

RECOMMENDATIONS FOR TACKLING FIRES CAUSED BY LITHIUM BATTERIES IN WEEE

Survey results (Part B) and compilation
of practices and recommendations

July 2021



Disclaimer

The information presented in this document was gathered from consultations to experts, the recycling and the manufacturing industry and literature research. Whilst we are doing our best to provide a good overview of good practices, we cannot guarantee that all existing practices currently available are comprised in the report. Reference to brands and service suppliers is anecdotal and does not intend to market, publicise, or provide a comprehensive overview of the companies providing such services.

Whilst the information in this report is believed to provide good practices and recommendations for tackling fires caused by batteries in WEEE, it is strongly recommended to test and thoroughly assess the convenience and effectiveness of all practices prior to their implementation and use the advice of an expert in fire emergency management.

Refer to this report as:

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Cover photo by Benny Van den Steen

Executive Summary

Batteries are increasingly used in all sorts of electrical and electronic products, which impacts their end-of-life treatment and often gives rise to thermal events.

In 2019, a number of organisations (hereinafter referred to as The Batteries Roundtable), representative of the industry that manages the collection and treatment of spent batteries and waste electrical and electronic equipment (WEEE) and of the manufacturers of home appliances and consumer electronics, gathered to exchange views about the growing issue of fires associated with WEEE that contain batteries, in order to design measures to address the problem. A survey was designed for pan-EU stakeholders to better understand the issue of fires in the WEEE management chain and collect good practices.

Based on the responses to the questionnaire for the second part (Part B) (see Annex C – Questionnaire) and on a thorough literature review and expert consultation, the report presents a set of recommendations and good practices for all stages of the (W)EEE value chain, aimed at addressing the issue of fire incidents caused by batteries in WEEE.

The current situation is affecting the industry managing WEEE containing batteries and single batteries. Fires caused by WEEE containing batteries can be a very serious problem for waste management facilities, costing millions of euros each year. Besides the economic costs that they bring, they also have consequences affecting the environment and human health.

Section 3 briefly describes the main issues arising from fires caused by WEEE containing batteries. As highlighted in the report named “Characterisation of fires caused by batteries in WEEE” [9], one of the major issues for the waste industry associated to fires caused by WEEE containing batteries are the additional and unexpected costs arising after the occurrence of fires. Costs are often related to repairing damages, loss of waste burned, temporary interruption of the activity, etc. Costs on prevention and firefighting measures may vary considerably depending on the detection, prevention and extinguishing measures implemented, hence it is strongly recommended to seek expert advice for the designing of an adequate and cost-effective plan.

Recommendations and good practices compiled in this report aim at reducing the occurrence of situations that may trigger a thermal event such as:

- Short circuit: caused by an external material that connects the poles of the same battery or cell.
- Physical impact or shock to WEEE or lithium batteries may also trigger a thermal event because it may damage and move materials in contact with the batteries.
- Heat exposure: exposure to extreme temperatures (> +60°C / < -20°C).

Damages to cells/modules caused by, for example, aging of the batteries can lead to a short circuit too, e.g. when vulnerable materials inside the battery deteriorate.

A thermal event may become a severe incident if is not rapidly detected and extinguished. Training, prevention, and detection measures are therefore essential for identifying and tackling risky situations. Recommendations and good practices have been grouped according to the following steps of the EEE and WEEE value chain:



Specific recommendations have been defined as well for:

- Producer Responsibility Organisations of WEEE and batteries (chapter 11),
- Municipalities (chapter 12), and
- Policy makers (chapter 13).

Initiatives described in chapters 6 to 13, aim at for example:

- Improving the identifiability of batteries in (W)EEE,
- Improving the removability and protection of lithium batteries in (W)EEE,
- Improving the stability of lithium batteries,
- Improving the handling, storage, manipulation, and treatment of WEEE containing batteries and lithium batteries to reduce risky situations that may trigger a thermal event, these include operational and technical aspects for WEEE management companies, training and information strategies and suggestions on containers, and
- Collecting statistics on thermal events that will help industry and policy makers design appropriate strategies.

There is no magic formula that will reduce to zero the risk of fires caused by WEEE containing batteries. **It is critically important that a range of actions are taken in all steps of the lifecycles of both electronic devices and lithium batteries: from design to disposal of WEEE and batteries and including handling, transport and treatment.** Most measures require a good level of understanding of the issue and others, support from policymakers. **Only a multi-stakeholder, co-ordinated response can address the issues effectively.**

The European Green Deal and the new Circular Economy Action Plan identify 'electronics' among key product value chains where recycling plays an obvious major role to achieve sustainability goals. The expected contribution of the waste management industry to the EU strategies is at risk. The waste management sector is in need of a strategy that will support its fight against fires caused by WEEE containing lithium batteries.

The current revision of the Batteries Directive and a possible revision of the Eco-design Directive provide good opportunities to take account of the initiatives described in this report. **However, statistics and testing are required to ensure that the measures identified and incorporated in such texts are valid and implementable under technically and economically viable conditions.**

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List of Recommendations

		Design	Collection	Logistics	Pre-treatment	Final treatment	Local entities	PROs	Policy makers
6.1	Labelling of EEE	+							
6.2	Improved design of EEE containing batteries	+							
6.3	Improved design of batteries	+							
7.1	Sorting of WEEE containing LBs at collection facilities. Proper handling		+						
7.2	Removal of batteries from WEEE at collection facilities. Proper handling		+						
7.3	Dedicated receptacles for WEEE containing LBs		+	+	+				
7.4	Dedicated receptacles for LBs		+	+	+	+			
7.5	Emergency measures at collection facilities: fire prevention, detection, and mitigation		+						
7.6	WEEE disposal at specific retail collection points		+						
7.7	Receptacles for retail collection points		+						
8.1	Specific training to staff Logistics			+					
8.2	Operational measures. Prevention of fires Logistics			+					
8.3	Emergency measures and infrastructure at logistics facilities. Fire detection and extinguishing			+					
8.4	Specific receptacles for WEEE containing LBs and LBs Logistics			+					
9.1	Specific training to staff Pre-treatment				+				
9.2	Operational measures. Prevention of fires Pre-treatment				+				
9.3	Emergency measures and infrastructure at pre-treatment facilities. Fire detection and extinguishing				+				
9.4	Specific receptacles for WEEE containing LBs and LBs Pre-treatment				+				
10.1	Specific training to staff Final treatment					+			
10.2	Operational measures. Fire prevention Final treatment					+			
10.3	Emergency measures and infrastructure at final treatment facilities. Fire detection and extinguishing					+			
10.4	Specific receptacles for LBs Final treatment					+			
11.1	Data collection on fires caused by WEEE containing LBs and LBs PROs							+	
11.2	Specific conditions in contracts with waste management companies PROs							+	
12.1	Enforce and raise awareness on prevention, detection, and extinguishing of fires						+	+	
13.1	Data collection on fires caused by WEEE containing LBs and single LBs								+
13.2	Address insurance coverage to waste management facilities				+	+			+

Acronyms

ADR	Agreement concerning the International Carriage of Dangerous Goods by Road
CAGR	Compound Annual Growth Rate
CCTV	Closed-circuit television
EEE	Electrical and Electronic Equipment
FRs	Flame retardants
LBS	Lithium batteries including lithium-ion type
LIBs	Lithium-ion batteries
PROs	Producer responsibility Organisations
SoC	State of Charge
WEEE	Waste Electrical and Electronic Equipment

1. Introduction

A group of organisations aiming at tackling the safety issues regarding the recycling of Waste Electrical and Electronic Equipment (WEEE) containing batteries came together on June 26th 2019. The roundtable formed by the aforementioned group of organizations was comprised of EU level associations of recyclers, Extended Producer Responsibility schemes, and Electric and Electronic Equipment (EEE) manufacturers (see Composition of the Batteries Roundtable at the end of this report).

Some of the members (EuRIC, WEEE Forum, WEEELABEX, EERA)¹ that met in June committed themselves to participate in a survey, which had two objectives, to:

- Characterize fires associated to WEEE containing batteries (Part A)
- Collect good practices at all stages of WEEE management (from collection to recycling), aimed at tackling the fires (Part B)

The survey, in the form of an online questionnaire, was launched and disseminated by the above-mentioned members of the roundtable on October 4th, 2019, and was intended for facilities carrying out collection, sorting, transporting, and recycling of WEEE containing batteries and single batteries. A total of 109 duly completed questionnaires were received in the period in which the survey was open.

The results of the first part (Part A) of the survey were included in the report “Characterisation of fires caused by batteries in WEEE” [9] and published in May 2020².

Based on the results of the questionnaire for the second part (Part B) (see Annex C – Questionnaire) and on a thorough literature review and expert consultation, the present report provides a set of recommendations and good practices for all stages of the (W)EEE value chain, aimed at addressing fire incidents caused by WEEE batteries.

¹ EuRIC: European recycling industries Confederation; EERA: European Electronics Recyclers Association; WEEE Forum: International Association of Electronic Waste Producer Responsibility Organisations; WEEELABEX: International non-profit legal entity to promote the adoption of the WEEELABEX standards to improve WEEE management practices in Europe.

² https://weee-forum.org/wp-content/uploads/2020/05/Report_Characterisation-of-fires-caused-by-batteries-in-WEEE.pdf

2. Useful information for understanding the issue

2.1. How do lithium batteries look like?

The term “lithium battery” refers to a family of batteries with different chemistries, comprising several types of cathodes and electrocytes. Lithium batteries (LBs) are generally divided into two categories (Picture 1). These include:

- Primary (non-rechargeable): Lithium metal batteries, lithium metal batteries that have lithium compounds and lithium metal as an anode.
- Secondary (rechargeable): Lithium-ion batteries where the lithium is only present in an ionic form in the electrolyte [1].



Picture 1. On the left side an example of a lithium metal battery and on the right side an example of a lithium-ion battery [1].

Regarding the latter type (lithium-ion batteries), it is a fact that they currently play an important role in the quality of life in modern society, as they are considered the dominant technology for use in a plethora of electronic and electrical equipment (EEE). For this reason, a more detailed description of lithium-ion batteries is provided below.

Lithium-ion cells in EEE may have different shapes, sizes, and colour. Typical lithium-ion cells are cylindrical, prismatic or pouch-shaped however this depends on the manufacturer and the reason for their manufacture. For example, older portable laptops often use cylindrical batteries, and their colour is usually either pink or blue depending once again on the battery manufacturer. The cylindrical cells are normally 18 mm in diameter and 65 mm in length. In the modern flat and portable laptops, we can find mostly lithium-polymer battery cells in the shape of a pouch built in.

Batteries in WEEE may be integrated in the device or removable without tools (see next section 2.2). Illustrating examples include, respectively, batteries typically integrated in a tablet or a toothbrush, and those that are removable in a TV remote control or a calculator. Some EEE may contain both, batteries that are easily removable and integrated at the same time.

2.2. Types of WEEE containing lithium batteries

Lithium batteries, primarily lithium-ion batteries, are widely used in our daily life. This is due to the fact that they can be much smaller and lighter than the previous generations of batteries, but still provide the same power [3].

As it has been stated above, lithium batteries are generally divided into two categories, lithium metal batteries and lithium-ion batteries. The first category type is generally used to power devices such as watches, cameras, defibrillators, calculators, temperature data loggers, and car key fobs, among others. The second category type is generally used to power devices such as laptop computers, power tools, mobile phones, tablets, and e-bikes [1]. Beyond these applications lithium-ion batteries are also the preferred option for the emerging electric vehicle sector [4].

Although lithium-ion batteries have seen a tremendous growth over the past decade, the market for lithium is anticipated to grow further and register a Compound Annual Growth Rate (CAGR) of over 10% within the next 5 years. Key factors driving the market growth include the rising usage and demand from portable consumer electronics, and the accelerating demand for electric vehicles in all corners of the world, among many others [5]. It should be mentioned that this trend will be further enhanced by innovation and technological advancement.

Many devices we use daily have integrated batteries, meaning they are embedded in the device by design and are not removable without tools. Most rechargeable batteries are integrated. When rechargeable batteries are not integrated, there is a functional reason such as easy exchange in the middle of a workflow for power tools, or to easily charge the battery of an e-bike (Source: www.digitaleurope.org)

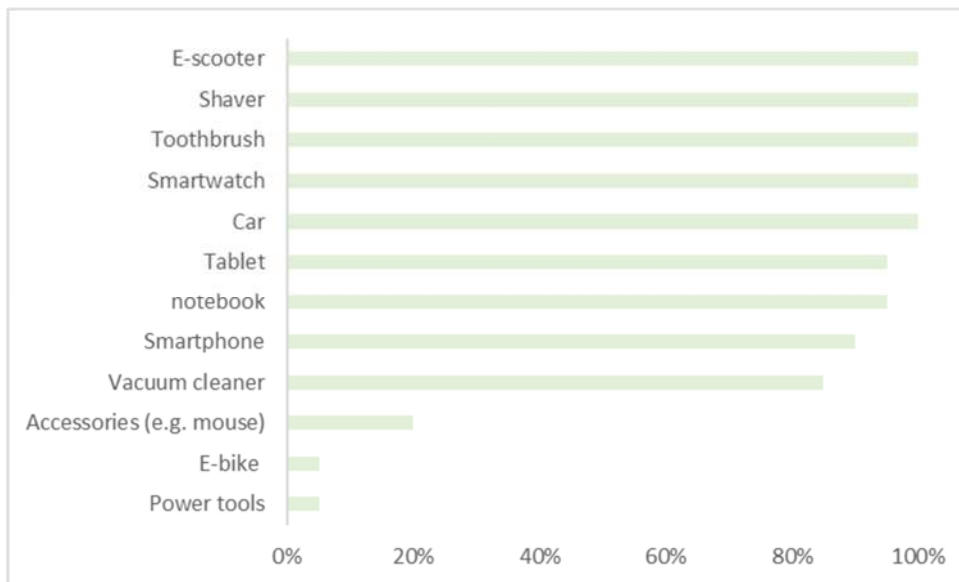
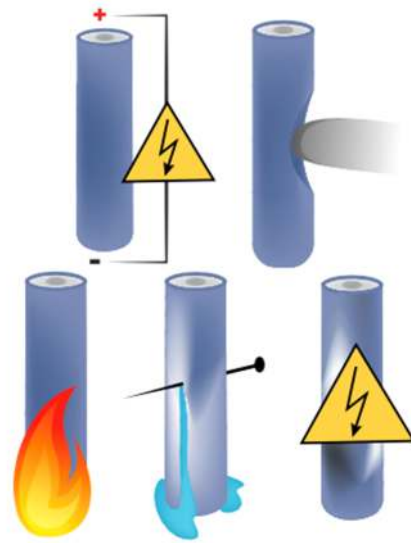


Figure 1. Share of integrated batteries per type of device (Source: digitaleurope.org, Avicenne Energy, 2020).

2.3. Actions that may trigger a fire

Lithium batteries are made to deliver high output with minimal weight. For this reason, battery components are designed to be lightweight, which translates into thin partitions between cells and a thin outer coating. The partitions or coatings are fragile, and they can be easily punctured. Most of the actions that may trigger a fire are listed and briefly described in this section. In many instances, actions cause the (internal or external) connection of the poles of the battery (+ and -) - that in normal and secure circumstances are separated - which can then cause a short circuit. Short circuits can either be harmless or responsible for the initiation of a thermal event (e.g., sparks, fire, explosion, etc.). This is very much dependent on whether the battery is still charged or not. A second reason is that the battery can heat to the point of thermal runaway. In that case, the heat of the contents exerts pressure on the battery, potentially producing an explosion [6].



Picture 2. Actions that may trigger a fire.
(Source: Viktor Haefeli).

Damages in batteries may be caused by design and EEE assembly issues, incorrect handling of LBs and EEE at different stages in a shipment cycle, incorrect use by users of EEE containing batteries, incorrect end of life storage and transport.

Most actions that may affect WEEE containing LBs or single LBs are:

- Short circuits are generally caused by an **external material** that connects the poles of the same battery or cell. This situation can cause a serious incident if the battery or cell has still enough power inside. An external material can be for instance another battery with metal coating, or waste surrounding the battery.
- **Physical impact or shock to WEEE or single LBs** may also trigger a thermal event because it may damage and move materials in contact with the batteries (e.g., printed circuit board), hence connecting the poles of the battery and causing a short circuit.
- **Heat exposure:** exposure to extreme temperatures ($> +60^{\circ}\text{C}$ / $< -20^{\circ}\text{C}$) may cause a short circuit.
- **Damages to cells/modules** caused by, for example, aging of the batteries which can lead to a short circuit too (i.e., when vulnerable materials inside the battery deteriorate). This includes dendrite formation, which refers to the growth of conductive crystals inside a lithium rechargeable battery. Crystals may protrude the separator of the poles and create an internal short circuit leading to a thermal runaway. Dendrite formation is usually caused by the combination of aging and an imperfect charging/discharging regime. LBs missing the casing (see Picture 3) are considered damaged as well. When the casing is missing, the poles of the battery are closer (e.g., less than 1 mm apart) and the risk of getting in contact and cause a short circuit increase.

Additionally, the metal cover that is protected by the external casing may act as a material connecting the poles and causing a short circuit.



Picture 4. Examples of damaged batteries (Source: INOBAT).

Batteries subject to recall due to manufacturing defects are prone to over-heating, a situation that could potentially cause a thermal event.

Pocket and flexible batteries must receive special attention and be handled as critical batteries when they show deformation or are swollen.

Additional examples of damaged batteries and ways to handle them appear in Annex A.



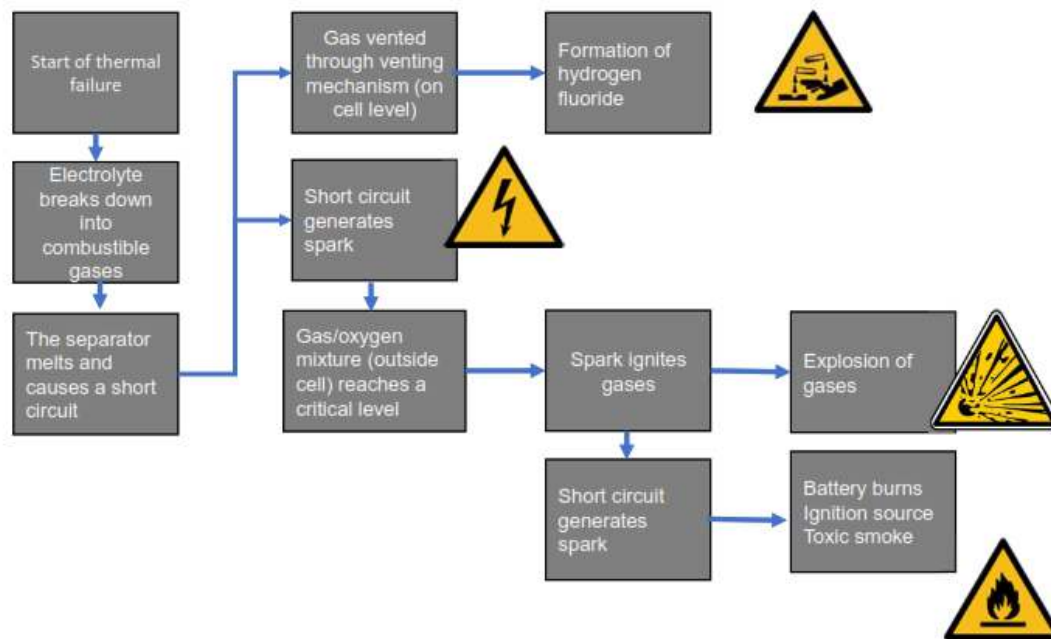
Picture 3. LBs missing the casing (naked).

2.4. What happens when a lithium battery fails?

At roughly 150 Wh/kg, the energy density of lithium-ion cells is low compared to common fuels. In most lithium-ion cells very reactive materials are combined in a tight space and are very close to volatile and highly flammable electrolytes. When the barriers separating these very reactive materials are damaged (see previous section), a chain of chemical reactions generating heat creates a domino effect that may increase the temperature up to 700-800 °C, making it very difficult to control the temperature of the cell.

In addition, during a thermal event, lithium batteries may release combustible gasses. The smoke from a fire of LBs contains combustible, carcinogenic, toxic, and corrosive substances. Safety measures must and should be implemented to avoid inhaling these gases.

What happens when a lithium-ion battery fails?



Picture 5. What happens when a lithium-ion battery fails? (Source: SENS Foundation | WEEE Forum Operations Committee, 3 December 2020).

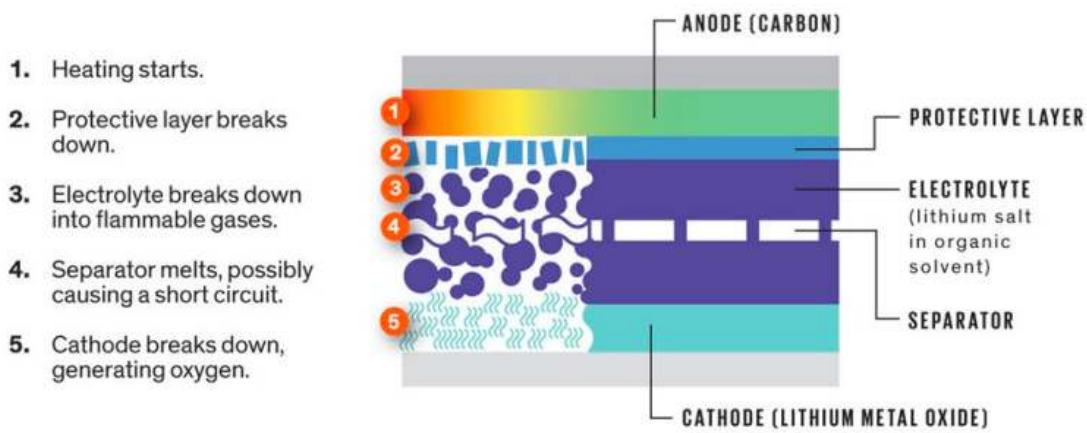
In most cases, a thermal event starts with an increase in the temperature of the battery (thermal failure). This may either affect only one part of the battery or the whole battery (the heat may extend to other parts of the battery later as well). Once the temperature has reached a certain point, gases are generated from the electrolyte (chemical source contained in batteries that is used to produce electricity). The material that separates the anode and cathode (separator) melts causing a short-circuit. This may trigger a series of chemical reactions (domino effect) that will lead to additional generation and release of gases, sparks or even the release of oxygen outside the cell.

Thermal runaway occurs when a cell has reached the temperature at which the temperature will continue to increase on its own, as it creates oxygen which feeds the fire (literally) [42]. Once the temperature of the cell reaches about 80 °C, the layer protecting the anode (SEI) begins to decompose and break down in a reaction generating heat due to the reaction of lithium with the solvents used in the electrolyte. At about 100 °C–120 °C the electrolyte begins to break down in another reaction liberating heat, which in turn generates various gases within the cell. The gases that may be created during this reaction, depending on cell chemistry, include carbon dioxide, carbon monoxide, methane, ethane, ethylene, and hydrogen (H₂) [6].

As the temperature nears 120 °C–130 °C, the separator (layer separating anode and cathode) eventually melts, allowing the anode and cathode electrodes to make contact and cause an internal short circuit, generating more heat. As the temperature continues to rise, roughly between 130 °C–150 °C, the cathode begins to break down in another chemical reaction that liberates heat with the electrolyte, which also generates oxygen. It is this release of oxygen

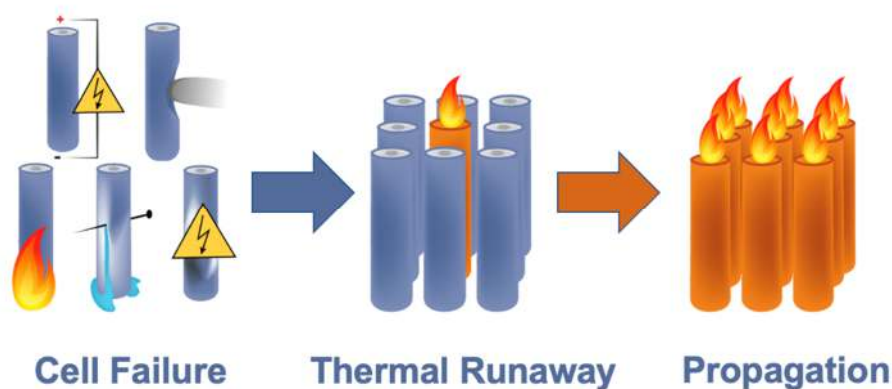
along with the carbonate LiPF_6 electrolyte that ultimately allows the cell to burn out and catch fire. The decomposition of the cathode active material is a highly exothermic reaction that generates a lot of heat and continues to drive the cell toward ultimate failure and fire.

When temperatures rise above $150\text{ }^\circ\text{C}$ – $180\text{ }^\circ\text{C}$, the reaction may become self-sustaining if the cell fails to rapidly dissipate the heat being generated. At this point, the cell is in what is referred to as “thermal runaway”, as the oxygen generation makes the fire self-sustaining until all the fuel has been consumed. If gases continue to build up inside the cell, the cell may rupture or vent through a safety valve, expelling flammable hydrocarbon gases and hydrofluorocarbon electrolytes at this point. The introduction of a spark could ignite the electrolyte and the gases, causing flame, fire, and potentially an explosion. But if the pressure continues to increase, it is also possible that the cell will burst open and eject the “jellyroll” from the housing [6].



Picture 6. Illustration of thermal runaway process in lithium-ion battery cells [40].

The onset temperature for the reactions to liberate heat and to drive thermal runaway varies with the chemistry of the battery cells and their state of charge. In general, the higher the cell voltage or the state of charge, the lower the thermal runaway start temperature. For battery cells with the same chemistry, it varies with the load history of the specific cell and the abuse event [41]. Tests carried out showed that temperatures over $170\text{ }^\circ\text{C}$ may trigger explosions which could quickly increase to temperatures up to $700\text{ }^\circ\text{C}$ – $800\text{ }^\circ\text{C}$ [25].



Picture 7. Evolution over time of a thermal runaway (Source: Viktor Haefeli).

3 Lithium hexafluorophosphate (LiPF_6) is a widely used salt in the electrolytes for commercial lithium-ion cells.

It should be noted that for WEEE recycling operators a battery incident is the source of ignition of the surrounding WEEE, which is usually a highly flammable mixture of metals and plastic, plus flammable contaminations (liquids, fats, dust, etc.). A severe event can destroy large volumes of WEEE, emit toxic fumes and damage buildings and treatment equipment, which are often equipped with expensive detection equipment and not built to withstand intensive heat.

2.5. Types of thermal events

1. Hot spot
2. Sparks
3. Smoke
4. Slow burning fire (no flame)
5. Slow burning fire (flame)
6. Intense fire (rapid fire)
7. Explosions

Thermal events caused by WEEE containing LBs and single LBs may range from simple hot spots to explosions. This report supports a harmonised categorisation of thermal events. Using a harmonised format will be extremely useful for compiling comparable statistics. Statistics may be used for assessing the efficacy of preventive measures implemented and quantify the relevance of the problem. In order to provide a greater understanding to the reader, the following thermal events have been defined in this section.

According to experts, usual reactions include heat (starting in minutes or hours), smoke, heavy smoke and a rapid fire (the last three may start in a few minutes). If the fire is close to combustible materials like wood, plastic, etc., then the dimension of the fire will increase.

Hotspot: Hotspot is defined as an event in which a battery operates with non-uniform temperature and sometimes can have localized-temperature hotspots from internal or external heat sources or from manufacturing non-uniformity and defects [7].

Sparks: Spark is defined as a small burst of fire that comes off a battery. More precisely, a spark may happen when combustible solids and liquid droplets are being ejected from the batteries at high speed, forming white sparks. This can happen when electric vehicle batteries and other big or small electric appliances containing batteries are being mechanically crushed during treatment at the end-of-life [8].



Picture 8. Sparks

Smoke: Smoke is defined as a mixture of carbon dioxide, water vapor and other gasses, usually containing particles or other solids, produced by the burning of carbon comprising material such as batteries. A single pouch cell can make a lot of smoke.

According to the survey conducted, smoke, sparks and hot spots are the events that occur more often, while the most frequent combination seems to be smoke associated to intense fire [9].

Slow burning (no flame): Slow burning (no flame) is defined as a thermal event that will not initiate a fire, since the material(s) involved or those in close proximity to the event, will not face significant increase in temperature and hence will not ignite or support combustion during its/their exposure.



Picture 9. Examples of smoke

Slow burning fire (flame): Slow burning fire (flame) is defined as a thermal event that will not start immediately, since the material(s) involved or those in close proximity to the event will not ignite or support combustion during its/their exposure for a certain amount of time (typically five minutes). It should be also mentioned that the time required for a material to ignite also depends on the nature of the material and the temperature that it is exposed to. Based on experiences from the recycling industry, in case of a thermal event, plastics will start emitting dioxins when smouldering at low temperatures. Whether the materials ignite depends on many factors, such as the material itself, the shape, the particle size, etc. Small particles with a large surface area tend to ignite faster than large pieces. The potential temperature of a burning battery far exceeds the ignition temperature of most plastics. It should also be noted that impurities may be present in the waste material that could be very flammable, such as dust, textiles, papers.



Picture 10. Slow burning fire (flame).

Intense fires (rapid fire): Intense fires, alternatively known as rapid fires, are described as fires that usually last between 1 and 6 hours. Fire intensity depends upon how much fuel is burnt and how fast it burns. For this reason, intense fires can be divided into 4 different categories [10]:

- a) Intense fires that can be suppressed with water-supported hand tools as a direct firefighting measure.
- b) Intense fires that can be suppressed by machines, tankers, and water bombers as a direct firefighting measure.
- c) Intense fires that can be suppressed by machines, tankers and water bombers using an indirect firefighting measure.

d) Intense fires unlikely to be suppressed.

It should be mentioned that the most severe cases of intense fires require the intervention of a fire brigade [9].

Explosion: The thermal runaway of lithium batteries – and batteries in general – results in scrap of batteries and fire, with the toxic and flammable gases generated [11]. At some later stage, the explosion may experience constraints that bound the event, for example, the reactants are depleted [12]. It should be noted however that the frequency of this type of thermal event is relatively low and that batteries often comprise a relief valve to control excessive pressure.

Thermal events, if not resolved in time, can escalate, and eventually lead to intense fires and/or even explosions.

3. Main issues arising from fires caused by WEEE

Fires caused by WEEE containing batteries can be a very serious problem for waste management facilities, costing millions of Euros each year. Besides the economic costs that they bring, they also have consequences affecting the environment and human health.

As highlighted in the report “Characterisation of fires caused by batteries in WEEE” [9], one of the major issues for the waste industry associated to fires caused by WEEE containing batteries are additional and unexpected costs arising after the occurrence of a fire.

Costs are often related to:

- repairing or replacing the equipment and infrastructure damaged during a thermal event,
- temporary interruption or final cessation of (part) of the activities,
- loss of waste burned during the thermal event,
- maintenance and replacement of extinguishing means,
- other associated costs recently identified are the treatment of water used during the extinguishing of the fires as it may contain persistent organic pollutants.

Other non-negligible costs deriving from the situation are costs associated to:

- the transportation of WEEE containing batteries to another treatment facility in the event of a planned or unforeseen shutdown due to a severe thermal event,
- installation of additional detection and mitigation measures,
- changes in the infrastructure of the facilities,
- adaptation of operational protocols and training,
- insurance costs,
- additional requirements and/or limits imposed by licencing authorities.

Costs may vary considerably depending on the type and frequency of the thermal event occurring. According to the survey conducted in 2019 [9], 36% of 109 respondents reported a severe incident in the last 4 years (period 2016-2019). Most respondents reporting severe incidents mentioned intense fires (69% of cases), followed by smoke (37% of the cases), hot spots (27% of the cases) and explosions (20% of the cases) when identifying the event typology.

The average cost of all those incidents in 2018 was estimated at €190,000⁴, which can represent a significant burden for an individual company. The most severe fires occurring at respondents’ facilities in the last four years gave rise to an average reported cost of damages of €1.3 million⁵.

⁴ Sample of 34 respondents out of 57 that reported a fire in 2018. Deviation: €444,000

⁵ Sample of 26 respondents out of 38 that reported a severe fire. Deviation: €4.1 million

The intervention of a fire brigade was required in the most severe cases.

Similarly, costs on prevention and firefighting measures may vary considerably depending on the detection, prevention and extinguishing measures implemented, hence it is strongly recommended expert advice to design an adequate and cost-effective plan.

More and more often, waste management companies face an increase of insurance premiums, coverage exclusions or simply cannot obtain an insurance.

The steady increase of fires caused by WEEE containing batteries is affecting the policies of insurance companies, and the waste industry has raised concerns about the difficulty to obtain proper insurance coverage. This poses a serious problem when the activity permit to operate is conditioned to obtaining insurance coverage.

After a severe thermal event, actions to recover normality are required as stated above. The impact to the environment and human health must be minimised. In this respect, it should be considered the generation of waste due to burned materials on site and the materials used for fire extinguishing (e.g., runoff water used for fire extinguishing may contain substances from burned WEEE). The facility in question must take the necessary steps to ensure that the contaminated water is contained, pumped by special trucks, and then sent to a hazardous waste treatment centre. Besides the additional economic costs involved, this process may also cause further operational delays.

When a fire occurs, depending on its severity, facilities may face an unforeseen (temporary) interruption of their activities for managing damages arising from the fire. When this happens, it is often not possible to meet contract terms with, for example, extended producer responsibility organisations that contracted regular treatment of WEEE. This as a result, may imply payment of penalties stipulated in contracts or additional costs for shipping the WEEE to other facilities that will treat the WEEE instead.

Although fires resulting in physical injuries on personnel rarely happen [9], the frequent phenomenon of fires is undoubtedly posing at risk employees of WEEE management facilities who are in danger to be mildly, moderately, seriously, or severely injured causing (severe) damage to the health of the workers and/or to nearby populated areas [14]. The type of injury depends on the scale of the thermal event. Additional training and health and safety measures are necessary at waste management facilities because of this.

The European Green Deal and the new Circular Economy Action Plan identify 'electronics' among key product value chains where recycling plays obviously a major role to achieve sustainability goals.

Currently a magic formula that will eradicate fires associated to LBs is not available, and only measures reducing the risks of fires have been identified. The expected contribution of the waste management industry to the EU strategies is at risk. The waste management sector needs a supporting multistakeholder strategy that will address properly the issue of fires caused by WEEE containing LBs and single LBs.

4. Summary of the survey results on good practices (Part B)

The data of the second part (Part B) of the survey (see Annex B) is analysed in an anonymous⁶ and aggregated manner, in this section of the report. In addition, it should be noted that the following results do not intend to be statistically representative on the topic, but rather to provide a description of the results obtained in the survey, reflecting the practical knowledge and experience of the respondents on the matter.

109 respondents in total participated in the survey, from all segments of the WEEE value chain (collection, sorting, pre-treatment, shredding, post-shredding), and with various management capacities, types of waste managed and localisation (refer to the report “Characterisation of fires caused by batteries in WEEE” [9] for more information and further analysis on the type of respondents and facilities participating in the survey, as well as on the characterisation of fires associated to WEEE containing batteries).

81 respondents out of 109 (74%) indicated having implemented good practices and mitigation measures at their facilities in recent years (2016-2019). Given that answers to the following parts of the questionnaire were conditioned by reporting a good practice and/or mitigation measure, the maximum number of respondents in this part should be 81 for all questions. Among those 81 respondents, 62% reported thermal incidents associated with batteries in 2018. This result can be interpreted by the facilities as a prevention procedure instead of a reversal procedure.

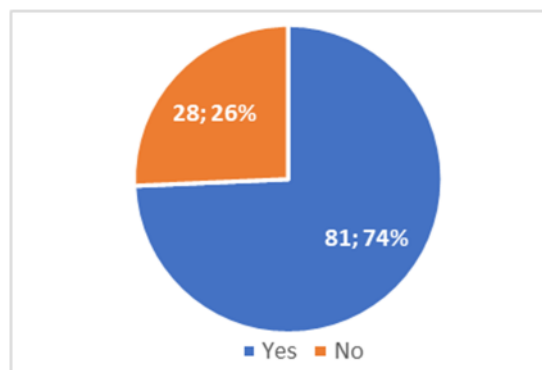


Figure 2. Respondents declaring having implemented good practices and mitigation measures in recent years (2016-2019), 109 responses – Q5.1

On the other hand, 72% of those respondents indicating experiencing a thermal associated with batteries in 2018, implemented good practices and mitigation measures at their facilities in recent years (2016-2019). In this case, the result could be interpreted as a reversal procedure at some point.

100% of those having implemented good practices and mitigation measures indicated that they did circumvent the number and/or intensity of the fires in 2018 (Q5.2). When respondents were asked later in the questionnaire (Q7.11) about the reduction in fire frequency, only 48% (39 of

⁶ The questionnaire and the terms in which information collected was treated appear in Annex C.

81) responded to the question. Of these, 41% indicated no reduction and 53% expressed a decrease in frequency at some point (23% a decrease greater than 50%, 15% less than 50% and finally 15% mentioned a total -100%- reduction of fires frequency). This difference may be since some of the measures implemented did not imply a reduction in the frequency/number of thermal events itself, but rather in the magnitude of the damage that such an event could cause. Only one of the respondents answered that not only had it not decreased, but it had increased.

Regarding the need for additional measures to the good practice implemented in order to improve its results, 65% of the respondents confirmed this statement (Q7.12). As it was an open text question, more specific responses included a ban on the collection and transport of non-depolluted material in (open) bulk containers (2 times) and staff training (1 time).

According to the results obtained from the questionnaire, there is no significant relationship between the type of activities carried out on site, those facilities that declared a thermal event in 2018 and those with good practices and mitigation measures implemented (2016-2019) (see Figure 3). The number of actors decreases down in the value chain, from collection to post-shredding treatments, while the frequency of fires incidents increases. This indirect relationship is also shown regarding good practices and mitigation measures implemented at the facilities but at higher values.

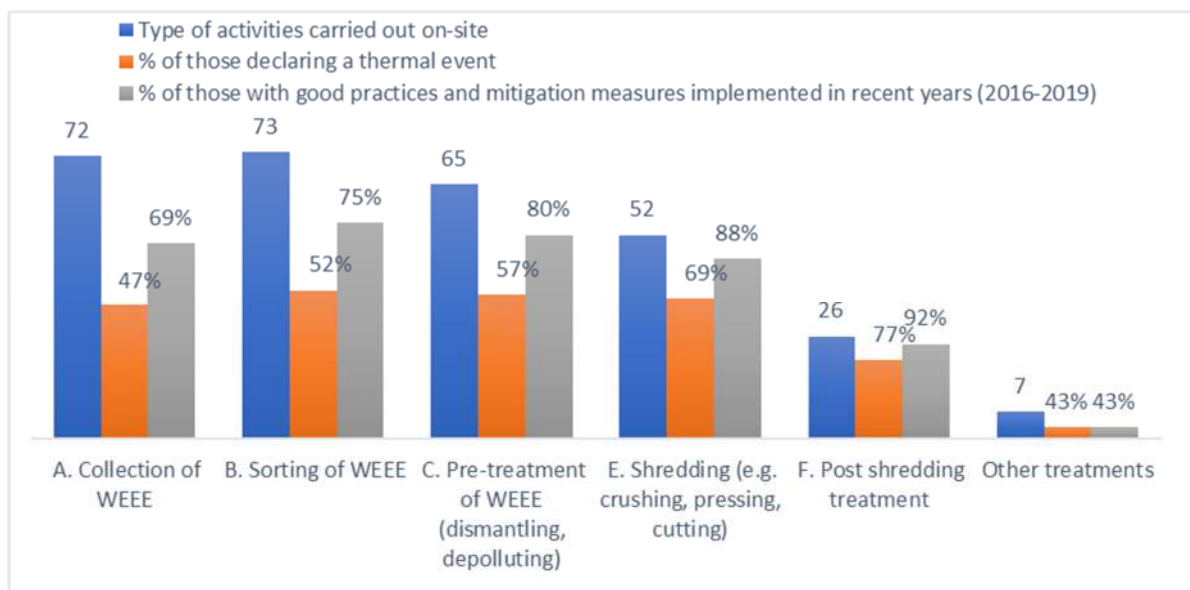


Figure 3. Respondents declaring thermal incidents during 2018 (58 responses – Q2.0) and those with good practices and mitigation measures implemented in recent years (81 responses – Q5.1), grouped by type of activities on-site (109 responses – Q1.3)

Figure 4 represents where the good practices were implemented in the recycling process. All steps in the chain result covered, but those mostly mentioned are:

- L. Pre-Treatment – Manual Dismantling /depolluting (33 times)
- E. Storage area of sorting/logistics centre (30 times)
- K. Storage area of (pre-) treatment site (25 times)

However, they were rarely mentioned alone, but as part of a response containing a combination of other areas.

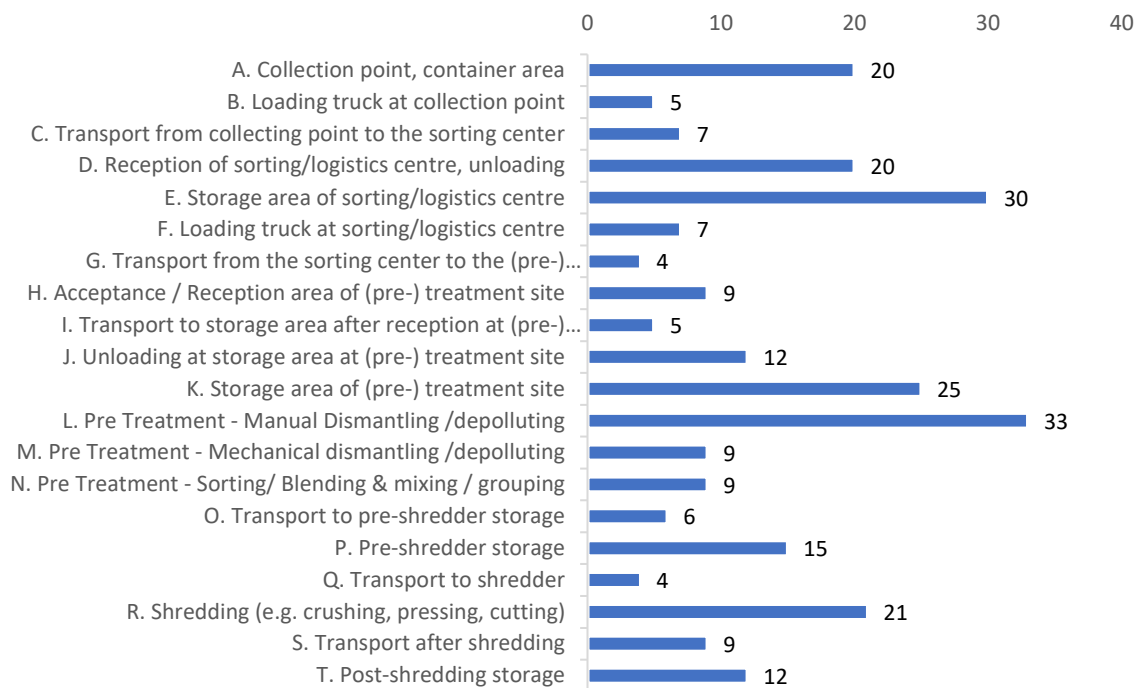


Figure 4. Number of times a stage is mentioned as being affected by the implementation of a best practice implemented. Respondents had the possibility to choose more than one stage within the process – Q6.1.

Following expert advice, the stages mentioned above have been grouped into the following broader procedural groups: 1. Collection (options A. and B.), 2. Transport from collection to sorting and logistics centre (C. to G. options), 3. Treatment facility: pre-treatment (H. to N. options), 4. Treatment facility: mechanical treatment / shredding (O. to S. options) and 5. Post-shredding storage (option T.). The result of this exercise is shown in Table 1, along with that obtained regarding thermal incidents associated with batteries in 2018. The results are surprisingly quite similar between the two clusters.

Treatment stages group	% of share (good practices)	% of share (thermal events)
1. Collection (options A. and B)	10%	4%
2. Transport from collection to sorting and logistics centre (C. to G.)	26%	30%
3. Treatment facility – pre-treatment (H. to N.)	39%	39%
4. Treatment facility – mechanical treatment/shredding (O. to S.)	21%	21%
5. Post-shredding storage (T.)	5%	6%

Table 1. Stages grouping where the best practices were implemented (frequency of answers), 81 respondents – Q6.1 and where most thermal events started in 2018 (frequency of answers), 58 respondents – Q3.2.

Most of the measures and best practices were performed within the last 3 years and 65% were implemented on-site.

The fixed amount invested per installation during the first year for the implementation of the good practice was less than €10,000 in 53% of the cases (76 out of 81). A similar result is obtained if recurring costs associated to the good practice are analysed: 54% of the respondents answering the question (48 out of 81) declared recurring costs less than €10,000 associated to the good practice per facility. Qualitative responses (13%) to the latter were grouped into personnel costs (4 times), training (1 time) and firefighting materials (1 time).

Figure 5 shows the comparison between the two types of costs that the implementation of a good practice may incur.

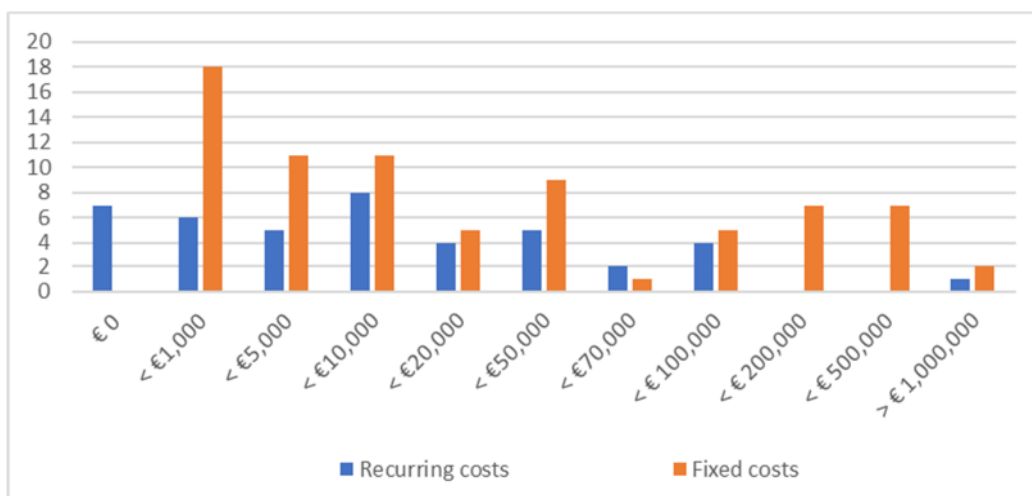


Figure 5. Comparison between fixed costs and recurring costs associated to the implementation of a good practice per facility.

Regarding the financing of the practices, 65% of the respondents indicated that they were financed by their own means, 25% did not know / answered the question and 10% used the provided open text “other” alternative to detail the answer: Management fee (3 times), Joint operation (3 times) and Training (2 times) were mentioned.

5. Types of recommendations and good practices (Part B)

This report comprises a set of recommendations and good practices that have been grouped according to the following steps of the EEE and WEEE value chain:



Specific recommendations have been defined as well for:

- Collective schemes of WEEE and batteries (PROs) (chapter 11),
- Local entities (chapter 12), and
- Policy makers (chapter 13).



In the scope of this report, ‘pre-treatment’ refers to facilities that may perform sorting, depollution, dismantling and mechanical treatment of WEEE containing batteries. This sort of treatment may be carried out by several facilities, or by only one. The risk of fires caused by batteries in this chain of facilities may arise when the removal of batteries in the first treatment steps is not efficient, and batteries may be present in the fractions resulting from the first treatment steps and destined to downstream acceptors.

In the context of this report, ‘final treatment’, refers to activities and facilities receiving lithium batteries as input, mostly facilities sorting and treating batteries. The final destination of the materials resulting from such facilities are smelters. Smelters are out of the scope of this report.

Finally, it should be noted that costs associated to the implementation of the measures illustrated in this section can vary largely depending on the departing situation and the type of measure to be implemented. Recommendations and good practices must be adapted to each situation and carefully assessed in terms of resources, so the benefits and results obtained from them are aligned with the investments required.

6. Recommendations and good practices | Design

To reduce the risk of fires, the design of products must include all aspects of safety, including the safe disposal and recycling at the end-of-life phase of these products. The Environmental Services Association and Eunomia, in the report named “Cutting Li-ion Battery Waste Fires” [34], proposed as a long-term solution to change Lithium-ion battery (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 flame-retardant coating to batteries. Recommendations arising from the consultation launched in 2019 in the context of this report refer to labelling and to improving the removability of the LBs from EEE.

6.1 Labelling of EEE



Design

Description of the problem:

Though safety instructions may exist when handling WEEE containing LBs, recipients of the instructions may not be aware of them, or instructions may simply not be available when they are needed. When there is no appropriate marking, the identification of WEEE containing LBs remains difficult in some cases, challenging the adequate channelling of the WEEE into the proper waste stream, safe handling and management and depollution of WEEE. Additionally, integrated batteries in EEE cannot be removed by users and have become a significant challenge for the treatment industry.

Challenges:

Harmonised labelling for all EEE containing batteries may be challenging. To implement a label, a relevant investment may be required by the manufacturing industry to carry out these actions. If labelling is implemented, an information campaign informing the waste management industry, as well as the general public would be required. Collaboration from the manufacturing and waste management industry will be required to issue a valid and useful labelling proposal.

Recommendation

Description:

Input from the consultation carried out in the frame of this study, provided several comments suggesting labelling of EEE containing batteries, in particular labelling aiming at:

- Informing users – and particularly end users – on the content of LBs and whether the battery in their device is a removable or a built-in one (sometimes this information can be found in manuals, EEE/Battery and/or packaging labelling, campaigns, etc.),
- Informing users on the potential hazards and correct handling of the WEEE containing batteries,
- Informing waste operators of the type of batteries contained in WEEE and include a website link should they need more information,

- Informing waste operators about the removability of the batteries,
- In case the battery is a built in one, to inform waste operators what type of adhesive has been used (soluble or not),
- In case the battery is removable, informing waste operators whether they need special tools for its removal,
- Informing waste operators about the lithium battery chemistry. Constant technological development resulted in a plethora of lithium batteries which contain different chemistries. These batteries should not be mixed during the recycling process as this could have effects on the efficiency and sustainability of the treatment of batteries,
- Informing waste operators on all battery levels. Batteries are comprised of several layers which may require different or multiple treatments,
- Introduction of colour coding depending on the battery types.

The European standard for marking of electrical and electronic equipment (EEE) in respect to separate collection of waste EEE (EN 50419:2006)⁷ [44] specifies a marking of (EEE) with a view to minimising the disposal of waste EEE (WEEE) as unsorted waste and to facilitating its separate collection. It applies to categories of EEE subject to WEEE collection, treatment, recovery, and environmentally sound disposal as defined by European and national regulations. The use of the EEE shall be informed by an appropriate mark as described in EN 50614:2006 [44] to facilitate that this EEE is subject to separate waste collection with a view to minimising the disposal of WEEE as unsorted municipal waste. The marking must be visible, legible, and indelible but could be also printed on the packaging and instructions of the product in some cases. If a marking of EEE containing batteries would be required, potentially the logic of EN 50419:2006 [44] could be used and even a combination with the WEEE marking symbol may be considered.

The IEC standard EN 62902:2019 was further identified (“Secondary cells and batteries - Marking symbols for identification of their chemistry”) [15] which may support and provide a starting point for denoting different battery types. This document specifies methods for the clear identification of secondary cells, batteries, battery modules and monoblocs according to their chemistry (electrochemical storage technology). The markings described in this document are applicable for secondary cells, batteries, battery modules and monoblocs with a volume of more than 900 cm³. The marking of the chemistry is useful for the installation, operation, and decommissioning phases of battery life. Many recycling processes are chemistry specific, thus undesired events can occur when a battery which is not of the appropriate chemistry enters a given recycling process. To ensure safe handling during sorting and recycling processes, therefore, the battery is marked so as to identify its chemistry.

This document defines the conditions of utilization of the markings indicating the chemistry of these secondary batteries. The details of markings and their application are defined in this document [15].

⁷ Future revision FprEN 50419:2021, Marking of electrical and electronic equipment (EEE) in respect to separate collection of waste EEE (WEEE).

Enforcement:

EU funded initiative for developing a pilot R&D project and partnership between manufacturing and waste industry.

Initial voluntary approach for testing and assessing impacts.

Information provided to waste industry via the I4R platform [16].

Further references:

Informative campaigns in Germany:

- Producer campaign
<https://e-schrott-entsorgen.org/download.html>
- Waste Management Association campaign
<https://www.bde.de/themen/brennpunkt-batterie/>
- Further information is available from other associations, authorities, and take-back systems.
<https://www.umweltbundesamt.de/umwelttipps-fuer-den-alltag/elektrogeraete/lithium-batterien-lithium-ionen-akkus#unsere-tipps>

[15] IEC standard EN 62902:2019, Secondary cells and batteries - Marking symbols for identification of their chemistry (2019).

[16] Information for Recyclers Platform. <https://i4r-platform.eu/>

[44] EN 50419:2006, Marking of electrical and electronic equipment in accordance with article 11(2) of Directive 2002/96/EC (WEEE), (2006).

6.2 Improved design of EEE containing batteries



Design

Description of the problem:

EEE placed on the market may contain non-easily removable LBs, hence it is difficult to replace or remove them during or at the end of their useful life. This on one hand limits the user to remove or switch battery in case a problem arises and on the other hand has been found to be a relevant obstacle for recyclers when attempting to remove LBs from WEEE, as requested by the WEEE Directive. More and more countries are requesting users to remove batteries at the event of disposal, and this is not possible when batteries are integrated into the device.

Challenges:

Design for removability of batteries in all EEE is challenging. Further research and additional investments may be required from the manufacturing industry to maintain the same life expectancy and quality of all devices containing batteries, in particular lithium-ion batteries. Collaboration between the waste management and manufacturing industry will be required for the development of a proposal that will ensure easy removability of LBs.

Recommendation

Description:

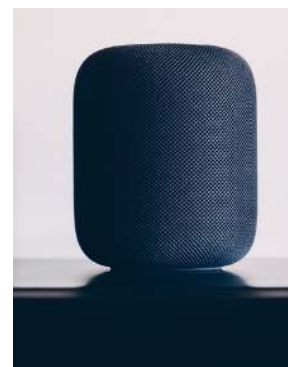
Design of EEE devices should consider easy removability of batteries at the EEE end-of-life or for reparation purposes. The following recommendations should be taken into consideration during the design phase:

- LBs should be removable manually or with commonly available tools.
- Preferably, removal of LBs should not require expert training.
- Substitution of built-in LBs with removable ones.
- The use of glue for placing LBs into the EEE should be avoided.
- In case the use of adhesives is necessary, the use of soluble adhesives should be the preferred option.
- Batteries, and particularly LBs, should be easily accessible to allow easy and fast removal. Therefore, in the scenario a battery is surrounded by other components, these components should be mechanically bounded, and the numbers of screws reduced to the minimum.
- Components that are surrounding a LB in a device should not have hidden screws to further ease the removal of the battery.

In some instances, appliances may contain both batteries that are easily removable and integrated batteries at the same time. This may mislead the recycler that may think only the most visible, clearly removable battery exists in the WEEE and send the WEEE to mechanical treatment once the visible battery has been removed. A clear indication of the existence of the integrated battery in the EEE would be very helpful for the recycling industry in these cases. Additionally, some EEE containing and non-containing batteries may look quite alike, e.g., e-bicycles, hence a clear distinction of both types of appliances can be very helpful.

Other appliances may represent a challenge in depollution for the recycling industry, examples are mostly focusing on integrated batteries. Interviews with experts indicated that recyclers had to invest in developing know-how for depolluting certain types of WEEE (see example in Picture 11 for waterproof Bluetooth speakers, also mobile phones with pouch batteries thermo-glued were often mentioned by recyclers as challenging). A fluid communication channel between recyclers and manufacturers to design know-how accessible to the recycling industry would be welcome.

It is strongly encouraged building partnerships with the WEEE recycling industry and preparing for re-use sector, so they can provide their experiences when removing and replacing LBs from used EEE and WEEE.



Picture 11. Some appliances require specifically designed dismantling practices and tools. (Source: Mark Tegethoff on Unsplash).

Enforcement:

A revision of the WEEE and Battery directives can provide the appropriate legal tools for improving the design of WEEE containing LBs. It is encouraged to have an EU approach rather than a national approach for defining requirements that will affect EEE design.

Further references:

6.3 Improved design of batteries



Design

Description of the problem:

EEE placed on the market may contain LBs that are prone to trigger thermal events.

Challenges:

Design for improved and safer LBs is a long and expensive process. Enforcement can be complicated and require additional resources.

Recommendation

Description:

In the report “Cutting Li-ion Battery Waste Fires”, Eunomia and ESA [34], suggest the following changes in the design:

- The development of non-flammable, solid electrolytes. An alternative option is to mix an additive into the conventional electrolyte for a LIB to create an impact-resistant electrolyte.
- More thermally stable electrolyte and/or cathode material.
- Adding flame retardants to the electrolyte or separator.
- Improved battery casings. Thicker casings with higher melting points could help to overcome this issue.

The report mentions that the development of the above technologies is at an early stage and therefore, changes to battery design appear to be at best a distant solution. How the changes can affect product design and the costs associated with them are not considered in Eunomia’s report.

The study “Li-ion Battery Fire Hazards and Safety Strategies” [38] concludes that batteries may prevent thermal runaways by:

- Using Separators: the separator is placed in the middle of the positive and negative electrodes inside a battery. From the battery operation perspective, a separator serves two functions: it prevents direct contact between the two electrodes, and it provides a pathway for the lithium ions. The separator is always made of insulation materials that will not cause an internal short circuit in the battery, and it has a porous structure that can absorb liquid electrolyte. The separator shutdown blocks the pathway between the positive and negative electrodes and stops the electrochemical reactions.
- Using Flame Retardants: one approach is to add flame retardants (FRs) to the electrolyte. Another strategy is to incorporate the FRs into the battery by confining them to the separator. The FRs in the separator are designed to be released at a certain temperature.
- Using Cell Venting: another strategy for improving battery safety is to add fail-safe mechanisms into the battery. Typically implemented fail-safe mechanisms include safety vents, thermal fuses, and shutdown separators. Safety vents are designed to release extra internal pressure and prevent the continuous increase of internal temperature.

It is strongly encouraged building partnerships with the battery and WEEE recycling industry and preparing for re-use sector, so they can provide their experiences when handling LBs from used EEE and WEEE.

Enforcement:

A revision of the Battery directive can provide the appropriate legal tool for improving the design of LBs. It is encouraged to have an EU approach rather than a national approach for defining requirements that will affect battery design. Additional available tools that can support enforcement are CE marking and CENELEC standards.

Further references:

[34] Cutting Li-ion Battery Waste Fires. Environmental Services Association and Eunomia (2020).

[38] Lingxi Kong, Chuan Li, Jiuchun Jiang and Michael G. Pecht (2018), Li-Ion Battery Fire Hazards and Safety Strategies.

7. Recommendations and good practices | Collection

Most recommendations and good practices identified are aiming at:

- Sorting WEEE containing LBs that may include additional removal of LBs from WEEE on site.
- Reduce damage to WEEE containing LBs during storage, handling, and preparation for transport.
- Information to users and collection facilities staff on the risks associated to WEEE containing batteries and the type of equipment that may contain LBs.
- Manage emergencies and fire extinguishing.

Users' behaviour may differ from country to country or even from region to region in the same country, therefore it is recommended to design collection strategies considering previous studies on citizen's attitudes towards disposal habits and pilots (see some examples of practices in reference [34]). A previous impact assessment and evaluation of investments vs results is highly recommended for each situation.

General measures to increase separate collection of LBs and WEEE containing LBs are part of national strategies in most countries where the Battery and WEEE Directives are implemented. Measures aiming at increasing return rates of both, single LBs and WEEE containing LBs will certainly contribute to reducing the risks of fires. Such strategies will result in the increase of batteries ending up in flows that can be properly controlled and managed against fires.

It should be noted that at the time of writing this report, the revision of the Battery Directive is underway. The recommendations and good practices described in this report should be aligned with the legislation applicable when it becomes into force.

A. Specific recommendations and good practices to civic amenities

7.1 Sorting of WEEE containing LBs at collection facilities. Proper handling



Collection

Description of the problem:

In some Member States, neither staff working at collection centres nor citizens contribute to sorting WEEE containing batteries at collection facilities. WEEE containing batteries may end up mixed with other types of WEEE and be handled as any non-containing batteries-WEEE. The Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) and special safety measures that can help reduce damage to batteries (and risk of fire) may not be applied. Collection facilities may lack a dedicated area for collecting/storing of WEEE containing LBs and single LBs. It should be noted that there are exemptions for ADR rules regarding WEEE containing LBs and single LBs. The application of ADR provisions to WEEE containing LBs and single LBs are limited.

Challenges:

Difficulty to identify WEEE containing LBs disposed of by users at collection facilities. Training to staff or instructions for users may be required. Additional receptacles are required to dispose of WEEE containing LBs may occupy additional space at collection facilities.

If batteries are reliably removed prior to transport, then bulk transport would be compliant with ADR but there are doubts whether sufficient separation can be achieved in practical operations. Updates on the types of WEEE containing LBs and the types of LBs received may be regularly required.

Good practice

Description:

The aim of this practice is to place WEEE containing LBs in a dedicated space/receptacle at the collection point. Experience has shown that it is difficult to identify the chemical type of batteries in WEEE. Therefore, it is recommended to apply the precautionary principle in the sorting procedure and handle all devices containing batteries in the same way. Staff working at collection facilities should be properly trained regularly and must have a good level of awareness and knowledge on the risks associated to WEEE containing LBs and procedures to carry out on site. Videos and on-line tutorials are recommended for training and on-site or face to face trainings should be encouraged.

When alternatively, users are required to place the WEEE containing batteries in a dedicated receptacle, special instructions clearly visible on site, or provided by the staff, are available and users are supervised by the staff. Staff providing instructions to consumers on where to place WEEE containing batteries will not only direct this particular type of WEEE into the right waste stream but will also increase consumer awareness over time.

Special containers (see fiche 7.3) are used for storing WEEE containing LBs.

The transport of WEEE containing LBs in bulk is prohibited (see ADR rules but also exemptions). Devices containing LBs are separated and placed into compliant containers. It

is difficult to identify the chemical type of batteries reliably and therefore it is an alternative to transport all small WEEE in ADR compliant containers.

ADR Special Provision 670 (SP 670) allows the transport of devices containing LBs in small containers (< 3m³). All WEEE devices containing batteries (embedded batteries) are to be collected and shipped in receptacles/containers compliant with ADR SP 670. Alternatively, according to the precautionary principle, all small WEEE devices may be collected and shipped in receptacles compliant with SP 670 (smaller than 3m³).

WEEE containing LBs and single LBs are never compacted at collection facilities (and neither for transport) as specified in CENELEC TS 50625-4. Devices are not dropped into boxes or containers and small collection boxes are not emptied into large containers/skips from a height to avoid damage of the LB that may trigger a thermal event.

Conclusions of the SaFER WEEE Project [14] describe several interventions which could potentially increase the likelihood of households removing batteries and recycling them separately. The project ran several pilots at different collection points across the UK. Some recommendations from this project are:

- Increased clear and continuous communication between product manufacturers, retailers, waste collectors, and fire and rescue services across the UK to highlight the safety issues and promote the separation of batteries for safe recycling (especially LIBs).
 - The aim should be to prime people, so they separate their batteries from their WEEE products before they visit the collection point.
- Prioritisation of the separation of batteries from small devices by collectors, especially on collection points by:
 - Co-locating small WEEE (including IT) and battery containers so it is easier for the public to recycle their batteries at the same time as dealing with their WEEE.
 - Repositioning the small WEEE (including IT) and battery containers to a more central location where operatives stand more chance of intercepting and 'policing' users.
 - Additional formal training on WEEE and batteries for collection points operatives (including 'meet and greet' staff) so they understand the issues and prioritise the proper separation of batteries from WEEE; and
 - Clear, bold instructional signage next to co-located WEEE/battery containers, highlighting the danger of fires and telling citizens to separate their batteries and recycle them separately.

Enforcement:

Dialogue and agreements between local entities managing civic amenities, collective schemes and recycling services companies can help implement this practice. Agreements may deal with:

- regular trainings scheduled for staff working at collection centres.
- Visits to schools.
- Awareness campaigns to citizens.
- Provision of informative and training materials to collection centres.
- Provision of dedicated space and receptacles for WEEE containing LBs and single LBs.

Enforcement and implementation can also be provided by implementing the European Technical Specification EN 50625 (CENELEC) “Collection, logistics & treatment requirements for WEEE - Part 4: Specification for the collection and logistics associated with WEEE or similar standards or regulations”.

Monitoring of the efficiency of this measure may be ensured via regular reports showing achievement of the agreements provided to a national or local committee in charge of supervising similar issues e.g., national clearing house or national waste multistakeholder committees.

Finally, when a system for collecting statistics on fires caused by WEEE containing batteries is in place, the efficiency of this practice can also be monitored and evaluated (see fiche 11.1).

Updated information on the WEEE arising that contains LBs could be shared with the recycling industry via a simple e-platform. The e-platform may allow communication between waste operators and manufacturers, both will be posting alerts on new devices spotted containing LBs and exchange good practices on safety.

Further references:

[14] McKinlay, R. and Morton, G. (2020), SAFeR WEEE Investigating a new collection method for Small Mixed WEEE to reduce fire risk.

[17] EERA technical guidance document. Safe collection and transport of electronic equipment with lithium batteries. Understanding ADR rules made easy. EERA (2019).

[18] UNECE site “About ADR”. <https://unece.org/transportdangerous-goods/adr-2021-files>

[19] Best practice sheet #2 based on the conclusions of the ecosystem and Ecologic study (2019).

[20] Guidelines for collection and transport of WEEE containing LIBs. SWICO and SENS eRecycling (FR, IT, DE).

[34] Cutting Li-ion Battery Waste Fires. Environmental Services Association and Eunomia (2020). [37] Sorting instruction. Removal of high energy accumulators in small household appliances. Ecobatterien, Ecotrel (V1.1) (FR, DE).

7.2 Removal of batteries from WEEE at collection facilities. Proper handling



Collection

Description of the problem:

Lithium batteries may be collected in other waste flows. Lithium batteries are then handled and treated incorrectly and damaged and may give rise to thermal events (fires).

Challenges:

Difficulty to identify WEEE containing LBs disposed of by users at collection facilities. Difficulty to remove the batteries. Dedicated containers for storing LBs will be required and may occupy additional space at collection facilities.

If batteries are reliably removed prior to transport, then bulk transport would be compliant with ADR but there are doubts whether sufficient separation can be achieved in practical operations.

Good practice

Description:

Staff working at civic amenities oversees sorting the WEEE containing LBs (reception/counter approach) and remove batteries when no tools are required. When human resources are not sufficient at the collection site, an alternative approach is that users separate WEEE containing batteries at public collection yards based on instructions provided on site and upon request of the staff members. A public display with a certain slot which allows only smaller batteries can be used, users may be asked to hand bigger batteries to a responsible person or placed on a sorting table or space.



Picture 12. Case study from Luxembourg, example of sorting instructions for a collection point in Luxembourg (Source: Ecotrel) [37].

Staff working at collection facilities are trained regularly and must have a good level of awareness and knowledge on the risks associated to WEEE containing LBs and single LBs, and procedures to carry out on site. Video and/or online tutorials are recommended for training and on-site or face to face trainings are encouraged.

When users are required to remove the LBs and place them into a dedicated receptacle, special instructions clearly visible on site, or provided by the staff, should be available and users are supervised by the staff.

Additional operations may reduce the risks of fires caused by batteries such as [22]:

- Protect the battery terminals by completely covering them with an insulating, non-conductive material.
- Perform discharging according to an approved process.
- If technically possible, discharge the battery/cell (lithium-ion) to a State of Charge (SoC) not exceeding 30%.

Damaged batteries should not be stored with other undamaged batteries [21]:

- Batteries that are swelling, smoking, leaking, or overheating should be treated with extreme caution.
- Immediately place them in an absorbent, non-flammable material in a cool, dry place.



Picture 13. Example of information to users (Source SAFeR WEEE)

- Store outdoors away from structures, vehicles, and equipment.
- Store in a non-combustible structure.
- Recommended storage materials include sand or vermiculite.

Special containers (see fiche 7.4) are used for storing lithium batteries and damaged batteries. It is recommended to:

- Store batteries in a dry, cool, and well-ventilated place.
- Keep batteries away from heat sources.
- Protect batteries from direct exposure to sunlight.
- Keep batteries away from water and condensation.
- Store batteries in closed containers or packaging to prevent short circuits and damage during storage and transport.

Instructions to identify damaged batteries (e.g., swollen, etc.) and handle them properly are also provided to the staff and users (see examples of damaged batteries in section 2.3 and Annex A). Compacting of LBs is prohibited.

Case study in Austria: Starting in 2018, most municipal collection points received information on how to handle LBs properly, and to remove LBs from WEEE when possible, without using tools. Information materials for citizens on the correct handling of LBs were also created and distributed. Specific 60l bins for LBs are used at collection facilities.

Enforcement:

Dialogue and agreements between local entities managing civic amenities, collective collection schemes and recycling services companies can help implementing this practice.

Agreements may deal with:

- Regular trainings scheduled for staff working at collection centres.
- Visits to schools.
- Awareness campaigns to citizens.
- Provision of informative and training materials to collection centres.
- Provision of dedicated space and receptacles for WEEE containing LBs and single LBs.

National waste legislations may require the removal of batteries by users before disposing of WEEE containing LBs, some examples are:

- In October 2017, a new Waste Treatment Ordinance set out specific technical requirements for handling LBs in Austria. More specifically, this legislation states that LBs must be removed from WEEE at the collection point if removable by the end-user prior to disposal.
- Spanish WEEE Decree 110/2015 (modified by Decree 27/2021, article 17.2.) that requires users to remove the batteries before disposing of WEEE, when not tools are required.

Monitoring of the efficiency of this measure may be ensured via regular reports showing achievement of the agreements provided to a national or local committee in charge of supervising similar issues e.g., national clearing house or national waste multistakeholder committees.

When a system for collecting statistics on fires caused by WEEE containing batteries is in place, the efficiency of this practice can also be monitored and evaluated (see fiche 11.1)

See also the (currently in proposal stage) recast of Directive 2006/66/EC on waste Batteries, in particular article 15.

Regularly updated information on the types of WEEE containing LBs could be shared with the recycling industry via a simple e-platform. This tool may allow communication between waste operators and manufacturers, since both would have the possibility of publishing alerts on new spotted devices containing LBs and exchanging good practices on safety.

Further references:

[19] Best practice sheet #2 based on the conclusions of the ecosystem and Ecologic study (2019).

[21] Guide for developing lithium battery management practices at materials recovery facilities. ISRI (2020).

[22] Lithium metal battery management guidelines in the reverse value chain. StEP initiative webinar, 27 March 2020.

[23] Austrian case informative fiches (EAK, clearing house). <https://www.eak-austria.at/pr-materialien/>

[36] Guide de bonnes pratiques pour la collecte de piles et accumulateurs au Luxembourg. Ecobatterien (V1.1) (FR, DE).

[37] Sorting instruction. Removal of high energy accumulators in small household appliances. Ecobatterien, Ecotrel (V1.1) (FR, DE).

Campaign from the Environmental Services Association (UK): <https://www.takecharge.org.uk/>



7.3 Dedicated receptacles for WEEE containing LBs

Description of the problem:

WEEE containing batteries may be damaged and trigger thermal events if not handled and stored properly. Receptacles used may not ensure protection to WEEE containing batteries, leakages of the WEEE and compliance with ADR.

Challenges:

Investment in specific containers may be required. Adaptation of the logistics service to the new ADR compliant containers may be needed. Additional space for receptacles may be necessary. It should be noted that there are exemptions for ADR rules regarding WEEE containing LBs and single LBs. The application of ADR provisions to WEEE containing LBs and single LBs are limited.

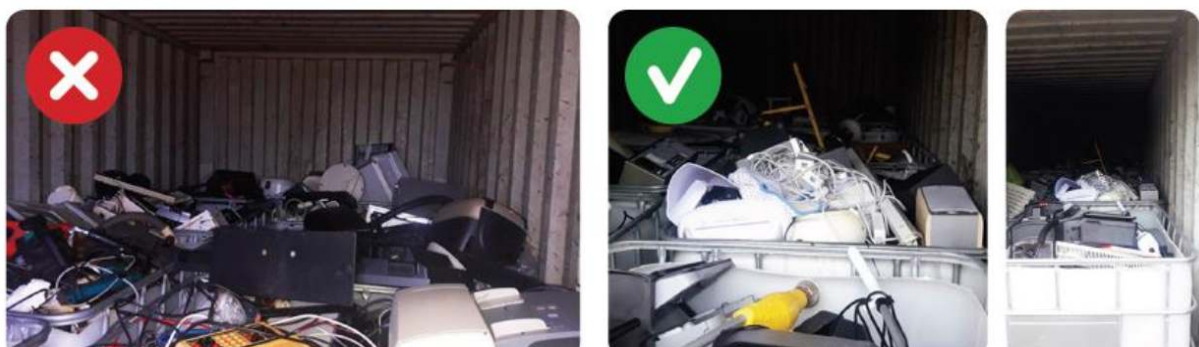
Good practice

Description:

Collection and logistics facilities use special containers for storing WEEE containing batteries. These may be used for storage at collection facilities and transport from the collection sites to intermediate logistic sites and WEEE treatment facilities.

Containers reduce the risk of damage and leakage of the WEEE containing batteries.

ADR Special Provision 670 allows the transport of devices containing LBs in small containers (< 3m³). All WEEE devices containing batteries (embedded batteries) are to be collected and shipped in receptacles/containers compliant with ADR SP 670. Alternatively, according to the precautionary principle, all small WEEE devices may be collected and shipped in receptacles compliant with SP 670 (smaller than 3m³).



Picture 14. Example of informative information for collection facilities. (Source: OPEN, NL).

Case study from the Netherlands: Picture 134 shows how Intermediate Bulk Containers (IBC) have been used for storing small WEEE at collection facilities in the Netherlands (Source: OPEN). In this case, maritime metal containers housing the IBCs are placed at collection points. Maritime containers play a double safety and security role, avoiding damage to WEEE and thefts at the same time. In this case, access to the maritime containers is allowed to individuals for disposing of the WEEE in the corresponding IBC.

According to ADR 2019 (please, always refer to the ADR version in force) equipment shall be packed as per packaging instruction P 909, or must be packed in strong outer packaging, such as specially designed collection receptacles which meet the following requirements:

- the packaging shall be constructed of suitable material and be of adequate strength and design,
- the packaging shall prevent any loss of contents during carriage (lids, strong inner liners, covers),
- measures shall be taken to minimize damage to the equipment when filling and handling the packaging (for example rubber mats),
- Packaging must not exceed 400 kg net weight or 3 m³.



Picture 15. Example of container for WEEE containing LBs [43].

Case study from Recupel (Belgium): an example of a receptacle is illustrated in Picture 15 [43]. The WEEE receptacle is suitable for the collection of small devices containing LBs such as mobile telephones, tablets, and small domestic equipment. Transparent plastic panels attached to the inside of the wooden frame prevent small parts from falling out, while remaining visible. The foldable box can be transported and stored compactly when empty for efficient transportation).

Additional protective housing may be used for storing the barrels containing LBs as illustrated in Picture 16 (left). This housing can be placed at collection points.



Picture 16. Left: protective housing for barrels containing LBs (Source MWE); Right: Cage for small WEEE containing integrated batteries (Source: EAK Austria).

Additional operations may reduce the risk of fires caused by batteries such as [22]:

- Protecting battery terminals by completely covering them with an insulating, non-conductive material.
- Discharging according to an approved process.
- If technically possible, discharging the battery/cell (lithium-ion) to a SoC not exceeding 30%.

Containers are clearly labelled indicating the content and potential risks associated at collection sites. For transport of specific waste and ADR, labelling is required (check ADR and applicable waste legislation).

Damaged batteries may require additional preventive measures (see fiche 7.2.2)

Enforcement:

Good practices identified show that PROs have partnered with logistic companies for designing and distributing ADR compliant containers (e.g., Belgian case of the national PRO Recupel and Pooling Partners, a supplier of pallets and boxes).

*Case study: Austrian collection points participating in the clearing system are subject to regular inspection from the national Clearing House. Inspections assess, among other things, the presence of specific drums for LBs and cages for small WEEE that may contain integrated batteries (Source: EAK Austria). Collection points must also count with a **sorting table** for the controlled takeover of lithium batteries or rechargeable batteries and electrical devices with non-removable lithium batteries (Source: EAK Austria, issue 41, 21 September 2019). Inspection results provide input to the payment of the annual infrastructure flat rate paid by the PROs to the collection facilities registered to the Clearing system.*

Further references:

- [17] EERA technical guidance document. Safe collection and transport of electronic equipment with lithium batteries. Understanding ADR rules made easy. EERA (2019).
- [18] UNECE site "About ADR". <https://unece.org/transportdangerous-goods/adr-2021-files>
- [22] Lithium metal battery management guidelines in the reverse value chain. StEP initiative webinar, 27 March 2020.
- [43] Recupel 2015 Annual report. Recupel (2016).

7.4 Dedicated receptacles for LBs



Description of the problem:

Lithium batteries may get damaged and trigger thermal events if not handled and stored properly.

Damaged batteries received at collection facilities may be unstable and trigger a thermal event easily. Batteries inside the receptacles are not sufficiently protected and may give rise to thermal events. Receptacles in use may not meet ADR conditions.

Challenges:

Investment in specific containers may be required. Adaptation of the logistics service may be needed. Additional space for receptacles may be necessary.

Good practice

Description:

Collection and logistics facilities use special containers for storing batteries. These may be used for storage at collection facilities and transport from the collection sites to intermediate logistic sites and batteries treatment facilities.

Containers can be used for all types of batteries when space allowed for containers is limited and it is difficult for users to distinguish between LBs and other batteries.

Containers reduce the risk of damage and leakage of the batteries and reduce the severity of potential thermal events and designed according to ADR.

Batteries removed from WEEE are stored separately from other materials in plastic or other drums with internal plastic liners. Batteries are isolated by layers of vermiculite. The battery storage area is located outside, and away from other buildings, under a roof or a canopy [24].

The batteries are packaged in a way that would prevent them from being crushed or damaged (incl. cardboard boxes if other options are not available [22]).

An example is represented in Picture 17 and Picture 18 [25]:

- Using a plastic bag inside the barrel,
- Tapping all battery contacts,
- Filling with vermiculite spaces between batteries to avoid direct contact between batteries,
- Closing the bag and the lid of the barrel.

The barrel is specially designed for containing LBs and it is made of steel. It is used to collect, store and transport end-of-life defective LBs according to SV 377 ADR. The lids are equipped with a spark filter and pressure relief so flue gases cannot ignite outside the barrel.



Picture 17. Example of barrel for LBs (Source: www.inobat.ch)

Case study from Switzerland: barrels illustrated in the examples of Picture 17 and Picture 18 can be ordered by collection points in Switzerland, by paying a deposit to selected transporters. The Battery scheme in the country provides a list of transporters and additional information, such as informative leaflets, to collection points (Source: www.inobat.ch). In this case, end-of-life and defective LBs can be stored and transported in the barrel. For LBs showing signs of a critical status such as high temperature (>30 °C), smoke, odour, sparks, etc., a quarantine process in a specifically protected area is envisaged.



Picture 18. Example of procedure for filling a LIB barrel (Source: INOBAT, LIB barrel)



Picture 19. 60L UN steel drum with lid including a tested ventilation device, used in Austrian collection points (Source: EAK)

Another steel drum solution is provided in Austria (Picture 19). It is a 60l steel drum with a pressure relief. Also, here the batteries are filled in the drum surrounded by vermiculite.

Containers are clearly labelled indicating the content and potential risks associated at collection sites. For transport of specific waste and ADR labelling is required (check ADR and applicable waste legislation).

When the receptacle for storing batteries does not guarantee storage for damaged-critical batteries, these are not stored with other undamaged batteries [21]:

- Batteries that are swelling, smoking, leaking, or overheating should be treated with extreme caution.

- Immediately place them in an absorbent, non-flammable material in a cool and dry place.
- Store outdoors away from structures, vehicles, and equipment of any kind.
- Store in a non-combustible structure.
- Recommended storage materials include sand or preferably vermiculite.

Other references [24] recommend that damaged batteries are further singled out and stored in plastic foil or bags, such as plastic wrapping foil and then placed in protective drums/receptacles.

It is recommended to [36]:

- Store batteries in a dry, cool, and well-ventilated place.
- Keep batteries away from heat sources.
- Protect batteries from direct exposure to sunlight.
- Keep batteries away from water and condensation.
- Store batteries in closed containers or packaging to prevent short circuits and damage during storage and transport.



Picture 20. Bebat new initiative for collection points without supervision: metal drums with automatic fill grade detection, heat detection with alarm and self-smothering fire function (Source: Bebat development).

Enforcement:

In the good practices identified, specific receptacles are often supplied by extended producer responsibility organisations (PROs) for free to municipal collection points. Agreements between logistic companies and PROs are set so logistic companies supply the containers upon request from the collection facilities. Supply of containers may take place upon payment of a caution like in the case described above for Switzerland.

Activity permits granted by competent authorities may require or recommend appropriate measures for ensuring appropriate storage for single LBs and WEEE containing LBs.

Further references:

[17] EERA technical guidance document. Safe collection and transport of electronic equipment with lithium batteries. Understanding ADR rules made easy. EERA (2019).

- [18] UNECE site "About ADR". <https://unece.org/transportdangerous-goods/adr-2021-files>
- [21] Guide for developing lithium battery management practices at materials recovery facilities. ISRI (2020).
- [22] Lithium metal battery management guidelines in the reverse value chain. StEP initiative webinar, 27 March 2020.
- [24] Sharing experiences and best practices with batteries in WEEE. EERA (2021).
- [25] Presentation SENS Foundation. WEEE Forum Operations Committee, 3 December 2020.
- [26] Recommendations on transport and packaging of batteries and button batteries collected. INOBAT (2017) (FR).
- [27] Best practice sheet #3 based on the conclusions of the Corepile/Screlec/INERIS study.
- [36] Guide de bonnes pratiques pour la collecte de piles et accumulateurs au Luxembourg. Ecobatterien (V1.1) (FR, DE).

7.5 Emergency measures at collection facilities: fire prevention, detection, and mitigation



Collection

Description of the problem:

Infrastructure and management of collection facilities accepting single LBs and WEEE containing LBs may not consider the risk of thermal events associated to such waste. Facilities may lack of appropriate or sufficient fire detection means. Fire extinguishing means may not be adapted to the waste received at the facility.

Challenges:

Additional practices and protocols to be implemented will require training and regular maintenance.

Good practice

Description:

A risk assessment performed by experts will identify the situations of high risk, and the measures and training to be implemented.

The risk assessment may as well indicate the need of an emergency plan that will describe the how to react in case of a fire.

Both documents will identify the required detection and extinguishing equipment and the appropriate measures and equipment for storing WEEE containing LBs and single LBs.

Enforcement:

Competent authorities may require a risk assessment and emergency plan for granting the corresponding activity license.

Local authorities may encourage training and connection between local fire brigades and civic amenities.

Further references:

[28] Best practice sheet #6 based on the conclusions of the ecosystem and Ecologic study (2019).

B. Specific recommendations and good practices to retail

7.6 WEEE disposal at specific retail collection points



Collection

Description of the problem:

Infrastructure and staff availability at retail collection points are usually limited and may not be suited for good practices identified in previous fiches ('counter approach'), except for shops that have a one-to-one relation between the seller and customer such as bicycle shops or repair shops. In this case, staff and customer can assess and react if some special action is required to ensure a safe disposal of the WEEE containing LBs and single LBs.

Challenges:

Mapping and identification of shops that may be able to implement this recommendation will be required. Informative sessions and materials are needed.

Recommendation

Description:

Retail shops working in a one-to-one relation between customer and seller - such as bicycle shops, electro shops, repair shops and likewise retail points - have the opportunity to check together with the customer bringing in the battery and decide if some special action is needed. This might be wrapping the battery to protect open contacts, cutting loose wiring (important: one wire at a time to avoid short circuits), isolating naked contacts, placing them in a special container or just in a separate area outside the building (check fiches 7.2.1 and 7.2.2 for more details on sorting protocols, and fiches 7.3 and 7.4 on containers).

Enforcement:

PROs operating in the country may set sectoral agreements with retail associations.

Agreements will set informative campaigns addressed to shops, and the rules for having access to informative materials and receptacles.

Further references:

[28] Best practice sheet #6 based on the conclusions of the ecosystem and Ecologic study (2019).

[29] Information for retail/collection points. INOBAT (2020) (FR, DE, IT).

7.7 Receptacles for retail collection points



Collection

Description of the problem:

Article 5 of the WEEE Directive (EU2012/19) requires that distributors provide for the collection, at retail shops with sales areas relating to EEE of at least 400 m², or in their immediate proximity, of very small WEEE (no external dimension more than 25 cm) free of charge to end-users and with no obligation to buy EEE of an equivalent type (...)

Although very few thermal incidents at retail points have been reported, infrastructure and staff availability at retail collection points are usually limited and may require additional measures to ensure safe disposal of WEEE containing LBs.

Challenges:

Mapping and identification of shops that may be able to implement this good practice will be required. Informative sessions and materials are needed. Additional space may also be required.

Good practice

Description:

This good practice was implemented in The Netherlands by the main national PRO OPEN. Instructions for handling of WEEE containing batteries (usually small devices) were created in collaboration with the Battery Collection Scheme, Stibat. Small WEEE (including IT) is collected in boxes. These boxes ensure that the amounts of WEEE managed and handled at the same time are low and allow for extra protection of the load by being integrated into a bigger container at the shop disposal area (see Picture 21 and Picture 22). The furniture of the collection area includes a box containing sand or a similar material for containment of potential fires.



Picture 21. Box for small WEEE (including IT)

Staff is trained to react adequately and know how to handle containers in case a thermal event is triggered.



Picture 22. Disposal area of the retail point. The red circle frames the sand of box. The container in the middle holds the box for small WEEE appearing in Picture 21.

Enforcement:

PROs operating in the country may set sectoral agreements with retail associations.

Agreements will set informative campaigns addressed to shops, and the rules for having access to informative materials and receptacles.

Further references:

OPEN: <https://stichting-open.org/english/>

8. Recommendations and good practices | Logistics

A logistic company may carry out operations of loading, transporting, unloading, storing, and sorting WEEE containing LBs and single LBs, in addition to these operations, some logistics companies may sort WEEE into different treatment categories. Good practices and recommendations in this chapter are dealing with the application of ADR measures, reduction of the damage of WEEE containing LBs batteries and single batteries during loading, (sorting), transporting and unloading operations, other practices deal with the detection and mitigation of thermal events during all operations and training to staff. In general, solutions should aim at reducing the handling steps in the logistics chain (e.g., no change of container between operators) to reduce damages in the WEEE containing LBs and single LBs.

8.1 Specific training to staff



Logistics

Description of the problem:

Difficulty to identify WEEE containing LBs. Staff may not be aware or forgot risks associated to WEEE containing LBs and single LBs. The company or its staff may not observe ADR rules. Staff may not apply preventive operational measures for reducing the risks of thermal events. Operational measures aiming at reducing risks of fires may not be applied due to the lack of training.

Challenges:

Training must be adapted to the facilities and regularly provided to the staff. Regular testing of the efficacy of the training is required. Additional planning for training and investment may be required. Updates on the types of WEEE containing LBs and the types of LBs received may be regularly required.

Good practice**Description:**

It is proposed to schedule regular training to staff aiming at:

- Identification of WEEE containing LBs and single LBs.
- Handling of WEEE containing LBs and single LBs.

- Proper storing of WEEE containing LBs and single LBs.
- Inspection before transport.
- Appropriate containers.
- Safety policy implemented by the company.
- Fire detection and prevention measures.
- Emergency response in case of fires caused by LBs.

Training should preferably be conducted on site for logistic facilities and trucks used for transport.

A risk assessment is to be conducted to identify areas and activities that require special attention. The risk assessment will define the training program of the company per area and job profile. Experts on fire prevention and emergency response will define protocols that will be explained regularly to the corresponding staff. Fire drills are to be carried out regularly (at least once a year or more often following fire expert's advice). Fire drills must assess the efficacy of the trainings as well as of prevention and extinguishing measures in place.

The staff of logistic centres and the drivers should be trained to provide emergency response when a fire occurs. Trucks should be equipped with fire extinguishers adapted to the possible fires (fires with presence of lithium) and drivers should be trained to limit the damages as much as possible to their trucks. In case of a severe fire, a fire extinguisher may not be of use and access to the burning waste can be too difficult. Drivers should be trained on the limitations of their role and be instructed to use other options (e.g., call fire local service) when required.

Informative signs and training materials are available on site for all workers. The informative material is adapted to the worker's needs and level of understanding.

It is advisable to have protocols in place that will deal with inspection of the load before transport and identification of potential risks (see next fiche). Training to ensure that the staff can implement the protocols is recommended.

Examples of risky situations and decision trees appear in Annex A and B, respectively.

Enforcement:

Contracts with PROs and activity permits may refer and require a risk assessment comprising risks associated to LBs, training, and emergency protocols.

Fire safety training should be included in the operators' training plans and each worker – temporary workers included - should be trained accordingly.

When waste transport licenses are required, competent authorities may require measures to be implemented by logistic companies. Informative/inspection sessions may be arranged with the local fire brigade.

Further references:

[19] Best practice sheet #2 based on the conclusions of the ecosystem and Ecologic study (2019).

[28] Best practice sheet #6 based on the conclusions of the ecosystem and Ecologic study (2019).

8.2 Operational measures. Prevention of fires.



Logistics

Description of the problem:

WEEE containing LBs requires proper handling and may be mixed with other types of waste. Operative procedures may not consider potential risks associated to fires caused by LBs.

Challenges:

A risk assessment and input from expert advisors is required to ensure preventive measures are adequate. Additional investment and resources (e.g., training) must be allocated.

Good practice

Description:

Although in some (very few cases) sorting of WEEE containing LBs may take place at logistic facilities, it is recommended that handling and manipulation of WEEE containing batteries is limited to a minimum to reduce risky situations and damaging of WEEE containing batteries and single LBs (see also fiche 7.2.1).

Measures must be identified based on a risk assessment and emergency plan, developed by expert advisors. For efficiency reasons, the above-mentioned plan should be adapted to the different situations and facilities (small, medium & large). Examples of good practices shared by a stakeholder consultation and literature review are discussed below:

Management measures

- Develop protocols for ensuring WEEE containing LBs is properly loaded and protected. These protocols will also serve for the identification of risky situations.
- Require clauses for ensuring compliance with ADR and appropriate receptacles in contracts with customers.
- Obtain adequate licenses, and make sure staff are trained regularly and certified for transporting hazardous goods [22].

Operational measures

- Aim to transport sorted batteries in fireproof containers [22].
- Increase the frequency of waste expeditions for reducing the amounts of batteries stored and transported.
- Organise storage (compartmentalise) according to the risk of fire of WEEE containing LBs.
- Isolate damaged batteries when these are identified.

Identify the locations in the facilities where batteries may arise [21], these can be a tip floor, manual sorting, etc. Any point where materials come into contact with machinery, electricity outlets or other equipment (e.g. boilers can also be characterized as areas of concern. This includes areas where there is high friction. These areas may be places where WEEE containing LBs are moved by a front-end loader, parts of the facility where WEEE is loaded onto a conveyor belt, or sections where the WEEE are being dropped to storage.

The following facility Inspections and Maintenance are highly recommended [21]:

- Maintain fire suppression for inspections.

- Dry system inspection.
- Ensure you have the right quantity and size of fire extinguishers.

Operational procedures include housekeeping procedures such as [21]:

- Regularly inspect material storage (i.e., tip floor, bales, loaded trucks), handling and transfer areas.
- Have an action plan and time frame for completion.
- Conduct routine preventative maintenance of equipment.
- Use checklists to maintain a consistent inspection program.
- Be sure that fire extinguishers and suppression systems are adequate and in proper working order.
- Access and egress routes must be clearly marked and kept clear at all times.
- Follow fire safety and watch requirements during all hot work procedures.
- Ensure all fire suppression systems are regularly maintained to National Fire Protection Association standards (or the equivalent to it in your country).
- Manage low point drains in dry systems in cold climates.
- Ensure fire extinguishers have the proper size and the type is appropriate for the area.
- Increase frequency of waste expeditions for reducing amounts stored and transported.

The employer should have written plans and trainings in place to identify and mitigate battery fires safely in conjunction (circumstantially) with their emergency action plan and fire prevention plan, while obtaining the appropriate level of outside assistance [21].

Consider monitoring daily operations for potential hot spots, always keeping fire prevention measures in mind.

Storage

It is important that material that may contain LBs, is kept separate from other waste fractions and stored in dedicated bunkers or containers. To achieve this, you may compartmentalise storage areas with fire-proof materials or alternate storage of flammable and non-flammable waste for example.

Bunkers should not be too large, but the roofing should be sufficiently high to allow access of a scrap-handler to remove critical spots of materials. Bunkers should be roofed, containers equipped with covers or parked under roofing. Recyclers located in southern Europe also recommend protection from excess heat and direct sunlight. Dividing walls between bunkers, are built high enough to prevent fires to cross divisions, and walls are thick enough and of suitable material (such as concrete) to withstand heat.

In general, quantities of single LBs and WEEE containing LBs should be minimised and storage areas must be designed and adapted considering a potential risk of fire. The height and volume of stockpiles should be limited and kept at a distance from other materials. Try to think of obvious visual methods to guide your operatives regarding the maximum safe capacity in your reception area. For example, painting an obvious 'max pile height' line on reception bunker walls above which waste must not be piled [35].

Storage areas should allow easy and quick access from 360° for firefighting measures.

If loose batteries are received, at the end of each day, batteries should be moved to a long-term storage location from their temporary location [21]:

- Must be stored in a remote location.

- Must have a stormwater plan, where required. (See: www.epa.gov/npdes/stormwater).
- Battery terminals must be protected or isolated to avoid spark or heat from a residual charge, at least for larger batteries. For smaller batteries other more practical protection means may be used, such as storing them in barrels with vermiculite (Picture 18).
- The positive (raised) terminal must be protected either by packing, duct, or electrical tape, at least for larger batteries when the terminals are close to each other. Alternatively, each battery can be placed in its own clear, sealable bag. For smaller batteries other more practical protection means may be used, such as storing them in barrels with vermiculite (Picture 18).
- Batteries that have been individually taped or bagged can be stored in a UN Rated steel drum (1A) with a plastic liner or a UN Rated polyethylene drum (1H).
- Batteries must be stored in a cool, dry location.

It is recommended that storage areas:

- Allow easy and quick access from 360° for firefighting actions.
- Are compartmentalized with fire-proof materials.
- Alternate storage of flammable and non-flammable waste.

Unloading

All unloading activities should be supervised by staff trained to identify and react to potential dangers (see fiche 9.1).

At earliest detection, establish a program for identification of LBs for drivers so they are sensitized while unloading full trucks and when on routes (if not automated) [21].

Tipping of WEEE from either trucks or large containers/skips is potentially dangerous, hence this practice should be avoided when there is the possibility that the WEEE contains LBs. The impact on the ground may immediately cause sparks or flames. Containers are to be placed on the ground before letting material slide out, to avoid or at least reduce ground impact. The use of walking-floor/push-floor trucks is critical under these aspects as there should not be any force applied to push material out of the vehicle.

When unloading onto the ground or onto a storage pile, a scrap-handler with sufficient range and long enough extension arm can be available to remove any hot or burning material from the pile and drop it into a safe area such as a bunker. This requires the scrap handler to be sufficiently mobile to reach the pile. Electrically powered scrap-handlers are often used to reduce emissions within the building, but sufficient range must be ensured to reach critical spots. Wheel loaders (wheeled front-end loaders) are not recommended to build stockpiles as they tend to compact materials.

If loose batteries arise from the load, once identified, frontline employees should inspect and collect them from the inbound material stream [21].

- Tip floor: Secure tip floor and idle all rolling stock while employees collect the battery.
- Sorting stations: Idle the conveyor system.

The employee should inspect the battery for damage. If undamaged (see examples of situations where protecting batteries is advisable in Annex A):

- The employee should tape the battery terminals, at least for larger batteries, and place it in a dedicated temporary storage container (typically a metal, 5-gallon ash can).
- Once placed in the can, the employee should scoop vermiculite on top of the battery.

Batteries should be managed between sorting and proper storage. For example, consider placing batteries in 5-gallon metal buckets containing vermiculite or sand on the line from which materials are being pulled, like an ash bucket [21].

Employers should make available plastic tongs, welding gloves and heat/spark masks to all employees handling batteries [21]. In all cases, the use of safety equipment requires appropriate training.

A protocol for damaged batteries should be in place [21]. Damaged batteries should not be stored with other undamaged batteries.

- Batteries that are swelling, smoking, leaking, or overheating should be treated with extreme caution.
- Immediately place them in an absorbent, non-flammable material in a cool, dry place.
- Store outdoors away from structures, vehicles, and equipment.
- Store in a non-combustible structure.
- Recommended storage materials include sand or vermiculite.

On-site security

On-site security is particularly important for the prevention of fires. Some examples of good practices include, among others:

- Safety surveillance on a 24/7 basis, being covered by a combination of external services, services in house and technical supervision.
- Regular temperature control and smoke detection during operation and non-operation times (e.g., security staff is often equipped with portable temperature control equipment such as handheld temperature cameras),
- Fire extinguishers are discharge tested and/or have hydrostatic tests completed to make sure the cylinder is still safe to operate. They are also mounted to the wall so that they are secure, visible, and readily accessible.

Responses from the consultation carried out in the frame of this study conclude the importance of strengthening contacts with local and regional firefighting services. Regular site visits by external fire services are important, practical on-site exercises are strongly recommended. Fire services should be informed about changes at the facility and alarm plans reviewed regularly.

Emergency response plan

Good communication with external local and regional fire services is recommended as well as site inspections.

Consider designating responders in the emergency action plan and providing them with specific training to implement your site-specific response procedures to battery incidents. These designated responders should have quick response availability to identified areas of concern for the ignition of batteries [21].

Other recommendations in the Institute of Scrap Recycling Industries (ISRI) guide [21] are:

- Have a stormwater program in place, especially for response, where required.
- Develop a “one fire extinguisher attempt”, call 112, and evacuate.
- Train employees in the PASS (pull, aim, squeeze, sweep) fire extinguisher method.
- Be aware of the batteries off-gassing and the dangers of smoke inhalation.
- Ensure evacuation plans are written and communicated with employees. Then, ensure training is provided to all employees.

The plan should ensure the “meeting point” is clearly identified and communicated and that signage is posted at the facility. Try to identify the following evacuation types:

- Shelter in place.
- Move to another structure onsite.
- Onsite outdoor evacuation locations.
- Offsite evacuation locations for large events.

Consider inviting first responders to the facility for familiarization purposes.

Have a Knox Box or similar device in place to hold an entry key to the facility.

During the extinguishment of a shredder or a crusher fire, there is the possibility of another flash fire as the material is pushed out, LBs are crushed and the heat of the crusher/shredder acts as the ignition source.

Fire risk assessments and plans can be complicated issues and it is likely to need competent advice if the site is at all complex. However, for smaller sites various cost-effective training courses are available and having one of your employees trained in fire risk assessment may be considered. Regardless the size of the site, this would also give an accessible and in-house source of fire assessment advice for basic and general fire issues at an operational level [35].

Additional information can be found in the references.

Enforcement:

Emergency protocols and plans considering hazards associated to WEEE containing LBs and single LBs.

Activity permits to require a risk assessment that will consider hazards associated to WEEE containing LBs and single LBs and measures to be implemented by operators.

Contracts with PROs may refer and require a risk assessment comprising risks associated to WEEE containing LBs and single LBs, and emergency protocols.

Informative/inspection sessions may be arranged with the local fire brigade.

Further references:

[19] Best practice sheet #2 based on the conclusions of the ecosystem and Ecologic study (2019).

[21] Guide for developing lithium battery management practices at materials recovery facilities. ISRI (2020).

[24] Sharing experiences and best practices with batteries in WEEE. EERA (2021).

[27] Best practice sheet #3 based on the conclusions of the Corepile/Screlec/INERIS study.

[28] Best practice sheet #6 based on the conclusions of the ecosystem and Ecologic study (2019).

[30] Best practice sheet #1 based on the conclusions of the ecosystem and Ecologic study (2019).

[31] Best practice sheet #4 based on the conclusions of the ecosystem and Ecologic study (2019).

[32] Best practice sheet #5 based on the conclusions of the ecosystem and Ecologic study (2019).

[33] Emergency Response Guidebook 2020. U.S Department of Transportation et al. (2020).

[34] Cutting Li-ion Battery Waste Fires. Environmental Services Association and Eunomia (2020).

[35] Reducing fire risk at waste management sites. WISH Waste Fires Working Group (2017).

8.3 Emergency measures and infrastructure at logistics facilities. Fire detection and extinguishing.



Logistics

Description of the problem:

Infrastructure and management of logistics facilities managing single LBs and WEEE containing LBs may not consider the risk of thermal events associated to such waste. Facilities may lack of appropriate or sufficient fire detection means. Fire extinguishing means may not be adapted to the waste managed at the facility.

Challenges:

A risk assessment and input from expert advisors is required to ensure preventive measures are adequate. Additional investment and resources (e.g., training) must be allocated. Measures should address not only fires, but smoke released during thermal events and reduction of damages.

Good practice

Description:

Measures must be identified based on a risk assessment and emergency plan produced by expert advisors and adapted to the situation of the facilities. Examples of good practices from the stakeholder consultation and literature review are discussed below.

Trucks should be equipped with fire extinguishers adapted to the possible fires (fires with presence of lithium) and drivers should be trained to limit the damages as much as possible to their trucks. In case of a severe fire, a fire extinguisher may not be of use and access to the burning waste can be too difficult. Drivers should be trained on the limitations of their role and be instructed to use other options (e.g., call fire local service) when required.

For technical aspects of fire controls, such as specialist firefighting equipment and the standards for the installation of detection systems, it is very likely to require external specialist advice, unless this competence is held in-house [35].

Technical measures

It is important that untreated materials that may contain LBs are kept separate from other waste types and stored in dedicated bunkers or containers. Recycling companies commented

on the benefit of sprinklers above bunkers. These provide high volumes of water to submerge burning material and to cool neighbouring stocks. During operating hours, recyclers give preference to sprinklers that are turned on remotely by supervising staff rather than the use of fire hoses. Fixed sprinklers can remain turned on even when staff has left the building due to heat or smoke.

Positive results were reported from installing turret extinguishing systems in combination with heat or smoke detection or infrared cameras. These systems have large throw ranges and allow reaching burning materials over big distances, ideally with automated directing of the turret. A combination of infrared cameras and laser distance measuring allows pointing the turret to hot spots.

Permanent temperature surveillance with for example infrared cameras, smoke, or heat detection units are recommended at bunkers and inside buildings. Some companies prefer smoke detectors rather than heat detectors as it might take some time for stockpiles to reach a detectable heat level. Smoke usually rises quite early from a stockpile. "Smart" infrared cameras allow for the programming of different temperature alarm levels within their range. These cameras were also cited as useful by recyclers in a sense that they can recognise other dangerous objects (e.g., gas cylinders).

Conveyor systems at sorting stations should be designed with easy, quick, and safe access to extinguish such burning material. It should be noted that recyclers prefer manual firefighting measures (like firehoses) on conveyor systems (there are both open and enclosed conveying systems, naturally enclosed systems must be opened. On conveyor belts the materials is spread out, but there could be aggregations of material at transfer points).

Loose batteries removed from WEEE are often stored separately from other materials in plastic or other drums with internal plastic liners. Batteries are isolated by layers of vermiculite, and it is recommended that the damaged ones are further singled out and stored in plastic foil or bags, such as plastic wrapping foil (see fiche 7.4). The battery storage area should be outside and away from other buildings under a roof or a canopy.

Infrastructural Measures

Segregation and separate storage of materials require enough bunkers that are built to prevent the spread of fire. It is also recommended to keep free a safe area, with easy access to it, where hot materials, emitting smoke or even already burning can be dropped far enough from other stored material.

Buildings should be divided by fire walls and smoke screens, but access for firefighting vehicles must be assured to all areas that may show potential risk of fire.

Bunkers for untreated waste should, if possible, be outside and away from buildings whilst remaining covered, roofed or under canopy. Bunkers should allow access to scrap handlers to hot spots (it is recommended to have machinery on hand to remove burning material like a scrap handler with an extension arm). Containers and bunkers must be accessible by fire fighting vehicles; "double parking" of containers must be avoided.

Bunkers should not be built against the walls of buildings. Bunkers must have their own fire-resistant back wall which must be at a distance from the building to avoid heat carried to the structure of the building.

Some of the measures illustrated in this section may require significant investments, hence it is important that the design and planning of safety and prevention strategies are based on expert advice.

Emergency response

An alarm system is in place, preferably automatic systems are recommended.

Quick reaction is essential for successful firefighting hence training an emergency response team and having adequate detection systems is very important. Regular training for staff and joint exercises with external fire service are recommended (see fiche 9.1 on training).

Management of treatment companies must commit with safety and ensure a management policy is implemented in this sense.

The insurance industry has produced its own codes on many aspects of fire safety management, including technical standards: insurers may provide advice as they will have access to these standards. For example, the guidance contained in standards and technical advice produced by the UK insurance industry through Fire Protection Association/RISC-A and the Loss Prevention Standards (LPS), now produced by BRE Global. Other useful documents include those produced by the US NFPA (National Fire Protection Association) and (FM Global Data Sheets). These standards are generally accepted by insurers and their technical advisors/experts. If the site does not meet these standards, then the purchase of insurance cover, or availability of insurance at an economic cost, may be difficult. Asking for insurer advice on technical standards in advance is likely to be better than arguing afterwards. But beware of applying general standards to waste management where it may not be appropriate (see [35] for further details).

For technical standards relating to issues such as the installation of fire detection, firefighting and fire suppression equipment, the suppliers of such equipment and reputable trade associations can often be a useful (and likely free) source of advice (although beware commercial interest, and in some cases contradictory advice). Such suppliers, especially when they hold third party certification will be familiar with applicable standards for the products they supply and how they should be installed. However, care should be exercised to ensure that the choice of equipment and supplier is appropriate to the site. For example, an installer of domestic fire equipment may not be that familiar with the standards required for industrial applications (see [35] for further details).

Enforcement:

Emergency protocols and plans considering hazards associated to LBs.

Regular informative and awareness-raising sessions with the local firefighting service.

Activity permits to require a risk assessment that will consider hazards associated to LBs and to ensure minimum detection and firefighting measures have been implemented and are regularly maintained.

Contracts with PROs may include clauses to ensure minimum detection and firefighting measures have been implemented and are regularly maintained.

Further references:

[19] Best practice sheet #2 based on the conclusions of the ecosystem and Ecologic study (2019).

- [24] Sharing experiences and best practices with batteries in WEEE. EERA (2021).
- [27] Best practice sheet #3 based on the conclusions of the Corepile/Screlec/INERIS study.
- [28] Best practice sheet #6 based on the conclusions of the ecosystem and Ecologic study (2019).
- [30] Best practice sheet #1 based on the conclusions of the ecosystem and Ecologic study (2019).
- [31] Best practice sheet #4 based on the conclusions of the ecosystem and Ecologic study (2019).
- [32] Best practice sheet #5 based on the conclusions of the ecosystem and Ecologic study (2019).

8.4 Specific receptacles for WEEE containing LBs and single LBs



Logistics

See fiches 7.3 and 7.4.

9. Recommendations and good practices | Pre-treatment

In the scope of this report, 'pre-treatment' refers to facilities that may perform sorting, depollution, dismantling and mechanical treatment of WEEE containing batteries. This sort of treatment may be carried out by several facilities, not only one. The risk of fires caused by batteries in this chain of facilities may arise when the removal of batteries in the first treatment steps is not efficient, and batteries may be present in the fractions resulting from the first treatment steps and destined to downstream acceptors.

9.1 Specific training to staff



Pre-treatment

Description of the problem:

The main problem linked to pre-treatment is the identification of WEEE containing LBs and their removal. Staff may not be aware or have forgotten the possible risks associated to the treatment of WEEE containing LBs and single LBs and hence may not apply preventive operational measures for reducing the risks of thermal events. Facilities may not have sufficient or required fire detection and extinguishing protocols and equipment. Operational measures aiming at reducing risks of fires may not be applied due to the lack of training.

Challenges:

Training must be tailored to the facilities' different needs and regularly provided to the staff. Regular testing of the efficacy of the training is required. Additional planning for training and investment may be required. Updates on the types of WEEE containing LBs and the types of LBs received may be regularly required.

Good practice

Description:

It is recommended to schedule regular training to staff aiming at:

- Identification of WEEE containing LBs and single LBs.
- Handling of WEEE containing LBs and single LBs.
- Proper storing of WEEE containing LBs and single LBs.
- Fire detection and prevention measures.
- Emergency response in case of fires caused by LBs.

A risk assessment should be conducted to identify areas and activities that require special attention. The risk assessment will define the training program of the company per area and job profile. Experts in fire prevention and emergency response will define protocols that will be explained regularly to the corresponding staff. Fire drills are carried out regularly (at least once a year or more often following fire expert's advice). Fire drills must assess the efficacy of the trainings and prevention and extinguishing measures in place.

Informative signs and material should be available on site for all workers. The material must be adapted to the worker's needs and level of understanding.

The ISRI guide for LB management [21] recommends developing a program and training for material inspection upon arrival at the waste management facilities that includes battery identification, safe removal, and proper storage. Typically, this program would include:

- Training for employees who are engaged in the inspection and acceptance of inbound materials on how to identify and properly handle batteries.
- Availability of safe removal supplies (i.e., storage, terminal tape).
- Scheduling and rotation of battery management in regular toolbox safety meetings.

The same guide recommends training associated to a response plan and educate and train employees on the fire prevention and response plan and make them aware on the use of proper personal protection equipment, non-flammable gloves (all leather), safety glasses, appropriate cotton long-sleeved shirt, etc.).

Examples of risky situations and decision trees appear in Annex A and B, respectively.

Enforcement:

Contracts with PROs and activity permits may refer and require a risk assessment comprising risks associated to LBs, training, and emergency protocols.

Fire safety training should be included in the operators' training plans and each worker should be trained accordingly, even temporary workers.

When licenses are required, competent authorities may include in them measures to be implemented by operators.

Informative/inspection sessions may be arranged with the local fire brigade.

Updated information on the WEEE arising that contains LBs could be shared with the recycling industry via a simple e-platform. The e-platform could allow communication between waste operators and manufacturers, both could be posting alerts on new devices spotted containing LBs and exchange good practices on safety.

Further references:

[19] Best practice sheet #2 based on the conclusions of the ecosystem and Ecologic study (2019).

[21] Guide for developing lithium battery management practices at materials recovery facilities. ISRI (2020).

[28] Best practice sheet #6 based on the conclusions of the ecosystem and Ecologic study (2019).



9.2 Operational measures. Prevention of fires.

Description of the problem:

WEEE containing LBs requires proper handling and depollution. Operations may damage or overlook batteries causing thermal events. Storage protocols and facilities may not be appropriate for reducing the risk and managing thermal events caused by LBs or WEEE containing LBs. Operative procedures may not consider, or underestimate, the potential risks associated to fires caused by LBs.

Challenges:

A risk assessment and input from expert advisors is required to ensure preventive measures are adequate. Additional investment and resources (e.g., training) must be allocated.

Good practice

Description:

Measures must be identified based on a risk assessment and emergency plan, produced by expert advisors and adapted to the situation of the facilities. Examples of good practices shared by a stakeholder consultation and literature review are discussed below:

Operational procedures

There are reports showing that many fires caused by WEEE containing LBs start with a delayed reaction because damaged batteries take some time for the chemical process to burn through the battery material. EERA members report improved safety when imposing 'just-in-time' deliveries (just-in-time unloading at the treatment line), and not accepting deliveries two hours before site closing time (no material movement after 1 or 2 hours before closing time) [24]. Communication with customers and logistics operators is required for reaching agreements that will adapt to the situation.

Facilities may consider developing metrics to raise awareness and identify potential trends such as periodic battery counts (found batteries per hour, per ton of WEEE) [21].

Identify the locations in the facilities where batteries may arise [21], these can be a tip floor, manual sorting, etc. Any point where materials come into contact with machinery, electricity outlets or other equipment (e.g. boilers) can also be characterized as areas of concern. This includes areas where there is high friction. These areas may be places where WEEE containing LBs are moved by a front-end loader, parts of the facility where WEEE is loaded onto a conveyor belt, or sections where the WEEE are being dropped to storage.

The following facility Inspections and Maintenance are highly recommended [21]:

- Maintain fire suppression for inspections.
- Dry system inspection.
- Ensure you have the right quantity and size of fire extinguishers.

Operational procedures include housekeeping procedures, such as [21]:

- Regularly inspect unprocessed and processed material storage (i.e., tip floor, bales, loaded trucks), handling and transfer areas.
- Have an action plan and time frame for completion.

- Conduct routine preventative maintenance of equipment.
- Use checklists to maintain a consistent inspection program.
- Be sure that fire extinguishers and suppression systems are adequate and in proper working order.
- Access and egress routes must be clearly marked and kept clear at all times.
- Follow fire safety and watch requirements during all hot work procedures.
- Ensure all fire suppression systems are maintained to National Fire Protection Association standards.
- Manage low point drains in dry systems in cold climates.
- Ensure fire extinguishers are the proper size and type for the area.
- Increase frequency of waste expeditions for reducing amounts stored and transported.

The employer should have written plans and trainings in place to identify and mitigate battery fires safely in conjunction (circumstantially) with their emergency action plan and fire prevention plan, while obtaining the appropriate level of outside assistance [21].

Consider monitoring daily operations for potential hot spots, always keeping fire prevention measures in mind.

Storage

Expertise shared by the respondents of the survey launched in the frame of this report show that recyclers consider it important that untreated materials, that may contain LBs, are kept separate from treated fractions and stored in bunkers or containers. Bunkers should not be too large, but the roofing should be sufficiently high to allow access of a scrap-handler to remove critical spots of materials. Bunkers should be roofed, containers equipped with covers or parked under roofing. Comments from recyclers in southern Europe also recommend protection from excess heat and direct sunlight. Dividing walls between bunkers are built high enough to prevent fires to cross divisions, and walls are thick enough and of suitable material (such as concrete) to withstand heat.

In general, quantities of LBs and WEEE containing LBs should be minimised and storage areas must be designed and adapted considering a potential risk of fire.

The WEEE that may contain LBs stored in the treatment hall should be limited to the quantity that can be processed by the end of the shift. Any excess material should be stored in dedicated and safe storage areas such as bunkers. Untreated material should not be stored in the treatment line area.

Establish dedicated temporary short-term and long-term storage options for batteries—including signage, barriers, and painted identification of areas (demarcations) [21]. The height and volume of stockpiles should be limited and kept at a distance from other materials. Try to think of obvious visual methods to guide operatives regarding the maximum safe capacity in the reception area. For example, painting an obvious ‘max pile height’ line on reception bunker walls above which waste must not be piled [35].

Treated fractions (plastics, metals, batteries) are to be stored completely separately from untreated materials, preferably not in the same building.

At the end of each day, batteries should be moved to a long-term storage location from their temporary location [21]:

- Must be stored in a remote location.
- Must have a stormwater plan, where required (see: www.epa.gov/npdes/stormwater).
- At least for larger batteries, when battery terminals are/can be close to each other, battery terminals must be protected or isolated to avoid sparks or heat from a residual charge. The positive (raised) terminal must be protected with tape: either packing, duct, or electrical tape. Alternatively, each battery can be placed in its own clear, sealable bag. For smaller batteries, other more practical protection means may be used, such as storing them in barrels with vermiculite (Picture 18).
- Batteries that have been individually taped or bagged can be stored in a UN Rated steel drum (1A) with a plastic liner or a UN Rated polyethylene drum (1H).
- Batteries must be stored in a cool, dry location.

It is recommended that storage areas:

- Allow easy and quick access from 360° for firefighting actions.
- Are compartmentalized with fire-proof materials.
- Alternate storage of flammable and non-flammable waste.

Unloading

All unloading activities should be supervised by staff trained to identify and react to potential dangers (see fiche 9.1).

At earliest detection, establish a program for identification of LBs for drivers so they are sensitized while unloading full trucks and when on routes (if not automated) [21].

Tipping of WEEE from either trucks or large containers/skips is potentially dangerous, hence this practice should be avoided when there is the possibility that the WEEE contains LBs. The impact on the ground may immediately cause sparks or flames. Containers should be placed on the ground before letting material slide out, to avoid or at least reduce ground impact. The use of walking-floor/push-floor trucks is critical under these aspects as there should not be any force applied to push material out of the vehicle.

When unloading onto the ground or onto a storage pile, a scrap-handler with sufficient range and long enough extension arm can be available to remove any hot or burning material from the pile and drop it into a safe area such as a bunker. This requires the scrap handler to be sufficiently mobile to reach the pile. Electrically powered scrap-handlers are often used to reduce emissions within the building but sufficient range must be ensured to reach critical spots. Wheel loaders (wheeled front-end loaders) are not recommended to build stockpiles as they tend to compact materials.

Cameras detecting hot spots are helpful during unloading operations.

Treatment

WEEE containing LBs should be sorted as early as possible to remove LBs. The objective is to avoid WEEE containing LBs to enter mechanical treatment processes. Mechanical treatment processes may damage LBs, if they are not removed before and this may cause a thermal event. Removal of batteries may take place in the WEEE treatment operator's facilities or in a previous step of the treatment chain, in a separate dismantling facility (see case study 4-13 of manual dismantling centres of the Eunomia report [34]).

To reduce the number of these fires, the Environmental Services Association and Eunomia suggest improving Best Available Treatment, Recovery and Recycling Techniques (BATRRRT) – or mandating the European CENELEC standards to require LIBs removal prior to shredding/fragmentation in WEEE reprocessing plants [34].

Once identified, frontline employees should inspect and extract any batteries from the inbound material stream [21].

- Tip floor: secure tip floor and idle all rolling stock while employees remove the battery.
- Sorting stations: Idle the conveyor system.
- The employee should inspect the battery for damage. If undamaged:
 - The employee should tape the battery terminals, at least for larger batteries, and place it in a dedicated temporary storage container (typically a metal, 5-gallon ash can). Smaller batteries can be stored in a barrel containing vermiculite.
 - Once placed in the can, the employee should scoop vermiculite (preferably) or sand (acceptable) on top of the battery.

Batteries should be managed between sorting and proper storage. For example, consider placing batteries in 5-gallon metal buckets containing vermiculite or sand on the line from which materials are being pulled, like an ash bucket [21]. Examples of decisions trees appear in Annex B.

Employers should make available plastic tongs, welding gloves and heat/spark masks to all employees handling batteries [21]. In all cases, the use of safety equipment requires appropriate training.

A protocol for damaged batteries should be in place [21]. Damaged batteries should not be stored with other undamaged batteries.

- Batteries that are swelling, smoking, leaking, or overheating should be treated with extreme caution.
- Immediately place them in an absorbent, non-flammable material in a cool, dry place.
- Store outdoors away from structures, vehicles, and equipment.
- Store in a non-combustible structure.
- Recommended storage materials include sand or vermiculite.

Battery removal of very small WEEE with integrated batteries remain a challenge in many cases for treatment operators.

On-site security

On-site security is particularly important for the prevention of fires. Some examples of good practices include, among others:

- Safety surveillance on a 24/7 basis. This can be covered by a combination of external services, services in house and technical supervision.
- Regular temperature control and smoke detection during operation and non-operation times (e.g., security staff is often equipped with portable temperature control equipment such as handheld temperature cameras).
- Fire extinguishers are discharge tested and/or have hydrostatic tests completed to make sure the cylinder is still safe to operate. They are also mounted to the wall so that they are secure, visible, and readily accessible.

Responses from the consultation carried out in the frame of this study conclude the importance of strengthening contacts with local and regional firefighting services. Regular site visits by external fire services are important, practical on-site exercises are recommended. Fire services should be informed about changes at the facility and alarm plans reviewed regularly, especially regarding changes to the location of inflammable or dangerous materials.

Other good operational practices for pre-treatment operators include using machinery to move the waste during unloading. For example, scrap handlers with long picker arms to remove parts of a burning pile (i.e., when a fire starts within a pile of WEEE it is often successful to grab the burning parts with a scrap handler and remove it to safe distance. Scrap handlers have enclosed cabins and long picker arms so that the operator is safe).

Emergency response plan

Good communication with external local and regional fire services is recommended as well as site inspections.

Consider designating responders in the emergency action plan and providing them with specific training to implement a site-specific response procedures to battery incidents. These designated responders should have quick response availability to identified areas of concern for the ignition of batteries [21].

Other recommendations in the Institute of Scrap Recycling Industries (ISRI) guide [21] are:

- Have a stormwater program in place, especially for response, where required.
- Develop a “one fire extinguisher attempt”, call 112, and evacuate.
- Train employees in the PASS (pull, aim, squeeze, sweep) fire extinguisher method.
- Be aware of the batteries off-gassing and the dangers of smoke inhalation.
- Ensure evacuation plans are written and communicated with employees. Then, ensure training is provided to all employees.

The plan should ensure the “meeting point” is clearly identified and communicated and signage is posted at the facility. Try to identify the following evacuation types:

- Shelter in place.
- Move to another structure onsite.
- Onsite outdoor evacuation locations.
- Offsite evacuation locations for large events.

Consider inviting first responders to the facility for familiarization purposes.

Have a Knox Box or similar device in place to hold an entry key to the facility.

During the extinguishment of a shredder or a crusher fire, there is the possibility of another flash fire as the material is pushed out, LBs are crushed and the heat of the crusher/shredder acts as the ignition source.

Fire risk assessments and plans can be complicated, and it is likely to need competent advice if the site is at all complex. However, for smaller sites various cost-effective training courses are available and having one of the employees trained in fire risk assessment may be considered. Whatever the size of the site, this would also give an accessible and in-house source of fire assessment advice for basic and general fire issues at an operational level [35].

Additional information can be found in the references.

Enforcement:

Emergency protocols and plans considering hazards associated to WEEE containing LBs and single LBs.

Activity permits to require a risk assessment that will consider hazards associated to WEEE containing LBs and single LBs and measures to be implemented by operators.

Contracts with PROs may refer and require a risk assessment comprising risks associated to WEEE containing LBs and single LBs, and emergency protocols.

Informative/inspection sessions may be arranged with the local fire brigade.

The relevant policymakers are encouraged to set the legislative framework for:

- Including specific prevention and safety criteria in public procurement calls.
- Setting up incentives addressed to the recycling industry for building the necessary infrastructure such as for example appropriate storage areas, separate areas on treatment sites for the dedicated processing of small WEEE containing LBs⁸ (identified as one of the main sources of fires) etc.

Further references:

[19] Best practice sheet #2 based on the conclusions of the ecosystem and Ecologic study (2019).

[21] Guide for developing lithium battery management practices at materials recovery facilities. ISRI (2020).

[24] Sharing experiences and best practices with batteries in WEEE. EERA (2021).

[27] Best practice sheet #3 based on the conclusions of the Corepile/Screlec/INERIS study.

[28] Best practice sheet #6 based on the conclusions of the ecosystem and Ecologic study (2019).

[30] Best practice sheet #1 based on the conclusions of the ecosystem and Ecologic study (2019).

[31] Best practice sheet #4 based on the conclusions of the ecosystem and Ecologic study (2019).

[32] Best practice sheet #5 based on the conclusions of the ecosystem and Ecologic study (2019).

[33] Emergency Response Guidebook 2020. U.S Department of Transportation et al. (2020).

[34] Cutting Li-ion Battery Waste Fires. Environmental Services Association and Eunomia (2020).

[35] Reducing fire risk at waste management sites. WISH Waste Fires Working Group (2017).

⁸ The term “small WEEE” does not correspond to the typology used in the Directive 2012/19/UE (“WEEE Directive”). In the context of this report, this typology was elaborated with members of the Roundtable, as opposed to large domestic appliances, to simply refer to small items.

9.3 Emergency measures and infrastructure at pre-treatment facilities. Fire detection and extinguishing.



Pre-treatment

Description of the problem:

Infrastructure and management do not consider the risk of thermal events associated to such waste. Facilities lack of appropriate or sufficient fire detection means. Fire extinguishing means are not adapted to the waste managed at the facility.

Challenges:

A risk assessment and input from expert advisors is required to ensure preventive measures are adequate. Additional investment and resources (e.g., training) must be allocated.

Good practice

Description:

Measures must be identified based on a risk assessment and emergency plan produced by expert advisors and adapted to the situation of the facilities. Examples of good practices from the stakeholder consultation and literature review are discussed below:

Technical measures

Expertise shared by the respondents of the survey, launched in the frame of this report, show that recyclers consider it important that untreated materials that may contain LBs are kept separate from treated fractions and stored in bunkers or containers. Recycling companies commented on the benefit of sprinklers above bunkers. These provide high volumes of water to submerge burning material and to cool neighbouring stocks. During operating hours, recyclers give preference to sprinklers that are turned on remotely by supervising staff rather than the use of fire hoses. Fixed sprinklers can remain turned on even when staff must leave the building due to heat or smoke.

Positive results were reported from installing turret extinguishing systems in combination with heat or smoke detection or infrared cameras. These systems have large throw ranges and allow reaching burning materials over big distances, ideally with automated directing of the turret. A combination of infrared cameras and laser distance measuring allows pointing the turret to hot spots.

Permanent temperature surveillance with for example infrared cameras, smoke, or heat detection units are recommended at bunkers and inside buildings. Some companies prefer smoke detectors rather than heat detectors as it might take some time for stockpiles to reach a detectable heat level. Smoke usually rises quite early from a stockpile. "Smart" infrared cameras allow for the programming of different temperature alarm levels within their range. These cameras were also cited as useful by recyclers in the way that they can recognise other dangerous objects (e.g., gas cylinders).

Treatment machines such as shredders or granulators often have inbuilt water injection systems. Often operators prefer to keep shredders running to bring out burning materials, and fight hotspots outside. Conveyor systems at machines or between machines should be designed with easy, quick, and safe access to extinguish such burning material. It should be noted that recyclers prefer manually concentrated firefighting measures (like firehoses) on conveyor systems.

Batteries removed from WEEE are often stored separately from other materials in plastic or other drums with internal plastic liners. Batteries are isolated by layers of vermiculite, and it is recommended that damaged batteries are further singled out and stored in plastic foil or bags, such as plastic wrapping foil (see fiche 7.4). The battery storage area should be outside and away from other buildings under roof or canopy.

Infrastructural Measures

Segregation and separate storage of materials require enough bunkers, that are built to prevent the spread of fire. Buildings for processing units and machinery should not be used as storage areas. Silos or similar feed stores within the treatment areas must not be obstructed by machines or conveyors.

It is also recommended to keep free a safe area, with easy access, where hot materials emitting smoke or even already burning can be dropped far enough from other stored material.

Buildings should be divided by fire walls and smoke screens, but access for fire fighting vehicles must be assured to all areas that may show potential risk of fire.

Bunkers for untreated waste should, if possible, be outside and away from buildings whilst remaining covered, roofed or under canopy. Bunkers should allow access to scrap handlers to hot spots (it is recommended to have machinery on hand to remove burning material like a scrap handler with an extension arm). Containers and bunkers must be accessible by fire fighting vehicles; “double parking” of containers must be avoided.

Bunkers should not be built against the wall of buildings. Bunkers must have their own fire-resistant back wall which must be at a distance from the building to avoid heat carried to the structure of the building.

Treated fractions (plastics, metals, batteries) are to be stored well separate from untreated materials, preferably not in the same building.

Additional information can be found in the references.

Emergency response

An alarm system is in place, preferably automatic systems are recommended.

Quick reaction is essential for successful firefighting, hence training an emergency response team and having adequate detection systems is very important. Regular training for staff and joint exercises with external fire service are recommended (see fiche 9.1 on training).

Management of treatment companies must commit with safety and ensure a management policy is implemented in this sense.

Forklifts with frontal protection can be used for transporting drums containing damaged/reactive batteries in vermiculite to a protected area far from the main operative building.

Interviews with recyclers recommend having a simple bucket with water in the sorting and depollution belts/areas where removal of batteries from WEEE takes place. Staff is trained to identify damaged batteries and immerse them in the water for cooling down, when required.

Proper respiration equipment should be used by fire fighters and/or staff involved in handling the incident. This can be ABEK filter masks or even independent respiration masks with

oxygen flasks (recommended). In all cases, the use of safety equipment requires appropriate training.

The insurance industry has produced its own codes on many aspects of fire safety management, including technical standards: insurers may provide advice as they will have access to these standards. For example, the guidance contained in standards and technical advice produced by the UK insurance industry through Fire Protection Association/RISC-A and the Loss Prevention Standards (LPS), now produced by BRE Global. Other useful documents include those produced by the US NFPA (National Fire Protection Association) and FM Insurance (FM Global Data Sheets). These standards are generally accepted by insurers and their technical advisors/experts. If the site does not meet these standards then the purchase of insurance cover, or availability of insurance at an economic cost, may be difficult. Asking for insurer advice on technical standards in advance is likely to be better than arguing afterwards. But beware of applying general standards to waste management where it may not be appropriate (see [35] for further details).

For technical standards relating to issues such as the installation of fire detection, firefighting and fire suppression equipment, the suppliers of such equipment and reputable trade associations can often be a useful (and likely free) source of advice (although beware commercial interest, and in some cases contradictory advice). Such suppliers, especially when they hold third party certification will be familiar with applicable standards for the products they supply and how they should be installed. However, care should be exercised to ensure that the choice of equipment and supplier is appropriate to the site. For example, an installer of domestic fire equipment may not be that familiar with the standards required for industrial applications (see [35] for further details).

Enforcement:

Emergency protocols and plans considering hazards associated to LBs.

Regular informative and awareness-raising sessions with the local firefighting service.

Activity permits to require a risk assessment that will consider hazards associated to LBs and to ensure minimum detection and firefighting measures have been implemented and are regularly maintained.

Contracts with PROs may include clauses to ensure minimum detection and firefighting measures have been implemented and are regularly maintained.

Further references:

[19] Best practice sheet #2 based on the conclusions of the ecosystem and Ecologic study (2019).

[24] Sharing experiences and best practices with batteries in WEEE. EERA (2021).

[27] Best practice sheet #3 based on the conclusions of the Corepile/Screelec/INERIS study.

[28] Best practice sheet #6 based on the conclusions of the ecosystem and Ecologic study (2019).

[30] Best practice sheet #1 based on the conclusions of the ecosystem and Ecologic study (2019).

[31] Best practice sheet #4 based on the conclusions of the ecosystem and Ecologic study (2019).

[32] Best practice sheet #5 based on the conclusions of the ecosystem and Ecologic study (2019).

9.4 Specific receptacles for WEEE containing LBs and single LBs



Pre-treatment

See fiches 7.3 and 7.4.

10. Recommendations and good practices | Final treatment

In the context of this report, ‘final treatment’, refers to activities and facilities receiving lithium batteries as input, these comprise mostly facilities sorting batteries and facilities treating batteries. The final destination of the materials resulting from such facilities are smelter-type. Smelters are out of the scope of this report.

Most recommendations in this chapter address early detection of fires, extinguishing measures, training to staff, adequate facilities, equipment, and practices for preventing fires and reducing damage to LBs.

10.1 Specific training to staff



Final treatment

Description of the problem:

Staff may not be aware or forgot risks associated to LBs. Staff may not apply (adequate) preventive operational measures for reducing the risks of thermal events. Operational measures aiming at reducing risks of fires may not be applied due to the lack of training.

Challenges:

Regular on-site training requires additional resources in terms of time and trainers. Training materials visible and adapted to the staff situation may require additional design. Updates on the type of batteries received may be required.

Good practice

Description:

A risk assessment should be conducted to identify areas and activities that require special attention. The risk assessment will define the training program of the company per area and job profile. Experts in fire prevention and emergency response will define protocols that will be explained regularly to the corresponding staff. Fire drills should be carried out regularly

(at least once a year or more often following fire expert's advice). Fire drills must assess the efficacy of the trainings and prevention and extinguishing measures in place.

Informative signs and material should be available on site for all workers. The material must be adapted to the worker's needs and level of understanding.

The ISRI guide for LBs management [21] recommends developing a program and training for material inspection upon arrival at the waste management facilities that includes battery identification, safe removal, and proper storage. Typically, this program would include all employees, and emphasis to employees having access to batteries (operative areas including inspection and acceptance of inbound materials on how to identify and properly handle batteries).

The same guide recommends training associated to a response plan and educate and train employees on the fire prevention and response plan and make them aware on the use of proper personal protection equipment, non-flammable gloves (all leather), safety glasses, appropriate cotton long-sleeved shirt, etc.).

Incoming batteries may have very different sources of origin, age, state of charge and different physical state. It may be important to perform regular samplings on incoming fractions to be able to distinguish low risk sources with (almost) no lithium content and medium-to high-risk sources with relatively high-volume content of lithium. It is important to design and set in place a performant incoming control system to be able to separate the low-risk fractions from the medium-and high-risk fractions. Adequate training is required to ensure this control system is effective.

It is recommended to at least provide regular training to staff on:

- Awareness of the risks in general.
- Recognizing risk batteries (at least what is clearly visible) and securing them.
- Handling risk batteries (no damaging/no heating/no short circuiting/no shock).
- Using non-conductive tools and materials (beware of steel tables for example).
- High Voltage training in cases where this is needed.
- Proper storing/separating of risk batteries apart from others.
- Use of protection gear and clothing (acid proof jacket/long gloves and safety glasses).
- Use of fire control procedures and/or materials (not limited to extinguishers).
- Early detection system (heating/smoke/gasses).
- Regular training with those procedures and materials (two to three times per year).
- Evaluating risky situations and taking necessary actions and/or communication.
- Have a trained and skilled intervention team which can act as a coordinated entity.
- Follow procedures and especially those need to be done before closing in the evening.
- Constant awareness and being alert (any small incident can become a big one if no intervention is done).

Examples of risky situations and decision trees appear in Annex A and B, respectively.

Enforcement:

Contracts with PROs and activity permits may refer and require a risk assessment comprising risks associated to LBs, training, and emergency protocols.

Informative/inspection sessions may be arranged with the local fire brigade.

Fire safety training should be included in the operators' training plans and each worker should be trained accordingly, even temporary workers.

When licenses are required, competent authorities may require measures to be implemented by operators.

Updated information on the types of LBs could be shared with the recycling industry via a simple e-platform. The e-platform may allow communication between waste operators and manufacturers, both could be posting alerts on new types of LBs and exchange good practices on safety.

Further references:

[31] Best practice sheet #4 based on the conclusions of the ecosystem and Ecologic study (2019).

10.2 Operational measures. Fire prevention



Final treatment

Description of the problem:

Lithium batteries require proper handling, storage, and treatment, operations may unintentionally damage them causing thermal events. Operative procedures may not consider, or underestimate, the potential risks associated to fires caused by LBs.

Challenges:

Changes in the operative areas and procedures will require planning, appropriate design and investing time and resources for ensuring an appropriate implementation.

Good practice

Description:

Measures must be identified based on a risk assessment and emergency plan produced by expert advisors and adapted to the situation of the facilities. Examples of good practices shared by a stakeholder consultation and literature review are discussed below:

Control and monitoring of incoming material

All unloading activities should be supervised by staff trained to identify and react to potential dangers (see fiche 10.1).

Incoming batteries may have very different sources of origin, age, state of charge and different physical state. It may be important to perform regular samplings on incomings fractions to be able to distinguish low risk sources with (almost) no lithium content and medium-to-high risk sources with relatively high-volume content of lithium. Especially LBs fractions coming from dismantling activities and/or repair activities may contain a high quantity of risk batteries able to cause a thermal event. Therefore, it is important to have a performant incoming control system to be able to separate the low-risk fractions from the medium-and high-risk fractions.

Stocks and storage areas

LBs considered high-risk should be kept in an area where – in case of incident – damages are limited to a minimum. This can be achieved by creating compartments separated by concrete blocks for example or using safe containers and/or battery vaults which can stay outside the main buildings. This area should be controlled and/or monitored. By storing these high-risk LBs in small containers potential damages are also limited.

Stocks of risk fractions should be monitored and controlled so the stored volumes are limited, and the time of storage is low. LBs that are considered high-risk should be shipped to the next acceptor on a regular basis for this purpose.

At the end of each day, batteries should be moved to a long-term storage location from their temporary location [21]:

- Must be stored in a remote location.
- Must have a stormwater plan, where required. (See: www.epa.gov/npdes/stormwater).
- At least for larger batteries, when battery terminals are/can be close to each other, battery terminals must be protected or isolated to avoid spark or heat from a residual charge. The positive (raised) terminal must be protected either by packing, duct, or electrical tape, alternatively, each battery can be placed in its own clear, sealable bag. For smaller batteries other more practical protection means may be used, such as storing them in barrels with vermiculite (Picture 18).
- Batteries that have been individually taped or bagged can be stored in a UN Rated steel drum (1A) with a plastic liner or a UN Rated polyethylene drum (1H).
- Batteries must be stored in a cool, dry location.

It is recommended that storage areas:

- allow easy and quick access from 360° for firefighting actions.
- Are compartmentalized with fire-proof materials.
- Alternate storage of flammable and non-flammable waste.

Treatment

A protocol for damaged batteries should be in place [21]. Damaged batteries should not be stored with other undamaged batteries.

- Batteries that are swelling, smoking, leaking, or overheating should be treated with extreme caution.
- Immediately place them in an absorbent, non-flammable material in a cool, dry place.
- Store outdoors away from structures, vehicles, and equipment.
- Store in a non-combustible structure.
- Recommended storage materials include sand or vermiculite.

Inspections and maintenance

Facility Inspections and Maintenance are highly recommended [21]:

- Maintain fire suppression for inspections.
- Dry system inspection.
- Ensure you have the right quantity and size of fire extinguishers.

Operational procedures include housekeeping procedures such as [21]:

- Regularly inspect unprocessed and processed material storage (i.e., tip floor, bales, loaded trucks), handling and transfer areas.

- Have an action plan and time frame for completion.
- Conduct routine preventative maintenance of equipment.
- Use checklists to maintain a consistent inspection program.
- Be sure that fire extinguishers and suppression systems are adequate and in proper working order.
- Access and egress routes must be clearly marked and kept clear at all times.
- Follow fire safety and watch requirements during all hot work procedures.
- Ensure all fire suppression systems are maintained to National Fire Protection Association standards.
- Manage low point drains in dry systems in cold climates.
- Ensure fire extinguishers are the proper size and type for the area.

The employer should have written plans and training in place to identify and mitigate battery fires safely in conjunction with their emergency action plan and fire prevention plan based on the circumstances, while obtaining the appropriate level of outside assistance [21]. Consider monitoring daily operations for potential hot spots, always keeping fire prevention measures in mind.

On-site security

On-site security is particularly important for the prevention of fires. Some examples of good practices include, among others (see also next fiche):

- Safety surveillance on a 24/7 basis. This can be covered by a combination of external services, services in house and technical supervision.
- Regular temperature control and smoke detection during operation and non-operation times (e.g., security staff is often equipped with portable temperature control equipment such as handheld temperature cameras).
- Fire extinguishers are discharge tested and or have hydrostatic tests completed to make sure the cylinder is still safe to operate. They are also mounted to the wall so that they are secure, visible, and readily accessible.

Responses from the consultation carried out in the frame of this study conclude the importance of strengthening contacts with local and regional firefighting services. Regular site visits by external fire services are important, practical on-site exercises are recommended. Fire services should be informed about changes at the facility and alarm plans reviewed regularly, especially regarding changes to the location of inflammable or dangerous materials.

Emergency response plan

Good communication with external local and regional fire services is recommended as well as site inspections.

Consider designating responders in the emergency action plan and providing them with specific training to implement site-specific response procedures to battery incidents. These designated responders should have quick response availability to identified areas of concern for the ignition of batteries [21].

Other recommendations in the ISRI guide [21] are:

- Have a stormwater program in place, especially for response, where required.
- Develop a “one fire extinguisher attempt”, call 112, and evacuate.
- Train employees in the PASS (pull, aim, squeeze, sweep) fire extinguisher method.

- Be aware of the batteries off-gassing and the dangers of smoke inhalation.
- Ensure evacuation plans are written and communicated with employees. Then, ensure training is provided to all employees.

The plan should ensure the “meeting point” is clearly identified and communicated and signage is posted at the facility. Try to identify the following evacuation types:

- Shelter in place.
- Move to another structure onsite.
- Onsite outdoor evacuation locations.
- Offsite evacuation locations for large events.

Consider inviting first responders to the facility for familiarization purposes.

Have a Knox Box or similar device in place to hold an entry key to the facility.

Fire risk assessments and plans can be complicated, and it is likely to need competent advice if the site is at all complex. However, for smaller sites various cost-effective training courses may be available and having one of the employees trained in fire risk assessment may be considered. Whatever the size of the site, this would also give an accessible and in-house source of fire assessment advice for basic and general fire issues at an operational level [35].

Additional information can be found in the references.

Other management and administrative measures

Additional measures for improving the quality of the incoming batteries are recommended, for example, contacting the sources of damaged batteries and providing good practices to them for reducing damages to LBs (track & trace procedure + action towards originator).

Examples of risky situations and decision trees appear in Annex A and B, respectively.

Enforcement:

Emergency protocols and plans considering hazards associated to LBs.

Activity permits to require a risk assessment that will consider hazards associated to LBs and measures to be implemented by operators.

Contracts with PROs may refer and require a risk assessment comprising risks associated to LBs, and emergency protocols.

Informative/inspection sessions may be arranged with the local fire brigade.

Further references:

[21] Guide for developing lithium battery management practices at materials recovery facilities. ISRI (2020).

[35] Reducing fire risk at waste management sites. WISH Waste Fires Working Group (2017).

10.3 Emergency measures and infrastructure at final treatment facilities. Fire detection and extinguishing



Final treatment

Description of the problem:

Infrastructure and management do not consider the risk of thermal events associated to such waste. Facilities lack of appropriate or sufficient fire detection means. Fire extinguishing means are not adapted to the waste managed at the facility.

Challenges:

A risk assessment and input from expert advisors is required to ensure preventive measures are adequate. Additional investment and resources (e.g., training) must be allocated.

Good practice

Description:

Measures must be identified based on a risk assessment and emergency plan produced by expert advisors and adapted to the situation of the facilities. Examples of good practices from the stakeholder consultation and literature review are discussed below.

For technical aspects of fire controls, such as specialist firefighting equipment and the standards for the installation of detection systems, it is very likely to require external specialist advice, unless this competence is held in-house [35].

Technical measures

It is important that untreated materials are kept separate from other waste types and stored in dedicated bunkers or containers. Recycling companies commented on the benefit of sprinklers above bunkers. These provide high volumes of water to submerge burning material and to cool neighbouring stocks. During operating hours recyclers give preference to sprinklers that are turned on remotely by supervising staff rather than the use of fire hoses. Fixed sprinklers can remain turned on even when staff has left the building due to heat or smoke.

Permanent temperature surveillance with for example infrared cameras, smoke, or heat detection units are recommended at bunkers and inside buildings. Some companies prefer smoke detectors rather than heat detectors as it might take some time for stockpiles to reach a detectable heat level. Smoke usually rises quite early from a stockpile. "Smart" infrared cameras allow for the programming of different temperature alarm levels within their range. These cameras were also cited as useful by recyclers in the way that they can recognise other dangerous objects (e.g., gas cylinders).

Conveyor systems at sorting stations should be designed with easy, quick, and safe access to extinguish such burning material. It should be noted that recyclers prefer manual firefighting measures (like firehoses) on conveyor systems (there are both open and enclosed conveying systems, naturally enclosed systems must be opened. On conveyor belts the materials is spread out, but there could be aggregations of material at transfer points).

Batteries are stored separately from other materials in plastic or other drums with internal plastic liners. Batteries are isolated by layers of vermiculite, and it is recommended that damaged batteries are further singled out and stored in plastic foil or bags, such as plastic

wrapping foil (see fiche 7.4). The battery storage area should be outside and away from other buildings under roof or canopy.

Infrastructural Measures

Segregation and separate storage of materials require enough bunkers that are built to prevent the spread of fire. It is also recommended to keep free a safe area, with easy access to it, where hot materials, emitting smoke or even already burning can be dropped far enough from other stored material.

Buildings should be divided by fire walls and smoke screens, but access for firefighting vehicles must be assured to all areas that may show potential risk of fire.

Bunkers for untreated waste should, if possible, be outside and away from buildings whilst remaining covered, roofed or under canopy. Bunkers should allow access to scrap handlers to hot spots (it is recommended to have machinery on hand to remove burning material like a scrap handler with an extension arm). Containers and bunkers must be accessible by fire fighting vehicles; “double parking” of containers must be avoided.

Bunkers should not be built against the walls of buildings. Bunkers must have their own fire-resistant back wall which must be at a distance from the building to avoid heat carried to the structure of the building.

Emergency response

An alarm system is in place, preferably automatic systems are recommended.

Quick reaction is essential for successful firefighting hence training an emergency response team and having adequate detection systems is very important. Regular training for staff and joint exercises with external fire service are recommended (see fiche 10.1 on training).

Management of treatment companies must commit with safety and ensure a management policy is implemented in this sense.



Picture 23. Vermiculite blanket (Source: SortBat).

Fire extinguishing equipment of use could be for example vermiculite blankets (Sortbat) to smother small incidents on the spot. The blanket can be placed over the battery or container on fire to protect any person handling the battery. It is also a good way to make the workplace safer while staff are briefly absent and prevent accidental touching of high voltage batteries. The blankets can be used without vermiculite filling, but the filled version is heavier, and its

weight ensures a better fit of the blanket around the battery.

Other fire extinguishing equipment used on site can be extinguishing agents with cooling effect and long-range effectiveness such as CAFS (compressed air foam system) and small and/or large containers filled with water to control incident batteries.

Forklifts with frontal protection can be used for transporting drums containing damaged/reactive batteries in vermiculite to a protected area far from the main operative building.

Proper respiration equipment should be used by fire fighters and/or staff involved in handling the incident. This can be ABEK filter masks or even independent respiration masks with oxygen flasks (recommended). In all cases, the use of safety equipment requires appropriate training.



Picture 24. CAFS fire extinguisher with pressure bottle.

The insurance industry has produced its own codes on many aspects of fire safety management, including technical standards: insurer may provide advice as they will have access to these standards. For example, the guidance contained in standards and technical advice produced by the UK insurance industry through Fire Protection Association/RISC-A and the Loss Prevention Standards (LPS), now produced by BRE Global. Other useful documents include those produced by the US NFPA (National Fire Protection Association) and FM Insurance (FM Global Data Sheets). These standards are generally accepted by insurers and their technical advisors/experts. If the site does not meet these standards then the purchase of insurance cover, or availability of insurance at an economic cost, may be difficult. Asking for insurer advice on technical standards in advance is likely to be better than arguing afterwards. But beware of applying general standards to waste

management where it may not be appropriate (see [35] for further details).

For technical standards relating to issues such as the installation of fire detection, firefighting and fire suppression equipment, the suppliers of such equipment and reputable trade associations can often be a useful (and likely free) source of advice (although beware commercial interest, and in some cases contradictory advice). Such suppliers, especially when they hold third party certification will be familiar with applicable standards for the products they supply and how they should be installed. However, care should be exercised to ensure that the choice of equipment and supplier is appropriate to the site. For example, an installer of domestic fire equipment may not be that familiar with the standards required for industrial applications (see [35] for further details).

Enforcement:

Emergency protocols and plans considering hazards associated to LBs.

Regular informative and awareness-raising sessions with the local firefighting service.

Activity permits to require a risk assessment that will consider hazards associated to LBs and to ensure minimum detection and firefighting measures have been implemented and are regularly maintained.

Contracts with PROs may include clauses to ensure minimum detection and firefighting measures have been implemented and are regularly maintained.

Further references:

[35] Reducing fire risk at waste management sites. WISH Waste Fires Working Group (2017).

10.4 Specific receptacles for lithium batteries



Final treatment

See fiche 7.4.

Additionally, dedicated containers for LBs exist that include a large pressure valve (avoiding flames escaping the container in case of a thermal event), limiting the release of heat from the container. These containers are equipped with an alarm system triggered by temperature changes. The alarm in this case is connected to a sound system, SMS, and signal alert in the facilities.



Picture 25. Types of containers for LBs (Source: Bebat).

11. Recommendations and good practices to PRO

Producer responsibility organisations set in place contracts with waste treatment facilities, collectors, and logistics companies. They need regular supply of collection, transport, and treatment services for the WEEE and LBs they manage on behalf of the EEE and LBs producers.

11.1 Data collection on fires caused by WEEE containing LBs and single LBs



Description of the problem:

Assessing the scale of the problem is difficult because few countries, if any, keep comprehensive records of fires in collection, vehicles, at transfer stations, sorting plants and other waste management facilities. Therefore, there exists a lack of information to support the design of preventive, detection, and mitigation measures.

Challenges:

Preferably, data collected should be harmonised and cover the entire EU territory and span across a good timeframe. A specific tool facilitating data collection and information to affected parties will require investment and building of partnerships and commitment from a good range of stakeholders.

Recommendation

Description of the recommendation:

It is recommended that data on fires caused by LBs is collected regularly on a national and EU level. An e-platform can be set for this purpose and to facilitate harmonised data collection. Data collected refers to:

- Geographic area where the fires occur.
- Date of the event.
- Type of facility and place where the fire occurred (e.g., collection facility, retail, storage area etc.).
- Type of waste affected by the fire.
- Type of fire occurring (see section 2.5).
- Damages.
- Prevention and extinguishing measures that were crucial during the event (i.e., because they reduced the risk/damages or because they were missing).
- Corrective and preventive actions implemented.
- Number of days of suspension of the activity due to the thermal event.

Any information collected that may be sensitive is anonymised and aggregated. Personal data protection rules are observed. Data collected is to be statistically treated to produce regular reports showing the evolution of the fires. Reports are to be publicly available and shared only with the most relevant actors such as: waste agencies, industry sectors, fire brigade, ADR working groups, standardisation organisations.

Additionally, the e-platform may work as an exchange forum and allow for sharing information between waste managers, such as information on successful prevention and

extinguishing practices and information on the identification of types of WEEE and batteries that may give rise to risky situations. It could also hold a repository of reports and studies providing useful information to the waste management industry.

A study run in Austria [39] aimed at collecting statistics via a stakeholder questionnaire, concluded that this approach regarding the collection and analysis of data obtained by a stakeholder questionnaire yielded no quantitatively assessable result. Reasons for this include: (1) concerns about privacy and data protection, (2) worries about adverse consequences in dealing with authorities or insurance providers or (3) missing or incomplete internal fire reporting systems, (4) the response rate by stakeholders was very low. Therefore, it is strongly recommended to have prior testing of the collection approach for ensuring a valid tool is implemented in practice.

Enforcement:

PROs may require data reporting to WEEE management suppliers they have contracts with.

Sectoral agreements may be set via the national clearing house or waste competence organisations in the country. European industry organisations may set agreements for ensuring data collection at an EU level. Information to other waste sectors may be spread to increase the coverage of the data collected.

Special care should be had on confidentiality of the provided information.

Further references:

[39] Thomas Nigl et al. (2019). Cause-oriented investigation of the fire incidents in Austrian waste management systems.

11.2 Specific conditions in contracts with waste management companies



Description of the problem:

PROs may set contracts with companies dealing with collection, logistics and treatment of WEEE containing batteries and single LBs. Such companies may not be aware of the risks associated to WEEE containing LBs and single LBs and therefore may not be fully prepared for preventing, detecting, and extinguishing fires.

Challenges:

Negotiation between parties on bearing the costs for implementing some of the measures and covering additional costs arising from a potential thermal event can be difficult.

Good practice

Collaboration between PROs and WEEE management companies may bring good results and speed up the process of raising awareness and implement prevention, detection, and extinguishing measures.

Recommendations in 11.1 may also be addressed via contracts between PROs and treatment operators.

PROs may set additional clauses in contracts with waste management companies. Clauses included may deal with the following requirements:

- Specific training to staff.
- Risk assessments comprising potential fires caused by WEEE containing batteries and LBs.
- Evidence of appropriate detection, prevention, and extinguishing measures for fires,
- Reporting of thermal events.
- Information on the period of inactivity after a thermal event and how additional costs arising from this situation will be covered.
- Compliance of ADR.

Additionally, specific clauses and materials may be addressed to:

Collection points and retail, clauses about:

- Implementing sorting protocols (provided by PROs).
- Using informative materials (often provided by PROs).
- Using specific containers for WEEE containing LBs and single LBs.
- Establishing decision trees (see [20]) and protocols that will allow to identify the best storage, handling, and transport option for WEEE containing LBs and single LBs.

Logistics facilities:

- Using specific containers.
- Implementing operational practices for preventing fires (see section 8).
- Establishing decision trees (see [20]) and protocols that will allow to identify the best storage, handling, and transport options for WEEE containing LBs and single LBs.

Pre-treatment facilities:

- Implementing operational practices for preventing fires such as the removal of LBs before shredding processes (see other potential practices in section 9).
- Establishing decision trees (see [20]) and protocols that will allow to identify the best storage, handling, and pre-treatment options for WEEE containing LBs and single LBs.

Final treatment facilities:

Final treatment facilities for batteries are usually battery sorting facilities. It is recommended to include clauses requiring that the waste batteries coming from WEEE are:

- Separated into sortable and non-sortable.
- Individually protected against incidents/short circuits as much as possible.
- Marked as hazardous if any specific condition might require this for safety reasons.
- Packed according to agreed protocols and containers.

Clauses about using appropriate protective containers and ways of packaging requested by the individual recycling companies, depending on battery chemistry may apply as well.

Enforcement:

Sectoral agreements may be set via the national clearing house or waste competence organisations in the country. European industry organisation may set agreements for ensuring data collection at EU level.

Further references:

[20] Guidelines for collection and transport of WEEE containing LIBs. SWICO and SENS eRecycling (FR, IT, DE).

12. Recommendations and good practices to local entities

12.1 Enforce and raise awareness on prevention, detection, and extinguishing of fires



Local entities, PROs

Description of the problem:

Activities managing WEEE containing batteries may not be aware of the preventive, detection and extinguishing measures for fires caused by LBs. Existing activity permits and risk assessments may not be adapted to the raising risks associated to LBs.

Challenges:

Training and awareness raising may be required from local entities managing permits and public tenders. External expert advice may be advisable.

Recommendation

Description of the recommendation:

Public entities in charge of issuing permits and managing public procurement procedures to address and raise awareness on the risks associated to batteries by:

- Organising local/regional informative sessions for fire brigade and companies managing waste containing LBs,
- Requiring a risk assessment that includes risks associated to LBs in the activity permits issued to waste management facilities,
- Including LBs fires prevention, detection and extinguishing when running inspections.
- Facilitating informative campaigns at collection points. It is important that information provided promotes safe collection and safe practices.

Associations of municipalities and the national WEEE/batteries coordination body can build efficient partnerships in what regards informative campaigns. The national coordination body can facilitate dissemination materials and channel the information to local entities.



Picture 26. Campaign in Austria promoted by EAK (Austrian clearing house).

Case study in Belgium: Bebat, the PRO for batteries in the country, developed a traceability plan for monitoring containers of batteries and assess whether the measures implemented by collection points are sufficient for ensuring safe collection. The PRO requires collection facilities to protect and/or isolate batteries. Collection facilities are asked to report risky situations by for example taking pictures, and further discuss with the PRO on how to improve prevention and mitigation of these situations in the future. Bebat prepared a training programme involving 550 recycling parks and their employees in evaluating the risks associated to large batteries and how to easily secure them.

*Case study: Austrian collection points participating in the clearing system are subject to regular inspection from the national Clearing House. Inspections assess, among other things, the presence of specific drums for LBs and cages for small WEEE that may contain integrated batteries (Source: EAK Austria). Collection points must also count with a **sorting table** for the controlled takeover of lithium batteries or rechargeable batteries and electrical devices with non-removable lithium batteries (Source: EAK Austria, issue 41, 21 September 2019). Inspection results provide input to the payment of the annual infrastructure flat rate paid by the PROs to the collection facilities registered to the Clearing system.*

See also good practices and recommendations in section 7.

Enforcement:

The national clearing house and/or national and EU industry associations may trigger dialogue and partnerships and promote activities that will raise awareness to policy makers and citizens.

Further references:

Video from EAK: <https://www.youtube.com/watch?v=pxJwzbp26NM> ;
<https://www.elektro-ade.at/>

13. Recommendations to policy makers

13.1 Data collection on fires caused by WEEE containing LBs and single LBs



Policymakers

Description of the problem:

Assessing the scale of the problem is difficult because few countries, if any, keep comprehensive records of fires in collection, vehicles, at transfer stations, sorting plants and other waste management facilities. Therefore, there is a lack of information to support the design of preventive, detection, and mitigation measures.

Challenges:

Preferably, data collected should be harmonised and cover the entire EU territory and span across a good timeframe. A specific tool facilitating data collection and providing information to affected parties will require investments and the building of partnerships and commitment from a wide range of stakeholders.

Recommendation

Description of the recommendation (note: this recommendation is also illustrated in fiche 11.1).

It is recommended that data on fires caused by LBs is collected regularly on a national and EU level. An e-platform can be set for this purpose and to facilitate harmonised data collection. Data collected refers to:

- Geographic area where the fires occur.
- Date of the event.
- Type of facility and place where the fire occurred (e.g., collection facility, retail, storage area, etc.).
- Type of waste affected by the fire.
- Type of fire (thermal event) occurring (see section 2.5).
- Damages.
- Prevention and extinguishing measures that were crucial during the event (i.e., because they reduced the risk/damages or because they were missing).
- Plan/course of actions of the facility during the thermal event.
- Corrective and preventive actions implemented.
- Number of days of suspension of the activity due to the thermal event.

Any information collected that may be sensitive can be anonymised and aggregated. Personal data protection rules must be observed. Data collected is to be statistically treated to produce regular reports showing the evolution of the fires. Reports are to be made publicly available and shared with the most relevant actors, such as: waste agencies, industry sectors, fire brigades, ADR working groups and standardisation organisations.

Additionally, the e-platform may work as an exchange forum and allow for sharing information between waste managers, such as, information on the successful prevention and extinguishing practices and identification of types of WEEE and batteries that may give rise

to risky situations. It may also hold a repository of reports and studies providing useful information to the waste management industry and not only.

A study run in Austria [39] aimed at collecting statistics via a stakeholder questionnaire, concluded that this approach regarding the collection and analysis of data obtained by a stakeholder questionnaire yielded no quantitatively assessable result. Reasons for this include: (1) concerns about privacy and data protection, (2) worries about adverse consequences in dealing with authorities or insurance providers or (3) missing or incomplete internal fire reporting systems, and (4) the stakeholders' response rate was very low. Therefore, it is strongly recommended to have prior testing of the collection approach for ensuring a valid tool is implemented in practice.

Enforcement:

Public funding for developing and testing an e-platform and ensuring its use by stakeholders. The project funded could work towards setting sectoral agreements with the main stakeholders at national and EU level and developing information channels for informing policymakers. The information collected could be then used for setting appropriate strategies.

Information to other waste sectors may be spread to increase the coverage of the data collected.

Further references:

[39] Thomas Nigl et al. (2019). Cause-oriented investigation of the fire incidents in Austrian waste management systems.

13.2 Address insurance coverage to waste management facilities



Description of the problem:

Waste management facilities are facing tougher conditions for contracting insurance covering their activities, due to the risks associated to LBs. This means increased premiums, increased deductibles, additional exclusions in the coverage or simply the impossibility to find an insurance company that will close a deal. This poses a serious problem when activity permits are conditioned to obtaining insurance coverage. The implementation of best practices to prevent and mitigate battery fires in the recycling value chain is not accompanied by requirements to guarantee the insurability of waste management companies.

Challenges:

Lack of awareness from policymakers and in particular of authorities issuing activity permits to waste management facilities. Lack of partnerships between firefighting services, insurance companies and the waste recycling sector. The insurance agents or brokers, as well as the subscription services of the insurance companies, are sometimes non-specialized in the waste sector.

Recommendation

Description of the recommendation:

It is recommended to create a roundtable composed of representatives from both WEEE managing facilities - handling both WEEE containing LBs and single LBs, and insurance companies.

This roundtable could be a very good starting point for discussing:

- The risks and prevention issues like the ever-increasing problem of battery fires, the reduction of the fire loads in processing lines and other areas at treatment facilities (particularly overnight), the different ignition sources both internal and external of the waste, relevant standards for surveillance systems (e.g., guard/tour of observation, CCTV), and protocols for automatic extinguishing systems in waste bunkers, sorting and processing areas.
- The fire protection standards to be implemented by the recycling companies to make the risks more insurable/acceptable. It is recommended to agree on the development of a specific standard to reach an acceptable prevention, mitigation and extinguishing system baseline, and example of this is provided by the Waste Industry, Safety and Health (WISH) initiative in the UK (see below).
- The possibility of including fire prevention and safety criteria in public procurement calls.
- The conditions that will act as a barrier for renewing the contracts between insurance and recycling companies.
- Agreements on a methodology to calculate insurance premiums to be paid by the recycling industry and other potential contributors, so that the collaboration can be beneficial and long-lasting for both. It is proposed to have a reduction of the insurance premium when a certain level of prevention/safety measures is reached by the treatment company. Insurance brokers/agents can assess the level of compliance through inspection. When deficiencies are identified during inspections, a period for applying corrective measures is suggested to allow treatment facilities to reach the required level of prevention/safety.
- The possibility to create a pool for joint coverage of treatment facilities of the waste management industry that will facilitate access to insurance coverage.

Standards referred above can deal with requirements applicable in the design of new treatment plants, examples of such requirements are:

- Avoid insulation materials made of plastic (e.g., in walls, roof etc. made from polycarbonate, polystyrene or polyurethane foam).
- Fire partitions between the processing area and waste bunkers but also local partitions for batteries charging.
- Fit the waste bunker and process area with automatic extinguishing systems (e.g., sprinkler system or automatic gun).

Additionally, increasing the awareness of policymakers is particularly important, especially when Europe is committed to switching from a linear to a circular economy through the ambitious targets set under the EU Green and the new Circular Economy Action Plan.

Increased awareness of policymakers can be achieved by:

- Providing data evidencing the severity of the ever-increasing problem of battery fires in WEEE treatment facilities (see fiches 11.1 and 13.1). Data will at the same time

show the need of better enforcement of the articles on separate collection laid down in the Directive 2008/98/EC.

- Showing to policymakers the negative impact that not insured treatment facilities will have on achieving a circular economy.

In order to get a better understanding of the problem, enhance dialogue, consensus and brainstorming for solutions, methodologies and tools like root cause analyses are strongly suggested in the discussions with the main stakeholders.

Enforcement:

Set up a workshop targeted at representatives of the relevant waste industry sectors, insurance brokers, insurance companies and engineers with expertise in the matter.

The workshop can focus on building awareness, instigating dialogue between the parties, and to identify and analyse the following:

- The key factors for both, fire safety and insurability.
- The responsibilities of each actor involved.
- Present and analyse the feedback of the WISH Initiative in UK, this will precede and analysis of the approach of the “endorsement of the London Market” and associated questionnaire.

Further references:

WISH initiative launched in 2009: <https://www.hse.gov.uk/waste/wish.htm>

Endorsement of London Market (see attached): Contact EuRIC to obtain a copy.

Questionnaire of London Market (see attached): Direct Insurance Group Plc (2021).

Recycling and Re-Use Scheme Material Damage Proposal Form [Contact EuRIC to obtain a copy].

14. Conclusions

The organisations involved in the preparation of this report acknowledge the efforts done by stakeholders which helped to better understand the situation and to develop measures for tackling fires caused by WEEE containing lithium batteries. Nevertheless, fires keep happening. It can be concluded that there is not a magic formula that will reduce the risk of fires caused by WEEE containing batteries and single batteries to zero. Therefore, it is utterly important that actions are taken in all steps of the lifecycles of EEE and lithium batteries: from design to disposal of WEEE and batteries, including their transport and treatment. Most measures require a good level of understanding of the issue and require additional support from policymakers.

A coordinated response in all steps of the lifecycle of WEEE containing lithium batteries and lithium batteries is required to achieve a positive change in the situation.

The European Green Deal and the new Circular Economy Action Plan identify “electronics” among key product value chains where recycling plays obviously a major role to achieve sustainability goals.

The expected contribution of the waste management industry to these EU strategies is at risk. The waste management sector needs a supporting multistakeholder strategy that will address properly the issue of fires caused by WEEE containing lithium batteries.

Programs for appropriate training and improved knowledge to assess the magnitude of the issue would improve the situation considerably. The testing and development of recommendations described in this report, that are not yet implemented, is still required.

Some issues, like the difficulty to contract insurance coverage by WEEE and lithium batteries management companies, have been explored in the Batteries Roundtable that dealt with this report, and some potential measures were identified. However, further work to assess the extent of the issue and potential solutions is required. Additionally, battery removal from very small WEEE with integrated batteries remains a challenge in many cases for treatment operators.

The current revision of the Batteries Directive and a possible revision of the Eco-design Directive provide good opportunities to materialise some of the initiatives described in this report. However, statistics and testing are required to ensure that the measures identified and incorporated in such texts are valid and implementable under technically & economically viable conditions.

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Composition of the Batteries Roundtable



The European Recycling Industries' Confederation is the umbrella organisation for European Recycling Industries. Through its Members, EuRIC represents companies involved in the collection, processing, recycling, transport, and trade of a variety of recyclables (metals, paper, plastics, batteries, textiles, glass and beyond) across Europe. By servicing its Members, EuRIC contributes to promote recycling, which is first and foremost a business activity driven by an ecosystem of thousands of Small and Medium-size Enterprises (SMEs) and fewer but equally important larger companies. All of them are local and global actors. They provide non-outsourcable job opportunities and produce locally commodities, which are traded and priced globally. Their activities offer massive environmental benefits by saving natural resources and drastically reduces energy consumption and pollution.

EERA, the European Electronics Recyclers Association is a professional association for recycling companies who are treating waste electrical and electronic equipment WEEE in Europe. Members recycle $\pm 2.500.000$ tonnes of WEEE annually and have more than 100 locations in 22 European countries. EERA members are pre-processors and end processors. EERA is a non-profit organisation and is the voice of WEEE recyclers. It aims for the harmonization of international and national regulations for WEEE recycling and the creation of a level playing field in order to obtain a free market for demand and supply of services. The vision of EERA is for a circular economy where WEEE is managed as a resource and is returned into the economy as equipment for reuse or as a raw material. EERA calls for an appropriate and enforced legal framework, better collection processes, good treatment based on mandatory standards and Best Available Technologies and the eradication of illegal practices. EERA supports product design integrated in a life-cycle approach.



Eucobat is the European association of national collection schemes for batteries. They assure that all waste batteries are collected and recycled in an ecological sound way and contribute this way to a better environment. Eucobat has been created to deal with matters which are of scientific, economic and institutional interest for national compliance organizations in general; to represent the interests of the national compliance organizations for batteries in Europe; and to harmonise the procedures, in particular in regard to participating companies, and activities of national compliance organizations that assume the financial and/or organisational responsibility of manufacturers for the management of waste batteries and accumulators.

ecosystem is a French non-profit organisation accredited by the Public Authorities to collect, decontaminate, and recycle household waste electrical and electronic equipment (WEEE), professional equipment (professional WEEE), lamps and small fire extinguishers. Many players are involved in this sector, which



is managed by ecosystem including manufacturers, importers, distributors, local authorities, solidarity networks, treatment and logistics suppliers, professionals in charge of electrical equipment maintenance, fire safety, waste managers and equipment users (both individuals and professionals). ecosystem is involved in many research projects and safety studies with several objectives: maximize depollution, improve treatment and separation of WEEE, protect workers, create circular loops for recycled materials.



Municipal Waste Europe is the European umbrella association representing public responsibility for waste. The members are national public waste associations and similar national or regional associations.

They are committed to sustainable waste management that minimises the impact of waste on the environment and promotes resource efficiency, taking into account local conditions. Municipal Waste Europe promotes the interests of its members at European level, through joint positions on waste management issues and legislation and keeps its members informed on the latest EU policy developments. The association encourages the sharing of information among its members, including the exchange of good practice in the local management of waste.

The WEEE Forum a.i.s.b.l. is an international association representing forty-three producer responsibility organisations across the globe. Together with our members, we are at the forefront of turning the extended producer responsibility principle into an effective electronic waste management policy approach through our combined knowledge of the technical, business, and operational aspects of collection, logistics, de-pollution, processing, preparing for reuse and reporting of e-waste. Our mission is to be the world's foremost e-waste competence centre excelling in the implementation of the circularity principle.



WEEELABEX is an international non-profit legal entity, headquartered in Prague, that sets up qualification auditors in the WEEELABEX standards, as well as promoting the adoption of these standards by operators and member states as a means of improving WEEE management practices in Europe.

Three constituent bodies make up the WEEELABEX organisation: the WEEELABEX General Assembly, composed by all member WEEELABEX systems (WEEE producer compliance schemes), the WEEELABEX Government Council, which is the executive body, and the WEEELABEX Office, that functions as Secretariat and WEEELABEX notary.

Annex A – Examples of batteries and cases

CASE 1. High risk of short circuit

Batteries (and battery packs) may be damaged, without casing, show open contacts or loose wires which are not isolated.



Pictures above and below show that there is a risk of short circuit. It is recommended to isolate wires with tape, tape contacts and wrap the battery 3-4 times in transparent foil. Avoid contact of the battery with metallic surfaces.



The next picture shows batteries without label or casing or with damaged label or casing. There is risk of short circuit, it is recommended to wrap cells

individually in plastic foil to protect them. Naked cells can easily short circuit or the metal sides might cause a short circuit to another battery:



A lithium polymer battery without casing, with open contacts and unprotected wires is shown in the next picture. It is recommended to isolate wires with tape and wrap the battery 3-4 times in transparent foil and to place the battery on top of a full container to avoid pressure on this battery.



Battery packs without casing and open contacts are illustrated in the next picture. It is recommended to wrap the battery 3-4 times in transparent foil:



CASE 2. Very low risk of short-circuit.

Undamaged battery (or battery pack). The contacts have been removed from the housing or isolated with connectors or similar.

Isolating or taping is not necessary in this case – the risk of short circuit is very low.

Undamaged laptop battery pack. The contacts have been removed from the housing:



A similar case is shown below: battery pack of golf cart which is not damaged and connector with contacts removed in the housing.



Battery pack of cordless vacuum cleaner which is not damaged. Contacts have been removed. Isolating or taping is not necessary in this case because the risk of short circuit is very low:



An undamaged battery pack appears in the next picture, wires are protected by connectors. The risk of short circuit is very low, isolating or taping is not necessary in this case:

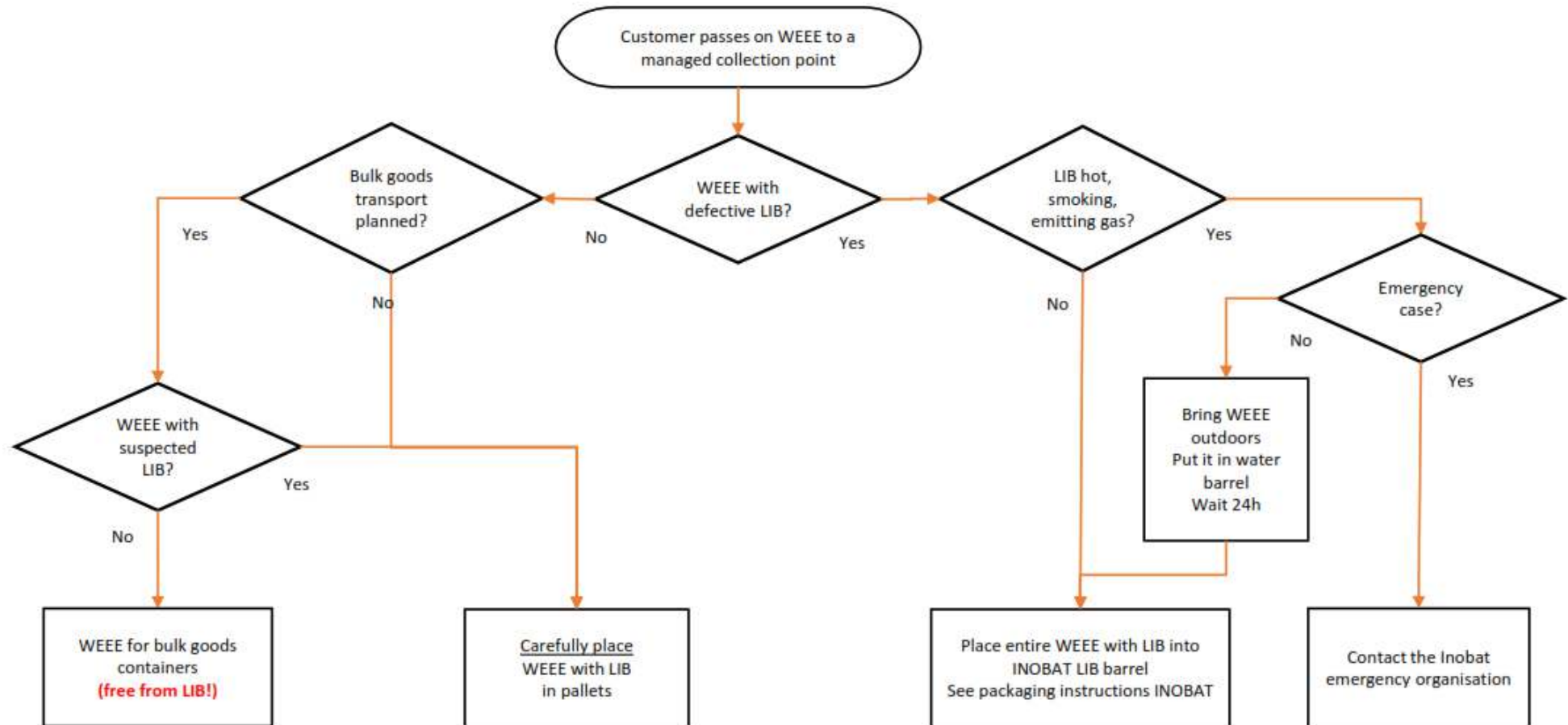


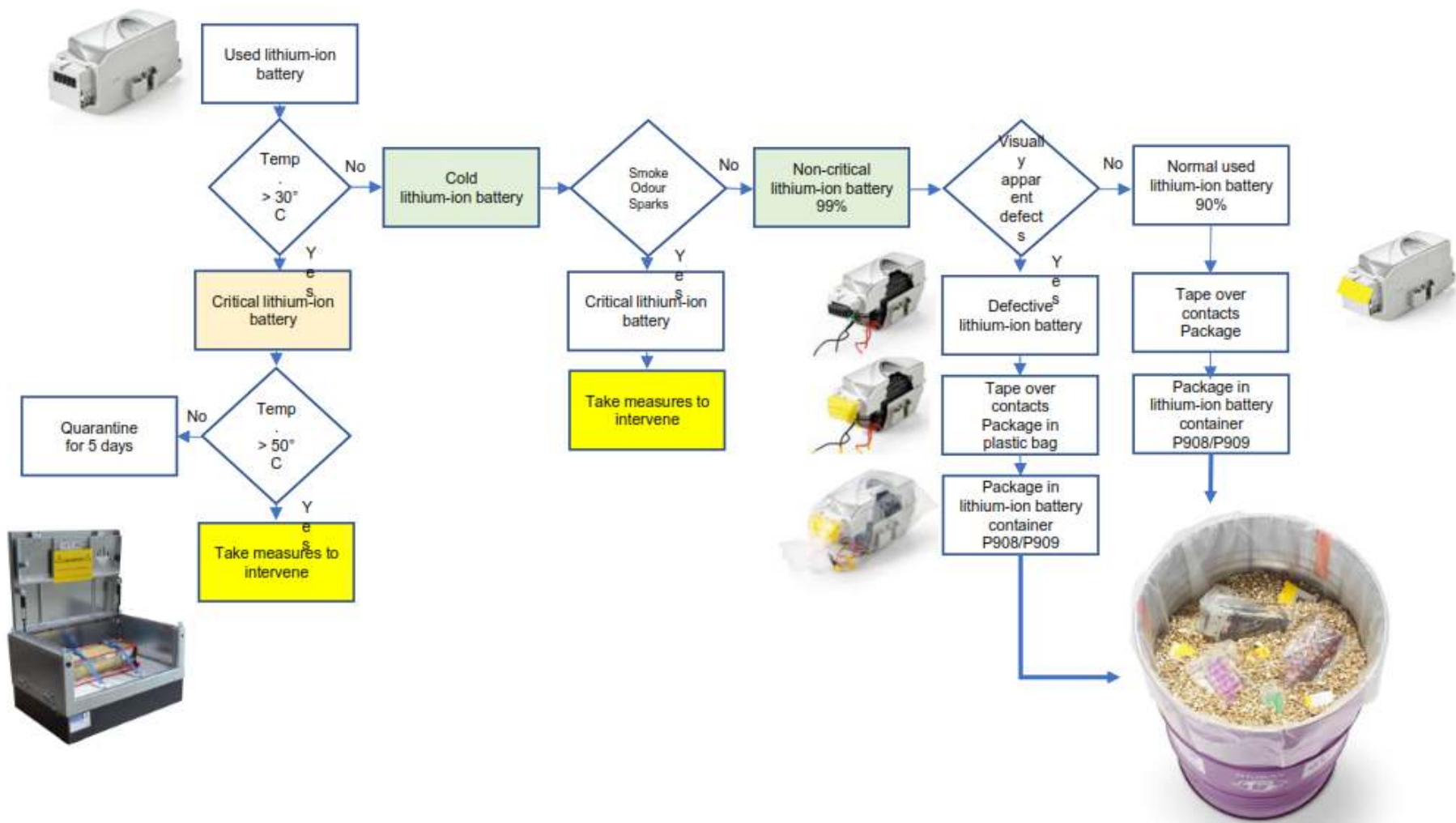
Undamaged battery pack of cordless drill. Contacts have been removed:



Annex B – Decision trees

Decision tree proposed for collection facilities. Source: SENS Foundation, WEEE Forum Operations Committee, 3 December 2020.





Possible decision tree proposed for Lithium batteries. Source: SENS Foundation, WEEE Forum Operations Committee, 3 December 2020).

Annex C – Questionnaire

Survey on fires caused by WEEE containing batteries and good practices implemented

The EEE industry, WEEE recycling industry, Eucobat and WEEE Forum gathered and set a roundtable discussion to address the issue of fires caused by WEEE containing batteries.

The survey is divided into two parts aimed at:

- Part A. Characterising the incidents caused by WEEE batteries.
- Part B. Collecting good practices implemented for tackling such fires.

The final goal of this exercise is to produce training materials and a compilation of recommendations for fighting against fires in the whole WEEE management chain.

Please, note that:

Part A on "Fires_characterization" is confidential and responses will be collected and anonymized by EuRIC only. EuRIC will remove data that may identify the respondent:

- Only anonymized data will be disclosed to the signatories of the survey (EuRIC/ WEEE Forum/WEEE Labex/EERA);
- Only aggregated data will be disclosed to the roundtable.

Part B on "Effective good practices" is not confidential (unless specified) as respondents with effective good practices might be contacted after the survey.

NOTE: data on parts A and B can be analyzed together in the questionnaire. However, only anonymized and aggregated data will be disclosed to the roundtable.

In compliance with the GDPR, we inform you that any contact data collected via the questionnaire will be strictly used for the purpose of this survey in case EuRIC (for part A) or the roundtable (for part B) may need to collect additional data or clarifications on your responses. You can contact us for requesting the [edition and](#) cancellation of such contact data. If you agree to receive any updates on the outcomes of the roundtable, your contact details will also be used for this purpose.

Deadline for submitting responses: 31 October 2019, thank you very much!

*Required

1. Email address *



Please, submit only one questionnaire per site.

A company holding more than one site may submit one response for each site, please make sure only ONE response is submitted for a site. Please send any documents supporting your responses (pictures, reports, websites, news) to [dedicated mail address].

0 - Data from respondents (optional)

Contact data collected in this section will be used for the purpose of this survey in case EuRIC (for part A) or the roundtable (for part B) may need to collect additional data or clarifications on your responses. If you agree to receive any updates on the outcomes of the roundtable, your contact details will also be used for this purpose. When displaying the results of the survey of part A, all data collected will be grouped and anonymized.

0.1 Please indicate the name of your company

0.2 Please indicate the country your site is based in

0.3 If more than one site, please indicate the site you are referring to

0.4 Please provide the name of a contact person

0.5 Please provide the email address of the contact person so we can contact you for clarifications

1 - Type of respondent

1.1 Waste streams managed on-site (if applicable, select more than one) *

Tick all that apply.

- A. Municipal Solid Waste
- B. Mixed metal scrap
- C. Hazardous waste
- E. End-of-Life Vehicles
- Other: _____

1.2 Main type of activity performed for WEEE (select more than one if necessary) *

Tick all that apply.

- A. Public collection site (e.g. local civic amenity)
- B. Other collection facility (e.g. retail shop)
- C. Sorting and logistics site

- D. Treatment facility
- E. Storage facility
- F. Dismantling facility
- Other: _____

1.3 Activities on-site (if applicable, select more than one) *

Tick all that apply.

- A. Collection of WEEE
- B. Sorting of WEEE
- C. Pre-treatment of WEEE (dismantling, depolluting)
- E. Shredding (e.g. crushing, pressing, cutting)
- F. Post shredding treatment
- Other: _____

1.4 Annual capacity of the site (tons/year) for WEEE usually containing batteries (e.g. small WEEE, etc.)

Mark only one oval.

- A. 0-5,000
- B. 5,000 - 25,000
- C. 25,000 - 100,000
- D. 100,000 +
- E. I don't know
- Other: _____

Part B. 5 - Good practices

Please refer to practices implemented during 2016-2019

5.1 Have you implemented any good practices and mitigation measures in recent years (2016-2019)? *

Mark only one oval.

- Yes
- No *Skip to question 67.*

In this section we would like to know more about the good practices implemented.

5.2 Were those good practices helpful to circumvent the number/intensity of fires in 2018? *

Mark only one oval.

- Yes
- No *Skip to question 46.*

Part B. 6 - Batteries: Effective Good practice - General questions

In this section we would like to know more about the good practices implemented that WORKED WELL.

6.1 Please indicate in which part of the chain was the best practice implemented? (if applicable, select more than one) *

Tick all that apply.

- A. Collection point, container area
- B. Loading truck at collection point
- C. Transport from collecting point to the sorting center
- D. Reception of sorting/logistics centre, unloading
- E. Storage area of sorting/logistics centre
- F. Loading truck at sorting/logistics centre
- G. Transport from the sorting center to the (pre-) treatment site
- H. Acceptance / Reception area of (pre-) treatment site
- I. Transport to storage area after reception at (pre-) treatment site
- J. Unloading at storage area at (pre-) treatment site
- K. Storage area of (pre-) treatment site
- L. Pre Treatment - Manual Dismantling /depolluting
- M. Pre Treatment - Mechanical dismantling /depolluting
- N. Pre Treatment - Sorting/ Blending & mixing /grouping
- O. Transport to pre-shredder storage
- P. Pre-shredder storage
- Q. Transport to shredder
- R. Shredding (e.g. crushing, pressing, cutting)
- S. Transport after shredding
- T. Post-shredding storage

6.2 Please explain the answer before; if necessary indicate if you know of additional measures that were implemented in other parts of the chain.

6.3 When was the best practice implemented? (year)

6.4 How many sites was the best practice implemented in?

6.5 Please describe the intended prevention objective of the good practice (e.g. prevention of short circuit, prevention of physical damage to the batteries, etc.)

Part B. 7 - Batteries: Effective Good practice - Description

Please feel free to share any materials supporting your answers, such as training protocols, fire drill procedures, description of specific containers or fire mitigation measures etc.

7.1 Was the good practice about organizational measures? (if applicable, select more than one)

Tick all that apply.

- A. No
- B. Yes, reinforced teams at reception points
- C. Yes, improved control procedure of incoming waste
- D. Yes, improved access to extinction means
- E. Yes, implemented specific fire drills
- Other: _____

7.2 Was the good practice about training? (if applicable, select more than one)

Tick all that apply.

- A. No
- B. Yes, reinforced training to staff
- C. Yes, improved fire drills
- D. Yes, improved training in handling extinguishers or other fire suppression devices
- Other: _____

7.3 Was the good practice about storage conditions?. Please describe (e.g. modified rhythm of shredding campaigns- to reduce storage time-, modified layout of the site, containers, etc.)

7.4 Was the good practice about fire detection techniques?. Please describe (e.g. improved fire detection system, fire detection system linked to an alarm system/fire department/phone of operators, etc.)

7.5 Was the good practice about fire suppression techniques?. Please describe (e.g. automatic fire suppression systems, foam/sand/powder used, etc.)

7.6 Please describe here with your words the good practice *

7.7 Please, indicate in ranges the approximate cost of implementing the measures per facility (FIXED costs for first year)

Mark only one oval.

- < €1,000
- < €5,000
- < €10,000
- < €20,000
- < €50,000
- < €70,000
- < € 100 000
- < € 200 000
- < € 500 000
- > € 1 000 000
- Other: _____

7.8 Please, indicate a range for annual RECURRING costs associated to the good practice (e.g hiring personnel)?

7.9 Did you finance the practice yourself? Please indicate if there were any financial aids available (e.g. subsidies, etc.)

7.10 Indicate, if possible, the frequency of fires before the measure was implemented

Mark only one oval.

- A. Fires or related incidents on a daily basis
- B. Weekly basis
- C. Monthly basis
- D. None
- Other: _____

7.11 Indicate the reduction (in %) of the frequency of fires after implementing the measure

7.12 Do you think this good practice requires additional measures to improve the results?

Mark only one oval.

- Yes
- No
- Other: _____

7.13 Do you have recommendations on the eco-design / labelling of batteries or EEE containing batteries? Please describe

7.14 Please indicate if there is any information provided on the good practice (Part B) that may be considered/treated as confidential

7.15 Please add any further clarifications or comments you might have

Untitled section

8.1 Would you like to receive an update of the results of this initiative? *

Mark only one oval.

Yes

No

8.2 if yes, please provide your e-mail address for receiving updates

8.3 Would you agree to be visited or contacted for an interview? *

Mark only one oval.

Yes No

8.4 If yes, please provide an e-mail address to be contacted
