to T&E analysis, almost half of Europe's battery recycling plans for the future are at risk. Altilium clean technology in the UK is currently building a hydrometallurgy refinery facility that will come online in 2027.

Figure 13: EU recycling battery value chain as of 2025*

Source: APC analysis

Discharging → Dismantling → Mechanical pre-treatment

Discharging / Dismantling:
- Stena Recycling
- Recyclus Group
- emr
- Cellcycle (part of the SER Group)

Mechanical pre-treatment:

Dry Shredding
- Duesenfeld
- SK tes
- URT Recycling Technology

Wet Shredding
- Batrec
- Lithibatt Closed Loop Battery Recycling Systems
- Accurec
- ecobat
- emr
- Cellcycle (part of the SER Group)

Hydro recycling
- fortum
- Veolia
- SungEel HiTech
- umicore
- BASF We create chemistry
- SK tes

Pyro recycling
- umicore
- SungEel HiTech

"The market for refining is challenging due to the competition from China and increasing OPEX in Europe."

*This list is not exhaustive

7. Profitability issues and challenges in recycling

Several industry challenges continue to hinder the acceleration of battery recycling infrastructure within Europe. Three key barriers within the EU have been identified within this report:

1. Challenges in traction battery returns and recycling
2. Cost drivers in the treatment of black mass
3. Challenges in recycling LFP batteries

Challenges in traction battery returns and recycling:

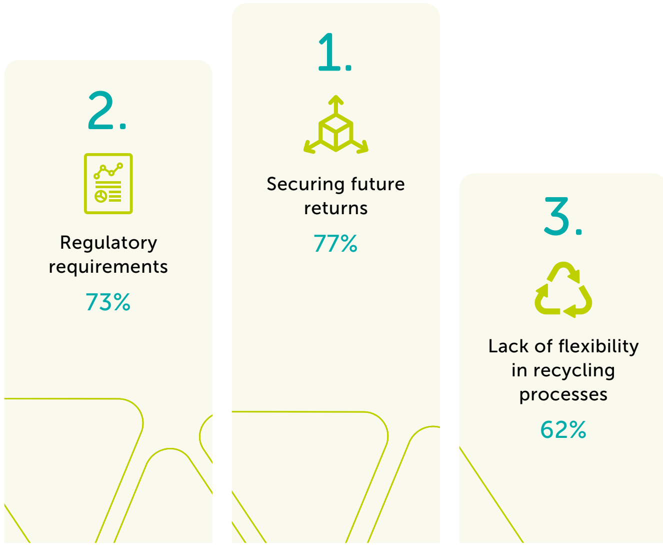
The research analysis[6] in the form of an industry survey with EU battery ecosystem partners identified the following issues within the region.

1) The most significant challenge found was the uncertainty around securing future returns, with over 75% of respondents highlighting this issue, as shown in Figure 14. Recycling companies identified difficulty in guaranteeing future returns from OEMs and battery owners. Success depends heavily on forming partnerships and alliances. Currently, the challenges between OEMs and recyclers are related to commercial business models that will provide confident future revenue returns.
2) The industry respondents were sceptical of meeting EU recycling targets of 95% efficiency, due to the current inefficiencies in the value chain of the recycling process.
3) The continual evolution of battery structures and chemistries underscores the importance of flexible recycling platforms and processes.

APC's analysis finds several challenges within the early stages of end-of-life battery recycling:

- **Variety:** Vehicle battery packs are constructed from different battery chemistries and materials, each requiring different disassembly requirements.
- **Non-detachable joints:** The use of non-detachable joints, such as welds and adhesives, complicates disassembly. Cell-to-pack technology will introduce additional challenges as joints are replaced with welds and other difficult-to-separate materials.
- **Component accessibility:** Challenges in accessing components within the battery pack. For example, accessing battery management systems (BMS), safely removing the pack upper cover, disconnecting high-voltage cables and ensuring safe discharge of residual voltage.
- **Manual operations:** Disassembly is highly labour-intensive, relying on manual labour, driving up operational expenditure (OPEX).

Figure 14: Survey results on battery recycling challenges
(% of respondents agreed the challenge to be important)
Source: Natalia Soldan.et.al 2025



[6]Economic and structural challenges of lithium-ion battery recycling in Europe

Cost drivers for recycling from the survey results:

1. Chemical recycling processes need specialised process plants and infrastructure capable of handling leaching agents. Proper disposal of waste products, such as sodium sulphate, is essential. The volume of sodium sulphate produced in battery recycling can be huge. Hydrometallurgical recycling can produce up to 800 kg of sodium sulphate for every 1000 kg of battery materials recycled. The disposal methods can take up an ample space and are operationally expensive[7].
2. Thermal treatments are energy-intensive and contribute significantly to energy costs.
3. Transporting batteries is a significant cost within the overall recycling process. Under current EU regulations, as part of the extended producer responsibility, collection responsibility is primarily assigned to battery manufacturers and OEMs. Moving waste batteries can be hazardous and involve significant costs and logistical challenges. There is a risk that waste batteries could catch fire in the recycling trucks[8].

The profitability of the refining industry is highly dependent on black mass pricing. Black mass pricing dictates the cost margins for refiners. The black mass pricing is, in general, provided in the percentage payable as of virgin materials. The lower the price of black mass, the higher the profitability for recyclers refining it as shown in Figure 16.

Figure 15: Survey results on cost drivers for battery recycling
(% of respondents agreed the cost driver to be important)
Source: Natalia Soldan.et.al 2025

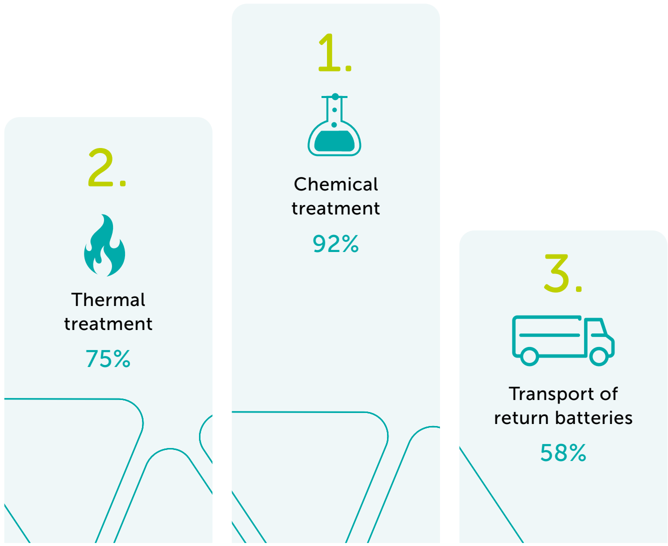
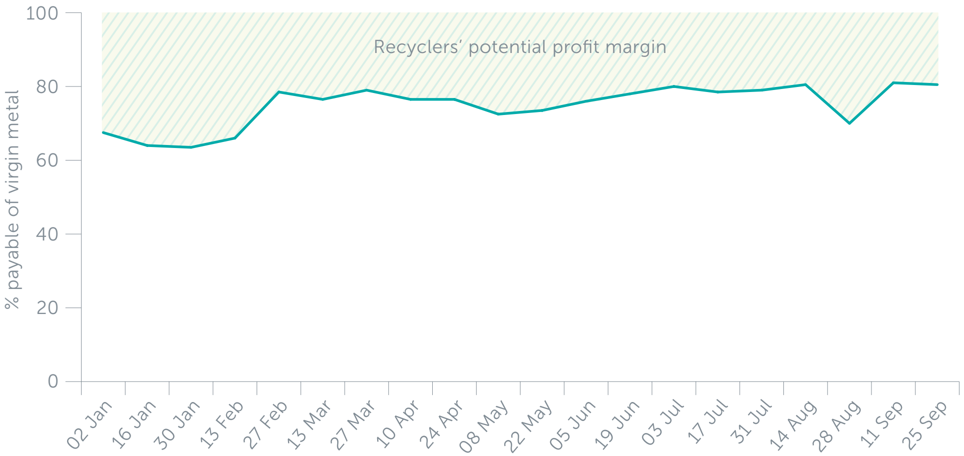


Figure 16: Battery recycling and cost margins
Source: Benchmark black mass pricing data 2025



"The profitability of the refining industry is highly dependent on black mass pricing. Black mass pricing dictates the cost margins for refiners."

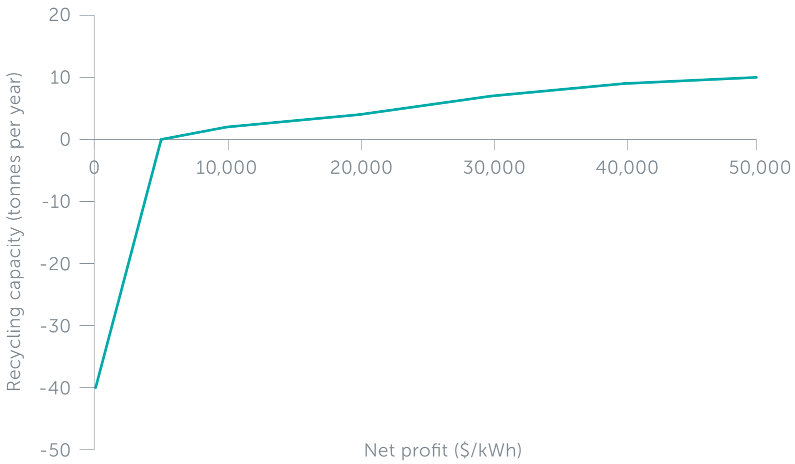
[7] Sodium sulphate challenges
[8] Recycling transport fire risks

In hydrometallurgy recycling, profitability depends on the scale of the processing plant. Larger plants benefit from economies of scale, helping offset the cost barriers posed by higher electricity and labour costs. Additionally, compliance and safety costs, particularly those related to the safe disposal of by-products such as sodium sulphate, add further financial pressure.

These challenges lead to a minimum viable scale for plant profitability. As shown in Figure 17, this is estimated to be at least 10,000[9] tonnes of feedstock per year needed to support recycling capacity and operate the refining plants profitably. Due to the operational cost differences and the ease of exporting waste batteries to China, there is currently less incentive to set up refining plants in Europe and the UK[10].

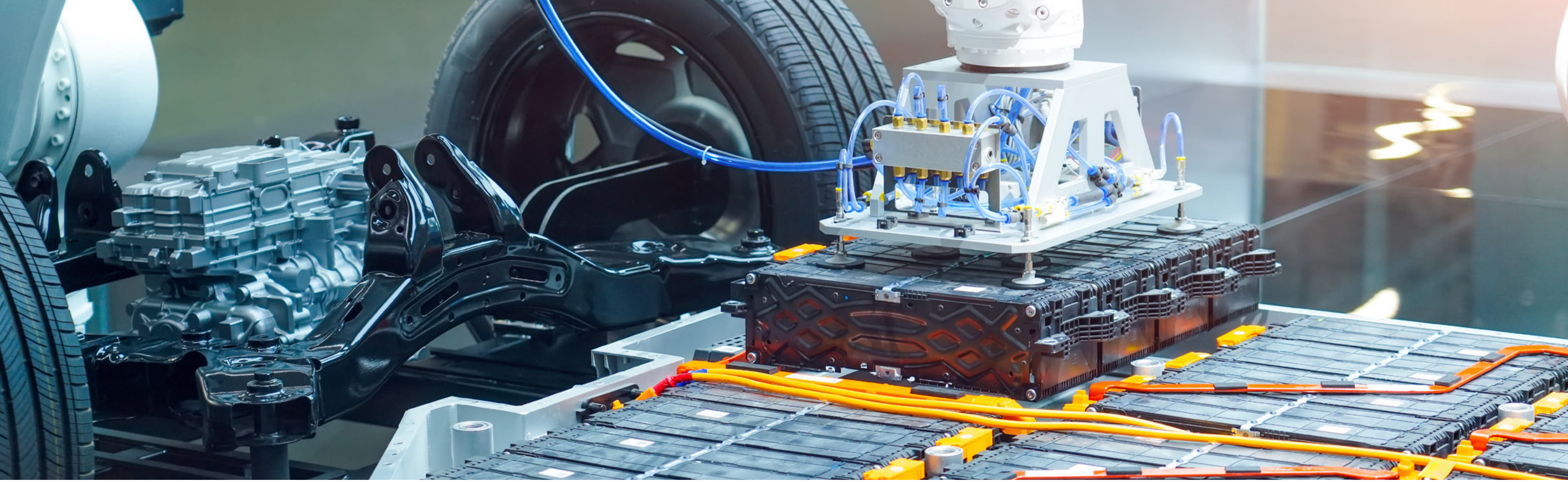
Figure 17: Net-recycling profit for hydrometallurgy refining

Source: Laura Lander.et.al 2021



"In hydrometallurgy recycling, profitability depends on the scale of the processing plant."

[9]Financial viability of electric vehicle lithium-ion battery recycling
[10]T&E recycling analysis



Recycling difficulties in Lithium Iron Phosphate (LFP) batteries:

Recycling alternative battery chemistries like LFP presents a wider challenge due to the absence of profitable metals, like nickel, cobalt, and manganese. This issue will get increasingly important as the EU increasingly adopts affordable EVs utilising LFP batteries over the next 15 years as shown in Figure 18.

Currently, European recyclers impose a gate fee for taking end-of-life batteries for recycling. This fee is due to the uncertainty surrounding the economic value of refined black mass, driven by limited scale and volume. The gate fee for LFP batteries is an order of magnitude higher than for nickel-manganese-cobalt (NMC) batteries due to LFP's lower profitability, as shown in Figure 19. This has complicated the recycling operations of LFP batteries in the EU.

[11] Fastmarkets research

Figure 18: APC demand report forecast and of growing importance of LFP chemistry in Europe

Source: APC Q2 2025 demand report

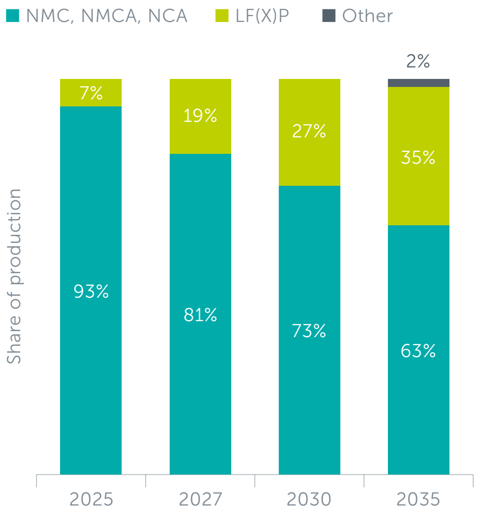
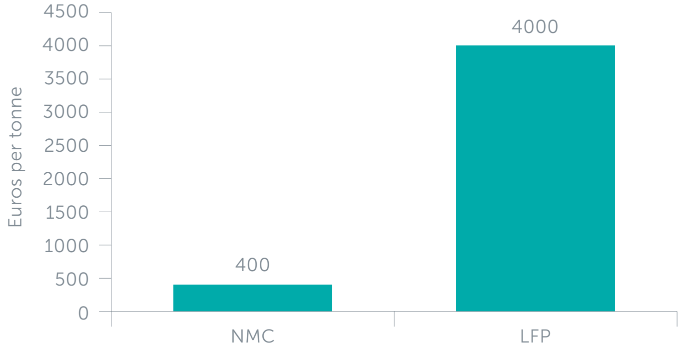


Figure 19: Gate fees for recycling with NMC and LFP[11]

Source: Fastmarkets, 2024



8. Conclusions and Recommendations

The future for battery recycling in the UK is promising and exciting, with the potential to meet up to one-fifth of the UK automotive production demand by 2035. Battery recycling demand is primarily driven by EU regulations mandating minimum recycling and recovery targets for critical materials such as lithium, nickel, and cobalt. However, several barriers could prevent the acceleration of battery recycling infrastructure in the UK:

1. **Cost and economic challenges:** The lack of scale and volume, particularly in refining black mass, has increased recycling cost per GWh, making it unprofitable within Europe. This issue is more pronounced for chemistries like LFP, which contain less valuable metals, resulting in even lower profitability.

2. **Technical issues:** Battery pack dismantling difficulty is a significant issue, creating complexity for the recycling business model. The lack of access to battery management systems, the difficulty of removing the upper cover of the pack, disconnecting the high-voltage cables, and the reliance on intensive manual process.

3. **Environmental and safety concerns:** Hydrometallurgy refining involves handling corrosive chemicals and hazardous by-products like sodium sulphate, which adds to compliance and safety management costs.

4. **Battery waste export challenges:** Despite recent EU black mass waste classification, there remains a risk of material being exported to OECD refining countries like South Korea and Japan. This makes the economics of recycling in Europe challenging. The UK faces vulnerability due to its lack of equivalent scale and volume compared with Europe, making it harder to compete for refinery plants.

"The future for battery recycling in the UK is promising and exciting, with the potential to meet up to one-fifth of the UK automotive production demand by 2035."

The following recommendations could help address the above challenges:

Category	Challenge	Recommendations
Disassembly	Labour-intensive process to dismantle battery packs	**R&D Investment:** Invest in automated, adaptable disassembly platforms to handle evolving battery chemistries and pack designs.
Production in the UK	Lack of scale and volume in the UK for black mass refining	**Scale-up:** Gigafactory production scrap will dominate for the next 5 years. Ramping up gigafactory capacity is key to ensuring the availability of feedstock.
Cost for refining (particularly hydrometallurgy process)	Handing the cost of aggressive chemical by-products like sodium-sulphate	**R&D investment:** Explore alternative cost-reducing processes, such as bio-inspired leaching and chromatography methods. Focus on LFP-based recycling in Europe.
Economic and operational challenge	High transport and a challenging return process for end-of-life batteries	**Establish:** Set up integrated recycling hubs to co-locate dismantling, shredding, and refining to reduce cost and maximise efficiency.
Battery waste challenge	Risk of export of black mass product outside the region	**Regulation:** Strengthen UK policy to retain black mass within the UK, encouraging recycling facilities with the necessary scale.

9. Glossary

BEV	Battery electric vehicle
CAM	Cathode active material
EU	European Union
EoL	End-of-life
LFP	Lithium iron phosphate batteries
NMC	Lithium nickel-manganese-cobalt-oxide batteries
OECD	Organisation for economic co-operation and development.
pCAM	Pre-cursor cathode active materials
R&D	Research and development

Technical definitions

Secondary materials: The chemical elements recovered from production waste and end-of-life batteries rather than from virgin mines.

Pre-treatment: Pre-processing of waste batteries before it is shredded to black mass for refinement

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Further information

If you have any questions or would like more detail on any of the graphs or data email info@apcuk.co.uk

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