ZERO WASTE SCOTLAND

TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Scottish Enterprise

BATTERY USE IN SCOTLAND NOW AND IN THE FUTURE

PHASE 1 - MAPPING THE CURRENT BATTERY SECTOR IN SCOTLAND

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Investing in a Smart, Sustainable and Inclusive Future

FOREWORD

Scotland's world-leading targets to help end the climate crisis include fuelling half of Scotland's heat, transport and electricity demand from renewable sources by 2030.

Achieving this rapid transition from fossil fuel producer and consumer to global pioneer of green power will involve a huge transformation of our energy systems. To get there, we need to move from centralised to local energy supplies and establish abundant energy storage to ensure supply meets demand.

We will also need more options for zero emission transport, such as electric vehicles. The UK Government's decision to outlaw the sale of new petrol and diesel cars by 2030 is accelerating the consumer shift to electric cars.

This rising use of electric vehicles is increasing the demand for batteries to power them. In parallel to this, the last decade has also seen an explosion in ownership of smart phones, laptops and other portable consumer electronics all powered by rechargeable batteries.

All batteries have a limited primary life span. But at their ultimate end-of-life they still contain valuable and potentially hazardous metals and other materials that should be collected and reprocessed. We need a system in place to keep batteries in use for as long as possible, and then to reuse the materials they contain in other ways. With no such system, the growth in demand will put unsustainable pressure on already vulnerable supply chains, depleting raw materials on a global scale.

The single biggest cause of the climate crisis in Scotland is everything we produce, consume and too often waste. Keeping products like batteries in a loop of use through the circular economy is key to ending this waste and the damaging emissions it creates.

It is already possible to reuse, repurpose, and remanufacture batteries but this is not currently taking place in Scotland at any significant level. As a result, these precious resources are being exported to other countries for disposal and recycling – losing their value and increasing carbon emissions.

Embedding the circular economy in Scotland's transition to green energy to help end the climate crisis would retain these resources and their value within our borders as use of batteries grows. This would give Scotland a way to produce batteries which reduces carbon emissions and creates significant new job opportunities in the process. Future innovation should also focus on producing new batteries designed with end-of-life in mind, which are easy to disassemble to increase their value.

This research is the result of an important new collaboration between Zero Waste Scotland, Transport Scotland, and Scottish Enterprise. This joint work recognises that future policy decisions will affect the growth in battery use and production in Scotland, and their wider environmental and economic impact. Our key objectives were to assess the current battery sector in Scotland, in order to identify the potential for Scottish companies to improve sustainability and increase circularity within the supply and disposal chains.

In this report, the first of three from the research, the current battery sector in Scotland has been mapped out. We looked at all batteries, recording the different quantities, types and uses, including how they are treated at end-of-life. The report evaluates the current systems and regulations in Scotland to see whether they enable the nation to recover maximum value from batteries. It also looks at several case studies from across Europe to assess what Scotland could learn from different approaches elsewhere. In addition, it includes a review of published literature, interviews with key stakeholders and analysis of sales and waste data.

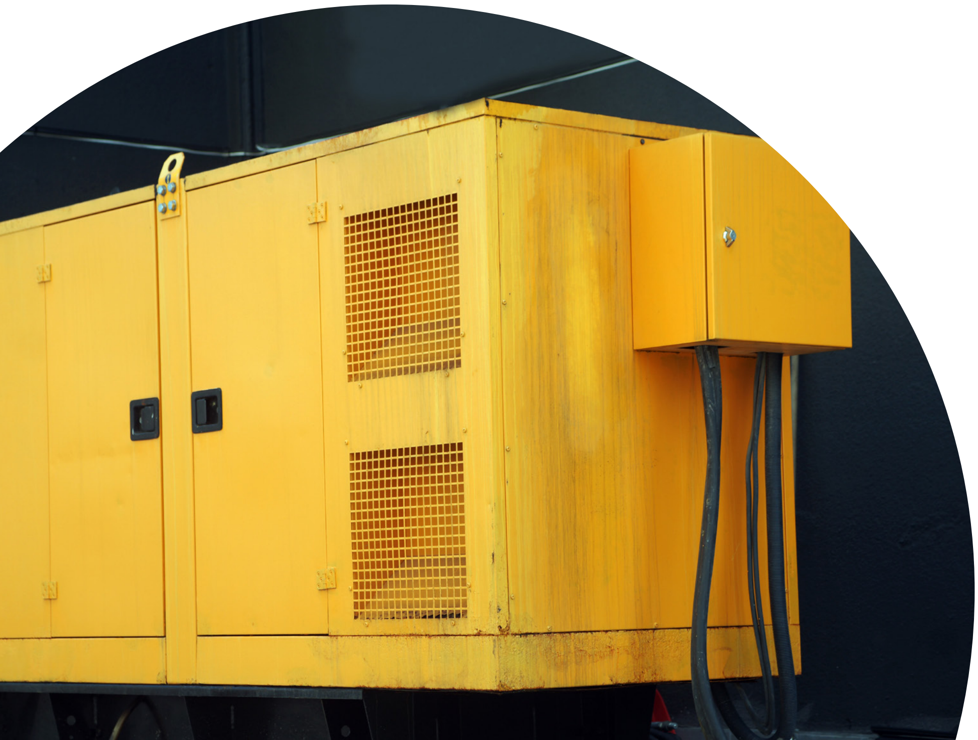
We now have a clearer understanding of how batteries are used and disposed of across Scotland to help inform policy decisions, data management, collection infrastructure, and waste management solutions to improve the sustainability of the battery supply chain. This information and knowledge will help in efforts to ensure the Scottish Government achieves its aim of ending the nation's contribution to the climate crisis by 2045.

This is the first time that Zero Waste Scotland, Transport Scotland and Scottish Enterprise have worked together as a project team to take a joined-up approach to the material aspects of the increasingly decarbonised transportation system. This sector will undergo rapid and transformational change in the next decade and we firmly believe that embedding a circular economy approach will deliver a just and prosperous transition for Scotland.

Zero Waste Scotland exists to lead Scotland to use products and resources responsibly, focusing on where we can have the greatest impact on climate change. Using evidence and insight, our goal is to inform policy, and motivate individuals and businesses to embrace the environmental, economic, and social benefits of a circular economy. We are a not-for-profit environmental organisation, funded by the Scottish Government and European Regional Development Fund.

Transport Scotland is the national transport agency for Scotland, delivering the Scottish Government's vision for transport.

Scottish Enterprise is Scotland's national economic development agency committed to growing the Scottish economy for the benefit of all, helping create more quality jobs and a brighter future for every region.



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1 INTRODUCTION

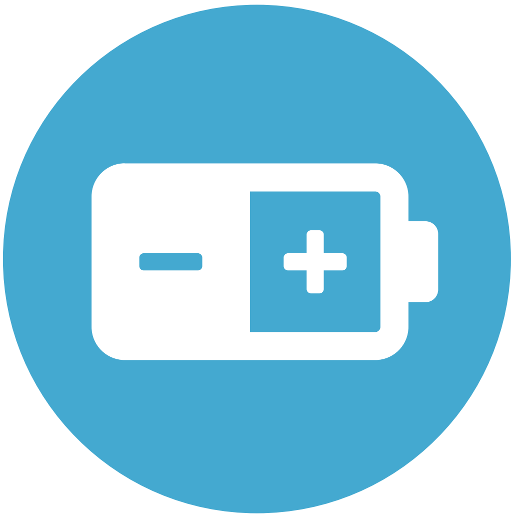
Batteries have the potential to serve as a key technology in the move to a more circular and decarbonised society as they provide flexible energy use and the ability to store renewable electricity. In doing so batteries have the potential to support the transition to a more fair, economically viable, sustainable future as imagined in the United Nation's Sustainable Development Goals. However, to achieve the sustainability benefits that batteries can offer, greater attention needs to be applied to their production, use and end-of-life phases. To ensure their sustainable deployment it is important that the regulatory and policy framework within which batteries operate is sufficiently robust.

The Batteries Directive[1] is transposed in the UK as the Waste Batteries and Accumulators Regulations (2009)[2]. The legislation originally came into force in 2006, and therefore does not take into account more recent objectives including the European Green Deal, Circular Economy Action Plan and Industrial Strategy for Europe[3]. Similarly, within the UK and Scotland, the inability of the Directive to address negative externalities affecting the environment (for example, resulting from the significant extraction of raw materials, or from energy and water intensive recycling processes) render it outdated and not aligned with Scotland's Circular Economy ambitions or the UK's Industrial Strategy and Environment Bill. The main focus of current legislation is to minimise the negative impact of batteries and accumulators.

The regulations classify batteries depending on their use, defining the following types:

- Portable batteries (those used in laptop or smartphones, and the typical cylindrical AAA or AA size and button cell batteries).
- Automotive batteries (e.g. for starting a vehicle engine or powering its lighting system) excluding traction batteries for electric vehicles (EVs)).
- Industrial batteries (e.g. for energy storage or for mobilising vehicles such as fully electric vehicles or electric bikes).

Since the current legislation has been in force a much wider variety of batteries and chemistries have been developed. The current regulatory framework has not managed to keep pace with these technological developments. For instance, the Directive outlines that recycling processes should recover the metal content to 'the highest degree that is technically feasible', without setting a specified target for doing so, and solely covers lead and cadmium, overlooking the wider range of chemical types which now exist. It is not just the battery technologies and chemistries that has changed but the scale of battery use.



[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006L0066-20131230&rid=1
[2] https://www.legislation.gov.uk/uksi/2009/890/contents/made
[3] https://ec.europa.eu/commission/presscorner/detail/en/QANDA_20_2311

On average, the worldwide battery market increased by 9% per year between 2010 – 2017[4] with global capacity demand set to reach a capacity demand of 2,600 Gigawatt hours (GWh) in 2030[5]. The Faraday Institution suggests that based on electric vehicle demand alone, the UK will need 140 GWh of battery production, equivalent to seven 'Gigafactories'[6].This growth is driven by moves towards a decarbonised society through centralised electric energy systems[7], increased global use of energy from renewable sources, and a shift towards non-carbon mobility. This shift will incorporate a rapid expansion in ownership of electronic devices[8], and expanding access to off-grid communities. The Scottish Government has set ambitious net zero targets for 2045 and it is widely accepted that battery adoption and associated infrastructure development is necessary. Whilst this growth will undoubtedly bring positive outcomes in emissions reductions, the vast use of often increasingly scarce resources including cobalt, lithium, nickel and manganese (with potential negative social impacts), and the sharp increase in environmentally toxic and often dangerous waste, mean that without careful management batteries could bring serious environmental consequences.

Already the impact of this is being realised, with battery waste in the EU rising by 29% between 2004 and 2014[9]. Following this, data suggests that, in 2015, 45.3% (128,000 tonnes) of waste portable batteries were not collected at all, with research carried out over seven countries suggesting an estimated 35,000 tonnes of waste portable batteries were disposed of as part of municipal waste[10]. This figure looks set to rise, with forecasts suggesting that in the next 20 years electric vehicles are estimated to create more than 11 million tonnes of battery waste worldwide each year[11]. Such market growth represents massive potential for any industry looking to provide goods and services which can be electrified. However, this transition is also highly complex as technologies develop manufacturing and end-of-life options and processes become much more important and challenging.

As Scotland seeks to respond to the challenges of grid and transport decarbonisation in continuing support of nationwide connectivity, via the use of personal electronics, it is imperative that battery use and waste are effectively managed, and the related opportunities maximised. In realising the capacity of applying circular principles to this important sector, Scotland can align social, economic and environmental objectives allowing the creation of a responsive and suitable energy mix, as well as a connected and accessible digital economy fit for the future.

1.1 Project aims

Zero Waste Scotland, Transport Scotland and Scottish Enterprise (hereafter referred to collectively as the Project Group), have commissioned Ricardo Energy & Environment to;

- Provide a detailed picture of current battery use in Scotland;
- Give short to medium-term projections for how that will develop, including specific electric vehicle battery projections; and
- Make recommendations for future policy/ regulation considerations to improve the sustainability and support a greater level of circularity across the entire battery life cycle.

[4] https://ec.europa.eu/environment/waste/pdf/Published%20Study%20Implementation.pdf

[5] http://www3.weforum.org/docs/WEF_A_Vision_for_a_Sustainable_Battery_Value_Chain_in_2030_Report.pdf

[6] https://faraday.ac.uk/wp-content/uploads/2020/03/2040_Gigafactory_Report_FINAL.pdf

[7] https://faraday.ac.uk/wp-content/uploads/2020/03/2040_Gigafactory_Report_FINAL.pdf

[8] https://faraday.ac.uk/wp-content/uploads/2020/01/High-Energy-battery-technologies-FINAL.pdf

[9] https://ec.europa.eu/commission/sites/beta-political/files/swd-report-batteries-accumulators-april2019_en.pdf

[10] https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_recycling_of_batteries_and_accumulators

[11] https://airqualitynews.com/2020/03/26/new-reusable-battery-to-tackle-the-problem-with-ev-waste/#:~:text=This%20raises%20a%20new%20issue,battery%20waste%20worldwide%20each%20year.&text=This%20will%20enable%20Aceleron%20to,'buy%2Dback'%20scheme.

The first phase of the project, as covered in this report (Phase 1), includes a review, gap-analysis and assessment of available battery lifecycle data, incorporating placed-on-the-market and end-of-life data and reporting routes. This is augmented by literature and desktop research, and a series of targeted, structured stakeholder interviews with regulators, compliance scheme operators, approved treatment operators and exporters, and academics. All of this is combined to present a thorough picture of the current battery supply chain and end-of-life situation in Scotland, along with a high-level discussion of the challenges and opportunities related to increasing the circularity of battery use.

The following phases of the project will build from this foundation to make projections for future battery use in Scotland, looking separately at electric vehicle batteries, and all other batteries. This will include consideration of potential developments and innovations in battery chemistries and manufacture processes, the economics of battery recycling and reuse, and impacts of potential policy interventions at the Scottish, UK and EU levels.

1.2 Methodology followed

This report details the results of Phase 1 of the research project, which focuses on developing a quantitative and qualitative understanding of the current levels of battery use in Scotland, and the associated regulatory and end-of-life processes.

The activities completed to develop this understanding were:

- Analysis of available battery supply and end-of-life data
- High-level policy and literature review
- Stakeholder engagement interviews

The methodology followed is described in the remainder of this section.

1.2.1 Data analysis

Data accessed

In order to understand the current levels for all battery use and end-of-life in Scotland data was sourced from the National Packaging Waste Database (NPWD)[12], the Office for Product and Safety Standards (OPSS)1[3], the Department for Environment, Food and Rural Affairs (DEFRA)[14] and the Scottish Environment Protection Agency (SEPA)[15].

For portable batteries, NPWD provided data in tonnes, from 2010 to 2019 and split between three chemistry types: Lead Acid (Pb/Acid), Nickel Cadmium (Ni-Cd), and 'other'. It included UK-wide summaries of portable batteries:

- Placed on the market (POM).
- Collected by battery compliance schemes.
- Delivered by battery compliance schemes to approved battery treatment operators (ABTO) and approved battery exporters (ABE).
- Received by ABTO and ABE.

For industrial and automotive batteries, the NPWD covered UK summaries, for the same date ranges and chemistry split, of;

- Batteries received by ABTOs and ABEs for 2010 – 2019
- Batteries POM for 2017 – 2019 (this was NPWD provided explicitly by OPSS is it is not publicly published)

For the broad category of batteries & accumulators, the following data were initially accessed:

- From DEFRA: the total of batteries & accumulators waste generated and sent to final treatment in England and the UK in tonnes, from 2012 to 2016

[12] https://npwd.environment-agency.gov.uk/
[13] https://www.gov.uk/government/organisations/office-for-product-safety-and-standards
[14] www.gov.uk/government/organisations/department-for-environment-food-rural-affairs
[15] www.sepa.org.uk/

- From SEPA: batteries & accumulators waste from all sources in tonnes, from 2011 to 2018 and covered whether battery waste was generated and disposed of in Scotland or elsewhere, and whether the waste batteries were recycled in Scotland or elsewhere
- From SEPA: batteries & accumulators waste entering and leaving approved waste management facilities in tonnes, from 2007 to 2019 and split between five chemistry types: PB/Acid, Ni-Cd, mercury-containing, alkaline and 'other'

As the DEFRA data did not provide any granularity on battery type and chemistry, and covered the whole of the UK, we excluded it from this data analysis. Similarly, since the SEPA dataset on waste entering and leaving approved waste management facilities did not provide any granularity on battery types, and did not include treatment methods, it was also excluded from this analysis.

Gaps, limitations and assumptions
Based on the data available for this study, the following gaps and limitations were identified:

- General low granularity of battery chemistry (two named types and 'other').
- No granularity in battery applications and chemistry types for battery waste in Scotland.
- No Scotland specific POM data for portable batteries.

To support filling these gaps the following assumptions were made:

- To estimate the split between the different battery applications and chemistry types of the SEPA waste data, Ricardo calculated a 10-year average from 2010 to 2019 of proportions of applications and chemistry using NPWD's batteries accepted/received by ABTO's and ABE's.
- To estimate the Scottish share of battery POM and waste in NPWD's data, Ricardo used the share that the Scottish population represents in the UK. Data from the Office for National Statistics[16] was used to calculate a 10-year average from mid-2010 to mid-2019. The result of this calculation is an average share of 8.28%.

Based on the gaps identified and the assumptions that Ricardo could make, it was decided to keep only NPWD's data, including that provided directly from OPSS, as it was providing the best level of granularity for battery use and waste, and for battery type and chemistry.

1.2.2 Policy and literature review
Before conducting the full literature review, it was important to gauge the policy landscape. This high-level overview looked at the key European and UK legislation which deals directly with battery use and end-of-life:

- EU The Batteries and Accumulators and Waste Batteries and Accumulators Directive (2006/66/EC)
  - o Including proposed new Regulation resulting from review of the Directive
- UK Waste Batteries and Accumulators Regulations 2009

With clarity on the policy and regulatory framework a wider literary review was conducted.

Review of key sources
The literature review used the following sources as a basis from which to better understand the available research, and to better identify any knowledge gaps which existed. These knowledge gaps could then be specifically addressed through the stakeholder consultation activities.

The Faraday Institution
As the UK's 'flagship battery research programme'[17], The Faraday Institution provides research which maps all aspects of the battery market, including:

- Economics
- Commercial potential
- Energy storage capacity
- Forecasts for future transition to a fully electric UK

Scotland's Energy Future[18]

This report, produced by Royal Society of Edinburgh sets out to inform public policy and was

selected to give perspective to Scotland-specific challenges faced in attempting to meet energy requirements, whilst ensuring carbon reduction targets are achieved.
The report looks at some of the options available to Scotland and attempts to quantify the potential challenges and advantages of each, including:

- Economic and infrastructure implications for scalability of low carbon technologies.
- The need for well-considered policy, which takes into consideration a range of competing issues including climate change, affordability, security and longevity.
- Necessity for Scottish and UK Governments to increase collaboration in order to ensure robust and sustainable energy policy.

The report provides projections for battery demand in Scotland's energy future, and was selected to better understand potential challenges and opportunities which may influence the market.

Automotive batteries: A £4.8bn a year supply chain opportunity by 2030 for UK[19]

This report highlights the chemical sector supply chain opportunities for low carbon vehicle demand growth. It mainly provides future projections, however it also provides useful insight into the current supply chain, including:

- Domestic availability of resources, including nickel and graphite cokes
- The curent flow of batteries, namely from the Asian battery market
- Existing gaps in the supply chain

Whilst this report focuses on automotive batteries and potential for the chemical sector, it was chosen as it provides valuable insight into the UK battery supply chain and examines opportunities for the development of battery manufacturing within the UK.

Specify research topics
Having used the initial resources described above to create a high-level view of the market, it was determined that in order to fully answer the research questions, key areas had to be identified and research had to be targeted towards these areas:

- Battery types
- Market
- End-of-life considerations
- Regulation & Policy

A brief summary of the key information sources which were able to contribute to these, are listed in **Table 1.1**.

16 www.ons.gov.uk
17 https://faraday.ac.uk/about-2/
18 https://www.rse.org.uk/wp-content/uploads/2019/06/Energy-Report-for-Web-2.pdf
19 https://www.apcuk.co.uk/app/uploads/2019/04/Automotive-Batteries-Report-Summary-April-2019.pdf

Year	Author	Document type	Report Title	Topics			
				Battery types	Market	End-of-life	Policy
2020	The Faraday Institution	Report	High Energy Battery Technologies	✓	✓	✓	
2020	Ofgem	Action Plan	Ofgem decarbonisation programme action plan		✓		
2019	European Commission	Project report	Circular Economy Perspectives for the Management of Batteries used in Electric Vehicles	✓		✓	
2019	Scottish Power	Scenario modelling	Scottish Power's scenarios for Central and South Scotland		✓		✓
2019	Royal Society of Edinburgh	Stakeholder evidence	Scotland's Energy Future				✓
2019	Advanced Propulsion Centre	Report	Automotive batteries: A £4.8bn a year supply chain opportunity by 2030 for UK chemical and material companies	✓	✓		✓
2018	European Commission	Legislation	2019. COMMISSION STAFF WORKING DOCUMENT on the evaluation of the Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators and waste batteries and accumulators	✓			✓

Table 1.1 Key information sources consulted

Gaps, limitations and assumptions

- There is a lack of detailed literature covering purely the current Scottish market (as was the focus of this Phase of the project) however, due to Scotland's highly interlinked trade and manufacturing relationship with the UK & EU and associated regulatory alignment, the UK and EU context is still relevant to Scotland.
- The assumption was made, and supported by stakeholder feedback, that following EU-Exit, much of the legislative framework will be closely aligned with the EU and therefore assessment of European market behaviour in response to legislation was considered relevant.
- Case studies were considered a useful means to illustrate differences in markets and end-of-life activities. In developing these, we considered it important to select countries similar in size to Scotland, under the assumption that this would be a much closer and therefore more valuable comparison.

The literature review laid out the current EU and UK policy context, and identified some good-practice approaches from other countries. The stakeholder engagement was designed to allow a targeted approach to filling the gaps in insight into how the Scottish system currently works in practice, and what opportunities there may be to improve its efficiency and circularity.

1.2.3 Stakeholder engagement

The primary objective of the stakeholder interview process was to collect information, expert opinion and insight from a wide range of stakeholders, to complement the desktop research and data analysis. The contacts were also asked to identify any further stakeholders across the battery value chain in Scotland who may be able to provide further insights or additional data sources.
The initial long list of stakeholders included regulators, compliance and collection schemes, operators, exporters, trade associations, manufacturers and academic institutions. From a long list of 55 stakeholders, 21 key organisations were chosen in collaboration with the Project Group, based on the collective knowledge of the Scottish battery value chains. Each category was represented in the short list, which is shown in **Table 1.2**.

Interviews were conducted during November and December of 2020 and January 2021 by members of Ricardo's project team. Interview questions were derived from the main project research questions, as outlined by the Project Group, and were then tailored to the type of stakeholder and specific business context.

Stakeholder Type	Number invited to interview	Reason for selection	Number completed
Regulators	5	Insights on regulatory environment and cumulative data	3
Operators	3	Insights on Scottish business context	1
Trade Associations	4	Trends and market growth, regulatory environment	1
Exporters	1	Information on export routes from Scotland	0
Compliance Schemes	5	Quantitative data and insights on policy & market trends	4
Collection Schemes	1	Quantitative data	0
Academia	2	Information on current research and novel technologies	1

Table 1.2 **Stakeholders invited and interviews completed**

2 POLICY REVIEW

2.1 European Union legislation

The Batteries and Accumulators and Waste Batteries and Accumulators Directive

The EU Batteries Directive (2006/66/EC) requires the compulsory collection and recycling of batteries and accumulators, the prevention of batteries and accumulators entering incineration or landfill, and the restriction of hazardous substance use. Responsibility for the safe management of batteries is placed on designers, manufactures and distributors. The Directive covers both primary batteries (i.e. non-rechargeable or disposable) and secondary batteries (i.e. accumulators or rechargeable) which are classified according to their use:

- portable batteries (e.g. for laptops, or smartphones or typical cylindrical AAA or AA-size batteries);
- automotive batteries (e.g. for starting a car's engine or powering its lighting system) excluding traction batteries for electric cars; and
- industrial batteries (e.g. for energy storage or for mobilising vehicles such as fully electric vehicles or electric bikes)

In December 2020, The European Commission published proposals for a revision of the Battery Directive, which intends to align sustainability objectives and join up the value chain for the treatment and management of batteries. This update, to be named the Battery Regulation, has been a result of developments in battery technologies, applications and sustainability requirements.

2.1.1 EU Batteries Directive Review (Regulation proposal, December 2020[20])

The development and production of batteries is an integral part of the EU's Green Deal[21], to ensure a reduction in greenhouse gas emissions and a transition to clean energy, especially in the transport sector. Therefore, the EU has stated that they aim to modernise the legislative framework for batteries to introduce circular design requirements throughout the battery life cycle. Including requirements to ensure that they are produced sustainably and can easily be reused or recycled.

The EU Commission is currently in the process of consulting on proposed legislative changes, with the consultation running until March 2021.

[20] https://ec.europa.eu/transparency/regdoc/rep/10102/2020/EN/SWD-2020-335-F1-EN-MAIN-PART-1.PDF

[21] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Green Deal (COM (2019) 640 final)

The policy options proposed by the EU are categorised into three levels of ambition - medium, high and very high - and include:

- A new classification for EV batteries, with a differentiation via weight of Portable and Industrial
- Producers of industrial and EV batteries could be obligated to provide a carbon footprint declaration
- Introduction of specific recycling/recovery targets per chemistry type with an emphasis on recycling efficiency has also been proposed, as well as an increase in the collection target for portable batteries to 65-70%
- Introduction and increase of target levels could also lead to mandatory levels of recycled content within batteries in the future.

To increase the circularity of batteries placed on the European market, the EU has proposed that there could be stronger obligations on design to ease removal and replacement of spent batteries. This could include labelling and technical documentation improvements to help increase end-user engagement to ensure suitable disposal of batteries at end-of-life.

More clarity of Extended Producer Responsibility (EPR) specification will be provided in the new legislation, for example, the second life of a battery will count as a new 'product' therefore EPR obligations for the new product will sit with the 're-manufacturer', not the original producer.

Measure 8[22] in the EU's Regulation proposal considers the regulation of non-rechargeable portable batteries to address the issue of their environmental impact. The options proposed range from the 'medium' level ambition of setting technical parameters for performance and durability, to the 'very high' level of a total phase out, with the former being the most likely course of action.

There is also the possibility of introducing electronic 'passports' for Industrial and EV batteries to have better traceability of them through their life-cycle.

During our stakeholder interviews, there was general agreement that regardless of EU-Exit taking place, any changes to the EU Battery Directive will still have an impact on UK possibilities within the European market and that, therefore, there is a need for future policy alignment.

2.2 United Kingdom legislation

Waste Batteries and Accumulators Regulations 2009

The Waste Batteries and Accumulators Regulations 2009 (as amended) implement the EU Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators (Batteries Directive). These Regulations apply to:

- all types of batteries, regardless of their shape, volume, weight, material composition or use; and
- all appliances into which a battery is or may be incorporated.

Under the UK's battery regulation, all producers of batteries are responsible for minimising negative effects of waste batteries on the environment and are required to pay for waste battery collection, treatment, recycling and disposal, following EPR principles. All producers are required to register with the relevant environment regulator (e.g. EA, SEPA, OPSS) and declare data confirming the chemistry and tonnage of batteries they have placed on to the market each year. Further details of the data declaration requirements are provided in **Section 4.1**.

Portable battery producers which place more than one tonne of batteries on to the market per year are required to register with a battery compliance scheme. There are currently five approved compliance schemes; BatteryBack, Ecosurety, ERP UK Ltd, REPIC and Valpak[23]. These compliance schemes simplify recycling and compliance on behalf of producers, and provide means of battery collection and sorting. For instance, ERP UK Ltd collects batteries from over 20,000 collection points in the UK: including shops, offices and schools[24]. Membership of the scheme requires payment to cover the collection, treatment and recycling of any batteries placed onto the market. For organisations placing less than a tonne of portable batteries on to the market, they must still register with an environmental regulator and submit tonnage and chemistries[25]. Producers of Industrial and Automotive batteries can choose to register with a compliance scheme or register directly with OPSS.

Scotland currently does not have any devolved legislation in place for batteries and accumulators. Organisations operating within the Scottish battery market are required to adhere to the UK-wide regulations.

2.3 Country case studies

Whilst the UK prepares to consult on and amend the Waste Batteries and Accumulators Regulations 2009, it is helpful to provide a few high-level examples of how the EU Battery Directive has been implemented in other countries.

The three examples detailed in this section (France, Croatia & Republic of Ireland) have been chosen to show a range of systems which have been implemented and have a higher portable batteries collection rate than the UK. The current collection target set out in the Batteries Directive[26] is 45% for portable batteries. There are no collection targets for industrial or automotive batteries. According to Eurostat data[27], Croatia has the highest portable battery collection rate for recycling in Europe at 96%, Ireland at 51% and France at 47%. The UK is currently reaching 45% collection rate for portable batteries recycling.

In comparison to the UK, these countries also require a greater granularity of chemistry type when producers declare the tonnage of batteries they place on to the market each year.

2.3.1 France

The EU Battery Directive was transposed into French law by decree n°2009-1139 of 22 September 2009 pertaining to marketing of B&A and disposal of B&A waste. It covers all types of batteries and accumulators (portable, automotive & industrial).

There are two principle battery compliance schemes in France for portable batteries - Screlec[28] and Corepile[29]. Together they operate 59,000 collection points in France[30]: 41% of tonnages are collected in retail stores, 29% by local authorities and 30% from other holders (schools, businesses, dismantlers, etc.). ERP in the UK have confirmed that in 2019 56% of portable batteries collected via their network came from local authority sites and 44% from other collection points, no further breakdown of 'other' available without further analysis. While in 2020, ERP saw a drop in local authority collections (possibly due to site closure because of Covid-19) to 52% while other increased to 48%. Other compliance scheme operators consulted on this point confirmed that, in absence of detailed analysis, they would expect their collection network to have similar percentage split to France.

Industrial battery producers in France are also able to join compliance schemes to offset their obligations under the regulations, however, industrial battery producers must organise the take back and disposal of their batteries individually.

[22] EC - Section 7.8. Measure 8: Non-rechargeable portable batteries p.52 (https://ec.europa.eu/transparency/regdoc/rep/10102/2020/EN/SWD-2020-335-F1-EN-MAIN-PART-1.PDF)
[23] https://npwd.environment-agency.gov.uk/PublicRegisterBatteriesSchemes.aspx
[24] https://erp-recycling.org/uk/batteries/
[25] https://www.gov.uk/guidance/waste-batteries-producer-responsibility
[26] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006L0066-20131230&rid=1
[27] https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_recycling_of_batteries_and_accumulators
[28] https://www.screlec.fr/
[29] https://www.corepile.fr/
[30] https://www.ademe.fr/sites/default/files/assets/documents/010008_rep_panorama2015_ven.pdf

There are currently no approved compliance schemes for automotive batteries. Producers of automotive batteries can transfer their obligations to users (other than household end users), by written agreement. The value chain for disposal of these batteries is self-financed by the automotive battery producers and is dictated by the market value of lead.

Obligated producers are required to submit data declarations to confirm the tonnage and quantity of batteries they have placed on to the French market in a given year. Portable battery producers are required to provide details on a much larger range of battery chemistries than in the UK, including: alkaline; saline; button cells; lithium; lithium-ion; nickel metal hydride; nickel cadmium; acid-free lead; zinc-air, 'other'.

Waste battery collectors are also required to sort the batteries into these chemistry categories as well which allows for a much higher recovery rate for valuable materials. Since there are a number of batteries recycling facilities available in France, including but not limited to:

- EURO DIEUZE INDUSTRY
- SNAM
- PAPREC D3E
- ERAMET
- WHITE METAL
- STCM
- GDE
- RECYLEX

The compliance schemes are able to ensure that the majority of the batteries they collect are recycled in France. For example, in 2019, Screlec collected 5,682 tonnes of used portable batteries and accumulators, a collection rate of 49%[31]. According to Screlec's annual report[32], 95% of the batteries they collected were recycled in France[33]. The recycling rate is between 50-80% depending on the electrochemical makeup of the battery. Based on Corepile's 2018 data, for 1 tonne of recycled cells and batteries, they were able to recover 420kg of zinc and zinc compounds, 260kg of iron and nickel-based alloys and 100kg of various metals such as cobalt or lead[34]. Comparative country-level data could not be found at the time of this report to set this in context with other nations' performance.

This data is reported consistently, showing that greater granularity of reporting is feasible within a complex supply chain. Similar reporting requirements in Scotland would allow for a more intuitive understanding of levels of battery usage and end-of-life volumes, and a subsequent ability to appreciate trends and make specific arrangements or interventions if deemed advantageous to circular economy aspirations.

2.3.2 Croatia

Croatia has the highest collection rate for portable batteries in Europe. Croatia's successful system is due to a relatively well-organised EPR system for collecting sold batteries and accumulators for recycling[35].

This takes place through seven companies registered with the Fund for Environmental Protection and Energy Efficiency (EPEEF), which has been established since 2007. Furthermore, the Ordinance on batteries and accumulators was adopted in 2015, consolidating previous legislation from 2006 and 2013 and prohibiting landfill disposal or incineration of waste batteries and accumulators[36] to authorised concessionaries having a contract with the Fund.

On average, the collection fee that the EPEEF receives amounts to (inc. VAT):

- 12,00 kn/kg for the quantities of waste portable batteries and accumulators accepted from the holder
- 7,50 kn/kg for the treatment operator for the treatment and/or recycling of waste portable batteries and accumulators
- 7,50 kn/kg for the treatment operator to cover the costs of export of waste portable batteries and accumulators that cannot be treated and/or recycled in the Republic of Croatia

Whilst Croatia is a relatively small country, with a corresponding sized market for batteries, the EPEEF[37] has invested in new collection systems and modern recovery facilities to encourage the treatment of waste within Croatia, and to only export the waste that cannot be treated because of the lack of technology/facilities[38].

For example, lead plates from waste accumulators cannot be melted in Croatia as there isn't a lead melting plant in the country.

[31] https://www.screlec.fr/jai-20-ans-decouvrez-le-rapport-annuel-2019-de-screlec/
[32] https://www.screlec.fr/wp-content/uploads/2020/06/screlec_rapport-annuel-2019_web-1.pdf
[33] https://www.screlec.fr/screlec-french-compliance-scheme-for-batteries-and-accumulators/
[34] https://www.corepile.fr/circuit-des-piles-et-batteries/valorisation/
[35] https://www.total-croatia-news.com/lifestyle/45508-eurostat
[36] https://ec.europa.eu/environment/waste/pdf/Published%20Study%20Implementation.pdf

The other parts of the accumulator are recovered, but lead plates are exported. In addition, there has been a lot of work done on raising public awareness to provide better results in waste recovery in future. All of which has enabled them to be successful in driving up the number of batteries being collected and recycled.

Under Croatia's Battery Ordinance and Waste Act, authorised collectors and treatment operators are reimbursed by the Fund for all quantities of batteries and accumulators recycled and recovered. Whilst all collected batteries and accumulators have been sent for recycling, with the exception of Ni-Cd batteries for which there is no domestic recycling facility. Mandatory reporting is also in place for all collectors and treatment operators to ensure monitoring of adherence to the Directive. There are eight companies authorised to collect waste batteries and accumulators in Croatia[39]. Three companies are authorised to disassemble accumulators. Hazardous waste exported from Croatia to Serbia, Slovenia, and the former Yugoslavia Republic of Macedonia or recycling includes lead from car batteries and accumulators.

The Ordinance also requires recyclers to report information on recycling efficiencies to the Croatian Agency. Regular site inspections at authorised collection facilities and landfills are carried out to ensure adherence to regulations.

2.3.3 Republic of Ireland

Obligated producers of portable, industrial and automotive batteries in Ireland are required to register with the national registration body on an annual basis - Producer Register Limited. Distance sellers of batteries placed on to the Irish market are considered as obligated under the Irish regulations [Reference - The Waste Management (Batteries and Accumulators) Regulations 2008 S.I. No. 268 of 2008] and are required to appoint an Authorised Representative (with a physical presence in Ireland) to act on their behalf.

To ensure the environmentally sound management of waste batteries producers can choose to either self-comply or join a compliance scheme. There are two battery compliance schemes which producers can join - WEEE Ireland or European Recycling Platform (ERP) Ireland. WEEE Ireland represents 96% of the Irish battery industry.

[37] https://www.fzoeu.hr/en/waste_management/special_categories_of_waste/waste_batteries_and_accumulators/
[38] https://sustainabledevelopment.un.org/content/documents/dsd/dsd_aofw_ni/ni_pdfs/NationalReports/croatia/waste.pdf
[39] https://unece.org/DAM/env/epr/epr_studies/ECE_CEP_172_En.pdf

The two compliance schemes also operate collection networks in partnership with retailers, schools, businesses and also by holding special events (for example, promoting European Battery Recycling Week). The compliance schemes are allocated specific local authority regions in which they can operate and collect waste batteries from civic amenity sites. WEEE Ireland operates across 75% of Ireland whilst the remaining 25% is covered by ERP. WEEE Ireland has confirmed the below split for their collection network[40]:

Business	Education	Health	Local Authority Recycling Centre	Public	Retail	Special Events	Waste Industry
16%	1%	2%	29%	1%	38%	1%	11%

All producers of batteries are required to submit monthly data declarations to the WEEE Blackbox - which is run independently by Deloitte. The data declaration is broken down into the following categories and chemistry types:

- Portable batteries - Non-rechargeable
    - o Alkaline
    - o Lithium
    - o Zinc Carbon
    - o Zinc Air
    - o Mercuric Oxide
    - o Silver Oxide
    - o Other
- Portable batteries – Rechargeable
    - o Nickel Cadmium
    - o Lead
    - o Nickel Metal Hydride
    - o Lithium Ion
    - o Lithium Polymer
    - o Other
- Automotive batteries
    - o Lead
    - o Acid
    - o Nickel Cadmium
    - o Other
- Industrial batteries
    - o Lead Acid
    - o Nickel Cadmium
    - o Nickel Metal Hydride
    - o Alkaline
    - o Lithium Ion
    - o Zinc Carbon
    - o Zinc Air
    - o Other

To increase their recovery rate of portable batteries, WEEE Ireland worked with the Mixed WEEE recycling facility KMK Metals to incorporate an additional screening process to identify any WEEE which contains batteries. Since 2014, KMK Metals "has recovered over 200 tonnes of waste portable batteries (the equivalent of 8 million AA batteries) that would otherwise be lost from national waste battery statistics"[41]. KMK Metals sorts the waste batteries by chemistry - Nickel Metal Hydride (NiMH), NiCd, Li-ion or Lithium.

All remaining batteries reach the end of the conveyor and are collected as are Alkaline/Zinc Carbon Batteries. No batteries are recycled in the Republic of Ireland, instead, KMK Metals and other treatment operators transport them to dedicated facilities in the UK and Germany[42].

[40] Insight gained via email correspondence with WEEE Ireland (29th January 2021)
[41] WEEE Ireland Annual Report 2019, p.19 (http://www.weee-ireland.ie/wordpress/wp-content/uploads/2019/06/WEEE-Ireland-environmental-report-2018.pdf)
[42] https://www.kmk.ie/battery-recycling/battery-sorting-separation

3 THE BATTERY LIFECYCLE

There are six main stages to the lifecycle of batteries:

1. **Raw material extraction**
2. **Manufacture/Production**
3. **Import & Sale**
4. **Use**
5. **Disposal, collection and sorting**
6. **Recycling and reuse**

These stages, and how they are currently administered in the UK, are presented in **igure 3.1**, with further detail on key processes and reporting requirements given in the following Sections.

Figure 3.2 presents an indicative material flow for batteries leaving and entering the Scottish market, based on data estimates calculated in **Sections 4 and 5** of this report.

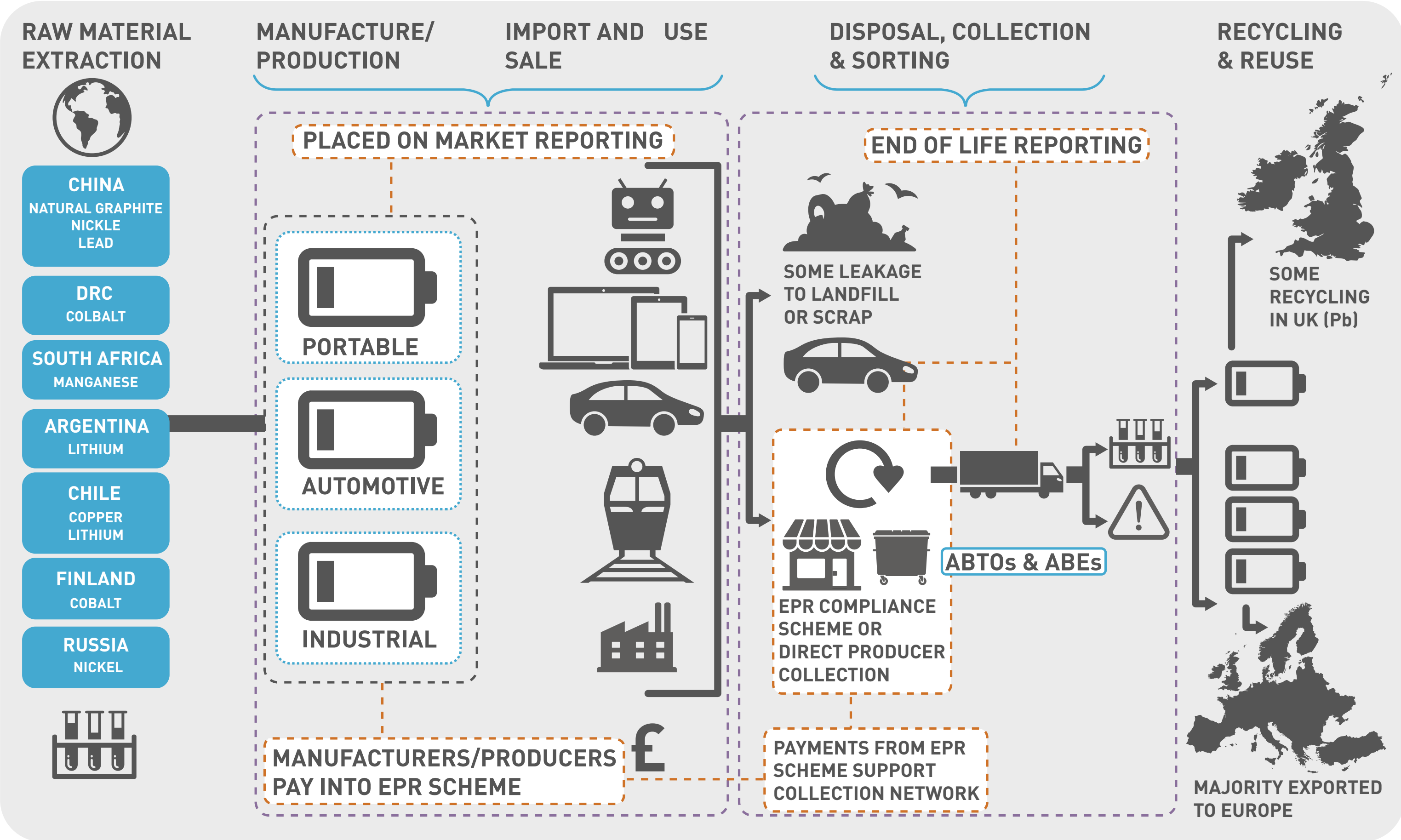


Figure 3.1 The battery lifecycle in the UK *(Source: Ricardo composition for this study)*

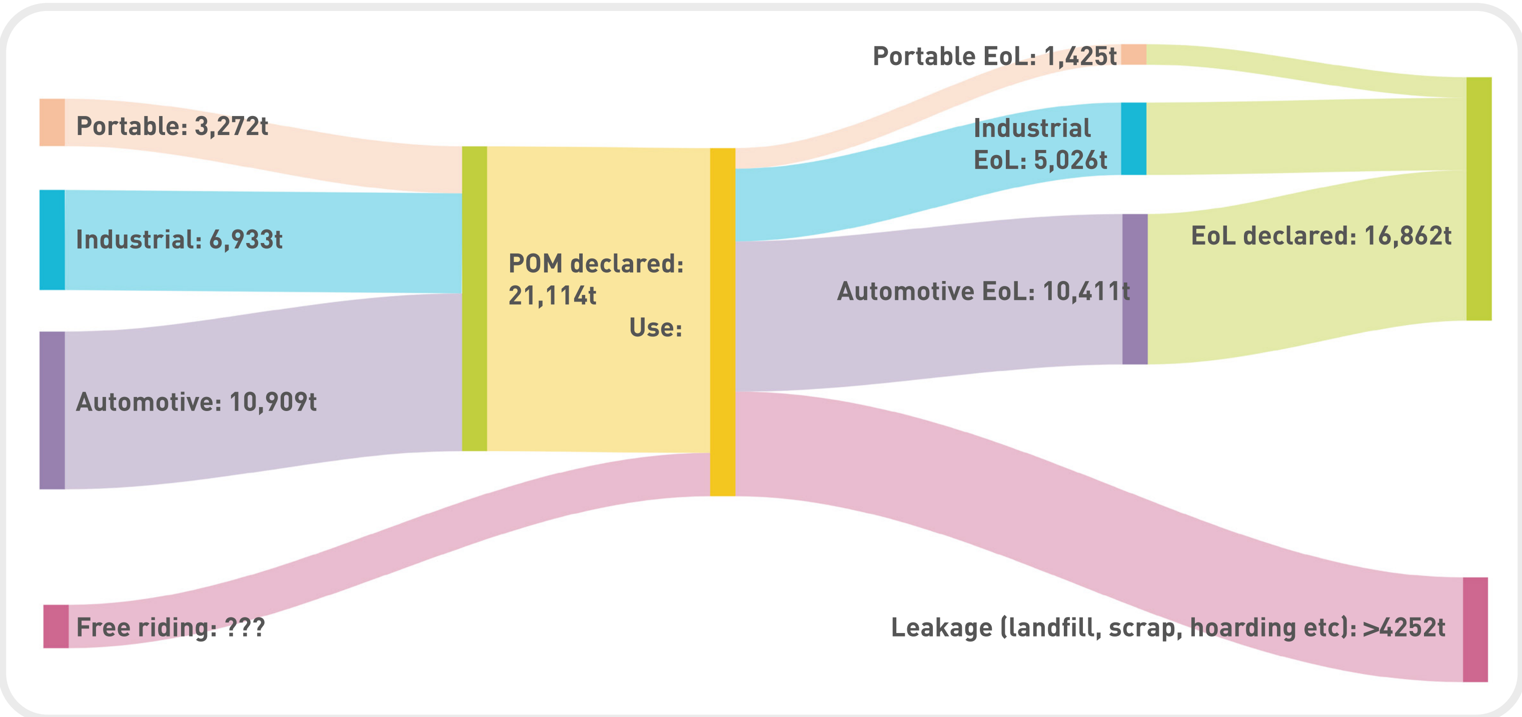


Figure 3.2 Indicative battery material flows in Scotland for 2019, in tonnes *(Source: Ricardo composition for this study)*
Note: Estimated tonnages from calculations detailed in Sections 4 and 5 of this report, and free-riding is discussed in Section 7.

The majority of batteries used in Scotland are imported, either directly from countries such as China, Japan, South Korea, USA and the European Union, or they enter Scotland after initially being imported into England.

There are a small number of battery manufacturers based in Scotland, including manufacture of actual cells and import of cells to build bespoke battery applications, examples of these include:

- AMTE Power[43] who produce lithium-ion batteries for the automotive, aerospace, defence, oil & gas and energy storage sectors.
- Denchi Group Ltd[44] who mainly produce a range of battery chemistries and types for the security and defence sector, but also for oil and gas and medical industries.
- MEP Technologies[45] design and manufacture battery packs and system solutions for a diverse range of markets.

Throughout the lifecycle of a battery, its origin, chemistry and type have to be considered to ensure safety in shipping and storage. Understanding different battery chemistries can help determine whether they are non-hazardous, hazardous or dangerous, and therefore what the appropriate handling requirements and recycling possibilities are. Common chemistries and classifications are shown in **Table 3.1**.

Chemistry	Definition	Uses
Alkaline, Manganese, Zinc, Zinc Carbon, Zinc Air (not rechargeable)	Non-hazardous	Remote controls, smoke detectors, torches
Nickel Metal Hydride = NiMH (rechargeable)	Non-hazardous (not dangerous by road, dangerous by sea)	Potable power applications such as power tools
Nickel Cadmium = Ni-Cd (rechargeable)	Hazardous	Toys, photographic equipment, emergency lighting
Automotive Batteries = Pb[46]= LEAD = WET (Acid) LEAD (rechargeable)	Hazardous & dangerous	Car or truck lead, not electric vehicle
Sealed Lead Acid= Pb = LEAD (not a liquid, but a gel) (rechargeable)	Hazardous & dangerous	Automobile staring, lighting and ignition, backup power supplies
Lithium – Lithium-ion (Li-ion) (rechargeable)[47]	Non-hazardous, dangerous	Laptops, electric cars, mobile phones
Lithium-Metal (Li) – e.g. coin size (not rechargeable)	Non-hazardous, dangerous	Pacemakers

Table 3.1 Common battery chemistries, classifications and uses

[43] https://amtepower.com/
[44] https://www.denchipower.com/
[45] http://meptec.co.uk/about.aspx
[46] Some Pb batteries can give a positive economic return on recycling, depending on the market, however other chemistries have a negative cost. Costs vary all the time.
[47] Lithium would then further be divided into Li-ion rechargeable, Li-ion other, lithium metal (non-rechargeable) and lithium with other chemistries.

4 BATTERIES PLACED ON THE MARKET IN SCOTLAND

4.1 Battery data reporting requirements

Producers of portable batteries must declare the tonnage of batteries per chemistry type they place on to the market. Small producers are required to complete an annual data declaration by 31st January each year. In comparison large battery producers are required to declare on a quarterly basis. A large producer's obligation (and compliance fee) is calculated based on the tonnage and chemistry data provided for the previous two years and the current compliance year.

Producers of industrial and automotive batteries must declare the total tonnage, chemistry type and brand name of the batteries placed on to the market for each compliance year by 31st March.

Automotive battery producers are required to collect automotive waste batteries from the final end-user for free and within a reasonable timescale. Industrial battery producers are also required to take back waste industrial batteries free of charge from end-users, irrespective of whether the end-of-life batteries in questions were originally placed on the market by them. Both automotive and industrial battery producers are also required to provide information to the relevant environmental regulator regarding the tonnage of waste batteries they have taken back or collected and delivered to ABTO's or ABE's.

4.2 Batteries placed on the Scottish market

Based on the methodology detailed in **section 1.3.1**, **Table 4.1** shows the estimation of the amount of portable batteries placed on the Scottish market in tonnes from 2015 to 2019 split by battery type and chemistry using NPWD's data with the Scottish population assumption applied, and **Table 4.2** shows the estimation of the amount of industrial and automotive batteries placed on the Scottish market in tonnes from 2017 to 2019 split by battery type and chemistry using OPSS's UK-wide data with the Scottish population assumption applied.

Type	Chemistry	2015	2016	2017	2018	2019
PORTABLE	**TOTAL**	**3,209**	**3,184**	**3,266**	**3,205**	**3,272**
	Pb / acid	191	157	141	115	100
	Ni - Cd	58	38	26	23	27
	Other	2,960	2,989	3,099	3,067	3,144

Table 4.1 Estimation of the amount of portable batteries placed on the Scottish market by type and chemistry in tonnes from 2015 to 2019

Type	Chemistry	2017	2018	2019
Industrial	**TOTAL**	**7,275**	**7,991**	**6,933**
	Pb	5,662	6,064	4,442
	Ni - Cd	260	173	138
	Other	1,353	1,755	2,354
Automotive	**TOTAL**	**12,893**	**13,620**	**10,909**
	Pb	12,880	13,438	10,565
	Ni - Cd	2	-	104
	Other	10	183	239

Table 4.2 Estimation of the amount of industrial and automotive batteries placed on the Scottish market by type and chemistry in tonnes from 2017 to 2019

Figure 4.1 shows the estimated trend of the amount of portable batteries placed on the Scottish market split by chemistry type from 2010 to 2019 in tonnes. Between 2010 and 2013, the estimated total amount of portable batteries placed on the Scottish market decreased by 15.30% before increasing from 2013 to 2019 (+7.61% over the period). When looking at the different types of chemistry, the quantity of batteries placed on the Scottish market for all types of chemistry was decreasing during the period 2010-2012 however, only the quantity of 'other' batteries started to increase in 2013 from 2,772 tonnes to 3,144 tonnes in 2019 (+13.44%). Indeed, the quantities of Pb/Acid and Ni-Cd kept declining over the same period. These opposing trends lead 'other' batteries to represent 96% of the total amount of portable batteries placed on the Scottish market (as opposed to 81% in 2010).

No firm product sales data was analysed to ascertain why this is, but it is likely to be linked to a continued rise in the use of items with batteries which do not fall into the traditional chemistry classifications, such as Li-ion batteries in smartphones and laptops. This illustrates one of the main issues of the current classification systems – the 'other' category is a catch-all and dominates the chemistry types. This will include batteries used widely in small household appliances and toys such as single use alkaline AA and AAAs, nickel based rechargeable batteries, lithium button cells, and batteries supplied 'free' with products which tend to be zinc-based. The breakdown of different chemistries within the 'other' category is obviously unclear for Scotland, but as an illustration the 2018 POM figures for France show that of the batteries which would fall into it, alkaline batteries were the most significant at around 59%, followed by lithium with 27%[48].

[48] https://www.ademe.fr/sites/default/files/assets/documents/piles-accumulateurs-donnees-2018-rapport-annuel.pdf

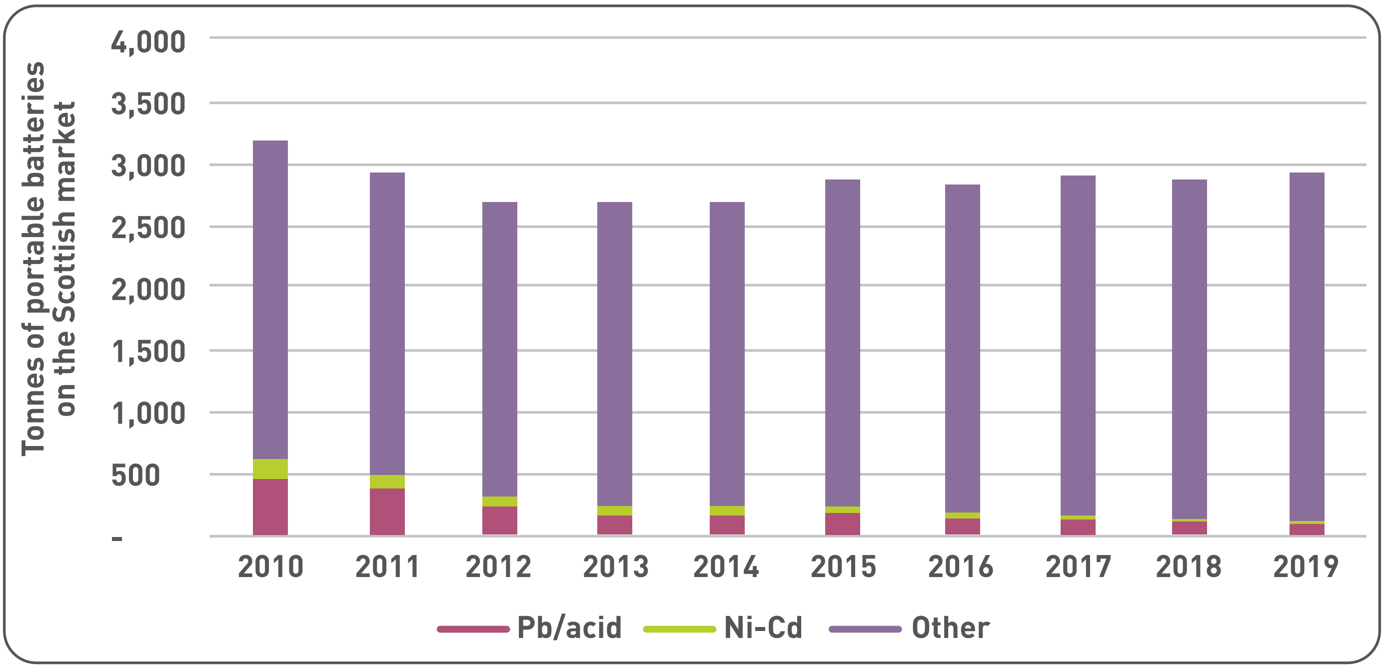


Figure 4.1 Estimated evolution of the amount of portable batteries placed on Scottish market by chemistry types in tonnes from 2010 to 2019

Figure 4.2 shows the estimated trend of the amount of industrial batteries placed on the Scottish market split by chemistry type from 2017 to 2019 in tonnes. Over this short period, the estimated total amount of industrial batteries placed on the Scottish market has been stable between 7,000 tonnes and 8,000 tonnes, however, the amount of Pb batteries placed on the Scottish market has been decreasing, compensated by an increase in 'other' batteries placed on the Scottish market.

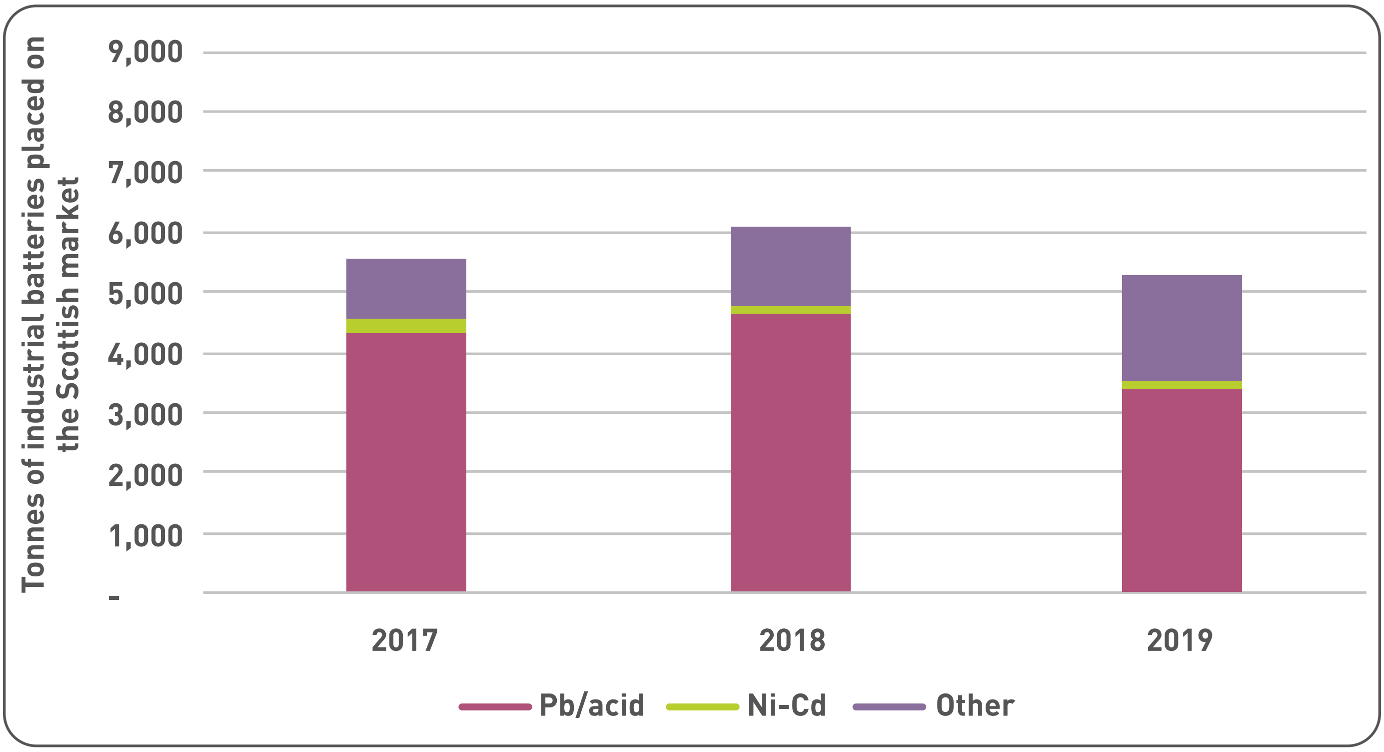


Figure 4.2 Estimated evolution of the amount of industrial batteries placed on Scottish market by chemistry types in tonnes from 2017 to 2019

Figure 4.3 shows the estimated trend of the amount of automotive batteries placed on the Scottish market split by chemistry type from 2017 to 2019 in tonnes. Even though automotive batteries are Pb only, the data shows that in 2019, an estimate of 104 tonnes of Ni-Cd batteries and 239 tonnes of 'other' batteries were reported, and in 2018, an estimate of 183 tonnes of 'other' batteries were reported. Over this short period, the estimated total amount of automotive batteries placed on the Scottish market has been slightly decreasing from 13,000 tonnes to 11,000 tonnes due to a decrease in the amount of Pb batteries placed on the Scottish market.

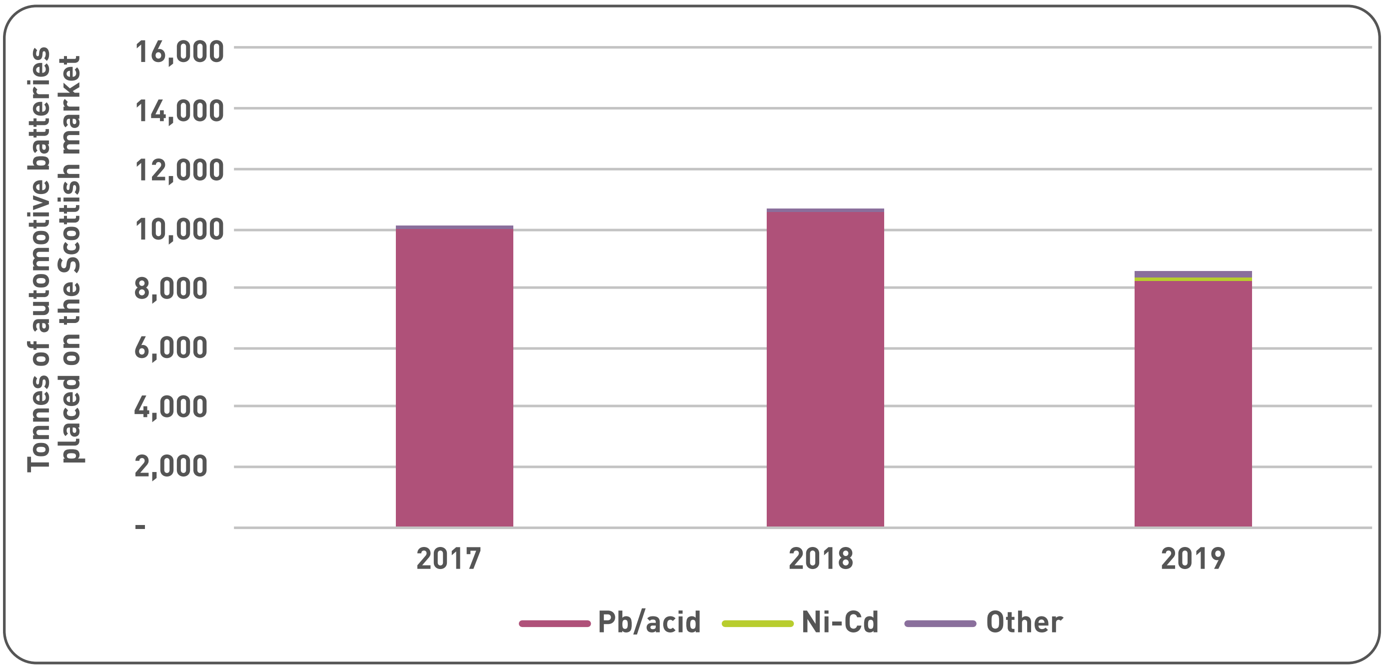
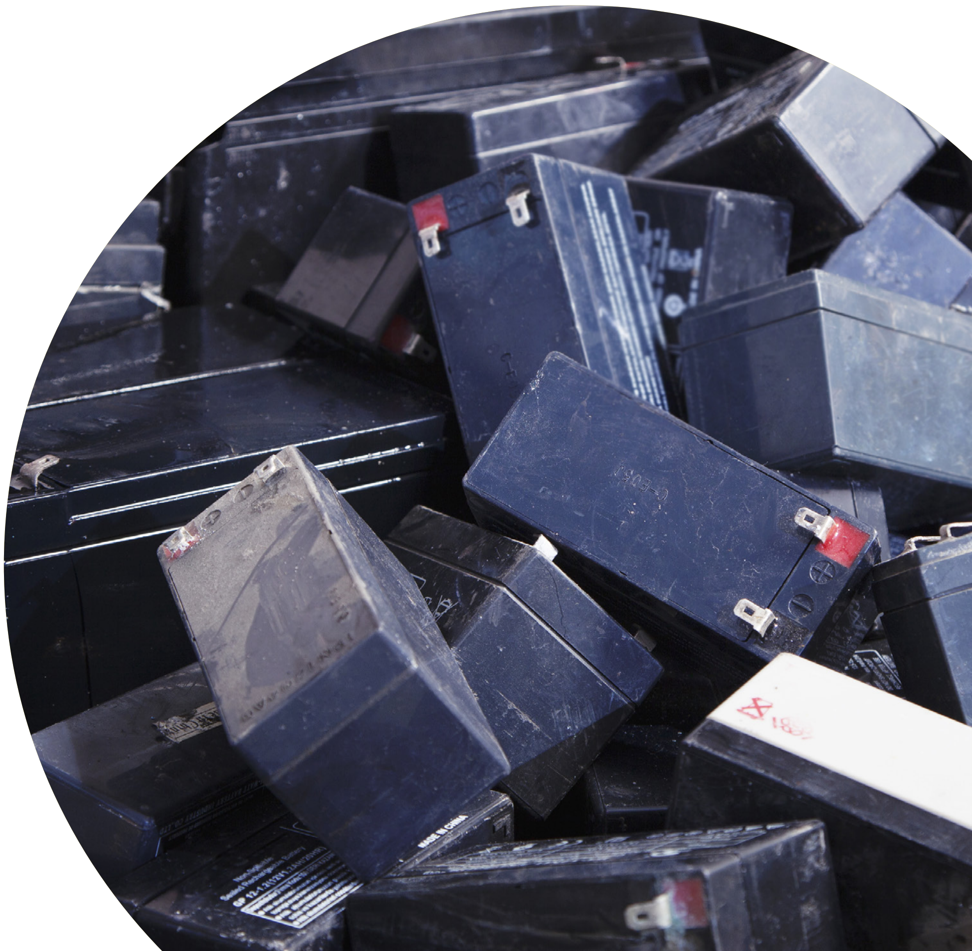


Figure 4.3 Estimated evolution of the amount of automotive batteries placed on Scottish market by chemistry types in tonnes from 2017 to 2019



5 DISPOSAL AND STORAGE ROUTES OF BATTERY WASTE IN SCOTLAND

5.1 Battery end-of-life process and reporting requirements

Portable

Producers of portable batteries which place more than 32kg of batteries on the UK market per year are required to provide end-consumers with a means to dispose of waste batteries. Portable battery producers can either set up their own collection networks or offset this requirement with membership of a compliance scheme. The compliance schemes offer a collection network for their members to join and provide collection tubes or boxes to be placed in visible locations, for example retail stores. The compliance schemes organise the logistical operation of waste battery collections from their networks across the UK. If batteries are incorporated into electrical equipment, these will be captured via WEEE collection points across the UK. The majority of WEEE collection points are provided in HWRCs run by local authorities, but also via retail stores as part of the producer's obligations. There is some level of battery removal from WEEE products by consumers.

Most batteries which are incorporated into electrical equipment will be removed during the pre-sorting process of Small Mixed WEEE (SMW), typically the material is grabbed and moved around then onto conveyors - during this many batteries are removed and the picked out manually by operatives. WEEE is then shredded and further mechanical/manual separation takes place, however, these batteries tend to be in a very poor condition. Approved authorised treatment facility are increasing the amount of manual removal from the SMW stream due to concerns over lithium batteries types and their volatility .

The collection infrastructure for waste batteries in Scotland is extensive for portable batteries. Compliance schemes have a collection network across Scotland, including the islands. Collection points tend to be located in retail outlets, schools, offices, community centres etc. Batteries which are collected from these points will be consolidated with those collected from Civic Amenity (CA) sites, where they are then collected by operators who will sort them into chemistry types for further processing.

Automotive & Industrial

Automotive battery producers are required to collect automotive waste batteries from the final end-user for free and within a reasonable timescale. Industrial battery producers are also required to take back waste industrial batteries free of charge from end-users. Both automotive and industrial battery producers are also required to provide information to the relevant environmental regulator regarding the tonnage of waste batteries they have taken back or collected and deliver to approved treatment operators or exporters. The collected waste batteries must then go to an ABTO or an ABE for treatment and recycling.

ABTOs and ABEs are then required to declare the tonnage of waste portable batteries on a quarterly basis and on an annual basis for waste industrial and automotive batteries to the relevant environmental regulator. The data declared must include the details of the site where waste batteries have been treated and the category and chemistry type of battery. ABEs must also include information on the total number of batteries evidence notes issued and which battery compliance schemes they accepted the waste batteries from.

Type	Chemistry	2015	2016	2017	2018	2019
Portable	**Total**	**1,261**	**1,426**	**1,439**	**1,426**	**1,425**
	Pb / acid	882	724	784	782	859
	Ni - Cd	33	43	82	75	63
	Other	346	660	573	569	503
Industrial	**Total**	**1,982**	**2,263**	**2,695**	**2,640**	**5,026**
	Pb / acid	1,937	2,213	2,648	2,594	4,975
	Ni - Cd	30	31	31	32	39
	Other	15	18	16	14	11
Automotive	**Total**	**11,533**	**12,779**	**13,466**	**13,110**	**10,411**
	Pb / acid	11,533	12,779	13,466	13,101	10,410
	Ni - Cd	0	0	0	0	0
	Other	0	0	0	9	1
TOTAL		**14,776**	**16,469**	**17,600**	**17,176**	**16,862**

Table 5.1 Estimation of the amount of battery waste in Scotland by type and chemistry in tonnes from 2015 to 2019

In Scotland, automotive batteries are mainly collected for disposal when a battery needs replacing. In many cases this takes place at a vehicle dealership and the producer of the battery (i.e. the car manufacturers) are responsible for end-of-life treatment. Alternatively, end-of-life vehicles enter the authorised treatment facilities (ATF) network to be recycled. There are a number of independent operators within the ATF network, but from our stakeholder interviews there are also believed to be a number of illegal operators taking end-of-life vehicles. If waste automotive batteries end up at an ATF operator, the operator will contact the producer on a case by case basis to arrange the most suitable method of recycling or disposal.

5.2 Baseline waste arisings

Based on the methodology detailed in **section 1.3.1, Table 5.1** shows the estimation of the amount of battery waste in Scotland in tonnes from 2015 to 2019 split by battery type and chemistry using NPWD's data with the Scottish population assumption applied.

Figure 5.1 shows the estimated trend of portable battery waste in Scotland, split by chemistry type from 2010 to 2019 in tonnes. Between 2010 and 2019, the estimated total amount of portable battery waste has increased from 358 tonnes to 1,425 tonnes (+298.16%). This is due to a significant increase of Pb/Acid battery waste between 2010 and 2013 (+465.66%) followed by a plateau, and a significant increase of 'other' battery waste between 2013 and 2016 (+586.70%) following a plateau since 2010 but followed by a decrease (-23.70%).

In total, across the three battery application categories, there is a consistent gap between volumes placed on the market and being reported at end-of-life, at an average of 5,900 tonnes over the last three years of complete data (2017-2019). Fully accounting for this gap is difficult. There are a huge range in battery lifetimes 'on the market' so we would not expect the POM and end-of-life figures to match exactly, but there is a known issue of batteries being disposed of incorrectly and therefore not being captured through the data reporting requirements of the EPR Compliance Schemes. This issue is likely to be particularly prevalent for small household item batteries, leading to a significant number being leaked from the system, albeit low in weight. Greater granularity in declaration of chemistries at all lifecycle stages, allied with an understanding and reporting of relevant expected lifetimes, would allow for more accurate future prediction of end-of-life volumes. This in turn would facilitate a better understanding of where the leakage from the system is occurring, and aid in the design and roll-out of specific measures to address it.

It is worth noting that the amount of portable batteries POM as detailed in **Table 4.1** is consistently around 100 tonne per year. However,

Table 5.1 highlights that the amount of portable batteries collected is consistently above 1400 tonnes. The anomaly can be explained by a 'bleeding' of batteries between categories. In effect, industrial batteries are being classified as portable at end-of-life. This is due to a lack of clarity on the definition of the different battery types.

It is also understood that industrial batteries are heavier and the 45% recycling target is easier to achieve through the collection of fewer larger batteries. This issue of bleeding of industrial into portable will also mask the leakage of portable batteries out of the system and lost to landfill/ incineration (final disposal).

The quantities of Ni-Cd portable battery waste have been slightly increasing over the 2010-2019 period but without effect on the total amount of portable battery waste as it represents only 4.44% of the total amount of battery portable waste in 2019. Over the same period Pb/Acid and 'other' portable battery waste represent respectively 60.25% and 35.31% of the total amount.

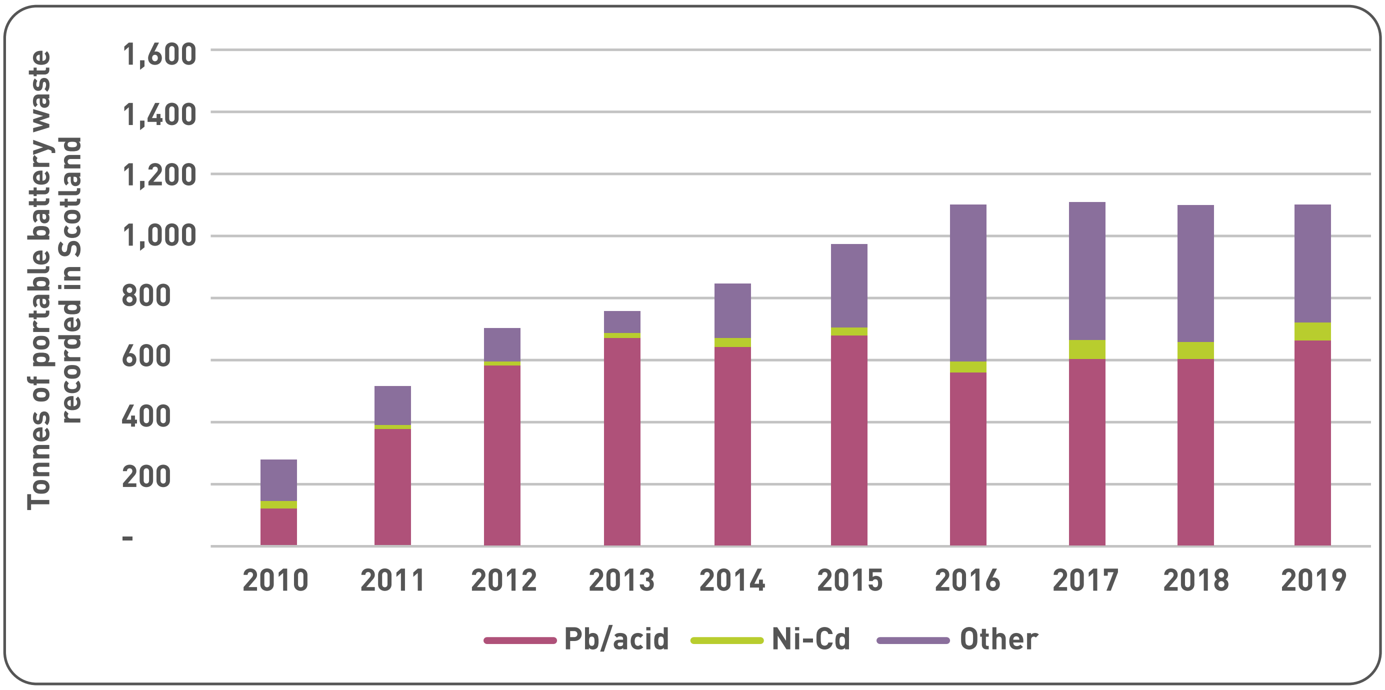


Figure 5.1 **Estimated evolution of the amount of portable battery waste in Scotland by chemistry types in tonnes from 2010 to 2019**

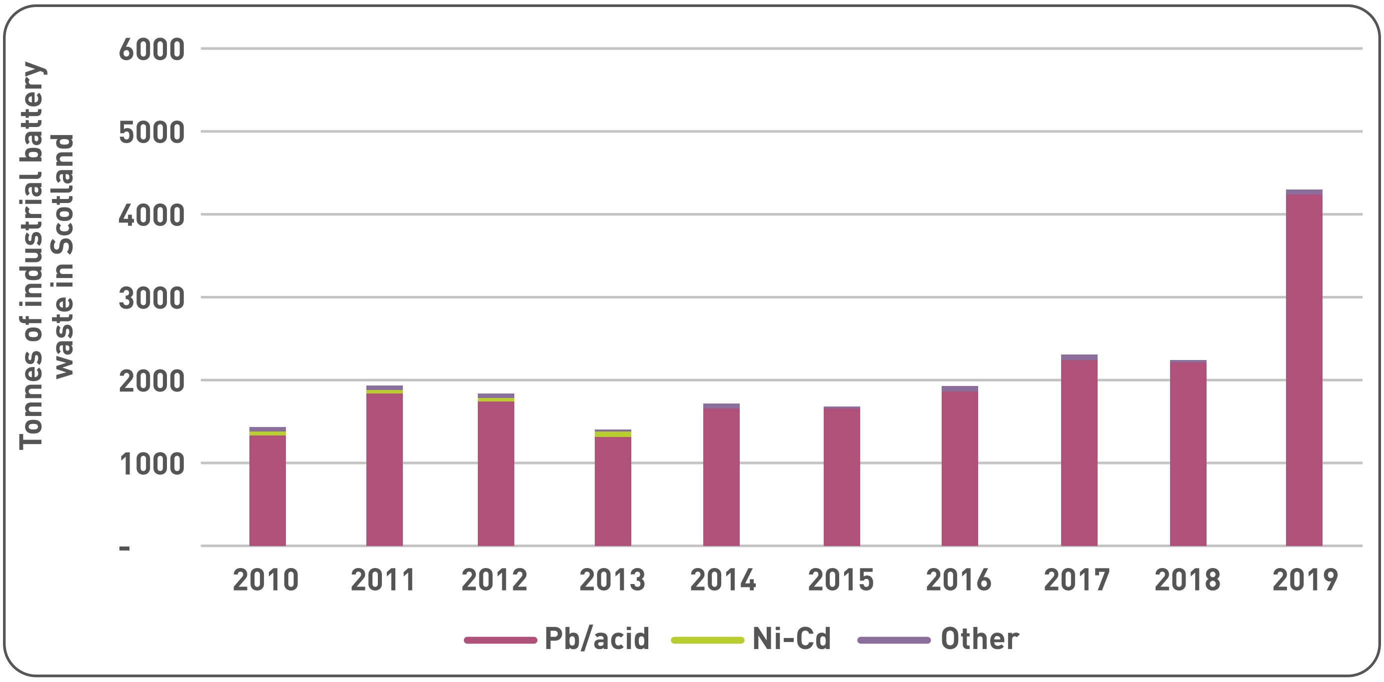


Figure 5.2 Estimated evolution of the amount of industrial battery waste in Scotland by chemistry types in tonnes from 2010 to 2019

The rapid increase in Pb/Acid during this period is particularly notable as the corresponding levels of POM reduced significantly, as described in **Section 4.2**. While it is obviously not realistic to expect a direct annual correlation of battery purchase and waste, the opposing trends are striking. One explanation for this, as was highlighted in several of our stakeholder interviews, is 'leakage' in the reporting of Pb/Acid batteries from the industrial categories to portable. The increase in Pb/Acid reported as portable battery waste corresponds with the introduction of the UK Waste Batteries and Accumulators Regulations 2009, which places responsibility of battery 'type' reporting with the treatment operators and imposes a weight-based target for recycling of portable batteries. Pb/Acid batteries are heavy, and cheaper to recycle than other common portable chemistries, rendering them an inexpensive way for targets to be met.

Figure 5.2 shows the trend of industrial battery waste in Scotland split by chemistry type from 2010 to 2019 in tonnes. The total amount of industrial battery waste in Scotland is mainly composed of Pb/Acid (99.00%). Over the period, the quantities of industrial battery waste were constant until it significantly increased between 2018 and 2019 (+91.80%).

Figure 5.3 shows the trend of automotive battery waste in Scotland split by chemistry type from 2010 to 2019 in tonnes. Even though automotive batteries are Pb/Acid only, the data shows that in 2018 and 2019, an estimate of 9.39 tonnes and 0.76 tonnes respectively of the chemistry type 'other' were reported. Therefore, the total amount of automotive battery waste in Scotland in 2019 is composed by Pb/Acid batteries at 99.99%. Over the period, the quantity of automotive battery waste has been increasing and decreasing periodically but stayed in the range of 10,000 tonnes and 14,000 tonnes. However, the latest decrease starting in 2017 is steeper than any previous change in trend. There is a broad correlation with reported end-of-life vehicle data for the UK reported through Eurostat[50], but this does not show 2019 figures and actually display a slight increase from 2017 to 2018.

[50] Statistics | Eurostat (europa.eu)

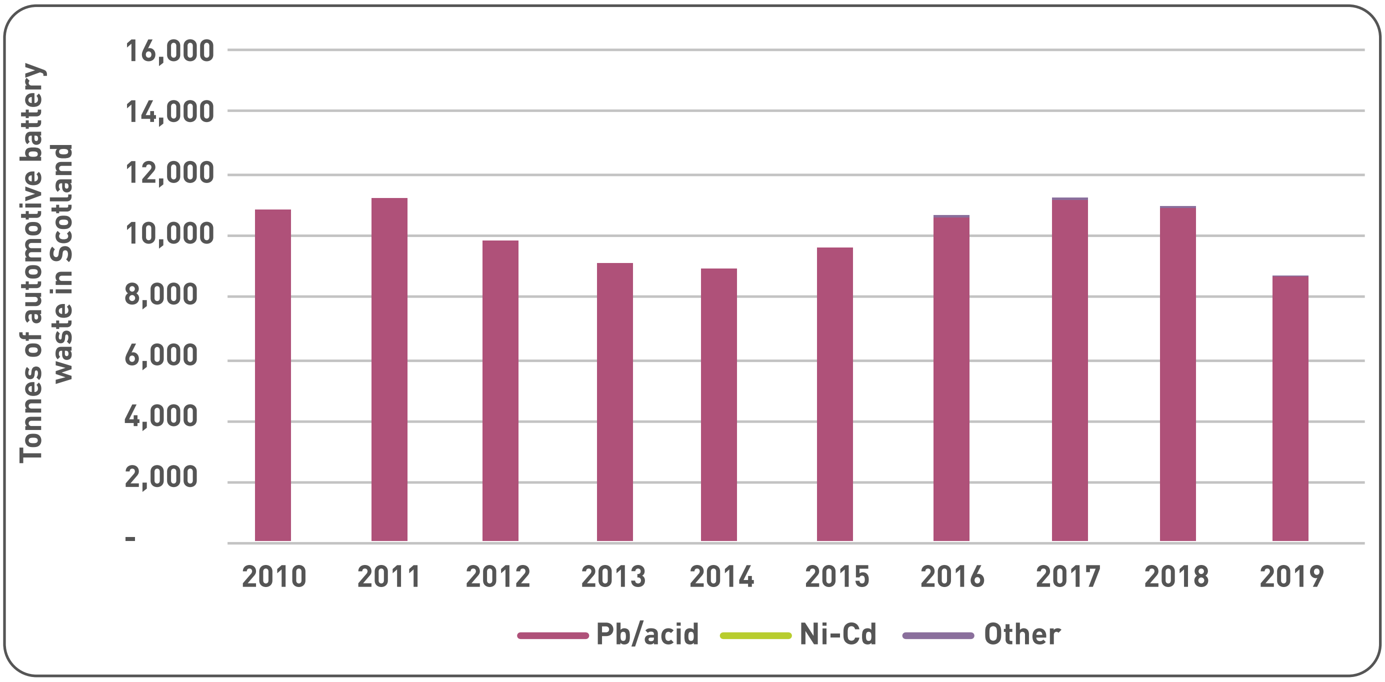


Figure 5.3 Estimated evolution of the amount of automotive battery waste in Scotland by chemistry types in tonnes from 2010 to 2019

6 BATTERY COLLECTION AND TREATMENT IN SCOTLAND

6.1 Description of current situation

Currently, there are four approved treatment operators and exporters registered in Scotland:

- Jet Environmental Services, Inc
  - o Exporter for automotive & industrial batteries
- WEEE Solutions Limited
  - o Treatment operator and exporter for portable, automotive and industrial batteries
- Blancomet Scot Limited
  - o Treatment operator for portable, automotive and industrial batteries
- CCL (North) Limited
  - o Treatment operator for portable, automotive and industrial batteries

There are, however, no processing and treatment facilities in Scotland to recycle batteries at end-of-life.

The majority of waste batteries which are collected in Scotland are transported to England for sorting by chemistry type. Three of the main sorting operators in the UK are BatteryBack[51], Ecobat[52] and, Mercury[53].

Other than Pb/Acid batteries, all other chemistry types are exported from the UK for recycling. The vast majority of batteries are exported to Europe with a small amount also exported to the USA. Umicore in Belgium is the main reprocessing facility for waste batteries in Europe. There are a small number of smelting facilities in the UK which are able to process waste Pb/Acid batteries.

Whilst the scope of battery recycling in the UK is quite narrow, there is one pilot plant in the UK – The Halifax Battery Hub[55] - operated by WasteCare, which recycles portable alkaline batteries. However, the facility would need a much larger feedstock than currently captured to make it viable in the long term. It is estimated that once the facility is fully operational it will have the capacity to meet the entire alkaline battery demand in the UK (approximately 20,000 tonnes per year)[56]. The Faraday Battery Challenge[57] aims to build capacity across the whole battery value chain in the UK, including recycling and recovery via funding for research, innovation and technical facility development.

[51]http://www.batteryback.org/battery-recycling.html
[52]https://www.ecobatindustrial.tech/battery-recycling/
[53]https://www.mercuryrecycling.co.uk/recycling/battery-recycling
[54]https://www.umicore.com/
[55]https://www.wastecare.co.uk/open-for-business/
[56]https://www.letsrecycle.com/news/latest-news/wastecare-2019-opening-battery-plant/
[57]https://faraday.ac.uk/post-with-video/

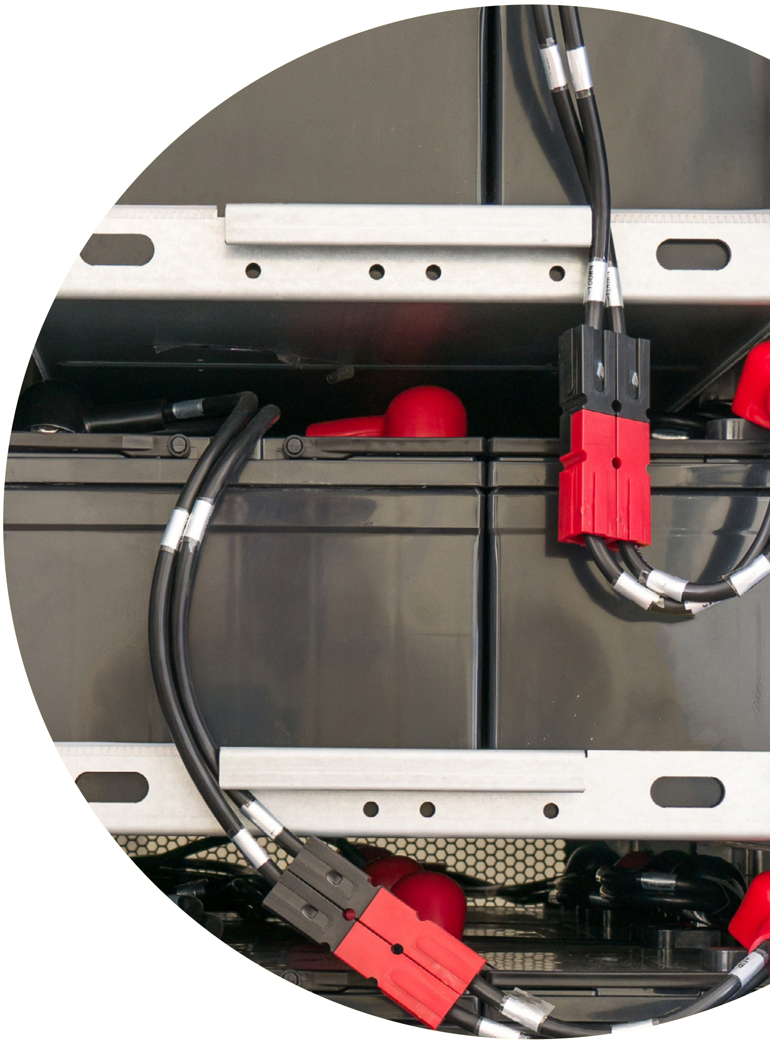
The total recycling capacity of the EU in 2020, was approximately 30,800 tonnes per year[58]. This is slightly ahead of the US, which had 28,700 tonnes. However, China has by far the world's largest capacity for battery recycling at 707,000 tonnes per year. Umicore (Europe's leading battery recycler), has a capacity of 7,000 tonnes per year, whereas China's largest, Brunphas a capacity of 120,000 tonnes per year. The recycling capacity in Europe has not been fully utilised as 18,200 tonnes of waste batteries were recycled in Europe while 17,900 tonnes were exported because of complex technical implications and high costs. One of the battery recycling facilities in France (Euro Dieuze Industrie) has the capacity to recycle between 5,000 to 6,000 tonnes of waste batteries and portable accumulators per year, which equates to 40% of the waste batteries collected in the French market[59]. Warwick University[60] has found that the break-even point for an automotive lithium-ion battery recycling plant is 2,500 – 3,000 tonnes per year if the chemistry contains nickel and cobalt. Their study also details the capacity of lithium-ion battery recycling across Europe's major facilities, summarised below:

- Duesenfeld, Germany – Pilot scale (commercial operation) ➔ 3,000t batteries per year
- Accurec Recycling GmbH, Germany – Pilot scale (commercial operation) ➔ 2,500t batteries per year
- Umicore, Belgium – Commercial process ➔ 7,000t batteries per year
- Euro Dieuze Industrie (EDI), France – Pilot scale process (commercial operation) ➔ 1,800t batteries per year
- Valdi (Eramet Group), France – Commercial process ➔ 20,000t batteries per year but Li ion only small portion of this
- Batrec Industries AG, Switzerland – Pilot scale process (in commercial operation) ➔ 200t batteries per year
- SNAM, France – Pilot scale process ➔ 300t batteries per year, looking to expand to 10,000t per year
- Recupyl, France – Pilot scale process ➔ 110t batteries per year
- uRecycle, Sweden – Pilot scale process ➔ 100t batteries per year
- REDUX, Germany – Commercial process ➔ 10,000t per year. Cells deactivated in a thermal treatment step prior to shredding and material separation
- Akkuser, Finland – Commercial process ➔ 4,000t per year (estimate). Cells shredded in a two-stage process assumed to occur in an inert atmosphere. Material separation is followed by acid leaching

Similar figures for minimum viable amounts and current activity levels could not be sourced at the time of writing for this report, but deeper investigation into recycling technologies and related economics will be important in assessing the feasibilty of any future potential battery recycling industry in Scotland.

6.2 Economic insights

The profitability of battery recycling is largely dependent on the fluctuations of the London Metal Exchange[61]. Certain chemistry types are more valuable than others – for example, Pb/Acid and nickel-metal hydride are valuable, whereas, alkaline is less valued. The type of battery can also play a role in the profitability of batteries recycling.



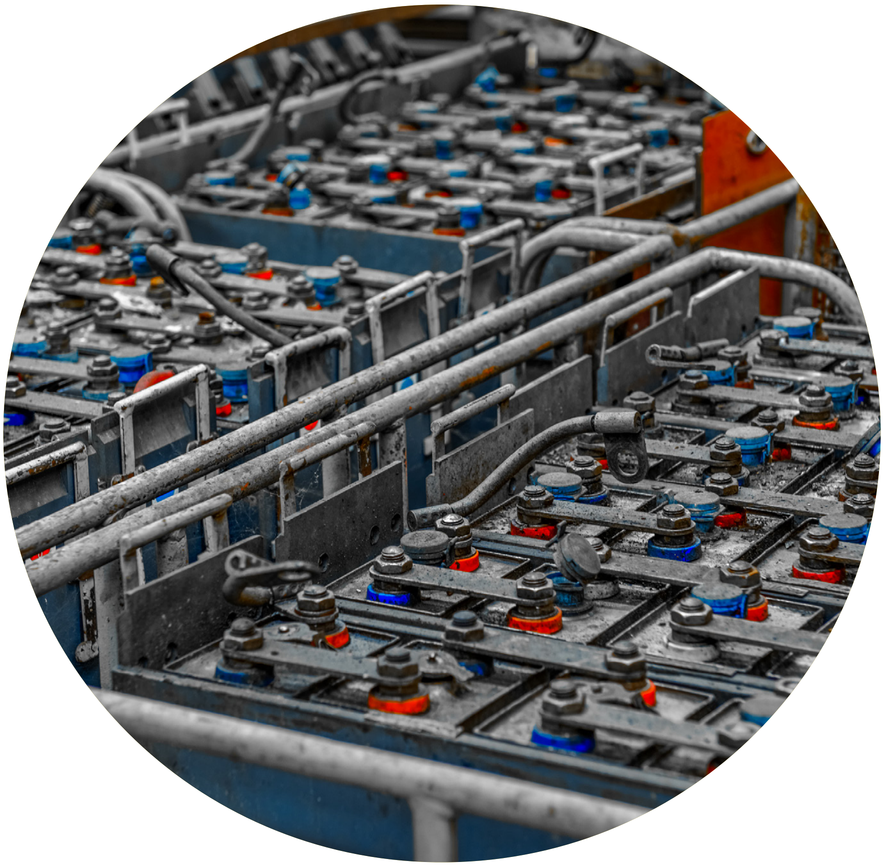
[58] https://www.pv-magazine.com/2020/12/16/europes-battery-recycling-quotas-are-blunt-and-a-decade-too-late/#:~:text=In%202020%2C%20recycling%20capacity%20in,lithium%2Dion%20battery%20recycling%20capacity
[59] https://www.planet.veolia.com/en/recycling-electric-car-batteries-renault
[60] https://warwick.ac.uk/fac/sci/wmg/business/transportelec/22350m_wmg_battery_recycling_report_v7.pdf

Overall, batteries recycling comes at a cost for most chemistry types. Exporters of waste batteries have operational costs and regulatory requirements in addition to the fluctuations of material value. There are additional costs for transportation, packaging, and insurance bonds which ABEs are required to cover when disposing of waste batteries, particularly industrial and automotive. Certain hazardous chemistry types require a higher insurance bond and are therefore more expensive for operators to export. An example provided by an ABE we interviewed stated that the cost of an operator exporting 96 tonnes of industrial batteries is approximately £2,000 to £3,000; they would be required to set aside £30,000 in a bond as insurance.

Interviews carried out suggested that it can take operators up to 6 months to process waste battery exports in accordance with the rules, during which material prices can change, making it a high-risk business model.

Whilst there has been an increase in lithium prices recently, there is little incentive to recycle new types of lithium-ion batteries, especially if all of the composite cells are spent, rendering them unsuitable for reuse or remanufacture. There is only a small amount of lithium in a Li-ion battery, cobalt and copper are generally more valuable metals included. It is expensive to extract value from end-of-life EV batteries, therefore batteries are often scrapped with the vehicle. As an EV's estimated lifespan is between 10-20 years[62], there are currently very few which have reached that point, rendering it difficult to incentivise a domestic recycling market for this type of battery at the moment. Greater clarity is needed on the volume and recyclability of batteries likely to reach end-of-life in the medium-long term to inform the viability of a Scottish or UK processing or recycling market.

The next section will provide further insights gained from the stakeholder interviews in Scotland.



[61] https://www.lme.com/
[62] https://www.edfenergy.com/electric-cars/batteries#:~:text=Electric%20car%20battery%20technology&text=This%20decreases%20the%20range%20and,they%20need%20to%20be%20replaced

7 KEY FINDINGS AND OPPORTUNITIES

From the information gathered and reviewed as part of the literature review, data analysis and stakeholder interviews a number of key themes for consideration emerge within the battery supply chain – policy, data, collection infrastructure, and waste management solutions. The main learnings are summarised here, and related opportunities or potential solutions resulting from them are **highlighted in bold**.

Policy

- As discussed in Section 2, there are proposals for a significant revision to the management of batteries across the EU, and any new UK or Scottish legislation will require alignment with the new regime to continue to operate within that market. Several of the changes proposed under the new EU Battery Regulation go some way towards addressing issues within the current system which have been highlighted through our research as barriers to improving the circularity of battery use in Scotland.

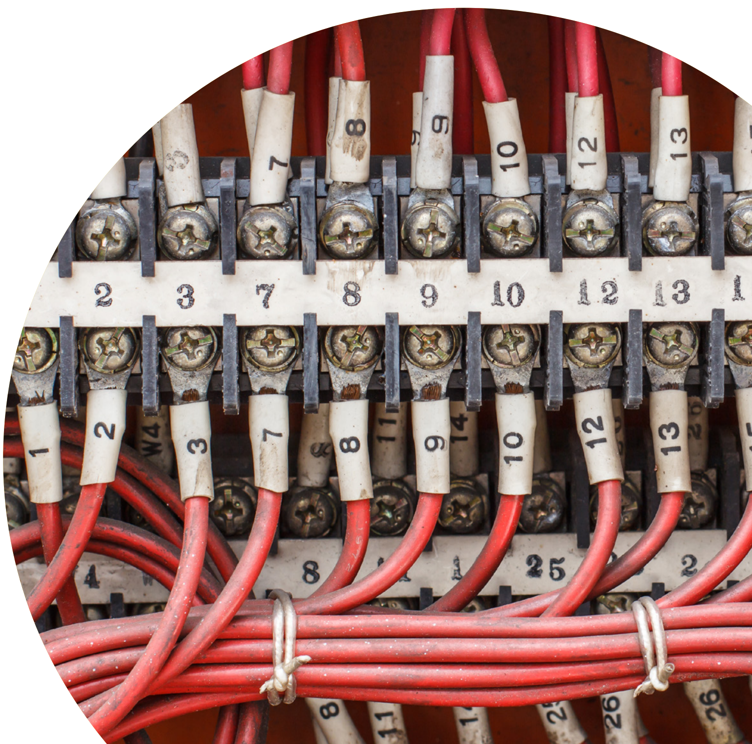
- The main issue, which has been highlighted in our own data analysis, and mentioned by most of the stakeholders interviewed, and illustrated through reviewing good practice in other countries, is the need to improve the transparency and granularity of the data declared per chemistry type. Data issues are discussed in more detail below, but **any new policy or regulation must have, as its cornerstone, reporting requirements which are relevant to the current and future shape of the market. This would allow for the design and implementation of specific interventions for the most challenging battery types and chemistries, and facilitate a deeper understanding of material and waste flows**. The absence of granular data makes policy development very challenging and hinders the establishment of new business models as the flows and economic opportunities cannot be qualified.

- The current regime allows operators to define the category of batteries reported as waste, and places a weight-based obligation target on recycling of portable batteries. This has led to a situation where heavy and cheap to recycle lead-based batteries can be falsely reported as portable, to achieve the target in the most cost-effective way. This was represented in the data as a 'bleeding' of batteries from industrial to portable.

  Targets have the effect of limiting collections. Targets are generally 'just' met and not much more, intimating that the levels they are set at are limiting actual recovery and recycling levels. In other EU countries the targets are higher and are achieved and so targets could either be removed or increased.

  Moving away from weight-based targets, potentially to separate ambitious yet achievable recovery targets for individual chemistries, would **disincentivise this leakage, allow the reported data to give a clearer picture of the true performance of the market, and likely lead to higher overall recovery/recycling levels.**

- All automotive and industrial batteries must be recovered and recycled, and currently, automotive and industrial battery producers are obligated to take back or collect batteries on request. In the case of industrial producers this is irrespective of where and by whom they were placed on the market.

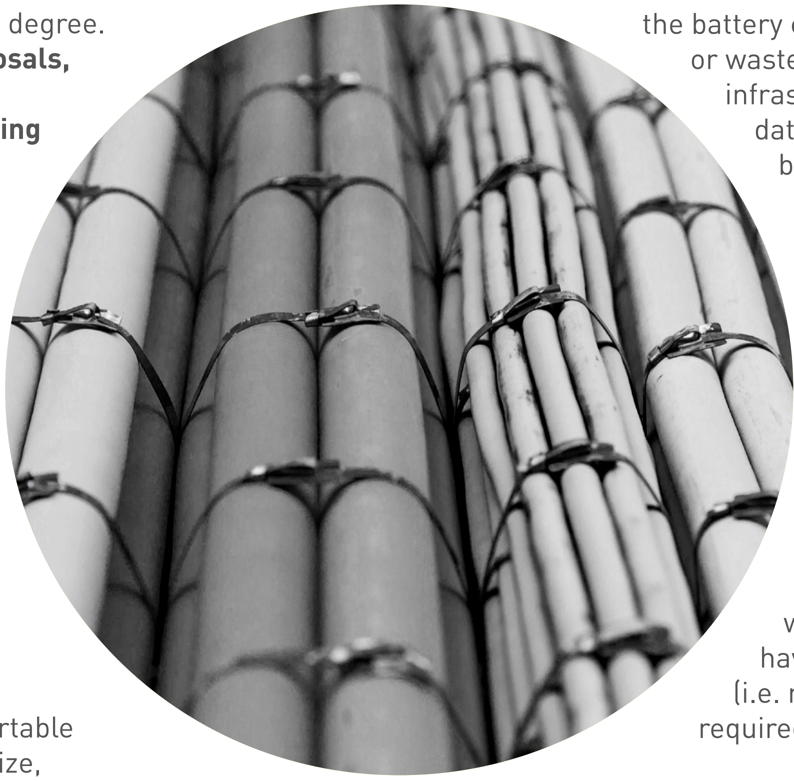


So in theory a single producer could face the obligation for dealing with all batteries. With relatively low costs in the system, as historically has been the case for Pb/Acid batteries, that does not present too much of an issue, but there are significant costs in dealing with Li-ion batteries, which is likely to be the predominant chemistry in the future. **So the system would benefit from a fundamental change where there are set obligations on individual producers to the treatment of industrial batteries. This requirement could then in turn encourage further investment in the sector**.

- The current regulations do not cover battery reuse to any degree. **As per the EU proposals, second life use for batteries is something that policy makers should include for consideration in amendments to the regulations. This should include a review of where the EPR obligations will sit for 2nd life batteries, with the original producer or the 're-manufacturer'**.

- Currently, there is a large diversity of portable battery shape and size, especially in those incorporated into electrical appliances (e.g. mobile phone/laptops), where they can differ based on equipment model or brand name. **If there were more standard formats for portable batteries incorporated into electrical equipment, it would make the removability of batteries and repairability of the electrical equipment much easier, fulfilling the principles of circular design requirements**.

  Product standards can act to restrict what can be placed on the market, this can then be followed up by incentivising best practice through the introduction of modulated fees. **The UK's Environment Bill introduces the concept of modulated fees for EPR systems. The most developed of these is for packaging EPR currently, however, there is an opportunity to introduce this for batteries too. Our research has suggested that the focus for battery modulated fees should be on the standardisation of format/size**. For example, AA batteries' shape, size and weight (to a certain extent) are standardised regardless of who has manufactured, branded or sold them to household consumers.



- There is an increasing challenge of free-riders, especially those who sell batteries from abroad directly to end users via the internet. Under the current regulations, non-domestic producers are not considered obligated and therefore do not have to register or participate in the EPR system here in the UK. They therefore do not contribute to the costs of the battery collection network or waste management infrastructure, or provide data on the volume of batteries entering the market. Whilst there is an issue with non-domestic producers, online retailers within the UK also pose challenges in that they are not required to provide collection points for waste portable batteries in the same way as retailers who have a physical presence (i.e. retail stores) are required to provide.

  There are obvious challenges for online retailers to provide a take-back system, however, **one option could be to introduce a Distributor Take-back Scheme (DTS) similar to the system implemented for WEEE. With this option, online retailers would offset the requirement to provide collection services but would still contribute to the costs of the national collection network and waste infrastructure for batteries**.

Data

- Across the battery sector there is consensus that the chemistry reporting categories are no longer fit for purpose, for example, Ni-Cd batteries are no longer a significant chemistry type being placed on the market and there is no traceability for Li-ion batteries which have increased dramatically in recent years. A large proportion of the tonnage placed on the market falls into the 'other' chemistry type currently, especially for portable batteries (as can be seen in **Table 4 1**. One way to breakdown the **'other' chemistry type would be to obligate battery producers to declare under a similar set of chemistry categories as in Ireland (See Section 2.3.3) or by using the Harmonised System (HS) Customs Codes[63]. HS Customs Codes classify goods on a common basis for customs purposes, are recognised internationally and use a six digit code system.**

- There are a number of challenges with the data being reported at various stages of the battery lifecycle - POM and at end-of-life management. Not only is there a lag time from when the battery is placed on the market to when it will be disposed of, but there is also a lack of consumer awareness of batteries disposal which can lead to hoarding, especially for portable batteries. The issue of free-riders placing unreported levels of batteries on the market, some proportion of which will eventually be included in end-of-life reporting, adds another intangible factor.

- The discrepancy between POM and collected battery figures is also partly due to waste batteries not entering the waste stream as anticipated. For example, portable batteries can often be disposed of by household consumers in their general household waste collections or incorporated in Waste Electrical and Electronic Equipment (WEEE). If batteries end up in these other waste streams, they aren't necessarily captured in the waste battery data reported at the national level. Automotive and Industrial batteries may also be disposed of via local scrap metal dealers or unapproved treatment operators, who may not always dispose of batteries in an environmentally sound manner. Local facilities are perceived as easier to use for disposal by some producers as they can reduce the cost of transporting waste batteries across the country to approved treatment operators.

- In addition, there might be some double counting in the data in certain situations. For example, if a small volume of batteries is collected and sorted by one ABTO, but instead of being sent for recycling or export, they are transferred to another ABTO's larger volume of batteries, the volume may be declared by both ABTOs.

Collection Infrastructure

- The collection infrastructure for waste batteries in Scotland is far-reaching for portable batteries. There are a number of collection points across the islands and mainland Scotland which are ostensibly easy for consumers to access. Despite this prevalence, however, UK level targets for collection are proving difficult to meet. Options for improving capture rates could therefore be investigated for feasibility. Also, battery compliance schemes have suggested that portable battery collection and recycling is the least profitable area for them, whereas automotive lead acid batteries have a closed loop profitable system for collections.

- Whilst the largest ABTOs and ABEs are based in England, there are a number based in Scotland. There is potential for more ABTOs and ABEs to be established in Scotland in future, however, there is currently capacity within the existing infrastructure to increase volumes of waste batteries being processed.

- **In order to increase the amount of waste batteries being collected for disposal, there are suggestions of introducing a Deposit Return System (DRS) for batteries or possibly introducing kerbside collections for portable batteries along with Waste Electrical and Electronic Equipment (WEEE). To ensure that the introduction of new collection systems is successful, it is paramount to engage and educate the general public on the requirements to dispose of batteries in a safe manner for recycling**.

Waste Management Solutions

- As discussed in Section 6.2, the economics of compliance with current regulations and fluctuating material market values do not sufficiently incentivise a large-scale battery recycling industry. It is generally felt that Scotland, and the UK in general, does not have sufficient volumes for domestic recycling sector at current levels of collection. **If a future battery regulatory landscape were to mandate for greater clarity of data for batteries placed on the market and traceability through the life cycle, it would allow for better planning and development of future collection and recycling infrastructure in the UK. Similarly, this clarity could help to expedite the regulatory process for operators, de-risking the economic opportunity connected to battery recycling**.

- One treatment operator interviewed as part of this project, suggested that one of the challenges of recycling industrial batteries is a lack of knowledge amongst end users of industrial batteries when it comes to what they should do with waste batteries at end-of-life, unless the producer has provided clear guidance. Another challenge facing treatment operators in Scotland, is the nature of its geography and low population density in certain regions. **One solution to this issue could be to create regional hubs to help optimise collections of portable and industrial batteries**.

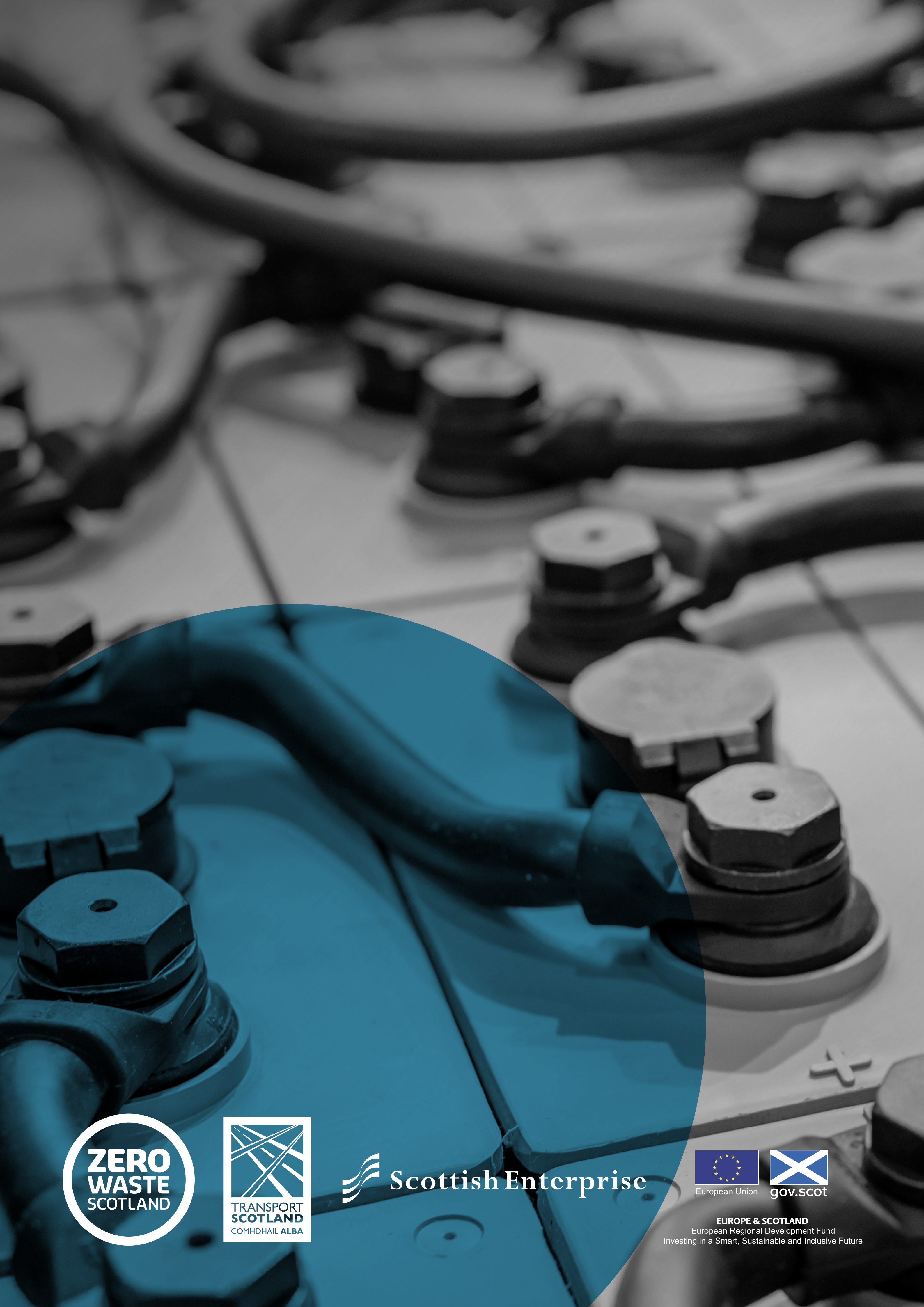
- Currently, the main challenge facing automotive battery recycling is the cost of transportation due to restrictions on dangerous goods movements. This same challenge will become prominent as EV use continues to increase, as Li-ion batteries will present similar risks. **Therefore, it could be beneficial to implement a centralised system for automotive battery take back by producers. In addition, if there were more recycling facilities in the UK the cost of recycling automotive batteries would be reduced.**

8 NEXT STEPS

This report has detailed the process followed, key findings and resultant points for further consideration of Phase 1 of this project, aiming to develop an understanding of the current situation.

Phases 2 and 3 of the project will develop in further detail the recommendations made herein, along with forecasting the short-medium term expected levels of batteries used and reaching end-of-life in Scotland.

The resultant Phase 2 and 3 reports will look separately at the future situation specifically for EV batteries, and all other batteries, considering detailed business model and value chain analysis, and new and emerging technologies. It has proven challenging through this phase to access good economic and value chain information due to the sensitivity of the data. However, a specific focus of the next phases should aim to address this data limitation.



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