Cutting Lithium-ion Battery Fires in the Waste Industry

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Executive Summary

Eunomia Research and Consulting Ltd. (Eunomia) and the Environmental Services Association (ESA), supported by the National Fire Chiefs Council (NFCC), the Waste Industry Safety and Health (WISH) Forum and the Environment Agency (EA), together with operator sponsors listed below, are pleased to present this report exploring the costs of, and potential measures to prevent, fires in the UK which are being started by lithium-ion batteries (LIBs) in residual and mixed recycling waste streams. Although not the focus of the report, we also investigate a possible measure to reduce LIB fires during waste electrical and electronic equipment (WEEE) reprocessing.

- CWM Environmental Ltd.
- SUEZ Recycling and Recovery UK Ltd.
- Totus Environmental
- Viridor Waste Ltd.

Waste fires are a serious problem. Costing millions of pounds each year, they cause serious damage through emissions released as the waste burns, recycling resources lost, water consumption while they are extinguished and water pollution through run-off. They also cause extra work for the fire service and disruption to society for example through rail and retail disruption[1], road closures when burning waste is emptied from refuse collection vehicles to be extinguished, or when smoke from an ablaze waste management site near to a road would obstruct drivers' sight.

The waste management industry has already made significant investment and changes to site infrastructure in an attempt to reduce and control fires, installing systems for fire detection and suppression, firewalls and implementing stricter waste acceptance and management procedures. This has been supported by new guidance and research data from WISH[2] which helps operators to understand current best practice of fire management on waste sites and tighter enforcement from the EA by integrating Fire Prevention Plan requirements[3] into new and existing waste site permits.

However, waste fires are still a problem, and in particular those caused by LIBs. LIBs currently outcompete all other rechargeable battery options in terms of energy density and are therefore one of the most popular types of rechargeable battery for portable electronics. They are found in a huge variety of appliances and consumer electronics. Unfortunately, the structure and chemistry of LIBs means that while they are safe for consumers to use, they can start fires when discarded and damaged in residual and

[1] https://www.letsrecycle.com/news/latest-news/averies-brothers-sentenced-following-disastrous-fire/
[2] https://www.wishforum.org.uk/wp-content/uploads/2020/05/WASTE-28.pdf
[3] https://www.gov.uk/government/publications/fire-prevention-plans-environmental-permits/fire-prevention-plans-environmental-permits

mixed recycling waste streams. Such damage can easily occur during normal waste handling operations, and LIBs that are disposed of in residual and mixed recycling waste streams are responsible for causing many waste fires.

The increase in use of LIBs is likely to continue, and with it the number of waste fires they cause unless better practices and related policy measures are introduced to capture LIBs and keep them out of residual and mixed recycling waste streams. In addition, lithium is a limited resource, with various mineral extraction impacts that have a negative effect on relatively pristine environments, and consequently it will become increasingly important to capture LIBs and recycle the lithium.

In a two-part study, this report first estimates the number of waste fires in the UK caused by LIBs, the cost of these waste fires to the UK economy and environment, and the distribution of these costs across the various parties affected. This report then presents the findings of an international review of 'up-stream' measures and policies designed to keep LIBs out of residual and mixed recycling waste streams. Behaviour change initiatives, although vital to this effort, were excluded from the scope of this research to avoid duplication of other work the ESA is currently conducting in this area.

Following this review, this report recommends the most effective measures to capture LIBs in the UK, thereby keeping them out of residual and mixed recycling waste streams and helping to reduce the number of fires they cause.

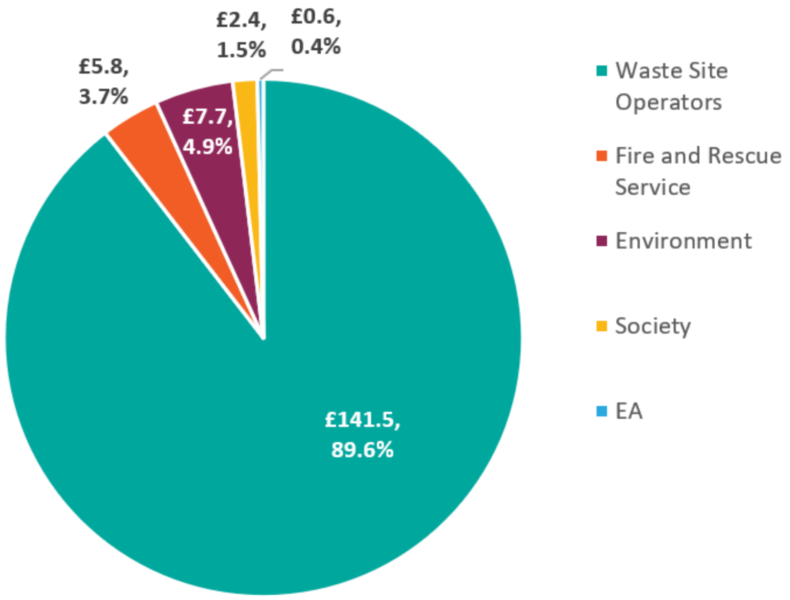
E.1.0 Key Findings

E.1.1 Number and Costs of Waste Fires Caused by LIBs

Through desk-based research and conversations with the EA, the Fire Service, WISH and other members of the Steering Group, we have been able to acquire data and gain an understanding of the number of waste fires and costs that can be attributed to waste fires caused by LIBs in the UK. We estimate that around **48%** of waste fires can be attributed to LIBs; this equates to approximately **201** waste fires in the UK each year.

Whilst individual fires vary significantly in terms of severity and duration, therefore influencing the cost implications, overall, we estimate that the total annual cost to the UK of waste fires caused by LIBs is **£158 million**. The breakdown of these costs, and who they are incurred by, is outlined in Figure E1-1.

Figure E1-1: UK Cost of Waste Fires Caused by LIBs by 'Cost Incurred By' (£mil, %)



Our modelling breaks waste fires into four categories, dependant on the fire severity, from 1 (most severe) to 4 (least severe). Despite the most severe fires having the highest cost implications per fire, it is the severity level 3 fires which have the highest cost implications year on year for the UK, due to these fires occurring most frequently. Table E1-1 breaks down these figures, showing the estimated cost per fire for each of the four severity levels, and annual cost to the UK.

Table E1-1: UK Cost of Waste Fires Caused by Li-ion Batteries

Fire Severity Category	% of Total Fires	Estimated Cost per Fire (£mil)	Annual number of waste fires attributed to Li-ion batteries	Estimated Annual Cost (£mil)
1	0.8%	£3.8	1.7	£6.6
2	5%	£1.8	10.4	£19.0
3	73%	£0.9	147.5	£128.6
4	21%	£0.1	41.8	£3.8
Total			**201**	**£158**

Although these findings are a crucial first step in understanding the real-life cost implications of waste fires caused by LIBs, it is important to note that there are still several gaps in the data. Using previous experience and industry expertise, assumptions have been developed, however due to data limitations, these outputs should be seen as indicative estimates. In reality, the true cost of waste fires may be significantly higher than we have estimated. This is due firstly to the fact that many smaller fires go unreported to the EA. As the EA fire numbers are used as the basis of our estimates, both for England and for scaling up to the UK, there are likely a portion of fires which have not been accounted for in our costs. Secondly, there are a range of wider cost impacts, e.g. to society and the environment, which can vary significantly between individual fires and are challenging to quantify in detail. These wider costs (as outlined in Section 2.2.2), have therefore also been excluded.

Furthermore, these costs represent a current snapshot of the total cost to the UK. It is clear from our research that there has been a historic increase in the use of LIBs, and this trend is likely to continue, therefore the number of incidents, and thus costs, are likely to increase further unless proactive interventions and policy measures are introduced to curb the growth in the number fires started by LIBs.

E.1.2 Key Measures to Reduce Waste Fires Caused by LIBs

The international review of 'up-steam' measures and policies identified a range of options that could be implemented to capture LIBs and keep them out of residual and mixed recycling waste streams. Two measures that could be introduced in the short-term to increase the number of LIBs which are separately collected are:

1) Separate kerbside battery and small WEEE collection from households; and
2) Increasing the number of retail collection points for batteries and small WEEE.

Complementary to these, several supporting policy mechanisms were identified that could help to fund system changes to capture more batteries, and financially incentivise or deter consumers from incorrectly disposing of batteries. In order of preference, the below could be enacted *alongside* an improved collection system:

1) Banning batteries from residual and mixed recycling waste streams, with the imposition of fines for non-compliance;
2) Enhanced extended producer responsibility (EPR) for batteries and small WEEE to pay for, and co-ordinate, improved collection and reflect the cost of fires;
3) Creating a deposit return scheme (DRS), or other incentivisation mechanism, to encourage the return of batteries and small WEEE (notably electronic gadgets) for recycling; and
4) Introducing fee modulation within the WEEE EPR system for design features that facilitate easier battery removal by consumers.

In addition, although not a focus of this report, LIB-caused fires are a problem in the WEEE management stream. To reduce the number of these fires, we suggest improving the UK's statutory guidance for WEEE – Best Available Treatment, Recovery and

Recycling Techniques (BATRRT) – or mandating the European CENELEC standards to require LIB removal prior to shredding/ fragmentation in WEEE reprocessing plants.

Finally, we suggest a long-term solution could be to change LIB design to reduce the risk of them starting fires when they are damaged. This could include a new battery chemistry, improving the integrity of battery casings or adding fire-retardant coatings to batteries. As we come to rely increasingly on portable, battery-powered devices, as well as LIBs in electric vehicles and in relation to electrical power storage on a larger scale, increasing focus and funding is going into battery research and design in the UK and abroad. Given the costs associated with managing waste fires caused by LIBs, waste operators and other stakeholders might want to influence government to increase funding in the specific area of R&D around fire-prevention in battery design.

E.2.0 Recommendations

All of the mechanisms mentioned above would help increase the separate capture of LIBs and thereby reduce the number of waste fires they cause. However, given the urgency of the problem of LIB-caused waste fires, and taking into consideration the proposed changes to the UK's waste collection and EPR systems, we recommend the following three-pronged approach to increase the separate capture of LIBs in order to reduce the waste fires they cause:

1) Ban the disposal of batteries and small WEEE in residual and mixed recycling waste to prevent this practice and increase the public's awareness of correct disposal routes.
2) Encourage separate kerbside collection of small WEEE and batteries by local authorities on a voluntary basis as soon as possible, with Government to add batteries and small WEEE to the Environment Bill and Waste and Resources Strategy's source separation requirements from 2023. The costs of this – and the costs of LIB-started waste fires – should ultimately be covered by enhanced EPR for batteries and WEEE once revised regimes have been put in place by Government, thereby reducing the financial barrier for local authorities.
3) Urgently investigate the role of DRS in supplementing retailer takeback for batteries and small WEEE, to achieve very high capture rates for target items (i.e. those with larger LIBs), so that, in the event that increasing kerbside and retail collections does not have the desired effect, Government will be better prepared to introduce an effective DRS quickly.

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List of Acronyms

Table 1-2: List of Acronyms

Abbreviation	Explanation
AATF	Approved Authorised Treatment Facility
BATRRT	Best Available Treatment, Recovery and Recycling Techniques (statutory UK guidance for WEEE)
BEIS	Department for Business, Energy & Industrial Strategy
CENELEC	French: Comité Européen de Normalisation Électrotechnique; English: European Committee for Electrotechnical Standardization
Defra	Department for Environment, Food & Rural Affairs
DRS	Deposit return scheme
DTS	Distributor Take Back Scheme
DCF	Designated collection facility
EEE	Electrical and electronic equipment
EPR	Extended producer responsibility
HWRC	Household waste recycling centre
LIB	Lithium-ion battery
Ni-Cd	Nickel cadmium battery
OPSS	Office for Product Safety and Standards
PCS	Producer Compliance Scheme
PRO	Producer Responsibility Organisation
RFID	Radio-frequency identification
RVM	Reverse vending machine
WEEE	Waste Electrical and Electronic Equipment
WEEELabex	Waste Electrical and Electronic Equipment Label of Excellence

1.0 Introduction

Eunomia Research and Consulting Ltd. (Eunomia) and the Environmental Services Association (ESA), supported by the National Fire Chiefs Council (NFCC), the Waste Industry Safety and Health (WISH) Forum and the Environment Agency, together with operator sponsors listed below, are pleased to present this report exploring the costs of, and potential measures to prevent, fires in the UK which are being started by Lithium-ion batteries (LIBs) in residual and mixed recycling waste streams.

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1.1 Background

Lithium-ion batteries (LIBs) currently outcompete all other rechargeable battery options in terms of energy density and are therefore one of the most popular types of rechargeable battery for portable electronics. They are found in a variety of appliances and consumer electronic products including mobile phones, laptops, cameras, shavers, electric toothbrushes, vacuum cleaners, power tools, e-cigarettes and singing birthday cards. Unfortunately, the structure and chemistry of LIBs means they can start fires when damaged (see Figure 1-1). Such damage can easily occur during normal waste operations, and LIBs incorrectly disposed of in residual and mixed recycling waste streams are responsible for causing waste fires (see Figure 1-2 and Figure 1-3). The increase in use of LIBs is likely to continue, and with it the number of waste fires they cause unless better practices and related policy measures are introduced. There is an approximate lag-time of five years between an item appearing on the market and that item – and any associated issues such as increase in fires caused – appearing in the waste stream, so it is important to be proactive and introduce measures to increase battery capture now, before even more fires are caused by incorrectly disposed of LIBs. In addition, lithium is a limited resource, and it will become increasingly important to capture LIBs and recycle the lithium.

Figure 1-1: Examples of Damaged LIBs Found in Waste Streams

To date, progress on improving the recyclability of LIBs has been slow, and there has been little focus on collecting them before they enter the waste stream, as there is limited economic advantage to recycling them. Instead, the focus has been on increasing the longevity and charge capacity of LIBs. LIBs have a lifespan of perhaps three or four years before they are spent and enter the waste stream. Some believe that battery producers have shown limited interest in the end-of-life management of LIBs, as it is seen as a problem for the future.[4] Additionally, it is difficult to create a standardised recycling procedure for LIBs as they can have different chemical properties depending on the manufacturing approach.

Figure 1-2: CCTV Still of an Ablaze LIB from a Cordless Hand Drill on a Recycling Plant Picking Line

Figure 1-3: Photo of a Large Fire at a Recycling Plant Likely Caused by a LIB

There have been some signs of development in LIB recyclability: in the UK the Reuse and Recycling of LIBs (ReLiB) project was created in 2018 to help improve LIB recycling,

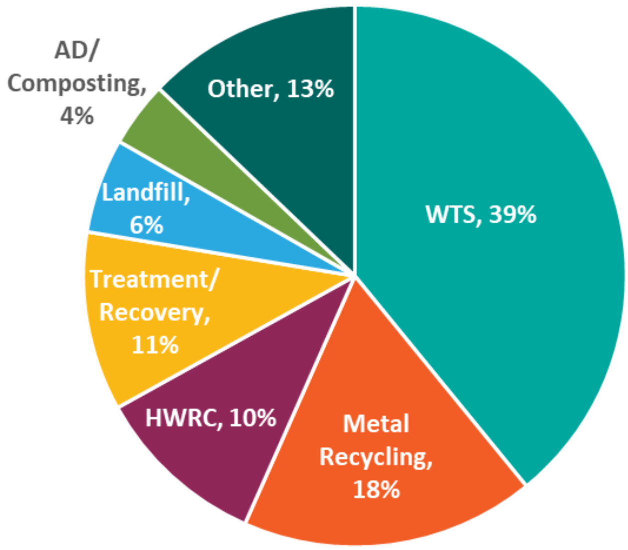
[4] Velazquez-Martinez et al (2019). A Critical Review of Lithium-Ion Battery Recycling Processes from a Circular Economy Perspective. *Circular Batteries Technologies*, 5(68), pp. 1-33

specifically from electric vehicles,[5] and in 2019 the first LIB recycling research and development centre, the ReCell Center, was built in America with the aim of making LIB recycling competitive and profitable.[6] However, more can and should be done to separately collect LIBs.

The waste management industry has already made significant investment and changes to site infrastructure in an attempt to reduce and control fires, installing systems for fire detection and suppression, firewalls and implementing stricter waste acceptance and management procedures. This has been supported by new guidance and research data from WISH[7] which helps operators to understand current best practice of fire management on waste sites and tighter enforcement from the EA by integrating FPP requirements[8] into new and existing waste site permits. However, preventable fires caused by incorrectly disposed of LIBs continue to be a huge problem.

EA data (presented below in Figure 1-4), shows that 38% of waste fires reported in 2017/18 occurred in WTSs, and 18% in Metal Recycling. Although this data reflects wider waste fire trends, rather than those specifically relating to LIBs, and will also be reflective of the number of each type of facility in England, it helps to paint a picture of where fires are a problem most prominently.

Figure 1-4: Waste Fires in England by Facility Type (2014-2019)



Source: EA data, provided by the EA on 15.10.20 (2020) Waste fires reported for England 2014 - 2019

[5] The Faraday Institution (2020), *Reuse and Recycling of Lithium Ion Batteries*, accessed August 2020, https://relib.org.uk/
[6] ReCell (2020) *Advanced Battery Recycling*, accessed August 2020, https://recellcenter.org/
[7] https://www.wishforum.org.uk/wp-content/uploads/2020/05/WASTE-28.pdf
[8] https://www.gov.uk/government/publications/fire-prevention-plans-environmental-permits/fire-prevention-plans-environmental-permits

LIBs entering waste sites in a residual or mixed recycling waste stream can be hard to detect at the point of waste acceptance, and mechanical damage to LIBs during waste collection and processing is causing regular fires which have become a significant financial burden to many stakeholders, including waste operators and the fire service. The Environmental Services Association (ESA), the trade body representing the UK's resource and waste management industry, reported that of the 670 fires recorded by ESA members across the UK in 2019-20, 38% were either recorded as LIB cause or a 'suspected' LIB cause. This is slightly higher than the percentages recorded in the previous three years by the body (21% in 2016-17, 25% in 2017-18 and 22% in 2018-19).

As discussed in more detail in Section 3.0, despite existing UK regulations and targets to promote the separate collection of batteries and products containing batteries, only 45% of portable batteries placed on the market in 2019 were collected, and WRAP estimates that ~37% of waste electrical and electronic equipment (WEEE) is not going through the proper system and instead ending up being disposed of as residual waste.[9]

Additionally, even WEEE that has been collected separately and sent to specialist reprocessors can cause fires if it contains batteries that have not been removed prior to shredding. The SAFeR WEEE project in Merseyside has recently explored methods to encourage members of the public to source separate batteries from WEEE to reduce fire risk (see Case Study 4-5).[10]

This research and the recommendations it makes are focused on measures to reduce the number of LIB-caused fires in residual and mixed recycling waste streams; however, the risks posed at WEEE processing facilities by failure to remove LIBs from products is recognised as some measures may be applicable to these operations. Potential interventions to reduce the number of battery-started fires at WEEE processing facilities are discussed briefly in Section 4.3.2.

1.2 Aims and Approach

Much work has been undertaken to improve operator best practice guidance and take account of the risks of battery fires. However, a substantial proportion of this has focussed on changing 'down-stream' activity; examples include the preparation and implementation of detailed advice and permitting requirements on fire detection, suppression, incident management and mitigation. There has also been an increased interest in communication campaigns, identifying the need for increased public awareness of the risks and understanding of how to dispose of batteries appropriately. Far less research has focussed on 'up-stream' interventions (e.g. policy measures) to

[9] WRAP (2012) *WEEE recovery in the UK: the current situation and the road ahead*, accessed August 2020, http://www.wrap.org.uk/sites/files/wrap/WEEE%20recovery%20in%20the%20UK.pdf

[10] Date, W. (2019) *Merseyside BeBatterySavvy HWRC campaign launches*, accessed 2 September 2020, https://www.letsrecycle.com/news/latest-news/merseyside-bebatterysavvy-hwrc-campaign-launches/

prevent LIBs entering residual and mixed recycling waste streams and thereby reduce the likelihood of LIB-started fires occurring in the first place.

The aim of this research is to develop an evidence base to confirm the extent to which LIBs are a cause of waste fires, estimate the financial costs of waste fires they may cause and thereby test the case for changing policy in this area to address this risk at source, before the batteries enter the waste stream. It also presents suggested up-stream measures that could be effective in the UK, drawn from an international review of measures employed.

This report is structured as follows:

- Section 2.0 gives an estimate of the cost of waste fires caused by LIBs, broken down by who typically incurs these costs (e.g. waste site operators or the taxpayer). The estimate includes direct financial costs (e.g. due to damage and site closures) and indirect costs (e.g. from health and environmental impacts).
- Section 3.0 gives an overview of the UK's regulatory landscape in relation to batteries and WEEE that contains batteries. This provides a baseline for the international review of best practice presented in the following section and context for the recommendations set out in Section 5.0.
- Section 4.0 reviews existing mechanisms and policies and broad classes of initiative, both in the UK and other comparable countries, that are designed to keep batteries out of residual and mixed recycling waste streams. Wherever possible, case studies of each mechanism or policy are provided, together with a discussion of how it could be implemented in the UK.
- Section 5.0 presents our key findings and recommendations for how the UK might reduce the number of fires in waste – and the associated costs – that are caused by LIBs.

The report is likely to be of interest to a wide range of stakeholders including regulators and policymakers – principally, key officials within Defra and BEIS – and manufacturers of LIBs and products that contain LIBs.

2.0 The Costs of Waste Fires Caused by Li-ion Batteries

Through the creation of a bespoke MS Excel model, a valuation exercise was conducted to estimate the cost to the UK economy and environment from waste fires caused by LIBs. We also sought to understand how these costs were likely distributed across the various parties affected, such as site operators, the fire brigade, the EA, wider society and the environment.

This section explains the modelling methodology behind this valuation exercise, outlines the key assumptions and data limitations and presents the main findings.

2.1 UK Waste Fire Numbers

As the first stage of our modelling, it was necessary to understand how many waste fires occur and, secondly, to estimate the portion of these which can be attributed to a LIB cause.

Based on the annual number of waste fires reported to the EA for England each year [11] when compared to all fires reported for England[12], it has been estimated that **0.2%** of reported fires are waste fires (~300 per year as shown in Table E1-1)

We are aware that the ESA typically reports higher annual waste fire numbers than ~300, despite only representing ~40% of the waste industry. In 2019-2020, for example, the ESA reported 520 waste fires. The reason for this difference is that not all ESA recorded fires will have been reported to the EA, the smaller fires in particular are likely to go unreported. Extrapolating the ESA data to represent England as a whole would have been challenging to model accurately, which is why the EA numbers have been used for the above '0.2%' calculation. Bearing this in mind, it is worth noting that our modelling will not be incorporating the smaller waste fires that are not reported and therefore the calculated costs attributed to LIB fires could be higher.

Despite not using the ESA data for calculating total waste fire numbers, it was, however, used alongside Eunomia calculations to estimate the portion of waste fires that can be attributed to LIBs, estimated at **48%** [13]. The data and method applied to calculate these estimates are presented in Appendix A.1.0.

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[11] EA data, provided by the EA on 15.10.20, (2020) average waste fires reported to the EA for 2014 – 2019
[12] National Statistics (2019), Fire and rescue incident statistics: England, year ending March 2019, accessed September 2020, https://www.gov.uk/government/statistics/fire-and-rescue-incident-statistics-england-year-ending-march-2019
[13] ESA data, waste fires reported by ESA members 2019-2020, provided by ESA on 03.11.20 (2020)

Using these percentages for England, it was possible to estimate the annual number of waste fires in the UK and each nation (Northern Ireland, Scotland and Wales) and the portion of these which are likely to have a LIB cause. Table 2-1 outlines our assumptions for the UK.

Table 2-1: UK Annual Fire Numbers

	England	Northern Ireland	Scotland	Wales	UK Total
Total Fires Reported 2018/19	182,825 [14]	24,586 [15]	26,726 [16]	12,912 [17]	247,049
Estimated Annual Waste Fires	309 [18]	42	45	22	418
Estimated Number Attributed to Li-ion Batteries	149	20	22	11	201

2.2 Costs of Waste Fires (per Fire)

In order to estimate the total cost of LIB-caused waste fires in the UK, it was necessary to first look at the cost of single waste fires. This cost could then be scaled up accordingly.

2.2.1 Key Assumptions

As waste fires vary significantly in terms of their size and duration, and therefore the amount of damage and cost caused, our modelling breaks waste fires into four categories, dependant on the fire severity, from 1 (most severe) to 4 (least severe). This numbering categorisation is one adopted by the EA, though it is important to note that is

[14] National Statistics (2019) Fire and rescue incident statistics: England, year ending March 2019, accessed September 2020, https://www.gov.uk/government/statistics/fire-and-rescue-incident-statistics-england-year-ending-march-2019

[15] Northern Ireland Fire and Rescue Service (2019) Annual Reports, accessed September 2020 https://www.nifrs.org/publications-subpage/publications/annual-reports/

[16] Scottish Fire and Rescue Service (2019) Fire and Rescue Incident Statistics, accessed September 2020, https://www.firescotland.gov.uk/media/1494628/incident_statistics_2018_19.pdf

[17] Welsh Government (2019), Fire and rescue incident statistics 2018-19,accessed September 2020, https://gov.wales/sites/default/files/statistics-and-research/2019-08/fire-and-rescue-incident-statistics-april-2018-to-march-2019-734.pdf

[18] EA data, provided by the EA on 15.10.20, (2020) average annual waste fires reported to the EA for 2014 – 2019

used fairly loosely, and, as far as we are aware, there are no EA guided quantitative measurements for each category.

The EA broadly categories the four severities as follows:

- **Category 1:** major, serious, persistent and/or extensive impact or effect on the environment, people and/or property.
- **Category 2:** significant impact or effect on the environment, people and /or property
- **Category 3:** minor or minimal impact or effect on the environment, people and /or property
- **Category 4:** substantiated incident with no impact

We have taken these categories, with their qualitative descriptions, and developed some quantitative assumptions for each severity category, as outlined in Table 2-2, as a means of distinguishing between the costs of fires with differing severities. As can be seen in the table, whilst we applied ranges for several factors (duration, waste tonnage burnt), it was necessary to choose a single value for the purpose of calculating a UK estimated impact, shown in the table as 'modelled duration' and 'modelled tonnage'.

Table 2-2: Key Assumptions

	Fire Severity			
	1	2	3	4
Duration Range (hours)	> 72	24 - 72	4 - 24	1 - 4
Modelled Duration (hours)	120	72	24	4
Waste Tonnage Burnt (t)	> 500	250 - 500	50 - 249	< 50
Modelled Tonnage Burnt (t)	1,000	375	150	25
No. Fire Trucks Attending	10	6	4	2

Based on the assumptions shown in Table 2-2 we calculated a 'Cost Impact' factor of increase, as shown in Table 2-3. This factor of increase was used to proportionally influence the costs incurred by waste site operators (such as material damage, business interruption etc) to reflect the fact that these costs would increase with fire severity. The 'Cost Impact' was calculated using confidential waste fire case studies and a comparison of how the key assumptions varied between severities.

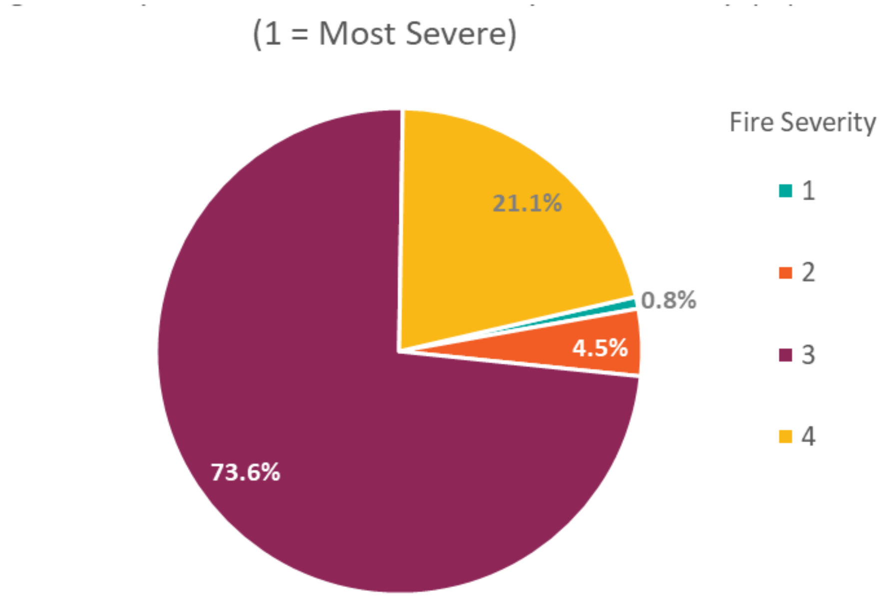
Table 2-3: Cost Impact

	Fire Severity			
	1	2	3	4
Cost Impact (factor of increase)	4.0	2.0	1.0	0.10

Figure 2-1 presents the percentage split of fires reported to the EA under each of the four severity categories. The EA has advised that these categories are initially assigned based on the scale of the incident when reported to the EA, and they can be recategorized throughout or after the event. These numbers are therefore subject to change, particularly due to the scale of environmental harm which is dependent upon the results of any analysis received post a fire event.

It is worth noting that the percentage split shown represents <u>all</u> waste fires reported to the EA, not just those caused by LIBs. In reality, the fires caused by LIBs could show different trends in terms of severity. Whilst there is an understanding across the industry that LIB fires mostly display unique characteristics at ignition - the ignition often being a short, intense spark or explosion, there is less understanding regarding how the characterising of the resulting fire may differ. For the purpose of developing a UK estimated impact, we have assumed that the percentage split of severity for all waste fires reported to the EA is also representative of the portion that are LIB caused.

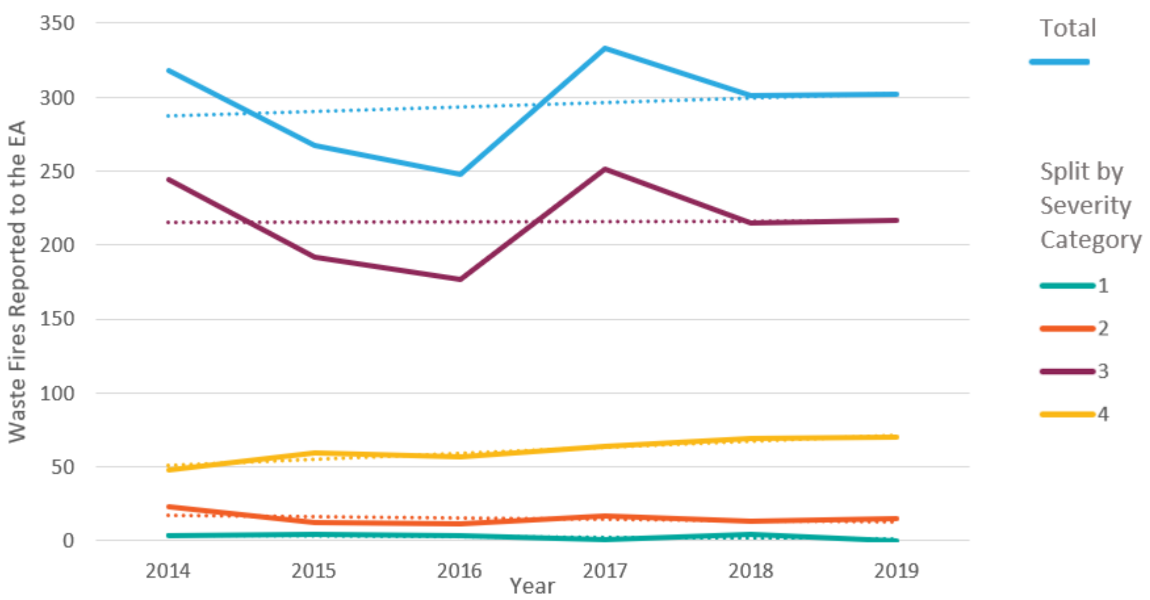
Figure 2-1: England Reported Waste Fire Occurrences by Fire Severity Category (%) 2014 - 2019



Source: EA data, provided by the EA on 15.10.20 (2020) average *% split of* waste fire *severity* reported to the EA *(*2014 – 2019)

Figure 2-2 presents the same EA data, this time showing the trend in waste fires reported annually for England. As can be seen by the blue dotted trend line, the total waste fires reported for England typically sits at around 300 per year.

Figure 2-2: England Reported Waste Fire Occurrences by Year (2014 – 2019) and by Fire Severity



Source: EA data, provided by the EA on 15.10.20 (2020) Waste fires reported for England 2014 – 2019
Note: Dotted lines represent linear trend lines

2.2.2 Scope of Costs Considered

The modelling aims to takes account of both direct costs (e.g. from material damage and business interruption) and indirect costs (e.g. due air quality and health impacts, and environmental impacts). Further, the modelling estimates the costs based on who they are incurred by. The costs considered are as follows:

- Costs incurred by **Waste Site Operators**
  - Material Damage
  - Business Interruption
  - Contents
  - Resources
  - Machine and plant
  - Stock
  - Other
- Costs incurred by **Fire and Rescue Service**
  - Resource Costs
- Costs incurred by **EA**
  - Attendance

- Costs incurred by **Society**
  - Air Pollution
- Costs incurred by **Environment**
  - Water
  - Greenhouse Gas Emissions

Please see Appendix A.1.2 for a more detailed breakdown of these costs, including the method for calculation and (where applicable) the source of any data referenced.

Regarding the costs incurred by waste site operators, our calculations use confidential case studies as a basis, and extrapolate the costs using a percentage breakdown as provided in the 2012 RISC Review Report[19], and the cost impact factor, as outlined in Table 2-3. Whilst this methodology provides our best estimate, it is worth noting that there are some complexities regarding how the cost of waste fires are recovered. It is our understanding that smaller fires (likely under £10k), are often not reported to insurance providers, as it is often cheaper for waste site operators to cover these costs directly, rather than paying an excess and increased premium. Medium cost fires can often be covered by 'captive' insurance, where a waste company has created a licenced insurance company to provide coverage for itself (essentially an 'in-house' insurance company that allows the waste company to self-insure). The larger cost fires (over £5million), however, are typically the cases which are claimed via a conventional insurance route. Firstly, this means that there may be a number of smaller fires that are not reported to the EA (or insurance companies) as outlined earlier in Section 2.1 when explaining the difference in EA figures verses ESA figures on fire numbers. This lack of reporting means that the total number of waste fires is likely higher than reported and thus the total cost incurred is underestimated. Secondly this could mean that the percentage split for the severity of fires used in our modelling may be biased towards the larger fires as these are the ones most often recorded.

There are some costs which, although known to be occurring, have not been included in scope of this model as, without further data, they have been too challenging to quantify accurately. The main excluded costs are outlined below:

- **Broader societal costs**
  - Such as road closures and traffic disruption but also, more broadly, factors such as the impact on schools, health systems etc.
- **Broader environmental costs**
  - Such as groundwater contamination or the cost of land remediation after an incident
  - The cost of energy consumption

[19] RISC Authority (2010) Review Report - Industrial Processing - Recycling, https://www.riscauthority.co.uk//index.cfm?originalUrl=free-document-library/RISCAuthority-Library_detail.risk-review-report-industrial-processing-recycling.html&_tkn=DAD2434F%2D3E35%2D4AE3%2DB97D8A5A558130A9

- **Broader business costs**
    - Such as the cost of closing neighbouring sites,
    - The loss of resource, (though 'contents' cost was covered at a high level in the costs incurred by waste site operators, we have not covered this in more detail due to the complexities with some wastes having a negative value), and
    - The loss/ damage of business reputation following a fire.
- **Costs of differing waste types burnt**
    - Regarding the cost of air pollution and air quality, these have been calculated dependent on the tonnage burnt under each severity scenario. It is worth noting that this will vary in reality dependant on the type of waste burnt, as these contain differing levels of pollutants and greenhouse gases.

2.2.3 Results

Looking at the scope of costs as outlined in Section 2.2.2, the estimated cost of a fire occurring in each of the four severity categories was calculated. These costs are presented below in Table 2-4.

It is important to note that the actual costs of fires will vary significantly depending on a range of factors, and these costs are purely indicative, used for the purpose of developing a UK estimated impact.

Table 2-4: Cost per Fire, by Severity Category

Fire Severity Category		Estimated Cost per Fire (£)
Most severe	1	£3,840,721
↕	2	£1,836,470
	3	£872,023
Least severe	4	£90,656

In terms of how these costs are broken down within each of the four severity levels, the trends are fairly similar, though this will be, in part, because of the model methodology adopted. Appendix A.1.3 presents a breakdown of who the costs are typically incurred by. Our modelling suggests that typically the majority of costs are incurred by waste site operators, followed by the Fire and Rescue Service or the environment (dependent on the fire severity) then society and then the EA.

2.3 Costs of Waste Fires – UK Scale

Using the costs per fire (as presented in Table 2-4) and the estimated number of waste fires occurring in the UK which could be attributed to LIBs (as presented in Table 2-1), it was possible to estimate an annual cost for waste fires in the UK caused by LIBs. The main findings are presented in Table 2-5. These costs cover all costs modelled (societal, environmental, material etc, as outlined in Section 2.2.2).

Table 2-5: UK Cost of Waste Fires Caused by Li-ion Batteries

Fire Severity Category	% of Total Fires	Estimated Cost per Fire (£mil)	Annual number of waste fires attributed to Li-ion batteries	Estimated Annual Cost (£mil)
1	0.8%	£3.8	1.7	£6.6
2	5%	£1.8	10.4	£19.0
3	73%	£0.9	147.5	£128.6
4	21%	£0.1	41.8	£3.8
Total				**£158**

Figure 2-3 presents these findings in a pie chart format, with each segment representing the annual cost to the UK for each severity category. Figure 2-4 presents the findings broken down by who the costs are incurred by.

As can be seen in the charts, although Severity 1 fires are modelled as the most costly (at approximately £3.8 million per fire), they represent only 0.8% of waste fires, thus the modelled total annual cost cause by these fires is fairly small (4% of the total).

Severity 3 waste fires, however, whilst modelled as the second least expensive (at £0.9 million per fire), they represent 73% of the UKs waste fires and therefore account for the vast majority of costs from waste fires caused by LIBs (82%).

In terms of who the costs are typically incurred by, waste site operators incur the largest portion of costs (89.6%). This is followed by the Fire and Rescue Service (3.7%), Environment (4.9%), Society (1.5%) and EA (0.4%).

Figure 2-3: UK Cost of Waste Fires Caused by Li-ion Batteries by Severity Category (£mil)

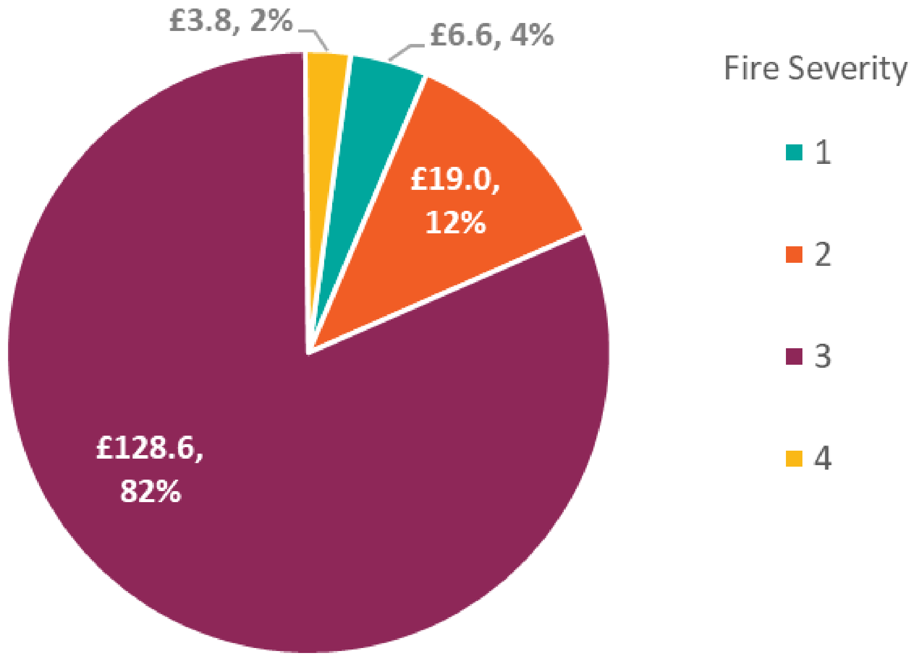
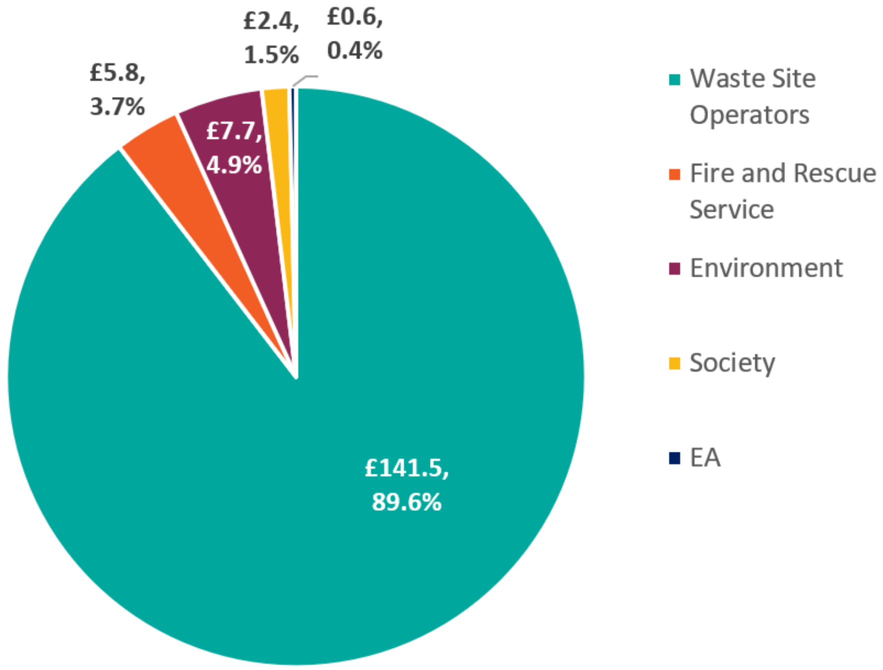


Figure 2-4: UK Cost of Waste Fires Caused by Li-ion Batteries by 'Cost Incurred By' (%)



2.4 Cost of Waste Fires Conclusions

Through desk-based research and conversations with the EA, Fire Service and members of the Steering Group, we have been able to acquire data and gain an understanding of the costs that can be attributed to waste fires caused by LIBs in the UK.

Through our research, we have estimated that around **48%** of waste fires can be attributed to LIBs. Whilst exact numbers are unknown, as this is not consistently reported on or investigated, it is clear that this is a very significant proportion of total waste fires and equates to approximately **201** waste fires in the UK each year.

Overall, we estimate that the total annual cost to the UK of waste fires caused by LIBs is **£158 million**. The breakdown of who these costs are incurred by each year is as follows:

- Waste Site Operators: 90%
- The Fire and Rescue Service: 4%
- The Environment: 5%
- Society: 2%
- The EA: 0.4%

These fires vary significantly in terms of severity, duration and categories and will therefore have different cost implications. Generally, the more severe a fire, the more significant the cost implications. Despite this, due to the high number of category 3 fires, it is estimated that these have the highest cost implications year on year for the UK.

Although these findings are a crucial first step in understanding the real-life cost implications of waste fires caused by LIBs, it is important to flag that there are still several gaps in the data. Using previous experience and industry expertise, assumptions have been developed, however due data limitations, these outputs should be seen as indicative estimates and in reality, the total cost may be underestimated.

Further, these costs represent a snapshot image of the total cost to the UK. It is clear from our research that there has been a historic increase in the use of LIBs and this trend is likely to continue, therefore the number of incidents and thus costs are likely to increase further, unless proactive interventions and policy measures are introduced to curb the growth in the number fires started by LIBs.

3.0 Current UK Regulatory Landscape

This section gives an overview of the current UK regulatory landscape for batteries and WEEE that contains batteries. It provides important context for possible new policy measures to help eliminate batteries from residual and mixed recycling waste streams, helping to ensure that additional measures genuinely advance beyond the regulations that are already written into law.

3.1 UK Waste Batteries and Accumulators Regulations

In the UK, batteries are primarily regulated by the 2006 EU Batteries and Accumulators and Waste Batteries and Accumulators Directive[20], amended by Directive 2013/56/EU.[21] Article 16 of Directive 2006/66/EC requires Member States to "ensure that producers, or third parties acting on their behalf, finance any net costs" arising from the collection and treatment of batteries and accumulators.

The Directive was transposed into UK law as the Batteries and Accumulators (Placing on the Market) Regulations 2008[22] amended by the Waste Batteries and Accumulators Regulations 2009[23] and the Batteries and Accumulators (Placing on the Market) (Amendment) Regulations 2015.[24] These regulations set out requirements for waste collection, treatment, recycling and disposal for all battery types. Of relevance to this report, these regulations require producers:

- To meet a collection target of 45% for waste portable batteries,[25] calculated by weight (not by number of batteries).
- To provide battery collection sites that are accessible and free of charge to the public.
- To join one of the registered Producer Compliance Schemes (PCS), if they place one tonne or more of portable batteries on the UK market. Through these

[20] European Union (2006) *Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC*, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:266:0001:0014:en:PDF
[21] European Union (2013) Directive 2013/56/EU amending Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and repealing Commission Decision 2009/603/EC, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:329:0005:0009:EN:PDF
[22] UK Government (2008) *The Batteries and Accumulators (Placing on the Market) Regulations 2008*, https://www.legislation.gov.uk/uksi/2008/2164/contents
[23] UK Government (2009) *The Waste Batteries and Accumulators Regulations 2009*, https://www.legislation.gov.uk/uksi/2009/890/contents/made
[24] UK Government (2015) *The Batteries and Accumulators (Placing on the Market) (Amendment) Regulations 2015*, https://www.legislation.gov.uk/uksi/2015/63/pdfs/uksi_20150063_en.pdf
[25] The UK government Office for Product Safety and Standards (OPSS) defines a portable battery as a battery that is sealed, under 4kg, and not for automotive nor industrial use.

schemes, producers must pay for the collection, treatment or recycling of a proportion of waste portable batteries, calculated by their market share of battery sales from the previous year. This is called Producer Responsibility.

- To ensure that batteries are visibly, legibly and indelibly labelled with their chemical composition. Batteries must also be labelled with a crossed out wheeled bin as shown in Figure 3-1 below, to indicate that they should not be placed in household waste.[26]

Figure 3-1: Crossed Out Wheeled Bin Label Required on All Batteries

Source: https://www.gov.uk/guidance/batteries#making-batteries-readily-removable

In 2018 and 2019, the UK exceeded its target collection rate for waste portable batteries with rates of 45.23% and 45.36% respectively.[27,28] However, these overall figures hide differences in collection rates between different types of portable battery. Government data groups portable batteries into three categories: lead acid, nickel cadmium (Ni-Cd) and 'other' (including LIBs). Although batteries in the 'other' category made up 96% of the 39,533 tonnes of batteries placed on the market in 2019, they only accounted for around 33% of the batteries separately collected in 2019, as shown in Figure 3-2.[29] Conversely, although lead-acid batteries only made up 4% of batteries placed on the market in 2019, they accounted for the majority (61%) of batteries collected in 2019 (in part down to the high weight per unit, although there is a question mark around the number of lead-acid batteries considered 'portable').

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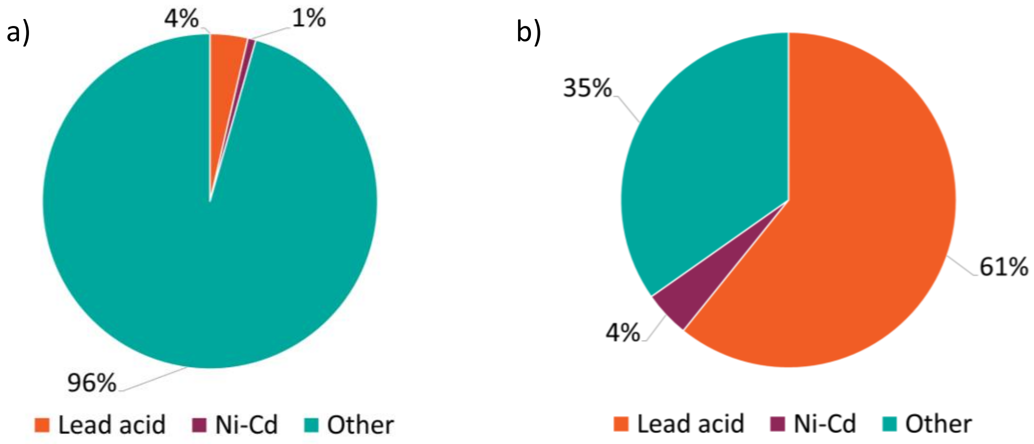
[26] BEIS, OPSS & DEFRA (2015) *Batteries and accumulators (placing on the market) regulations: compliance and guidance*, https://www.gov.uk/guidance/batteries#making-batteries-readily-removable

[27] Environment Agency (2018) *Summary of Portable Batteries Data for the 2018 Compliance Period - as at 28th May 2018*, https://npwd.environment-agency.gov.uk/FileDownload.ashx?FileId=d1dddb70-4c7f-4d68-a6f0-e95f0c5d8826

[28] Environment Agency (2020) *Summary of Portable Batteries Data for the 2019 Compliance Period - as at 29 June 2020*, https://npwd.environment-agency.gov.uk/FileDownload.ashx?FileId=20666d33-b6b4-4a91-aaaa-704f6b05de45

[29] Ibid.

Figure 3-2: Percentage by Weight of a) 2017-19 Batteries Placed on the Market by Category and b) 2019 Batteries Collected by Category



Source: Environment Agency (2020) Summary of Portable Batteries Data for the 2019 Compliance Period - as at 29 June 2020 https://npwd.environment-agency.gov.uk/FileDownload.ashx?FileId=20666d33-b6b4-4a91-aaaa-704f6b05de45

Possible reasons for the percentage of LIBs collected being so much lower than those placed could firstly, be attributed to the lag-time between batteries being placed on the market and when they first enter the waste stream (LIBs placed on the market in 2019 may not enter the waste stream for several years). Secondly, most LIBs are in modern cordless devices designed to be slim and lightweight, with the LIBs often integrated or encapsulated within the product.[30] Correctly disposed of LIBs will be collected in WEEE, but it is thought that some batteries are not adequately captured during WEEE processing because battery removal prior to fragmentation/ shredding is not mandatory. There is also a difficulty in recording exported LIBs in functional second-hand devices – these batteries effectively escape the UK collection network, despite having been recorded as being placed on the market.[31]

However, in addition, consumers may not realise that a product contains a LIB that needs to be removed for disposal, or if they do, it may require a professional to remove the battery so they may choose to avoid the hassle of taking it to a professional and simply throw the whole product in the general or mixed recycling bin, which means they are not collected as batteries. Some devices are designed so that the battery can be removed easily and safely, e.g. a battery-powered hand drill, while for others, e.g. most smart phones, battery removal is not practical without dismantling the device. If a battery can be removed easily and safely, then members of the public should do so and dispose of it separately. But if not, then the whole item must be disposed of as WEEE

[30] Sims Lifecycle Services (2019) *A Closer Look: Lithium-Ion Batteries in E-waste*, accessed August 2020, https://www.simsrecycling.com/2019/05/21/a-closer-look-lithium-ion-batteries-in-e-waste/

[31] Ecosurety (2019) *The UK exceeds its 2018 battery collection target of 45%*, accessed 21 August 2020, https://www.ecosurety.com/news/the-uk-exceeds-its-2018-battery-collection-target-of-45/

and the battery removed by a professional as part of the WEEE stream (see Section 4.3.2 for our recommendation for reducing fires at WEEE reprocessing plants).

Another barrier to consumers correctly disposing of LIBs or WEEE containing LIBs – and these being recorded as collected in the Environment Agency's data – is that the majority of battery collection points are at Household Waste Recycling Centres (HWRCs) which are often out of town and need a car to access. There are also collection points in retail locations (which must provide free take-back if more than 32kg of batteries are sold each year) and community collection points such as schools, but these are invariably for very small AAA, AA and 9v batteries, and not designed for the larger LIBs. Small domestic batteries such as AA and AAA rarely cause major fires, unless there are many of them together – it is larger LIBs such as those in power tools and electric scooters that cause the biggest fires.

Finally, the tonnage of 'portable' lead acid batteries collected as shown in Figure 3-2 may be exaggerated due to battery producers and recyclers categorising lead acid batteries as 'portable' or 'industrial' differently at the beginning and end of life, resulting in more 'portable' lead acid batteries being collected for recycling than producers are obligated to finance.[32,33] While the definition of portable batteries had been somewhat ambiguous, from 1 January 2016 any battery under 4 kg has been classed as portable unless designed exclusively for professional or industrial use, in which case they are industrial. Nevertheless, recyclers claim that they are still often unable to determine the original use of some lead acid batteries and therefore are unable to correctly categorise them[34] (e.g. those used to power portable and wheeled applications – they are the preferred power source for biomedical and healthcare instruments in hospitals and retirement homes).

As a result, there is some doubt over the effectiveness of the EPR scheme for portable batteries, and the reliability of the data in terms of meeting the 45% collection target. Greater effort needs to be made to increase the capture of portable LIBs discarded by householders in order to meet the targets without such reliance on 'portable' lead-acid batteries. In terms of fire risk, it is far too easy for portable LIBs to be disposed of in residual waste, particularly given the general lack of kerbside battery collection for households.

The compliance scheme Batteryback has been working with Defra to try and solve some of these reporting problems and one suggestion is to have chemistry-specific targets and charges, as done in certain EU countries.[35] This might at least help with the problem that

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[32] *Ibid.*
[33] Letsrecycle (2020) *Lead acid concern UK battery recycling,* accessed 21 August 2020, https://www.letsrecycle.com/news/latest-news/lead-acid-concern-uk-battery-recycling/
[34] Letsrecycle (2019) *Battery recycling target for 2018 met,* accessed 21 August 2020, https://www.letsrecycle.com/news/latest-news/battery-recycling-target-for-2018-met/
[35] Letsrecycle (2019) *Battery recycling target for 2018 met,* accessed 21 August, 2020, https://www.letsrecycle.com/news/latest-news/battery-recycling-target-for-2018-met/

calculating targets by weight arguably undervalues LIBs, which are relatively small, lightweight, and energy dense compared to other battery types.[36] In the Resources and Waste Strategy, Defra announced its intent to review the regulations in 2020.[37]

3.2 UK WEEE Regulations

WEEE is defined as any equipment that requires electrical current (from a battery or the mains) to perform its primary function.[38] WEEE often contains LIBs and its management is relevant to this report. The EU WEEE Directive was updated in 2012.[39] Article 7 of Directive 2012/19/EU requires Member States to "ensure the implementation of the 'producer responsibility'" in respect of meeting collection and recycling targets for waste electrical and electronic equipment. The Directive is incorporated into UK law in the Waste Electrical and Electronic Equipment Regulations 2013 (as amended)[40] and Defra is reviewing the UK Regulations this year.

The Office for Product Safety and Standards (OPSS), part of BEIS, is responsible for enforcing the regulations in relation to marking electrical and electronic equipment (EEE) with the crossed-out wheeled bin symbol (see Figure 3-1) and ensuring distributors meet their obligations. The Environment Agency and its equivalents in the devolved administrations are responsible for enforcing the regulations in relation to the operation of Producer Compliance Schemes (PCSs), Approved Authorised Treatment Facilities (AATFs) and designated collection facilities (DCFs).[41]

Defra calculates a guideline amount of WEEE to be collected, based on the Directive's 65% collection target (related to the average of the previous three year's placed on market figure by weight).[42] WEEE is primarily collected via consumers depositing it at DCFs – principally, local authority household waste recycling centres (HWRCs). As with batteries, the cost of collection and treatment or recycling is covered by producers via their compliance schemes (see Section 3.1).[43] Battery weights are deducted from the

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[36] Letsrecycle (2019) *Battery recycling target for 2018 met*, accessed 21 August 2020, https://www.letsrecycle.com/news/latest-news/battery-recycling-target-for-2018-met/
[37] Defra (2018) *Our Waste, Our Resources: A Strategy for England,* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/765914/resources-waste-strategy-dec-2018.pdf
[38] 360 Environmental (2020) *WEEE Regulations,* accessed 21 August 2020, https://www.360environmental.co.uk/legislation/producer_responsibility/weee_regulations/
[39] (2012) Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast)
[40] UK Government (2013) The Waste Electrical and Electronic Equipment Regulations 2013
[41] OPSS (2018) *Regulations: waste electrical and electronic equipment (WEEE)* https://www.gov.uk/guidance/regulations-waste-electrical-and-electronic-equipment
[42]360 Environmental (2020) *WEEE Regulations,* accessed 21 August 2020, https://www.360environmental.co.uk/legislation/producer_responsibility/weee_regulations/
[43] Environment Agency (2020) *Household Waste electrical and electronic equipment (WEEE) Collected in the UK,*

total weight of WEEE.[44] If a producer places EEE that contains batteries on the market, they must separately calculate the weight of WEEE and the weight of batteries for the separate WEEE and battery producer compliance schemes.

The UK has repeatedly missed the collection target for household WEEE, despite the use of substantiated estimates for WEEE dealt with outside the formal EPR channels.[45] Recent studies, e.g. by Eunomia for Defra[46] and the DTS[47], and recent survey work for Material Change, have shown that, in general, small WEEE (small appliances and electronic devices) poses the greatest challenges to WEEE collection and recycling.

The UK is unusual (perhaps unique) in that considerable use is made of the derogation option under Article 5 (2) of the WEEE Directive, to allow distributors/retailers to help to finance local authorities via the Distributor Take Back Scheme (DTS) to collect WEEE free of charge, primarily through the HWRCs.

Article 5 states that derogations may only be applied in regard to retailer take-back "*provided that they ensure that returning the WEEE is not thereby made more difficult for the final holder and that it remains free of charge for the final holder*" and where "*alternative existing collection schemes are likely to be at least as effective. Such assessments shall be available to the public.*"

It is not unreasonable to suggest that taking WEEE to a relatively distant (often out of town) HWRC – for which the UK density is very low as noted above – is often less convenient for some consumers than taking WEEE to an in-town retailer, and impossible for those without cars. Consequently, they may be more likely to hoard or dispose of WEEE (and small WEEE in particular) in their residual bin. Moreover, LIBs are more integrated into the product and so more difficult to remove for recycling by the consumer or during reprocessing.

With regard to fire risk, we believe that the current WEEE EPR system is not doing enough to a) prevent WEEE containing batteries from entering the residual waste stream and b) to effectively capture (undamaged) LIBs during reprocessing even when WEEE is separately collected (see section 3.3). A report published by EuRIC and the WEEE Forum in May 2020 found that fires occur at every stage of the WEEE collection and treatment

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https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/786012/WEEE_collected_in_the_UK.ods

[44] Environment Agency (2020) *WEEE: evidence and national protocols guidance,* https://www.gov.uk/government/publications/weee-evidence-and-national-protocols-guidance/waste-electrical-and-electronic-equipment-weee-evidence-and-national-protocols-guidance

[45] Environment Agency (2020) *Household Waste electrical and electronic equipment (WEEE) Collected in the UK,* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/786012/WEEE_collected_in_the_UK.ods

[46] Defra 2020. Electrical and Electronic Equipment: Ingredients for Successful Extended Producer Responsibility.

[47] Valpak/DTS 2020. Assessment of WEEE collection systems and their effectiveness in other European countries

chain, but that the highest prevalence was at the shredding stage of treatment and during storage in the logistics and pre-treatment stages, and that damaged batteries cause these fires in the large majority of cases.[48]

3.3 WEEE Treatment Guidelines and Standards

WEEE treatment guidelines and standards are relevant insofar as they are the means by which governments and compliance schemes seek to ensure that batteries are removed from WEEE effectively and without fire risk. This is not the main focus of the report but has been included briefly for completeness.

3.3.1 UK BATRRT

The Best Available Treatment, Recovery and Recycling Techniques (BATRRT) provide statutory guidance for dealing with waste batteries in the UK.[49] These were published in 2006 and have not been updated. The guidelines are somewhat vague and although they specify that batteries should be removed from WEEE, they do not specify at what stage in the treatment process this should occur, and therefore are not fully effective in preventing fires at WEEE treatment sites caused by damaged batteries. In general, in the UK fragmentation/shredding is undertaken and afterwards batteries that can be identified are removed on picking lines.

3.3.2 WEEELabex and CENELEC

The WEEE Label of Excellence (WEEELabex) is a private organization, established in 2011, that audits and certifies WEEE treatment sites to the WEEELabex standards.[50] The European Committee for Electrotechnical Standardization (CENELEC) is another private organisation that subsequently turned the WEEELabex requirements into a European standard – the European Standards for Waste Electrical and Electronic Equipment (WEEE).[51] WEEELabex/CENELEC have much more prescriptive guidelines about battery removal prior to shredding than the UK's BATRRT. WEEELabex certified operators are subject to targets for battery removal. The CENELEC standard says in Annex A:[52]

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[48] EuRIC & WEEE Forum (2020) *Characterisation of Fires Caused by Batteries in WEEE* https://1ur6751k3lsj3droh41tcsra-wpengine.netdna-ssl.com/wp-content/uploads/2020/05/26.05.2020-Report-Characterisation-of-fires-caused-by-batteries-in-WEEE.pdf

[49] Defra (2006) Guidance on Best Available Treatment Recovery and Recycling Techniques (BATRRT) and treatment of Waste Electrical and Electronic Equipment (WEEE), https://webarchive.nationalarchives.gov.uk/20130403043343/http://archive.defra.gov.uk/environment/waste/producer/electrical/documents/weee-batrrt-guidance.pdf

[50] WEEELABEX (2020) *About us*, accessed August 2020, https://www.weeelabex.org/about-us/

[51] CENELEC (2017) *European Standards for Waste Electrical and Electronic Equipment (WEEE),* https://www.cencenelec.eu/news/publications/publications/weee-brochure.pdf

[52] CENELEC (2013) *Draft standard for treatment of WEEE,* https://www.eera-recyclers.com/files/fpren50625-1-general-treatment-standard.pdf

- Batteries which are accessible in WEEE without using tools shall be removed as a distinct step during the treatment process and prior to size reduction and separation (i.e. before any treatment process that can cause damage to them).
- Batteries which are not accessible in WEEE without using tools shall be removed as an identifiable stream during the treatment process.

Bi-annual audits include monitoring the removal process, checking compliance with targets on batteries and checking the condition of the removed batteries. Compliance with WEEELabex is voluntary, but it is expected that the CENELEC standard will be integrated as a requirement under the EU WEEE Directive in its next update.[53] Although the UK is no longer part of the EU, it could voluntarily replace BATRRT with the WEEELabex/CENELEC standard, or at least move closer to these in terms of battery removal. Currently the UK has no WEEELabex or CENELEC accredited Small Mixed WEEE Treatment facilities.

[53] Sustainable Recycling Industries (2015) *Comparison of WEEE-Standards from Switzerland, Europe and the US,* https://www.sustainable-recycling.org/wp-content/uploads/2015/07/SRI_ComparisonStandards_2015en.pdf

4.0 International Review of Best Practice

This section reports the findings of an international review conducted of ‘up-stream’ practices that are designed to keep batteries out of residual and mixed recycling waste streams, thereby preventing or dramatically reducing the number of fires in waste caused by LIBs. While these measures are generally complemented by behaviour change initiatives, such as household communication programmes, such initiatives were excluded from the scope of this research to avoid duplication of other work the ESA is currently conducting in this area. We include improved labelling of batteries and products containing batteries under communications; therefore they are also excluded from the scope of this research.

The focus of this research is on solutions that are practical to implement in the UK. It examines interventions that could have an impact in the short term, as well as medium- to long- term interventions that could be fed into ongoing policy change processes, such as the consultations on Waste Carriers and Duty of Care and Waste Batteries and Accumulators Regulations promised in Defra’s Resources and Waste Strategy[54] or changes to the WEEE EPR regime.

As previously highlighted in Section 3.1, the collection rate for individual LIBs (many of which have to be removed from WEEE) is generally quite low compared to other battery types. This is thought to be due largely to hoarding, the placing of batteries and small WEEE into residual waste, and the inherent difficulty in their removal from products. To address this, the following policy and practice suggestions include measures that aim to reduce the number of small WEEE items and separate LIBs from entering household residual/recycling bins, and measures to help prevent battery fires during WEEE reprocessing.

It seems intuitive that consumers are more likely to respond to measures targeting either batteries in general or small WEEE in general, whereas a focus on LIBs in particular might be confusing. There are a number of different types of battery on the market that can be difficult for consumers to differentiate between,[55] and so any measure that targets only one type of battery is likely to be made less effective due to a lack of public awareness regarding which products specifically contain LIBs.

Wherever possible, case studies of each policy or practice are provided, to evidence whether they can be successful in preventing LIB-caused waste fires, with an appraisal of their relevance to the UK regulatory environment. Within these case studies we highlight

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[54] Defra (2018) *Our Waste, Our Resources: A Strategy for England* , Accessed August 2020, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/765914/resources-waste-strategy-dec-2018.pdf

[55] Circular (2020) *New research shows public ‘still confused’ about recycling*, accessed August 2020, https://www.circularonline.co.uk/news/new-research-shows-public-still-confused-about-recycling/

the aim of the measure, the method of execution and its effectiveness, together with a discussion of how it could be implemented in the UK. The results of the review feed into the recommendations presented in Section 5.0.

The mechanisms and policies are grouped into the following categories:

- Section 4.1 outlines options to ensure that a higher proportion of batteries and WEEE are captured and therefore prevented from entering residual and mixed recycling waste streams;
- Section 4.2 looks at supporting policy mechanisms to cover costs of improved battery capture, incentivise producers to improve battery and EEE design and to ensure consumer compliance with collection schemes;
- Section 4.3 explores wider mechanisms including a long-term option to change battery design to reduce the risk of them causing fires, and options to ensure that batteries are removed from products before shredding at WEEE processing facilities.

4.1 Better Mechanisms to Capture Batteries

The mechanisms explored in this section are designed to increase the capture of batteries by making it easier for consumers to correctly dispose of batteries/small WEEE.

4.1.1 Separate Kerbside Battery and/or Small WEEE Collections

Establishing widespread separate kerbside collections for small WEEE and/or batteries has the potential to substantially increase LIB collection rates by removing the need for consumers to travel to a collection point.

Collection trials conducted by WRAP between 2005 and 2008 found that kerbside collection was the most effective way to maximise yields of waste portable household waste batteries. WRAP concluded that this was because residents are accustomed to kerbside collections of other recyclable materials and respond positively to the collection of additional materials (see Case Study 4-1). However, adding kerbside collections to existing services can give rise to substantial costs and operational challenges.

In the UK there are two main types of kerbside collection systems:

- co-mingled (single-stream or two-stream), and
- multi-stream.

Co-mingled systems use compacting collection trucks (with either one or two compacting compartments), whereas multi-stream systems use trucks with multiple (mostly non-compacting) compartments. Co-mingled collection systems are considerably more widely used across the UK than multi-stream systems, which are the leading collection model only in Wales.

Multi-stream systems typically involve recyclables being presented in boxes or bags, with operatives separating them onto the correct compartments on the vehicle. Material streams such as WEEE and batteries can be added to such a system relatively straightforwardly, whether presented in the same container or a separate bag. Doing so does not create significant operational inefficiencies, provided that vehicles are designed with appropriately sized compartments for these materials – which may only be feasible at the point of fleet renewal. Some multi-stream collections already include separate collections of WEEE and batteries. Examples include:

- Anglesey County Borough Council (batteries and mobile phones only)
- Bath & North East Somerset Council
- Blaenau Gwent County Borough Council
- Bridgend County Borough Council
- Bristol City Council
- Conwy County Borough Council
- Falkirk Council
- Flintshire County Council (batteries only)
- London Borough of Bromley
- London Borough of Hounslow (WEEE only)
- Mid Devon District Council
- Neath Port Talbot County Borough Council (batteries only)
- Newport City Council (WEEE only)
- North Devon Council (WEEE only)
- North Somerset Council
- Pembrokeshire County Borough Council (batteries only)
- Rhondda Cynon Taf County Borough Council (batteries only)
- Stockton on Tees Council (batteries only)
- West Devon Council (batteries only)

Somerset Waste Partnership is also shortly to add WEEE and batteries to its collection service.

In a co-mingled collection system, (most of the) dry recycling is typically presented in a wheeled bin and emptied mechanically into the back of a compacting vehicle. An extra compartment can be installed underneath the main body of the vehicle, as shown in Figure 4-1. However, this approach to collection has the following limitations:

- The number of additional compartments that can be added per vehicle is very limited, and separately presented mixed batteries collected from households are legally required to be kept separate from other wastes (apart from small WEEE with which they can be mixed, though preferably in separate bags). They are also classified as dangerous goods and therefore must be collected in a suitable container on the vehicle.[56] Since batteries together with small WEEE cannot be mixed with other low volume materials, each authority might need to make a

[56] Croner-i (2020) *Transport of Lithium Batteries: In-depth*, accessed 15 August 2020, https://app.croneri.co.uk/topics/transport-lithiumbatteries/indepth#:~:text=All%20lithium%20batteries%20are%20Class,Criteria%20Part%20III%20subsection%2038.3.

decision that batteries are the highest priority as they strive to improve their recycling performance.

- Operatives would occasionally need to move to the side of the vehicle to deposit batteries/small WEEE, adding some time to each collection where batteries are presented. This could have an impact on collection efficiency, although discussions with waste management companies suggest that this is marginal.
- If battery and small WEEE yields are high, the cage may fill up at a faster rate than the main vehicle compartment, potentially requiring the vehicle to tip before the main compartment is full. This would take up time on the round, affecting collection efficiency. In reality this seems to be rare once the initial ‘clear out’ has taken place as the separate collection is introduced on a round.

Figure 4-1: Compartment Added to Recycling Collection Vehicle for Small WEEE

WEEE and battery collections on co-mingled services are relatively rare, although one example is Guildford Borough Council, which allows residents to present WEEE and batteries in tied bags alongside their dry recycling wheeled bin.

In summary, both co-mingled and multi-stream kerbside collection vehicles can be adapted to accommodate separate battery collections. A proportion of multi-stream services already offer collections of batteries, small WEEE, or both, and those that do not should consider doing so. In most cases it is not necessary to buy a whole new fleet to add batteries and small WEEE to kerbside collections and retrofitting a collection cage to a vehicle could cost less than £850 per vehicle.[57] Other costs associated with setting up kerbside collections include: [58]

- internal training of the collection crews;
- production and distribution of bags or boxes used in the kerbside schemes to collect the batteries from residents;
- communication campaigns and promotional material (including market research and development);
- additional operational costs resulting from operatives spending additional time sorting WEEE and/or batteries into a separate compartment on the vehicle;
- providing adequate room at the depot for battery storage at the end of the collection round before onward transport to sorting and recycling facilities;
- ensuring that the depot has the appropriate environmental permit in place;
- registering and licensing hazardous/special waste consignment notes; and
- long/short haul transportation to sorting and recycling facilities.

However, it is rare that co-mingled services include separate collections of WEEE or batteries, and it appears unlikely that this will change without the government introducing a requirement for separate collections on the kerbside, as it would be likely to entail additional costs that councils will struggle to resource.

Additional costs for adding batteries and small WEEE to the existing collection system could, however, be provided through improving the Extended Producer Responsibility system, as suggested in Section 4.2.1.1. Furthermore, over time, a significant saving should be achieved by a) the reduction of costs associated with managing fire incidents in collection vehicles and at treatment and transfer sites, as detailed in Section 2.0, and b) by selling some of the small WEEE that has residual value.

Below are three case studies from the UK (Case Study 4-1, Case Study 4-2 and Case Study 4-3). Other models, and bespoke containers, are used in other countries as Case Study 4-4 describes.

[57] Mid Sussex Council (2019) *Proposal for an Enhanced Recycling and Collection Service for Textiles and Small Waste Electrical and Electronic Equipment*, accessed August 2020, https://midsussex.moderngov.co.uk/documents/s6370/Proposal%20for%20an%20Enhanced%20Recycling%20Collection%20Service%20for%20Textiles%20and%20Small%20Waste%20Electrical%20and%20El.pdf
[58] WRAP (2008) *Household Battery Collection Trials April 2005 – March 2008*, accessed July 2020, http://www.wrapni.org.uk/sites/files/wrap/Batteries%20report%20-%20final.pdf

Case Study 4-1: WRAP Collection Trials 2005-2008

Location	Nationwide
Aim	To gain a better understanding of the most cost-efficient ways to collect portable household waste batteries.
Results	The study examined yields of batteries resulting from the introduction of different collection approaches in areas where people previously had no battery collection option. WRAP found that kerbside collection of batteries had the best collection rate at 81g per capita over the 22-month period of the trial, compared to just 22g per capita for retail take-back.[59] If this result was scaled up for the whole UK population, it would equate to approximately 3,000 tonnes of batteries recycled per annum, many of which would be diverted from residual and mixed recycling waste streams.

Overview

From 2005-2008 WRAP carried out a series of battery collection trials to gain a better understanding of the most cost-efficient ways to collect portable household waste batteries. The different collection schemes included:

- kerbside collection
- retail take-back
- community drop-off
- postal collections
- NHS collections
- Fire Service collections

The kerbside collection trials were run in conjunction with either single material collections or a kerbside sort scheme where batteries had not previously been collected. The batteries were collected alongside the normal dry recyclable collection. Residents involved in the trial were given recycling bags by collection crews on their rounds or via a door-to-door service (run by the Royal Mail). Each household received a roll of bags (3-6 bags) along with an informative leaflet that described the trials and why they were running, what residents should do with their batteries and what type of batteries were being collected.

The study found that the success of kerbside collections is likely to be enhanced if a marketing campaign is used to raise awareness of the collection of batteries at the kerbside and that residents would be encouraged to recycle their household batteries if they were provided with special containers in which to store their used batteries.

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[59] WRAP (2008) *Household Battery Collection Trials April 2005 – March 2008*, accessed July 2020, http://www.wrapni.org.uk/sites/files/wrap/Batteries%20report%20-%20final.pdf

Case Study 4-2: Separate Household Battery Collection

Location	London Borough of Bromley
Aim	The London Borough of Bromley Council (LBBC) wanted to improve their waste and recycling services. They wanted to add extra materials to their kerbside collections and have a fleet that was also more environmentally friendly and produced fewer emissions.[60]
Results	After the first month of operation of the new service, it was reported that 480kg of household batteries had been recycled, where previously there had been no battery collection service.[61] Unfortunately, data on the service's ongoing performance is not yet publicly available, although it will in due course be reported through WasteDataFlow.

Overview

In September 2019, the LBBC introduced a new range of waste collection vehicles which were specifically designed to allow for a number of new materials to be added to the council's recycling services, including batteries, textiles and small WEEE. Veolia invested £6 million in this new fleet.[62] The new vehicles are equipped with storage cages and residents are encouraged to put their used batteries or small WEEE into loosely tied plastic bags (not black sacks) and place them next to their other recycling bins and boxes for collection.

[60] London Borough of Bromley Council (2019) *New collection vehicles help improve recycling*, https://www.bromley.gov.uk/press/article/1545/new_collection_vehicles_help_improve_recycling
[61] Bromley Times (2019) *Bromley's new waste trucks mean more recycling*, accessed 10 August 2020, https://www.bromleytimes.co.uk/news/new-recycling-vehicles-1-6298201
[62] Letsrecycle (2019) *Veolia invests in £6m Bromley fleet*, accessed 10 August 2020, https://www.letsrecycle.com/news/latest-news/veolia-invests-in-6m-bromley-fleet/

Case Study 4-3: Welsh Multi-Stream Collections

Location	Wales (nationally implemented)
Aim	The Welsh Assembly Government aimed to substantially increase household waste recycling performance across Wales. This was not specifically directed at batteries or small WEEE but is relevant because it led to the implementation of multi-stream waste collection services, which in some instances led authorities to introduce WEEE and/or battery collections.
Results	Eleven out of the 22 Welsh local authorities now run multi-stream services and, according to WasteDataFlow, five had implemented separate collections of small WEEE and batteries as at March 2019.[63] In 2013/2014, the first date for which data is available, 26 tonnes of small WEEE were collected separately in Wales; by 2018/19, this had risen to 28 tonnes of separately collected batteries and 133 tonnes of small WEEE.[64]

Overview

In 2011, the Welsh Assembly Government set out its Collections Blueprint, which proposed a series of recommendations to maximise recycling, including a multi-stream kerbside sort system.[65] The Welsh Government also invested heavily in local authority waste services, supporting councils with capital investment grants to achieve higher recycling rates.

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[63] WasteDataFlow 2018-19, www.wastedataflow.org
[64] Ibid.
[65] Welsh Assembly Government (2011) Collections Blueprint for affordable and sustainable local authority collection services for recyclable, compostable and residual waste, http://www.wrapcymru.org.uk/sites/files/wrap/Municipal%20Sector%20Plan%20Wales%20-%20Collections%20Buleprint.pdf

Case Study 4-4: European Small WEEE & Battery Household Collection Boxes

Location	The Netherlands and Sweden
Aim	To provide a visual cue and make it easier for consumers to separate their waste batteries and small WEEE for collection.

Overview

In the Netherlands in 2017, Wecycle launched a doorstep collection programme for small WEEE with Thuiswinkel and PostNL. The programme enables consumers in several cities to hand-over WEEE with every delivery of an item, without needing to package it or to pre-inform the collector.[66] Wecycle also provides 'Jekko boxes' to householders, to use at home for small WEEE, batteries and lamps, as shown in Figure 4-2. Once full, Jekko boxes can be returned to Wecycle for recycling.

Figure 4-2: Wecycle Jekko Collection Box for Households in the Netherlands

The municipality of Aneby in southern Sweden, with a population of 6,800,[67] collects a range of household waste, including WEEE and batteries. All houses are provided with red boxes (pictured) for kerbside collections. These have an opening and closing

[66] DG Environment, E.C., Deloitte, and BiPRO (2018) *Final Report: WEEE compliance promotion exercise*, April 2018, https://publications.europa.eu/en/publication-detail/-/publication/09c7215a-49c5-11e8-be1d-01aa75ed71a1/language-en/format-PDF/source-69738062

[67] https://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-composition/population-statistics/pong/tables-and-graphs/yearly-statistics--municipalities-counties-and-the-whole-country/population-in-the-country-counties-and-municipalities-on-31122017-and-population-change-in-2017/

mechanism that is designed to be child-proof. Batteries and light bulbs must be placed in transparent plastic bags to make emptying the boxes easier for the driver.

Figure 4-3: Red Box for Kerbside WEEE and Battery Collection in Sweden

4.1.2 Increased Retail Collection Points

In the UK, most batteries and WEEE are collected at municipal collection points such as Household Waste Recycling Centres (HWRCs), and at retail locations that offer battery banks (e.g. supermarkets, DIY stores). UK regulations on batteries already require retailers that sell on average more than one pack of 4x AA batteries per day to provide free in-store take-back of waste portable batteries. Battery compliance schemes provide thousands of collection points. For example, BatteryBack is a producer compliance scheme with over 30,000 battery collection points in places like schools, colleges and public buildings.[68] The Office for Product Safety and Standards manages the retail takeback scheme and has the power to issue fines of up to £5,000 if a business is found to be non-compliant.[69]

However, while stores are required to provide appropriate information for customers to let them know about the battery take-back facility, many do not make this facility very prominent. In addition, they are often designed for very small batteries only, with limited space to accommodate LIBs from cordless appliances and electronics. Furthermore, there is currently very limited provision for the take back of WEEE in retail, with most EEE retailers joining the Distributor Take-back Scheme (DTS) to avoid the obligation, or doing little to promote the take back facility (which would be over the counter rather than through a container).

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[68] Battery Back (2020), *About Battery Back*, accessed 14 August 2020, http://www.batteryback.org/about.html

[69] UK Government (2020) *Battery waste: retailer and distributor responsibilities*, accessed 13 August 2020, https://www.gov.uk/battery-waste-supplier-reponsibilities

Increasing the number and prominence of retail collection points would reduce the distance consumers have to travel to drop off their waste batteries and small WEEE containing LIBs, and the increased visibility and convenience could increase collection rates. Our work for the DTS[70] revealed that the UK has one of the lowest densities of municipal WEEE collection points in the EU per inhabitant: 1.7 per 100,000 compared to 9 in Germany at the other extreme; a quarter of the number per km^2 compared with Belgium; and half the number per km^2 compared to France. It also revealed that the UK has the lowest number of retail collection points per inhabitant for WEEE.

To encourage consumers to take their used batteries and small WEEE to collection points, appropriate containers must be provided and the containers need to be serviced regularly. Containers must be appropriately designed to accept all types of batteries, and small WEEE, although there could be the option to have different containers for different batteries and separate containers for small WEEE. This would be significantly cheaper than establishing a separate kerbside collection (as opposed to an add-on to an existing recycling service), although it is likely to yield lower collection performance than kerbside as our work for the DTS showed in regard to small WEEE collection (also see Case Study 4-1). The effectiveness of this option depends to some degree on the number and location of collection points, but also on consumer awareness and willingness as well as retailer commitment to support and promote such collections.

In terms of in-store collection, some countries offer far more substantial collection containers for batteries than the typical small transparent UK containers. These larger and more substantial containers make it easier to collect LIBs as opposed to AA, AAA etc., and these are usually co-located with, or actually integrated with, small WEEE and lamps as shown in Figure 4-4 – the systems in Belgium (Recupel) and the Netherlands (WeCycle) respectively. In-store collection containers in EU countries are almost always located inside retail stores – either in the front entrance, or at the checkout – as opposed to being located in exterior locations, such as carparks – to ensure containers are secure and highly visible and convenient for customers to access.

[70] Valpak/DTS 2020. Assessment of WEEE collection systems and their effectiveness in other European countries

Figure 4-4: In-store Collection Containers in a) Belgium and b) the Netherlands

a)

b)

It is worth noting that the Netherlands collects approximately 35% of WEEE via the retail route, despite a high density of municipal collection points (higher than the UK). Ireland also collects 56% of WEEE via retail. Several EU countries financially compensate retailers for providing WEEE collection services, which is typically on a cost per tonne basis, ranging from €60 - €140 per tonne.

Case Study 4-5: SAFer WEEE Project

Location	Merseyside
Aim	To trial a protocol that requires householders to segregate LIBs from small WEEE at HWRCs so as improve the handling of LIBs following a spate of fires at waste and recycling sites in the UK.
Results	Overall, the results from the four-month trial period found that the campaign had very little impact on the number of LIBs collected at the HWRCs involved. It was concluded that site users either did not understand the concept of disposing of 'battery containing devices' separately (because the battery was not easy or safe for them to remove) or were unwilling to do so.

Overview

In June 2019 the SAFeR WEEE project set up the 'BeBatterySavvy' campaign as a collaborative initiative between Merseyside Recycling and Waste Authority (and other waste operators, including Viridor and Veolia) and Mersey Fire and Rescue Service to improve the handling of LIBs following a spate of fires at waste and recycling sites in the UK. The trial period of the project ran for four months and was financed by the WEEE Fund (now Material Focus). The project involved setting up special recycling containers, supported by communication campaigns, including the use of the slogan 'Be Battery Savvy', new site signage, training for site operatives and hi-vis clothing (shown in Figure 4-5) to raise awareness.[71]

Householders were asked to segregate their small mixed WEEE into three streams before disposing of them at the three HWRCS that were involved in the trial: South Sefton HWRC, Old Swan HWRC and Huyton HWRC. The three streams were:

1) Batteries (of all types);
2) Small appliances with batteries that cannot be taken out; and
3) Small appliances with the batteries taken out (these would go in the existing WEEE containers).

By separating batteries from small WEEE it was hoped that fire risks could be minimised by ensuring that the batteries were correctly handled, treated and recycled.[72] The results from the campaign highlighted that a HWRC is a busy environment and when on site, residents appeared either unable or unwilling to spend the time it takes to make an informed decision on how to dispose of their small WEEE and/or batteries properly. It was noted that it would be beneficial for future communication campaigns to encourage people to separate their batteries from their small WEEE products before they visit the HWRC.[73]

Figure 4-5: Hi-vis Design for HWRC Staff to Wear as Part of the BeBatterySavvy Campaign

[71] Eunomia (2019) *Encouraging Merseyside Residents to Recycle Batteries*, accessed 21 August 2020, https://www.eunomia.co.uk/encouraging-residents-recycle-batteries/
[72] AvSax (2016) *How everyone may have to do far more to make disposing of lithium ion batteries safer*, accessed 8 August 2020, http://avsax.com/news/how-everyone-may-have-to-do-far-more-to-make-disposing-of-lithium-ion-batteries-safer
[73] McKinlay, R and Morton, G (2019) SaFeR WEEE Investigating a new collection method for Small Mixed WEEE to reduce fire risk, Axion Circular Economy Specialists

Case Study 4-6: Currys PC World Home Collection Scheme

Location	Cardiff / Nationwide
Aim	To improve the collection and recycling of used batteries and small WEEE by collecting used batteries from customers' homes.
Results	Over the six-week period of the trial, 11.2 tonnes[74] of small WEEE was collected from households in Cardiff. If this were extrapolated to include all the Knowhow locations across the UK, this would equate to an estimated 2,565 tonnes of small WEEE collected per annum. [75]

Overview

In 2016, a six-week trial of the collection of small WEEE by Knowhow (the delivery and installation service used by Currys PC World) was carried out in Cardiff. Overall, the trial indicated that collecting small WEEE from households presented a viable and convenient opportunity to take-back these items to help remove them from the residual waste stream. The results of this trial highlighted the success of small WEEE collections from households and prompted Currys PC World to launch a free small WEEE collection service in conjunction with its home delivery and installation team in 2019, which continues.[76]

In addition, in October 2018, Currys PC World launched a collection scheme for used batteries. When the firm's home installation teams come to deliver and install new appliances, they offered to collect customers' used domestic batteries at the same time. In addition to home collection, the firm created special battery bins and eye-catching signage to encourage customers to return their used batteries in store.[77] They also offer a 'trade-in', which is similar to a deposit return scheme: customers are encouraged to bring their old device, such as a laptop or games console, into the store for recycling. In return, they are given a gift card towards a new product.[78]

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[74] This amount was estimated from the initial results as the study found that direct engagement with customers resulted in significantly higher ratio of products collected.

[75] WRAP (2016) WEEE Collection Monitoring: Research to trial and evaluate WEEE collection for re-use and recycling through Knowhow's Cardiff Customer Service Centre, accessed September 2020, https://www.wrap.org.uk/sites/files/wrap/WEEE%20Collections%20-%20Retailer%20Take%20Back%20-%20Knowhow.pdf

[76] Letsrecycle (2019) *Picking up the big problem of small WEEE*, accessed September 2020, https://www.letsrecycle.com/news/latest-news/picking-up-the-big-problem-of-small-weee/

[77] Letsrecycle (2018) *Currys PC World launches collection scheme for used batteries*, accessed 16 August 2020, https://www.letsrecycle.com/news/latest-news/currys-pc-world-launches-collection-scheme-for-used-batteries/

[78] Currys PC World (2020), *Ways to pay: Trade-in*, accessed 20 August 2020, https://www.currys.co.uk/gbuk/tkh-trade-in-1538-commercial.html?ntid=B%7Ed%7ETrade%20in

Case Study 4-7: Increased WEEE Collection Points, France

Location	France (nationwide)
Aim	France implemented the 2002 EU WEEE Directive in 2005, with the aim of increasing WEEE collection rates to 45% by 2016, and to 65% by 2019.[79]
Results	In 2006, only 10,000 tonnes of household WEEE was collected, and the household WEEE collection rate was less than 5%.[80,81] France's household WEEE collection rate increased to 49% in 2016, with over 10kg of WEEE collected per inhabitant. Collection rates continued to rise and were expected to reach the 65% target by 2019. France's collection of small WEEE specifically increased by 24% between 2010 and 2014 (see Figure 4-6). In 2014, 68% of collected WEEE originated from municipal collection points and 23% from retail collection points.[82,83]

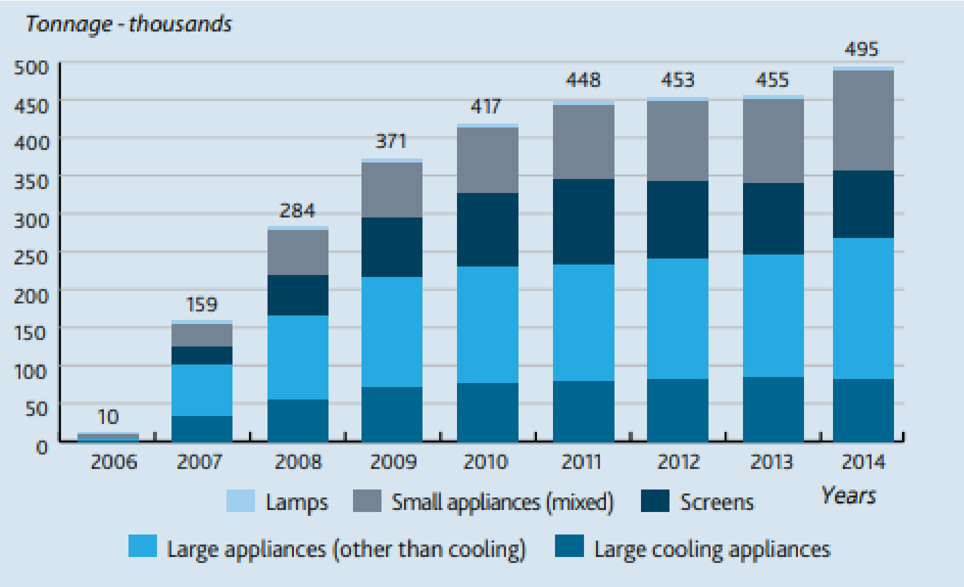
Overview

The French government increased the number of retail and municipal collection points and ran a supporting national public awareness campaign.[84] In 2005 a non-profit organisation called Ecologic was set up by WEEE producers to support WEEE collection and treatment through an Extended Producer Responsibility system. Ecologic has since setup 4,000 municipal WEEE collection points.[85] Additionally, there are now more than 24,000 specific WEEE collection points set up by distributers.[86] Data is unavailable for the number of distributer collection points that existed in 2005/6, prior to the scheme. In

[79] Eco-systèmes (2016) WEEE organization in France and Eco-systèmes, http://twinningweee.com.ua/sites/default/files/media/eco-system_ecobodies_in_france.pdf
[80] ADEME (2014) *Electrical and Electronic Equipment in France*, https://www.ademe.fr/sites/default/files/assets/documents/eee-donnees-2014_8584_en-v2.pdf
[81] Eco-systèmes (2016) *Rapport 2016: Collection Development*, accessed 5 August 2020, http://rapport2016.ecosystem.eco/en/developpementcollecte
[82] Eco-systèmes (2016) *Rapport 2016: Collection Development*, accessed 5 August 2020, http://rapport2016.ecosystem.eco/en/developpementcollecte
[83] ADEME (2014) *Electrical and Electronic Equipment in France*, https://www.ademe.fr/sites/default/files/assets/documents/eee-donnees-2014_8584_en-v2.pdf
[84] ADEME (2014) *Electrical and Electronic Equipment in France*, https://www.ademe.fr/sites/default/files/assets/documents/eee-donnees-2014_8584_en-v2.pdf
[85] WEEE Forum (2011) *Ecologic factsheet*, https://weee-forum.org/wp-content/uploads/2019/03/Ecologic_2pages_March-2011.pdf
[86] ADEME (2014) *Electrical and Electronic Equipment in France*, https://www.ademe.fr/sites/default/files/assets/documents/eee-donnees-2014_8584_en-v2.pdf

addition, some local authorities also introduced kerbside collections of small WEEE in urban areas, but these were not considered to be the most cost-effective method of collection by Ecologic (although no data was provided), and so the main focus was on increasing municipal and retail collection points.[87]

Figure 4-6: Tonnes of Household WEEE Collected in France from 2006 to 2014, by Type of WEEE



Source: *https://www.ademe.fr/sites/default/files/assets/documents/eee-donnees-2014_8584_en-v2.pdf*

[87] Eunomia (2020) *Electrical and Electronic Equipment: Ingredients for Successful Extended Producer Responsibility*, https://www.complydirect.com/media/2429/14695_eunomia-weeeepr-redactedversion-1.pdf

Case Study 4-8: Germany's Common Recycling System for Portable Batteries[88]

Location	Germany (nationwide)
Aim	To establish a common collection and recycling scheme for portable batteries (not WEEE).
Results	In 2019, 76.1% of used portable batteries in Germany were recycled by GRS, which equates to 17,686 tonnes of batteries. When compared with the 45% of portable batteries collected in the UK, Germany has a much higher battery collection rate. Approximately 59% of these batteries were collected from retail collection points.

Overview

In 1998, the 'Common Recycling System', in Germany known as the Gemeinsames Rucknahme System (GRS) Foundation, was established. The GRS was promoted by the main German battery manufacturers and the German Electronic and Electrical Manufacturers Association. In Germany, battery producers are legally obliged to collect their products from consumers (this is a form of Extended Producer Responsibility discussed in more detail in Section 4.2). The GRS provides containers on behalf of the producers to collect used batteries from retail outlets, local authorities and public institutions. Battery companies can share the GRS's recycling network if they pay certain funds to the Foundation based on their annual battery production. For example, Tesvolt is a company that produces LIBs. Tesvolt is therefore legally required to take back the batteries it produces and joined the GRS Foundation to fulfil this obligation. Tesvolt pays a fee to GRS for each battery module sold and in return GRS ensures that their batteries are collected. The customer has the option to either take the used battery to a collection point or can call GRS directly and arrange a collection time free of charge.[89] The GRS Foundation has more than 170,000 recycling points across Germany. For German consumers, battery recycling is not a difficult task. Stores and supermarkets in Germany usually have numerous special battery recycling bins in place.

[88] Gemeinsames Rucknahme System (2019) *Annual Review 2019*, accessed July 2020, http://www.grs-batterien.com/fileadmin/user_upload/Download/Dokumente_2019/GRS_AnnualReview2019Web.pdf
[89] Tesvolt (2019) *GRS Batteries- Joint Collection System For Used Batteries*, accessed August 2020, https://www.tesvolt.com/en/products/recycling.html

4.2 Supporting Policy Mechanisms

The policies in this section could support any improvements to the battery collection system, thereby further ensuring batteries are kept out of residual and mixed recycling waste streams and preventing them from starting waste fires. This section outlines a range of policy suggestions that could:

- improve battery/WEEE collection funding under EPR;
- incorporate the cost of battery fires under EPR;
- create a financial incentive for consumers to dispose of their batteries at collection points;
- create a financial incentive for designing batteries/EEE that are less flammable and/or allow easier battery removal from WEEE; and
- deter people from putting batteries/WEEE in household residual or recycling bins.

4.2.1 Improving the EPR Systems for Battery/WEEE Collection

In the UK, we have Extended Producer Responsibility (EPR) schemes to fund and organise the collection of waste portable batteries and WEEE, as explained in Sections 3.1 and 3.2. The associated regulations are under review by Defra, with consultations on EPR under the Resources and Waste Strategy due to take place in early 2021, and with a wide range of possible changes being considered for both batteries and WEEE. These include better collection models such as kerbside collection across the UK and/or enhanced facilities in municipal and retail locations. As noted in our recent work for Defra and the DTS[90], the best performing countries in terms of WEEE collection rates, tend to be those that have comprehensive and high-density collection provisions that are very convenient for consumers. A recent survey of householders for Material Focus (formerly the WEEE Fund) found that 42% of people would use WEEE recycling banks at supermarkets and shops if they were available, and 61% would use in-store drop off points in electrical retail stores.

Defra has already made it a requirement (from 2021) for larger EEE retailers to take-back WEEE, with no DTS opt-out allowed. In addition, funds collected via the Compliance Fee for WEEE are making it possible to run national communication campaigns. Enhanced collection provisions, alongside better communications, should improve LIB collection rates (both in small WEEE and as separate batteries) and hence reduce the risks associated with them being in residual waste. While this will add cost, if a full cost recovery model is established in line with best practice in the EU, this will enable these higher costs to be covered by producers rather than by local authorities.

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[90] Eunomia for Defra (2020), *Electrical and Electronic Equipment: Ingredients for Successful Extended Producer Responsibility,* https://www.eunomia.co.uk/reports-tools/electrical-and-electronic-equipment-ingredients-for-successful-extended-producer-responsibility/

4.2.1.1 Including the Cost of Battery Fires Under EPR

We propose that where a fire can be attributed as being caused by a LIB, this could be charged back evenly to all producers that use LIBs. Acknowledging that it is not always easy to be certain that a LIB was the cause of a fire, we still feel that when it is viable, it would help to highlight the issue of waste fires with producers such that they are incentivised to improve design and more willing to support better collection arrangements. Our estimate is that the total annual cost to the UK of waste fires caused by LIBs is £158 million, which is of the same order of magnitude as the cost of the current EPR system. This indicates that the cost of these fires is not insignificant and covering them as part of Defra’s planned improvements to the two EPR schemes would relieve waste operators, the Fire and Rescue Service, the environment, society and the EA of a substantial financial burden. In some ways this would be similar to adding litter clean-up to EPR for packaging, as is now being done as a result of the Single Use Plastics Directive.

4.2.2 Deposit Return Schemes

While improving collection provisions (as recommended in Section 4.1.2) would make battery and small WEEE recycling more convenient, we cannot guarantee that people will use them. While it would seem logical to give kerbside and enhanced retailer collections an opportunity to demonstrate their efficacy before considering a Deposit Refund System (DRS), should such approaches fail to collect enough LIBs to significantly reduce LIB-related fires, a DRS could be used alongside EPR to further incentivise the return of batteries and specific types of small WEEE that contain LIBs (i.e. consumer gadgets and electronics).

It would almost certainly be easier to implement a DRS system for all portable battery types, rather than just LIBs. A DRS would work by applying a fee to all batteries, and potentially certain electronics, at the point of purchase, which would then be returned to the consumer if the battery/WEEE items was deposited at a collection point, possibly via a reverse vending machine (RVM) (example shown in Figure 4-7).

A battery DRS would be easiest to implement for separate portable batteries but could also be applied to batteries in WEEE that can be removed from products and returned separately. For batteries embedded in products, a DRS may work more effectively if targeted at small WEEE items, rather than the batteries they contain, since we do not want to encourage members of the public to retrieve a battery from a product when this would be unsafe.

Unfortunately, of all battery types, LIBs are the ones most often embedded in products in ways that make them difficult to remove. As a result, a battery DRS would reach a smaller proportion of LIBs than of other battery types. As outlined in Section 3.1, LIBs already have much lower collection rates than other chemistries.

A further challenge is whether to levy a fee on all batteries purchased, removable or not, or only on products that contain removable batteries. Some products may have batteries that are technically removable, but not easy to remove, such as batteries from very small objects like car keys or children's toys. It may not be desirable to encourage members of the public to dismantle WEEE at home in order to separate out batteries. The WEEE Directive only requires batteries to be "readily removed by qualified professionals that are independent of the manufacturer" as a minimum. As such, a DRS for separate batteries and small WEEE that contains batteries would likely capture a higher proportion of LIBs than one for batteries alone.

DRSs can be operated separately by each producer but may be more effective if operated collectively by the industry as whole.[91] Under an industry-wide scheme, all batteries of the same kind would be likely to be subject to the same deposit, and refunds would be managed collectively, regardless of the original producer. An industry-wide DRS would be simpler for consumers, who would have a wider choice of collection points. It would also avoid issues regarding whether all collection points would take the products of every manufacturer.

DRSs have proven to be successful for recycling products such as glass and plastic bottles, cans and beverage cartons. In Norway, the government place an environmental tax on all producers of plastic bottles. The more they recycle, the more the tax is reduced and if they collectively recycle more than 95% then they do not have to pay the tax at all. The 95% target may seem high, but the country's DRS has enabled this target to be reached every year since 2011.[92] Consumers pay a deposit of 10p-25p (depending on the size of the bottle) and have the option to take their bottles to the reverse vending machine or return it over the counter at a retailer. Norway has an estimated 3,700 RVMs and an additional 11,000 manual collection points at smaller stores. Every store that takes part in the scheme gets a small fee per bottle received and the scheme has the reported additional benefit of increasing footfall to participating stores.[93]

It would be difficult for a battery DRS in the UK to reach the same collection rates as the bottle DRS in Norway for several reasons:

- batteries can be difficult to remove from WEEE when they are integrated into a product, as is often the case for LIBs in particular; and
- LIBs are designed to be used by a consumer for a longer period of time than a plastic bottle, leading to a longer time between purchase and disposal, and therefore a period of time during which consumers may forget that a deposit can be redeemed.

[91] OECD (2014) *Creating Incentives for Greener Products: Policy Manual for the Eastern Partnership Countries*, accessed August 2020, https://www.oecd.org/environment/outreach/Creating%20Incentives%20for%20Greener%20Products.pdf

[92] Science Alert (2019) *Norway's Insanely Efficient Scheme Recycles 97% of All Plastic Bottles They Use*, access August 2020, https://www.sciencealert.com/norway-s-recycling-scheme-is-so-effective-92-percent-of-plastic-bottles-can-be-reused

[93] The Guardian (2018) *Can Norway help us solve the plastic crisis, one bottle at a time?,* accessed July 2020, https://www.theguardian.com/environment/2018/jul/12/can-norway-help-us-solve-the-plastic-crisis-one-bottle-at-a-time

The success of beverage container DRSs in Norway and elsewhere is impressive, and an increasing number of countries, including the UK, are moving towards implementing similar schemes. This suggests that a well-designed battery and small WEEE DRS could achieve a high recycling rate, reducing the number of batteries entering residual and mixed recycling waste streams. Furthermore, batteries have a much higher intrinsic value than packaging, and given the annual cost to the UK economy of fires caused by LIBs, any effort expended in the creation of a DRS could be seen as good value. However, because of the differences between packaging and batteries/small WEEE, and consumer attitudes towards them, proper investigation would need to be conducted into the role a DRS could play in supplementing increased retailer collection points and separate kerbside collections of batteries and small WEEE.

Case Study 4-9: Battery Deposit Return Scheme, Norway	
Location	Norway
Aim	To improve recycling of spent batteries (no precise targets could be found online).
Results	In the first three weeks that the machines were in operation it was reported that 2,500 batteries had been collected.[94] However, it is unclear if the trial was deemed successful and if the reverse vending machines for batteries are still being used in Norway today. Nevertheless, the Swedish company (Refind Technologies) that made the machine is still working on improving battery recycling as well as looking into other innovative solutions to use technology to help sort portable batteries into separate streams based on their chemistry once they have been collected.[95]

[94] Treehugger (2018*) Battery Recycling Machine Gives Grocery Store Coupons in Exchange for Your Old Batteries*, accessed July 2020, https://www.treehugger.com/battery-recycling-machine-gives-grocery-store-coupons-exchange-your-old-batteries-4851304
[95] Refind technologies (2020) *The OBS 500,* https://www.refind.se/optical-battery-sorter-500

Overview

In 2017, one of Norway's largest supermarket chains, Coop Norway installed the world's first commercial reverse vending machine for batteries (Figure 4-7) in three stores across the country. The battery recycling machine works just like the more common bottle recycling machines – customers place their used product, the spent battery, into the machine's deposit slot and then the machine issues the customer with a voucher that can be redeemed in store. In Norway, the machine gave 1 krone (~£0.12) for every battery returned. The machine can accept AA, AAA, C, D and 9V batteries and can identify the size of the battery when it is inserted into the machine.[96] The reverse vending machine was made by a company called Refind Technologies, who partnered with Energizer for its launch. This demonstrates that one of the largest battery producers is interested in exploring innovative ways to improve battery recycling.

Figure 4-7: Reverse Vending Machine for Batteries Used in Norway

Image courtesy of Refind Technologies

[96] Refind technologies (2017) *The world's first reverse vending machine for batteries is launched in Norway*, accessed July 2020, https://www.refind.se/worlds-first-reverse-vending-machine-for-batteries#:~:text=The%20machine%20is%20developed%20by,used%20when%20buying%20new%20batteries.

4.2.3 EPR Fee Modulation for Batteries and EEE

At present, there are no clear incentives for producers to make batteries easier to remove from products or less prone to combusting. An overview of research into battery design features that may reduce combustion risk is provided in Section 4.3.

The UK's enhanced producer responsibility (EPR) systems for batteries and for WEEE charge a flat fee per tonne of product of a particular type that is placed on the market. However, producers could be financially incentivised to include recycling-friendly design features and avoid designs that are problematic, which could help improve battery and EEE design to aid battery fire safety and battery removal. Within a producer responsibility scheme, this is called "eco fee modulation". Encouragingly eco-design is on the government's agenda as indicated by BEIS's recent call for evidence on how eco-design policies in the UK could be used to achieve greater energy and carbon savings in energy-related products, however there is currently no focus on battery fire safety and battery removal.[97]

France is currently world-leading in fee modulation as demonstrated in Case Study 4-10 and Case Study 4-11. Under the provisions of Article 8a of the revised EU Waste Framework Directive, all EPR schemes in the future will have to apply some form of eco-modulation to EPR fees, although the extent to which this applies to the UK is in question, post-Brexit.

Potential modulation criteria put forward for battery and WEEE fee modulation by the EU as guidance to Member States include disassembly and recyclability, although nothing specific to fire safety.[98] EPR fee modulation is logistically complex, especially in the context of multiple producer responsibility schemes across two product groups (EEE and batteries). Incentivising more removable batteries through modulating WEEE EPR is complicated by the fact that not all EEE products contain batteries and non-LIBs are generally easier to remove.

It is important to note that easy removal of batteries from WEEE by qualified professionals is already mandated under the WEEE Directive and corresponding UK regulations (although this is not necessarily always the case in practice for some designs) and hence the use of modulation in this regard could only be used to reflect ease of removal by the consumer. Although they are more likely to cause fires if damaged, LIBs are in many ways preferable to other technologies due to their high energy density, and so penalising their use (where non-removable by consumers) may not be helpful in terms of encouraging good product design.

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[97] BEIS (2020) *Energy-related products: call for evidence*, accessed 5th October 2020, https://www.gov.uk/government/consultations/energy-related-products-call-for-evidence

[98] Eunomia (2020) *Study to Support Preparation of the Commission's Guidance for Extended Producer Responsibility Schemes* https://www.eunomia.co.uk/reports-tools/ec-waste-framework-directive-epr-recommendations-for-guidance/

Case Study 4-10: Fee Modulation for EEE, France

Location	France (nationwide)
Aim	To create a compliance fee that is more likely to incentivise producers to manufacture products that are more 'environmentally friendly' through creative eco-design processes.
Results	It is difficult to determine the extent to which fee modulation to date has contributed to stimulating changes to product design, and there is little doubt that an EU-wide or global modulation system would have a greater effect. Nevertheless, a review by Ademe, notes that modulation has resulted in:[99] • Better eco-design of products, extension of the lifetime of products, better recyclability, use of recycled materials in the manufacturing of equipment, decrease of pollutants; • Limited impact on the consumer, much greater impact on the producer; • A measure which penalizes the low-cost products; and • Support to the repair sector.

France is the only country using an explicit fee modulation method for EEE. Modulation in France is restricted to specific EEE categories. Modulation for EEE products aims to promote the true cost of recycling the product and makes sure the producer has the financial responsibility. For WEEE products the producer's fees are modulated according to set of environmental criteria: reusability, recyclability, lifetime, presence of hazardous substances, ease of disassembly etc.[100] Modulation criteria for EEE products have focused on design for disassembly (relevant to repair, upgrade and end-of-life recycling), the availability of reasonably-priced spare parts, the extent of the free warranty period, the reduction in hazardous substances over and above the Restriction of Hazardous Substances Directive requirements and the inclusion of post-consumer recycled content plastics.[101]

The system uses (in broad terms) a -/+ 20% bonus/malus adjustment to the base fee under the Visible Fee (recycling charge) shown at the point of sale. The product has to meet all of the criteria in the sub-category to get the bonus, and only fail on one criterion to get the

[99] Fangeat, E. (2017) French experience Modulation of fees, Brussels, 24 October 2017

[100] Eunomia (2020) *Study to Support Preparation of the Commission's Guidance for Extended Producer Responsibility Schemes*, accessed September 2020, https://www.eunomia.co.uk/reports-tools/ec-waste-framework-directive-epr-recommendations-for-guidance/

[101] Eunomia (2020) *What are modulated Fees and how do they work?* accessed September 2020, https://www.eunomia.co.uk/modulated-fees-and-how-they-work/

malus. The malus and bonus charges (ex VAT) for a sample of EEE (as charged by ESR – the merged Eco-Systeme/Recyclum, PRO) are shown in the final column of Table 4-1.

Table 4-1: Example of ESR Bonuses/Maluses

WASHING MACHINE DISHWASHER	Availability of spare parts essential for the equipment use during 11 years or Integration of postconsumer recycled plastic (minimum threshold of 10%)	—	CAT 04	14010	€ 6.67
	Unavailability of spare parts essential for the equipment use during 11 years and no integration of postconsumer recycled plastic (minimum threshold of 10%)	—	CAT 04	14011	€ 8.33
VACUUM CLEANER	Lack of plastic parts >25 g containing brominated flame retardants. and availability of technical documentation for authorised repairers and availability of spare parts essential for the equipment use	—	CAT 05	25010	€ 0.83
	Presence of plastic pieces >25 g containing brominated flame retardants. or unavailability of technical documentation for authorised repairers or unavailability of spare parts essential for the equipment use	—	CAT 05	25011	€ 1.00
TABLET	Lack of brominated flame retardants in the tablet plastic structure and presence of software updates, compatible with each other and essential for the good working of the appliance	≥ 7 "	CAT 02	32060	€ 0.42
	Presence of brominated flame retardants in the tablet plastic structure or lack of software updates, compatible with each other and essential for the good working of the appliance	≥ 7 "	CAT 02	32061	€ 0.84

Source: ESR

Case Study 4-11: Fee Modulation for Batteries, France

Location	France (nationwide)
Aim	To create a compliance fee that is more likely to incentivise producers to manufacture batteries that are cheaper and easier to recycle, but also more durable (i.e. rechargeable) and use more sustainable battery materials.
Results	Collection rates of portable batteries in France increased from 38% in 2015 to 45% in 2016.[102] However, as mentioned in Case Study 4-10, it is difficult to determine the extent to which fee modulation to date has contributed to stimulating changes to product design, and there is little doubt that an EU-wide or global modulation system would have a greater effect.

In France in 2015 a Decree was published which introduced new requirements for Producer Responsibility Organisations (PROs), including the requirement to 'charge fees for certain environmentally preferable batteries that are modulated by prescribed percentages', for example there was a 20% increase in fees for rechargeable LIBs due to the danger of lithium.[103] France currently has the most developed eco-modulation system for portable batteries in Europe. They have two main PROs – SCRELEC and Corepile. Together SCRELEC and Corepile quantify the volumes of batteries on the market, assess the average composition of battery types and monetize the environmental impact of different battery types using environmental footprint databases.[104] In addition, they integrate aspects such as re-use cycles of rechargeable batteries and safety risks that affect the image of the sector. SCRELEC fees for portable batteries, rechargeable ('secondary batteries' or accumulators) and single use (primary) batteries are shown for 2018 in Figure 4-8. PROs try to introduce graduations of fees in order to reward those who actively contribute to decreasing end of life costs and/or make eco-design efforts.

[102] EPBA (2017) The collection of waste portable batteries in Europe in view of the achievability of the collection targets set by Batteries Directive 2006/66/EC, accessed September 2020, https://www.epbaeurope.net/wp-content/uploads/2018/03/Report-on-the-portable-battery-collection-rates-Update-Dec-17.pdf

[103] Ibid

[104] BIO by Deloitte (2014) *Development of Guidance on Extended Producer Responsibility (EPR),* accessed September 2020, https://www2.deloitte.com/content/dam/Deloitte/fr/Documents/sustainability-services/deloitte_sustainability-les-filieres-a-responsabilite-elargie-du-producteur-en-europe_dec-15.pdf

Figure 4-8: SCRELEC Fees 2018

Accumulator	Contribution in Euros excl. taxes per kilo
Secondary Lithium	0,479
Nickel metal hydride (Ni-MH)	0,398
Lead	0,559
Nickel-Cadmium (Ni-Cd)	0,998

Battery	Contribution in Euros excl. taxes per kilo
Alkaline	0,372
Zinc carbon	0,559
Primary lithium (cylindrical and button cell)	2,448
Button Cell (alkaline, Silver oxyde, zinc air…)	3,672
Zinc Air	0,439

Bonus	Contribution in Euros excl. taxes per kilo
Lithium accumulators with Cobalt	0,456
Alkaline battery « Eco »	0,360

Source: SCRELEC

It is notable that:

- the secondary (rechargeable) batteries have a lower fee in general than the primary single use batteries;
- a bonus is applied for use of recycled content (Eco Alkaline) and less harmful chemistries (lithium with cobalt which Screlec suggest have "a positive economic and environmental impact due to their composition and lifetime";[105]
- the bonus is small – 0.456 vs 0.479 (5% reduction) and 0.36 vs 0.372 (a little over 3% reduction); and
- the fees per battery are very small – e.g. €0.0086 for a single LR6 (AA) that might cost at least €0.5, i.e. just 2% or so of the product price.

[105] Eucobat do not believe that the use of Cobalt offers an environmental benefit.

4.2.4 Banning Batteries from Residual and Mixed Recycling Waste Streams

Improving access to battery collections and creating financial incentives for recycling (through a DRS) relies on voluntary consumer engagement. Even with these incentives in place, there is still the potential that LIBs will end up in the wrong stream and remain a potential cause of waste fires. Improved services could be accompanied by a restriction on how batteries are disposed of, which may be a way of reaching people who are less engaged with the positive case for recycling.

Drafting a law to ban people from putting batteries in residual and mixed recycling waste streams would be relatively easy; encouraging and enforcing compliance would be rather less so, as batteries are small and not readily identified in a residual waste bin. Some countries and cities already have laws banning disposal of batteries to general waste (see Case Study 4-12 below). A possible method for identifying the source of the battery could be radio-frequency identification (RFID) tags and/or visual spot-checking individual bins/ bags on collection rounds to identify the presence of LIBs.

It is worth noting that many countries (including leading recyclers such as Belgium and Switzerland) use ‘pay as you throw’ arrangements for residual waste, deterring the disposal of heavier items (such as small WEEE and LIBs) in particular. In the Flanders region, residents can pay more than €2 per bag of residual waste, up to five times more than they pay for bin bags sorted for recyclable waste. Residents can also be given fines if they do not sort their refuse properly (spot checks are undertaken by inspectors alongside collection operatives), though most infringements only result in a warning from the local municipality.

RFID uses radio waves to identify and track tags attached to objects and a detector would penetrate a wheeled bin at short range. If a RFID tag (which are now tiny and very cheap) were attached to every LIB, it would allow waste operators/inspectors to easily spot-check bins or bags for the presence of LIBs to stop them entering the stream at source. If such a measure were to be introduced, a system would need to be implemented for what to do with the contents of a residual waste bin/bag containing a battery. If a battery were identified in a kerbside container, the bin/bag could be labelled to indicate that battery contamination has been identified.

It is already quite normal for residents to be left contamination notices for their recycling, so this is something that would not be out of the ordinary. The usual approach is the use of the equivalent of football yellow and red cards to provide a warning to residents in advance of stricter action. The threat of fines could be seen as draconian (although it has been done by some councils in the UK in regard to those that repeatedly do not recycle), although a corresponding communications campaign, highlighting the fire risk, combined with better battery collection provisions, should moderate any negative consumer response.

The resolution might be for the resident to remove the battery before the next collection, or for a separate, non-compacting vehicle to be sent to remove the waste. Repeat offenders might then be subject to a fine. If battery contamination was identified at a later stage in the waste collection process, making it difficult to identify the source, the material should be quarantined and disposed of appropriately.

The downside is that this system would require all manufacturers to put RFID tags on all LIBs and so would need to be mandated in UK law. Manufacturers would then have to comply to be able to access the UK market. If the UK was alone in implementing such a requirement, it might add to the costs of products due to the need to source or manufacture special batteries for one, relatively small (in global terms) market. Indeed, some producers might decide not to bring certain products into the UK market at all. The ideal solution would be for this to be mandated at the EU-level (e.g. under the Eco-design Directive), which would then drive the global market, however the UK's withdrawal from the EU makes this less likely.

There are other possible technical solutions in development, such as scanners that can identify LIBs in a waste load by their material and chemical signature, rather than require a tag on the battery.[106] These solutions are still in development but may be an effective alternative to RFID tagging in the future.

Case Study 4-12: Law Against Discarding Batteries in Residual Waste, New York City

Location	New York City, USA
Aim	To reduce the number of rechargeable batteries that end up in the residual waste stream.
Results	Since the initial New York City (NYC) Council law was officially launched in 2006 the city has collected 172.8 tonnes of rechargeable batteries over the first 5-year period with a 154% increase in battery collections. Between 2006-2012 LIB collections increased by a huge 2,263%, however it is worth noting that LIBs percentage share of the market will have also greatly increased during this time period through increase in the number of LIB containing products, such as smart phones.[107]

Overview

In 2006, NYC Council passed 'Local Law 91' which made it illegal for residents to discard rechargeable batteries in residual waste. The NYC Department of Sanitation (DSNY) is responsible for implementing the law and maintaining its enforcement. The DSNY

[106] Information shared in discussion with one such technology developer, Vigilant Scanning Ltd.
[107] Call 2 recycle (2020) *What Does a City Like New York Do With 173 Tons of Rechargeable Batteries?*, accessed 15 August 2020, https://www.call2recycle.org/what-does-a-city-like-new-york-do-with-173-tons-of-rechargeable-batteries/

partnered with a stewardship organisation called Call2Recycle to develop an awareness campaign and organise collection and reporting programmes for rechargeable batteries. Over 20,000 retailers were approached by Call2Recyle and were educated about the new law and given collection kits and window displays to notify customers. City staff were also trained to increase awareness amongst citizens by learning key information on batteries and where the nearest recycling collection was located.[108]

In addition, in 2010, the New York State Rechargeable Battery Act was signed into law. This put further emphasis on the appropriate end-of-life management of rechargeable batteries and placed a shared responsibility for disposing of batteries on stakeholders including manufactures, consumers and retailers. The law makes manufacturers responsible for the collection and recycling of batteries in a manufacturer-funded program at no cost to consumers. Additionally, since 2011, retailers that sell rechargeable batteries are required to accept used batteries from customers and to produce promotional material to inform customers about these requirements.

In 2011, the Environmental Conservation Law (Subdivision 1-0303(18)) made it a requirement that '*no person shall knowingly dispose of covered rechargeable batteries as solid waste at any time in the state*'.[109] The Department of Environmental Conservation is responsible for the oversight of this law including its enforcement and the analysis of information provided by battery manufactures. There are civil penalties in place for anyone who violates the law, including a maximum $200 fine for residents, maximum $500 fine for retailers and a maximum $5000 fine for manufactures.[108]

4.3 Other Mechanisms

The mechanisms in this section sit outside those previously discussed but are worth mentioning as their adoption could considerably reduce the number of waste fires caused by LIBs. Explored are a long-term option to change battery design to reduce their risk of causing fires, and a downstream option to ensure that batteries are removed from products before shredding at WEEE processing facilities, thereby reducing their risk of starting fires in these facilities.

4.3.1 Changing Battery Design

In addition to reducing the quantity of LIBs that enter the waste stream, a further way to reduce fire risk would be to alter the chemical and/or physical design of LIBs so that they are less likely to catch fire. If effective, it has the potential to solve the problem altogether. However, the development of such technologies is at an early stage and

[108] Ibid
[109] *New York State Rechargeable Battery Recycling Act*, *Chapter 562* (2010) https://www.dec.ny.gov/docs/materials_minerals_pdf/batterylaw.pdf

therefore, changes to battery design appear to be at best a more distant solution than the capture and related policy options discussed in Sections 4.1 and 4.2.

4.3.1.1 Solid State Batteries

The development of non-flammable, solid electrolytes would be a good solution for eliminating waste fires from LIBs as this would prevent the electrodes touching when hit and remove the risk of thermal runaway. This is an active area of research that has attracted significant attention recently due to the superior safety and energy density of solid-state LIBs.[110,111]

Solid-state sodium-ion (Na-ion) cells are discussed as a possible next generation battery to replace LIBs but are still some way from commercial viability. Their advantages include the relative abundance of sodium, which should reduce raw material costs.[112] However, their safety benefits are debatable, since a broken open solid Na-ion battery is only fractionally less likely to catch fire than a solid LIB. Nevertheless, the company Faradion Ltd was founded in 2011 to develop solid-state sodium ion technology and bring it to the market.[113] Additionally, Toyota was planning to unveil a vehicle powered by a solid-state sodium-ion battery at the (now-delayed) 2020 Olympics.[114]

An alternative option is to mix an additive into the conventional electrolyte for a LIB to create an impact-resistant electrolyte.[115] It solidifies when hit, preventing the electrodes from touching in the event that the battery is damaged. Incorporating the additive would require only minor adjustments to the conventional battery manufacturing process and would greatly reduce the possibility of a LIB starting a fire.

4.3.1.2 More Thermally Stable Electrolyte and/or Cathode Material

The standard LIB electrolyte is a carbonate-based organic solvent. This is thermally unstable and breaks down upon heating to release flammable gases. Recent research has shown the possibility of replacing the standard electrolyte with alternatives that

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[110] Wang, C. et al. (2018), Boosting the performance of lithium batteries with solid-liquid hybrid electrolytes: Interfacial properties and effects of liquid electrolytes, *Science Direct*, Vol.48, p.35-43 https://www.sciencedirect.com/science/article/abs/pii/S2211285518301551

[111] Liu, K., Liu, Y., Lin, D., Pei, A., and Cui, Y. (2018) Materials for lithium-ion battery safety, *Science Advances*, p.12 https://advances.sciencemag.org/content/4/6/eaas9820

[112] Wang, Y., Song, S., Xu, C., Hu, N., Molenda, J., and Lu, L. (2019) Development of solid-state electrolytes for sodium-ion battery–A short review, *Nano Materials Science*, Vol.1, No.2, pp.91–100

[113] Faradion (2020) *About Us*, accessed 13 August 2020, https://www.faradion.co.uk/about-us/

[114] Autocar (2019) *Toyota to reveal solid state battery-powered prototype next year*, accessed 20 July 2020, https://www.autocar.co.uk/car-news/motor-shows-tokyo-motor-show/toyota-reveal-solid-state-battery-powered-prototype-next-year

[115] American Chemical Society (2018) *These lithium-ion batteries can't catch fire because they harden on impact*, accessed 20 July 2020, https://www.sciencedaily.com/releases/2018/08/180822082645.htm

have higher thermal stability.[116] Using this type of alternative electrolyte would reduce the chance of LIBs breaking down and releasing flammable gases if heated. In turn this would reduce the likelihood of a LIB-started fire.

The cathodes of LIBs are mostly made from transition metal oxides. These cathode materials are not combustible, but they are not thermally stable.[117] They decompose upon heating and release oxygen, which is needed to burn fuel (in the combustion process fuel reacts with oxygen to produce water and carbon dioxide). Different materials and structures have slightly different thermal stability. Choosing more thermally stable cathodes could reduce, but not eliminate, fire risk.[118] Similarly to using a more thermally stable electrolyte, it would reduce the chances of the cathode decomposing and releasing oxygen to allow combustion, should a LIB be heated during the waste collection or treatment process.

4.3.1.3 Adding Flame Retardants to Electrolyte or Separator

Another battery design change that could reduce the risk of mechanical failure resulting in a waste fire is adding flame retardants (FRs) directly to the electrolyte, but efforts to date have resulted in greatly reduced battery performance.[119] To try to avoid this, there is ongoing research into whether FRs can be encased in tiny plastic sheaths before being added to either the separator or the electrolyte, so that the FR gases are only released when a certain temperature is reached. In theory, this could provide flame-retarding ability within the battery unit without hindering performance.[120,121]

4.3.1.4 Improved Battery Casings

A final suggestion for changing LIB design to reduce the chance of them starting a fire is to improve the battery casing. Batteries often consist of multiple battery cells in parallel. If heating of the battery during the waste collection or treatment process leads to thermal runaway in one battery cell, this can cause the casing that separates the cell to melt or rupture, leading the thermal runaway to propagate throughout an entire battery pack. This strand of research to reduce LIB flammability is of particular interest to NASA

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[116] Pham, H.Q., Lee, H.-Y., Hwang, E.-H., Kwon, Y.-G., and Song, S.-W. (2018) Non-flammable organic liquid electrolyte for high-safety and high-energy density Li-ion batteries, *Journal of Power Sources*, Vol.404, pp.13–19

[117] Tubke et al (2019) Li-Secondary Battery: Damage Control, in Electrochemical Power Sources: Fundamentals, Systems, and Applications, 2019 https://www.sciencedirect.com/topics/materials-science/cathode-material

[118] Peng, P., and Jiang, F. (2016) Thermal safety of lithium-ion batteries with various cathode materials: A numerical study, *International Journal of Heat and Mass Transfer*, Vol.103, pp.1008–1016

[119] Zhang, S.S. (2006) A review on electrolyte additives for lithium-ion batteries, *Journal of Power Sources*, Vol.162, No.2, pp.1379–1394

[120] Liu, K., Liu, W., Qiu, Y., et al. (2017) Electrospun core-shell microfiber separator with thermal-triggered flame-retardant properties for lithium-ion batteries, *Science Advances*, Vol.3, No.1, p.1-8

[121] Yirka (2017) *A novel way to put flame retardant in a lithium ion battery*, accessed 20 July 2020, https://phys.org/news/2017-01-flame-retardant-lithium-ion-battery.html

for the batteries they use to power elements of human spaceflight. LIBs are perfect for this use due to their high energy density and lightweight properties, but must withstand the extreme temperatures of space (including take-off and landing) without the risk of the potentially devastating consequences of a LIB exploding in a pressurised capsule like the space station.[122]

Thicker casings with higher melting points could help to overcome this issue.[123] However, this can be expensive, can increase the battery weight and thickness (not helpful when the trend is for electronic devices to get thinner and thinner) and can also increase the potential hazard of an explosion event. Further research is needed to determine whether improved casings offer a practical solution for reducing LIB-caused waste fires.

4.3.2 Removing Batteries Before Shredding at WEEE Reprocessing Plants

While finding solutions to prevent fires in residual and mixed recycling waste streams being started by LIBs is the main focus of this report, if increasing quantities of WEEE are collected separately and recycled (to reduce waste fires at residual and mixed recycling waste processing sites) it would be counter-productive for this to lead to an increase in waste fires at WEEE reprocessing facilities (AATFs). Therefore, some suggested measures for how to prevent fires at WEEE reprocessing plants are outlined below.

The UK statutory BATRRT guidelines do not specify that batteries need to be removed prior to shredding, as discussed in Section 3.3.1, whereas the European WEEElabex/CENELEC standard is far more rigorous around this issue (see Section 3.3.2). Making compliance with the CENELEC standard mandatory in the UK would therefore be likely to reduce the number and extent of waste fires at WEEE reprocessing sites.

Manual disassembly prior to shredding/fragmentation is time consuming and costly and is not commonplace in the UK. Nevertheless, it could be key to addressing fires at WEEE processing facilities as the shredding process is when LIBs are most likely to be damaged and give rise to waste fires.

A potential mechanism for removing LIBs from WEEE would be to establish a network of manual dismantling centres to help achieve a higher battery removal from WEEE products. If implemented, the cost of these centres could be incorporated into the improved EPR scheme in the UK for WEEE (see Section 4.2). Switzerland is one of the leading countries for WEEE collection and recycling and makes use of manual disassembly prior to shredding.

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[122] The Verge (2018) *NASA is prepared if a battery ever explodes in space*, accessed 20 July 2020, https://www.theverge.com/2018/8/17/17681422/nasa-lithium-ion-batteries-thermal-runaway-human-spaceflight

[123] Lao, L., Su, Y., Zhang, Q., and Wu, S. (2020) Thermal Runaway Induced Casing Rupture: Formation Mechanism and Effect on Propagation in Cylindrical Lithium Ion Battery Module, Journal of The Electrochemical Society, Vol.167, No.9

Case Study 4-13: Manual Dismantling Centres and Advance Recycling Fee, Switzerland

Location	Switzerland
Aim	Switzerland aimed to not only improve WEEE collection rates but also improve the recycling process to ensure low contamination, high recycling rates and reduced hazard risk. To this end, the country funded the manual dismantling of WEEE containing potentially hazardous components such as batteries.
Results	No specific data is available for the impact of the dismantling centres on battery removal rates. However, the fact that the centres are still running suggests that the scheme has been reasonably successful and economically viable.

Overview

In Switzerland, an 'advance recycling fee' (ARF) has been levied on all new EEE since 1994. This fee is charged to consumers and is used to fund the appropriate disposal of EEE, which includes the pre-shredding dismantling process. In fact, the majority of the fee is used for dismantling and reprocessing.[124]

Responsibility for take back and recycling of WEEE in Switzerland is shared by three non-profit producer responsibility organisations: Swico, SENS and SLRS. Swico is responsible for electronics, SENS for appliances and SLRS for lighting equipment. Swico and SENS aim to remove most batteries from products before mechanical reprocessing and around 30% of this separation work is done manually at one of around 120 manual dismantling centres.[125,126] In addition to its recycling and safety benefits, these dismantling centres also provide social benefits by employing over 1,000 disadvantaged people in Switzerland.

[124] Khetriwal, D.S., Kraeuchi, P., and Widmer, R. (2009) Producer responsibility for e-waste management: Key issues for consideration – Learning from the Swiss experience, *Journal of Environmental Management*, Vol.90, No.1, pp.153–165

[125] Swico, SENS Foundation, Swiss Lighting Recycling Foundation (SLRS) (2019) *Technical report 2019: news about electrical and electronics recycling,* https://www.erecycling.ch/dam/jcr:15a3a714-7b11-41f6-b75a-f548b9c060ab/2019_Fachbericht_Recycling_E_190716_Technical%20report.pdf

[126] Swiss Federal Laboratories for Materials Science and Technology (2018) *Recycling and Recovery Targets: Can WEEE reach them?*, https://www.eera-recyclers.com/files/care-innovation-eera-track-181220-care-widmer-v01.pdf

5.0 Key Findings & Recommendations

5.1 The Costs of Waste Fires Started by LIBs

We estimate that around **48%** of waste fires can be attributed to LIBs. Whilst exact numbers are unknown, as this is not consistently reported on or investigated, it is clear that this is a very significant proportion of total waste fires and equates to approximately **201** waste fires in the UK each year.

Overall, we estimate that the total annual cost to the UK of waste fires caused by LIBs is **£158 million**. The breakdown of who these costs are incurred by each year is as follows:

- Waste Site Operators: 90% (£141 mil)
- The Environment: 5% (£8 mil)
- The Fire and Rescue Service: 4% (£6 mil)
- Society: 2% (£2 mil)
- The EA: 0.4% (£1 mil)

The highest financial burden of waste fires can be attributed to category three fires, whilst they are the third least severe, due to the frequency of the events they accumulate the highest cost (£128.6 million per year). Whilst the largest incidents (category one) cost on average £6.6 million per year, as only one to two of these fires occur each year and therefore the total cost to the UK is lower.

Whilst these findings are a crucial first step in understanding the real-life cost implications of waste fires caused by LIBs, further reporting of all waste fires and the costs that are incurred would allow more detailed analysis to be undertaken.

Furthermore, as the use of LIBs continues to increase, unless proactive interventions and policy measures intervene to curb the growth in the number fires started by LIBs, the year-on-year cost of these fires will continue to increase.

5.2 Key Measures to Reduce Waste Fires

Taking the review, and case studies in Section 4.0 into account, we have assessed the measures to reduce waste fires caused by LIBs that could be implemented in the UK. Our assessment includes when the measure may start to have an impact, its costliness (in broad terms), practicality and the likely response of consumers and industry to the measure.

5.2.1 Short-term Mechanisms to Capture Batteries

Section 4.1 reviewed two mechanisms that can be implemented in the short-term to increase the separate capture of batteries, thereby keeping them out of residual and mixed recycling waste streams and preventing them from causing waste fires:

1) Separate kerbside battery and small WEEE collections; and

2) Increased retail collection points.

Table 5-1 summarises our assessment of these two mechanisms based on the following criteria:

- Cost (both cap-ex and op-ex): low-cost £; medium-cost ££; high-cost £££
- Practicality: very challenging ✓; somewhat challenging ✓✓; straightforward ✓✓✓
- Effectiveness: not very effective ★☆☆; effective ★★☆; very effective ★★★

Table 5-1: Summary Assessment of Short-term Mechanisms to Capture Batteries

Mechanism	Cost	Practicality	Effectiveness
Separate Kerbside Collection	£	✓✓✓	★★★
Increased Collection Points	£	✓✓	★★☆

Based on this assessment – explained in further detail in sub-sections 5.2.1.1 and 5.2.1.2 – our preferred mechanism to capture batteries and thereby keep them out of residual and mixed recycling waste streams is separate kerbside collection. This is because it can be implemented voluntarily by local authorities relatively quickly and practically, for a relatively low cost, by adding a cage to existing collection vehicles, and – when accompanied by an appropriate public awareness campaign – has proven to be extremely effective. Furthermore, this could tie in with separate collection requirements and EPR changes currently under consideration at Defra, and therefore would not necessarily come at an additional cost to local authorities.

5.2.1.1 Separate Kerbside Collection

Criteria	Assessment
Timescale 🕓	A cage/compartment for batteries and/or small WEEE could be added to existing collection vehicles relatively quickly. Guidance could be developed for the design and location of these e.g. do not use a straight steel cage that could damage batteries collected and do not locate next to the vehicle's fuel tank. Distributing separate collection containers for householders would be relatively easy, and while not strictly necessary is recommended as it would encourage and remind householders to separate batteries and small WEEE. (If adding cages/compartments to a co-mingled fleet was not an option, switching to a multi-stream fleet should be considered as a solution in the long term.) The Environment Bill and Waste and Resources Strategy for England have introduced source separation requirements, currently in the

	consultation phase. From 2023, local authorities must separately collect food waste, garden waste, and mixed dry recycling comprised of metal, plastic, paper and card. This change is still going through parliament and the Secretary of State must issue statutory guidance on what materials must be source separated – there is no reason why batteries could not be added to this materials list. While individual local authorities could sooner opt to separately collect batteries and/or small WEEE, joining the list of those that already do in Section 4.1.1, we think that a policy requirement for separate kerbside collection is unlikely to be achieved sooner than in the next 3 years.
Cost £	Adding a compartment to collection vehicles is a relatively cost-effective short-term option and could be less than £850 per vehicle.[127,128] Local authorities may require financial support to implement and maintain this service. This should be done through full cost-recovery under EPR as suggested in Section 4.2.1.1. (A new multi-stream collection fleet would cost several million pounds but would only be necessary when there is a need to replace existing vehicles, at which point accommodating separate battery collection should be considered. Adding a separate kerbside battery collection to the multi-stream Welsh collection systems (see Case Study 4-3) was cheaper and easier than it would be for the single- and two-stream systems in most English councils. In the Welsh case study, clear government guidelines and substantial funding helped facilitate the transition to multi-stream collections.)
Practicality ✓✓✓	Adding a compartment to the bottom of a compacting truck to collect batteries from kerbside collections is a practical, low-cost solution for removing batteries and small WEEE from residual and mixed recycling waste streams. However, as councils push for improved recycling performance other separate collections may increasingly compete for this space.
Effectiveness ★★★	As demonstrated in Case Study 4-1, kerbside collection of batteries and small WEEE is an extremely effective means of capturing batteries and keeping them out of residual and mixed recycling waste streams.

[127] Torbay Council (2019) *Replacement Vehicles (Draft Council Report)*, accessed August 2020, http://www.torbay.gov.uk/DemocraticServices/documents/s72961/Replacement%20Vehicles%20Draft%20Council%20Report.pdf

[128] Mid Sussex Council (2019) *Proposal for an Enhanced Recycling and Collection Service for Textiles and Small Waste Electrical and Electronic Equipment*, accessed August 2020, https://midsussex.moderngov.co.uk/documents/s6370/Proposal%20for%20an%20Enhanced%20Recycling%20Collection%20Service%20for%20Textiles%20and%20Small%20Waste%20Electrical%20and%20El.pdf

	It is likely to have a high response from consumers because it is by far the most convenient collection system for them. As Case Study 4-1 and Case Study 4-3 indicate, a complementary public awareness campaign helps to ensure the maximum response rate.

5.2.1.2 Increased Retail Collection Points

Criteria	Assessment
Timescale	This could be a quick solution as it builds on the current predominant WEEE/battery collection system. The fastest way to expand the network would be to install more battery deposit containers in secure retail locations e.g. supermarkets and other battery retail outlets.
Cost £	Installing additional retail battery and small WEEE collection points would come at a small extra cost to retailers that would be covered by EPR.
Practicality ✓✓	Increasing the number of retail battery collection points would be relatively straightforward.
Effectiveness ★★☆	Consumers need to travel and remember to take spent batteries/WEEE with them or make a deliberate trip to drop off spent batteries/WEEE at collection points, so this system has been found to have less of a response compared to a kerbside collection scheme, as suggested by Case Study 4-1. However, if collection points are numerous and easy to access this may have a reasonably good response rate, as shown in Germany where 59% of batteries recycled are collected from collection points. If collection points are placed in retail stores, consumers do not need to make a special journey, they just need to remember to bring their spent batteries with them, for example when buying new ones. A complementary public awareness campaign would be vital to ensure the effectiveness of this mechanism.

5.2.2 Supporting Policy Mechanisms

Section 4.2 reviewed supporting policy mechanisms that could help to fund any system changes to capture more batteries, and financially incentivise and deter consumers from incorrectly disposing of batteries. In order of preference, the below could be enacted *alongside* an improved collection system:

1) Banning batteries from residual and mixed recycling waste streams with the imposition of fines for non-compliance;
2) Enhanced EPR for batteries and small WEEE to pay for and co-ordinate improved collection and reflect the cost of fires;
3) Creating a deposit return scheme (DRS), or other incentivisation mechanism, to encourage the return of batteries and small WEEE (notably electronic gadgets) for recycling;
4) Improving BATTRT, or mandating CENELEC standards, for WEEE to require LIB removal prior to shredding/fragmentation; and
5) Introducing fee modulation within the WEEE EPR system for design features that facilitate easier battery removal by consumers.

The following sub-sections give more detail on our reasoning.

5.2.2.1 Banning Batteries from Residual Waste and Mixed Recycling Streams

Introducing a UK law to ban batteries from being incorrectly disposed of in the residual waste or mixed recycling and imposing fines to ensure compliance could be a relatively quick and straightforward measure, although allowance should be made for parliamentary time, consultation, etc. It would be accompanied by national communications and media campaign to send a clear message to consumers that there is a right and wrong way to dispose of their batteries. It would also work to deter those consumers who are less engaged with voluntary recycling. It should be done in combination with increasing collection points/separate kerbside collection/a DRS to help consumers dispose of batteries and small WEEE correctly.

Whilst we acknowledge there may be some enforcement issues associated with identifying the source of incorrectly disposed of batteries, we do not think that this negates the potential effectiveness of such a ban. This is because a) consumers' awareness of how to correctly dispose of batteries will have been raised, and b) the threat of a fine for incorrect disposal will encourage consumers to comply irrespective of the likelihood of being caught. A system of visual spot checks could be publicised to increase the likelihood of compliance.

Employing RFID tags to allow proper enforcement by identifying the source of incorrectly disposed of batteries, while desirable, would be a longer-term exercise. It would require rigorous testing to make sure that adding the tags to batteries was safe and all new batteries sold in the UK (in small WEEE and otherwise) would then need to be tagged. However, unless RFID tagging was adopted at an EU-level or higher level, we think this is unlikely to become a production standard. In addition, local authorities would need to invest in scanning equipment for spot checking (between £800 - £1200 (inc VAT) for a handheld scanner) and extra time for scanning would be added to collection rounds, increasing the costs and impracticality. Alternatively, these costs could be lowered if RFID scanning equipment were installed at the front of materials recovery facilities/ transfer stations to scan incoming loads and remove battery products prior to processing at the plant (rather than at point of kerbside collection). Or gantry mounted scanning technologies which are currently being developed, which are based on identifying LIBs in a waste load by their material and chemical signature[129], and would allow vehicles to be scanned whilst on the site weighbridge to identify and quarantine contaminated loads could reduce cost and maintain current collection efficiencies. Consistent with EPR recommendations elsewhere in this report, costs associated with tracking and/or scanning for batteries in waste loads could be covered by a full-cost recovery EPR.

5.2.2.2 Improving the EPR System for Battery and Small WEEE Collection

The WEEE and batteries producer responsibility regimes are under review by Defra with likely extensive changes to both. This is in many ways the ideal time to better integrate the two systems, as done in other leading countries, for example combining battery, small WEEE and lamp collections and making far more of retail outlets as well as introducing UK-wide kerbside collections. Changes to collections are required in any case to ensure that EPR collection targets can be guaranteed to be met.

Given the ambitions towards full cost-recovery, the cost of these enhanced collection arrangements would be covered by the producers. We would also suggest that any enhanced EPR system also encompasses the cost of battery fires, passed back to those producers using LIBs. This would remove funding barriers for local authorities and help to remove LIBs from residual waste and mixed recycling streams.

5.2.2.3 Battery and Small WEEE Deposit Return Scheme

While it would seem logical to give kerbside and enhanced retailer collections an opportunity to demonstrate their efficacy before considering a DRS, should such approaches fail to collect enough LIBs to significantly reduce LIB-related fires, a DRS could be used alongside EPR to further incentivise the return of batteries and specific types of small WEEE that contain LIBs (i.e. consumer gadgets and electronics). It would almost certainly be easier to implement a DRS system for all portable battery types, rather than just LIBs. A DRS can be a very focused instrument, allowing the targeting of very specific problematic small WEEE for example, particularly where there are RVMs that can reject everything apart from what is required.

DRSs have proven to be more effective for packaging than separate kerbside collection. However, given the obvious differences between packaging and batteries/small WEEE, and consumer attitudes towards them, it is not clear how best a DRS could be used for batteries/small WEEE. Also, we anticipate that the introduction of any DRS would take at least three years to implement. This is not a fast enough solution to the urgent LIB waste fires problem. However, if Government began investigations into the role DRS could play in supplementing retailer takeback for batteries and small WEEE now, then in the event that increasing kerbside and retail collections does not have the desired effect, Government will be better prepared to introduce an effective DRS quickly.

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[129] Information shared in discussion with one such technology developer, Vigilant Scanning Ltd.

5.2.2.4 EPR Fee Modulation for Batteries and EEE

Eco-modulation is a practical policy measure that has already been introduced in France (see Case Study 4-10 and Case Study 4-11) and is now mandated under the Waste Framework Directive at the EU-level. Eco-modulation criteria that support the easy removal of batteries from WEEE by consumers (as well as professionals as mandated under the WEEE Directive), and better battery design to reduce the risk of fires, should be sought as part of Defra's changes to the EPR regimes for the two product groups.

Furthermore, this would fit well alongside the 'right to repair' concept introduced in the EU's Circular Economy Action Plan under which EEE will need to be designed to allow for rechargeable batteries to be replaceable. Unless the UK has a hard EU-exit, the UK will likely be subject to changes to the European market such as these anyway.

5.2.2.5 Removing Batteries Before Shredding at WEEE AATFs

While a downstream measure, this is also a serious issue for the waste sector. BATTRT is also under review as part of the wider Defra work, and 2018 WRAP guidance already suggests that good practice involves checking and removing dangerous items such as LIBs. It is recommended that BATTRT is brought in line with WEEELabex/CENELEC in this regard. This should not be overly burdensome for operators as it is an existing standard already voluntarily adopted by many waste operators across Europe.

5.2.3 Other Mechanisms – Changing Battery Design

Given the nature of research and development in battery chemistry and design, this is a long-term solution and as such not a short-term fix for the relatively urgent battery fires issue. As we come to rely increasingly on portable, battery-powered devices, as well as LIBs in electric vehicles and in relation to electrical power storage on a larger scale, increasing focus and funding is going into battery research and design in the UK and abroad. Given the costs associated with managing waste fires caused by LIBs, waste operators and other stakeholders might want to influence government to increase funding in the specific area of R&D around fire-prevention in battery design.

5.3 Recommendations

All of the mechanisms covered in Section 5.2 would help increase the capture of LIBs and thereby reduce the number of waste fires they cause. However, given the urgency of the problem of LIB-caused waste fires, and taking into consideration the existing changes to the UK's waste collection and EPR systems, we recommend the following three-pronged approach to increase the capture of LIBs in order to reduce the waste fires they cause:

1) Ban the disposal of batteries and small WEEE in residual and mixed recycling waste to prevent this practice and increase the public's awareness of correct disposal routes.
2) Encourage separate kerbside collection of small WEEE and batteries by local authorities on a voluntary basis as soon as possible, with Government to add batteries and small WEEE to the Environment Bill and Waste and Resources Strategy's source separation requirements from 2023. The costs of this – and the

costs of LIB-started waste fires – should ultimately be covered by enhanced EPR for batteries and WEEE once revised regimes have been put in place by Government, thereby reducing the financial barrier for local authorities.

3) Urgently investigate the role of DRS in supplementing retailer takeback for batteries and small WEEE, to achieve very high capture rates for target items (i.e. those with larger LIBs), so that, in the event that increasing kerbside and retail collections does not have the desired effect, Government will be better prepared to introduce an effective DRS quickly.

APPENDICES

A.1.0 Appendix 1: Cost Modelling Assumptions

A.1.1 Waste Fire Numbers

Our modelling assumes that:

- **0.2%** of UK reported fires are waste fires; and
- **47%** of waste fires can be attributed to LIBs.

The calculations and assumptions behind these figures are presented in Table 0-1 below.

Table 0-1: Waste Fire Number Assumptions

Item	Figure	Source
% of Total Reported Fires which are Waste Fires	0.2%	Based on the ratio between the average annual waste fires reported in England [130], compared to the total fires reported in England in 2018/2019[131]
% of Waste Fires which are <u>known</u> or <u>suspected</u> LIB cause	38%	ESA waste fire data, 2020 [132]
% of Waste Fires which are <u>unknown</u> cause	39%	
Total % of Waste Fires attributed to LIBs	48%	Eunomia estimate. Accounts for all fires reported by the ESA as 'Known' or 'Suspected' LIB cause, and an assumption that 25% of 'Unknown' cause fires are actually due to LIBs.

[130] EA data, provided by the EA on 15.10.20, (2020) average waste fires reported to the EA for 2014 - 2019
[131] National Statistics (2019), Fire and rescue incident statistics: England, year ending March 2019, accessed September 2020, https://www.gov.uk/government/statistics/fire-and-rescue-incident-statistics-england-year-ending-march-2019
[132] ESA data, waste fires reported by ESA members 2019-2020, provided by ESA on 03.11.20 (2020)

A.1.2 Waste Fire Cost Calculations

Our cost calculations have been based on the sources and assumptions as outlined below in Figure 0-2.

Figure 0-1: Waste Fire Cost Calculations

Cost Incurred By	Cost (Item)	Cost per unit (£)	Unit	Source
Waste Site Operators	Material Damage	£300,000	per incident and by cost impact factor	Confidential case studies of waste fires and associated costs
	Business Interruption	Worked out proportionally based on RISC % split		'% split' below, provided in the - Industrial Processing - Recycling, (2012)'[133]
	Contents			% Split of Costs Incurred:
	Resources			- Material Damage: 38% - Business Interruption: 27% - Contents: 1% - Resources: 3%
	Machine and plant			- Machine and Plant: 4%
	Stock			- Stock: 6%

[133] RISC Authority (2010) Review Report - Industrial Processing - Recycling, https://www.riscauthority.co.uk//index.cfm?originalUrl=free-document-library/RISCAuthority-Library_detail.risk-review-report-industrial-processing-recycling.html&_tkn=DAD2434F%2D3E35%2D4AE3%2DB97D8A5A558130A9

Cost Incurred By	Cost (Item)	Cost per unit (£)	Unit	Source
	Other			- Other: 1%
Fire and Rescue Service	Resource Costs	£275	per hour and dependent on number of fire trucks attending	Average figure used following quotes from two sources: 1) a call with the EA on 16/07/2020 and 2) a call with the London Fire Service on 19/08/2020
EA	Attendance	£125	per hour	Based on EA 2019 charging scheme, 2019 Version 1.0[134]
Society	Air Pollution	£84	Per tonne of waste burnt	Eunomia estimate. This accounts for NOx, SOx and PM2.5 emissions. The kg of emissions for each tonne of waste burnt was calculated and scaled up proportionately dependent on the estimated tonnage under each severity scenario.
Environment	Water	£1.5	per m^3 of water used	Eunomia estimate. Assumes that Severity 1 fires will have the biggest waste pile currently allowed by the EA FPP regulations, and therefore require 900,000 litres for 3 hours of the fire burning[135]. Cost of water estimated through Bristol Water rates and rounded up.[136] Costs for other severities worked out proportionately.

[134] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790217/EPR-charging-scheme-with-schedule-consolidated-2019.pdf

[135] WISH (2020) reducing fire risk at waste management sites, accessed 03.11.20 https://www.wishforum.org.uk/wp-content/uploads/2020/05/WASTE-28.pdf
[136] Bristol Water, 2020, Charges Scheme, accessed 02.11.20 https://www.bristolwater.co.uk/wp-content/uploads/2020/01/Charges-Scheme-20-21-FINAL.pdf

Cost Incurred By	Cost (Item)	Cost per unit (£)	Unit	Source
	Greenhouse Gas Emissions	£241	per tonne of waste burnt.	Eunomia estimate. Accounts for conventional GHGs and Black Carbon

A.1.3 Who Incurs the Cost per fire?

Looking in more detail at the modelled cost per fire, Table 0-2 breaks the costs down by percentage, dependent on who the costs are incurred by. This is representative of a single modelled waste fire, averaged across the severity levels. The numbers shown in Table 0-2 therefore differ to the percentage breakdown presented in Section 2.3 which (through incorporating the number of fires occurring under each severity level each year), represents the cost breakdown on an annual scale for the UK.

Figure 0-2 presents these average waste fire costs in pie chart format, by severity level.

Looking at the costs incurred by waste site operators, the largest cost incurred is that from material damage, followed by business interruption, then machine and plant damage. This result is, perhaps, not surprising, with waste fires, and larger waste fires in particular often producing a great deal of smoke and fire damage to buildings and equipment on site, and often requiring sites to be closed for days, weeks and months at a time.

Table 0-2: Li-ion Battery Caused Waste Fires, Who Incurs the Cost per fire?

Cost Incurred By	Type of Cost	Overall Cost Breakdown (%)	Further Breakdown by 'Cost Incurred By' (%)
Waste Site Operators	Material Damage	84.4%	38%
	Business Interruption		27%
	Contents		1%
	Resources		3%
	Machine and plant		24%
	Stock		6%
	Other		1%
Fire and Rescue Service	Resource Costs	7.2	100%
Environmental	Water	6.0	6.8%

	Greenhouse Gas Emissions		93.2%
EA	Attendance	0.4	100%
Society	Air Pollution	2.0	100%

Figure 0-2: Cost Breakdown by Severity Category