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SERIES L: ENVIRONMENT AND ICTS, CLIMATE
CHANGE, E-WASTE, ENERGY EFFICIENCY;
CONSTRUCTION, INSTALLATION AND PROTECTION
OF CABLES AND OTHER ELEMENTS OF OUTSIDE
PLANT

E-waste and circular economy

Sustainable management of batteries

Recommendation ITU-T L.1035

ITU-T

ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Recommendation ITU-T L.1035

Sustainable management of batteries

Summary

Recommendation ITU-T L.1035 provides guidance on the sustainable management of used batteries from information and communication technology (ICT) equipment and their environmentally responsible management, including waste prevention, minimization, recycling, recovery and final disposal. This Recommendation also provides information on best practices in recycling batteries for dissemination.

Batteries are crucial for the functioning of ICTs. Improving their design, prolonging their lifespan, improving their recyclability and preventing the dumping of waste batteries can lower their overall energy consumption, reduce exposure of humans and the environment to hazardous substances, as well as reducing global greenhouse gas emissions.

History

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Batteries, e-waste, recycling, sustainable management of used and waste batteries.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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Introduction

Waste electrical and electronic equipment (WEEE), such as waste phones, laptops, refrigerators, sensors and TVs, is also known as e-waste. E-waste is a growing challenge, matching the growth of the information and communication technology (ICT) industry.

- About 80% of e-waste is discarded in landfill, burned or illegally traded every year.
- E-waste contains substances that can be hazardous to human health and the environment if not dealt with properly – including mercury, cadmium and lead.
- ITU member states have set a global e-waste target for 2023 to increase the recycling rate of e-waste to 30% and raise the percentage of countries with e-waste legislation to 50%.
- By adopting the Connect 2030 agenda, ITU member states have also committed to reduce the volume of redundant e-waste by 50%.
- Addressing e-waste helps to address the Sustainable Development Goals, in particular Nos. 3, 8, 9, 11, 12 and 13 [b-ITU media e-waste].

The challenges

E-waste is used to refer to almost any discarded household or business item with circuitry or electrical components with a power or battery supply [b-ITU media e-waste]. Waste batteries fall within this category.

Latest estimates show that, as ICT networks and services have grown, the world now discards approximately 57 Mt of e-waste per year (2019), of which less than 20% is recycled [b-ITU media e-waste].

Batteries are important components of portable electrical and electronic devices. For example, the use of the lithium-ion (Li^+) batteries (LIBs) in portable electronic devices, such as mobile phones, laptop, cameras, toys, e-cigarettes, and electric and garden tools, has doubled from 2014 to 2019 [b-Mossali].

The LIB has been used widely for a wide range of applications because of its high performance in a number of important functional criteria, e.g., battery life, high storage capacity, small size, low mass, efficient self-discharging capacity to withstand different climatic and temperature environments. However, due to the demand for new gadgets and the availability to buy them, tonnes of LIBs have been discharged when they were still functional. It is anticipated that 11 Mt of end-of-life LIBs will be produced cumulatively by 2030. The flows of waste LIBs from portable electrical and electronic devices will be augmented by waste LIBs employed in electric vehicles (EVs), with their annual waste flow reaching 340 000 t by 2040 [b-Chandran]. Because of their use in EVs, the projected requirement for LIBs is enormous, and this may lead to risk of short supply in the trade market due to the natural supply limitations of lithium metal resources after 2023. It is anticipated that the call for lithium carbonate will rise from 265 000 t in 2015 to 498 000 t in 2025. This may create a gap between demand for lithium against market supplies that ultimately may lead to a price hike of lithium carbonate. To address the risk of short supply and to reduce the cost of production, it appears crucial to recover lithium metal from all potential resources [b-Mohanty].

Batteries contain dangerous substances, including mercury, cadmium and lead, which can end up polluting land, air and water, and pose health risks, especially if they are not treated properly.

- Untreated used batteries put the health and lives of some of the world's poorest adult and child workers at risk: those who dispose of dangerous waste, risking exposure to toxins and poisoning.
- Improper management of used batteries can result in the unnecessary loss of scarce and valuable natural materials, through failure to recycle other less toxic, but high-value rare materials, such as gold, platinum and cobalt, putting pressure on the limited natural resources available.

Only 30% to 50% of the population properly dispose of portable LIBs, being unaware of the potential harmfulness of post-use products. Metallic lithium, resulting from incorrect recycling of LIBs, is highly reactive with moisture, and in the presence of a flammable electrolyte could cause explosive reactions and the emission of harmful gases (such as hydrogen fluoride) in case of mechanical damage, overheating or degradation phenomena, exposing people to the risk of serious injury [b-Mossali].

Opportunities

On the upside, e-waste could represent an opportunity worth over USD 62.5 billion per year if treated through appropriate recycling channels and methods, with the potential of creating millions of "clean and green" jobs worldwide.

Through greater collaboration among multinationals, small- and medium-sized enterprises, entrepreneurs, academia, trade unions, civil society and associations to create a "circular economy" for electronics, including batteries, where waste is designed out, the environmental impact could be reduced, and decent work created for millions.

A system in which all discarded products are collected and then the materials or components reintegrated into new products will:

- reduce the need for new raw materials, waste disposal and energy;
- potentially create new economic growth, "green" jobs, and business opportunities;
- reduce carbon dioxide (CO₂) emissions;
- promote a shared responsibility for waste batteries along the full supply chain, including consumers.

For example, although the amounts of produced and sold portable LIBs are huge, only 29.5% of the population properly collect them, versus 59.6% that store LIBs at home and 15.9% who throw them into dustbins [b-Mossali].

In a circular economy scenario for batteries, design should facilitate second use and final disposal of the product. For LIBs, for example, through appropriate labelling (e.g., quick response (QR) codes, radio frequency identification device tags), a standardization of formats, structure and component materials, a reversible assembly strategy and a clear classification of inner hazardous components. On this topic, the US Society of Automotive Engineers and the European EUROBAT have created a series of working groups to discuss and develop solutions for sustainable re-design of LIBs [b-Mossali]. Consumers can try to: get ICT equipment repaired instead of replaced; delay upgrading or exchanging functional smartphones for the latest model; use certified recycling points or disposal firms; consider giving ICT equipment a second life through resale.

Recommendation ITU-T L.1035

Sustainable management of batteries

1 Scope

This Recommendation focuses on managing used and waste batteries in information and communication technology (ICT). The main objectives include the following:

- criteria for the recyclability of different types of batteries.
- identification of hazardous substances in batteries;
- safe handling of batteries by recyclers and workers;
- best practices for battery recycling and final disposal;
- minimization of the environmental impact generated by heavy metals and other hazardous chemicals in used and waste batteries that are disposed of both as municipal solid waste and as hazardous waste and during battery recycling.

This Recommendation examines methods for recycling of batteries effectively. This Recommendation also includes proposals for worker safety in the management of waste batteries, as well as policies, legislation and management plans for batteries.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[IEC 60086-4] IEC 60086-4:2019, *Primary batteries – Part 4: Safety of lithium batteries*.

[IEC 62133-2] IEC 62133-2:2021, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications – Part 2: Lithium systems*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 battery capacity [b-ISO/TS 23625]: Capacity of the battery, expressed in ampere-hours (Ah) at a nominal voltage or in watt hours (Wh), from the manufacturer's specified fully charged to discharged voltage levels.

NOTE – Ah capacity rating at a given discharge rate or time.

3.1.2 electrochemical cell [b-IEC 60050]: Composite system in which the supplied electric energy mainly produces chemical reactions or, conversely, in which the energy released by chemical reactions is mainly delivered by the system as electric energy.

3.1.3 waste electrical and electronic equipment [b-Basel TG]: Electrical or electronic equipment that is waste, including all components, sub-assemblies and consumables that are part of the equipment at the time the equipment becomes waste.

3.1.4 recycling (Appendix I of [b-Basel Manuals]): Recycling operations usually involves [sic] the reprocessing of waste into products, materials or substances, though not necessarily for the original purpose. Resources are saved by recovering material benefits from the waste. Recycling is to be distinguished from operations that recover energy from the waste. In some countries, where material is used once merely for its physical properties e.g., for backfilling, this does not amount to recycling. An example is used lubricating oil re-refined which could result in high grade oil which is valuable for its chemical properties and hence that would be a recycling operation. Used oil could also simply be used as a fuel so that the recovery operation would be energy recovery and not recycling.

NOTE – Recycling may be defined by national legislation differently in each country.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 battery: Any source of electrical energy generated by direct conversion of chemical energy and consisting of one or more primary battery cells (non-rechargeable) or consisting of one or more secondary battery cells (rechargeable).

NOTE – [b-EU Battery] reviews the new EU regulatory framework in this field and is expected to contain a similar definition.

3.2.2 battery pack: Energy storage device, which is composed of one or more cells or modules electrically connected together inside a mechanical pack with electronics as required for safety and operation. The battery pack may incorporate a protective housing and be provided with terminals or other interconnection arrangement. It may include protective devices and control and monitoring required for safe and proper operation. It may provide detailed information (e.g., cell voltage, temperature, capacity) to a higher-level battery system management device.

3.2.3 box; casing: Container subdivided with intermediary walls where the individual elements will be inserted along with electrolyte.

3.2.4 cap; cover: Part intended to close the box of the battery.

3.2.5 charge: Operation through which electrical energy is supplied by an external electrical source and converted into chemical energy in the battery.

3.2.6 connector: Metallic lead conductor used to interconnect not only the individual plates, forming elements, but also the elements between each other forming the internal electric circuit.

3.2.7 electrical accumulator: Device constituted by an electrolyte, an element, and a container housing them, capable of storing the electrical energy as chemical energy and releasing this energy when connected to an external consuming circuit.

3.2.8 lead-acid accumulator; lead-acid battery: An electrical accumulator in which the active material of the positive plates is made up of lead compounds and that of the negative plates is essentially lead, the electrolyte being a dilute sulphuric acid solution.

3.2.9 electrolyte: Ionic conductor into which the plates are submerged. In lead-acid batteries, the electrolyte is a dilute sulphuric acid solution. In other batteries, such as lithium-ion, the electrolyte is a polymer.

3.2.10 element: A series of negative and positive plates, placed consecutively and isolated between each other with plate separators. Plates of the same polarity are electrically connected. Therefore, an element may be considered as a set of electrochemical cells in parallel connection.

3.2.11 negative plate; anode: Plate where the oxidative reactions take place.

3.2.12 positive plate; cathode: Plate where the reductive reactions take place.

NOTE 1 – A rechargeable battery is also often described as accumulator.

NOTE 2 – Batteries can be connected together or encapsulated within an outer casing, sometimes with additional parts such as a battery management system, to form a complete unit that the end user is not intended to split up or open. This is also called a battery pack.

3.2.13 disposal: Includes refurbishment, recycling, material recovery and final operations, such as incineration, incineration with energy recovery and landfill.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC	Alternating Current
BIGP	Battery Identity Global Passport
DC	Direct Current
ESM	Environmentally Sound Management
EV	Electric Vehicle
HTMR	High Temperature Metal Recovery
ICT	Information and Communication Technology
IMDG	International Maritime Dangerous Goods
LCO	Lithium Cobalt Oxide
LFP	Lithium Iron Phosphate
LIB	Lithium-Ion Battery
LMO	Lithium Manganese Oxide
LMR	Lithium- and Manganese-Rich
LTO	Lithium Titanium Oxide
NCA	lithium Nickel Cobalt Aluminium oxide
NMC	lithium Nickel Manganese Cobalt oxide
PPE	Personal Protective Equipment
QR	Quick Response
SELV	Safety Extra Low Voltage
UPS	Uninterruptable Power Supply
WEEE	Waste Electrical and Electronic Equipment
WLAB	waste lead-acid battery

5 Conventions

None.

6 Types of battery used in ICTs

A battery consists of one or more cells that can undergo a chemical reaction that causes electrons to flow in a circuit. Research is under way and advances are being made in many areas of battery technology. Advanced battery technology is therefore being tested or deployed around the world. Batteries have gained in significance because of the increasing need to store electrical energy. While the capacity to generate electrical energy is important, so is the ability to store it for extended periods of time when generation is not available, particularly for applications that need to be operated independently from a power grid. It should be noted that batteries on their own can only be used to store direct current (DC) power, and not alternating current (AC) power.

Batteries are commonly classified according to various criteria: chemical process used and composition; size; form factor; application; and rechargeability.

For example, in mobile computing and mobile telecommunication equipment, the most common types of battery are based on lithium-ion chemistry. The use of lithium-ion batteries (LIBs) in portable electronic devices, such as mobile phones, laptop, cameras, toys, e-cigarettes, and electric and garden tools, are reported to be mainly of three main chemical compositions: 37.2% are lithium cobalt oxide (LCO), 29% lithium nickel manganese cobalt oxide (NMC) and 5.2% lithium iron phosphate (LFP) [b-Mossali].

In stationary ICT, lead-acid batteries are also used to ensure uninterrupted power supply. Nickel metal hydride and zinc-based primary batteries can be found in a limited number of appliances and accessories. Batteries have different compositions depending on their types. Lithium batteries, as mentioned in [b-ITU-T L.1221], are becoming more deployed for stationary use in both classical telecommunication installations and sites (see [b-ITU-T L.1382]), than in ICT installations. Some types can be treated in the same process, whereas others need different treatment ones.

Clauses 6.1 to 6.3 highlight the most common types of battery used in ICTs.

6.1 Primary (non-rechargeable) batteries

If the chemical reaction within it that produces electricity is not reversible, the battery is not rechargeable. Battery disposal is required once all chemical energy has been consumed in its electrical form. For example, not only zinc-based technologies, such as alkaline manganese and zinc carbon, but also lithium metal chemistry are not rechargeable.

6.2 Secondary (rechargeable) batteries

If the chemical reaction within it that produces electricity is reversible, the battery can be recharged via the input of electricity and used repeatedly. The available capacity might deteriorate over time, but this depends on the chemical system, the use and charging patterns. Examples are batteries based on lead-acid, lithium-ion, and nickel-based chemistries.

6.3 The categorization of batteries based on type and composition

Batteries vary in their composition and applications. Table 1 classifies batteries based on their rechargeability and composition.

This Recommendation uses the categorization in Table 1 for clarity.

Table 1 – Composition of batteries

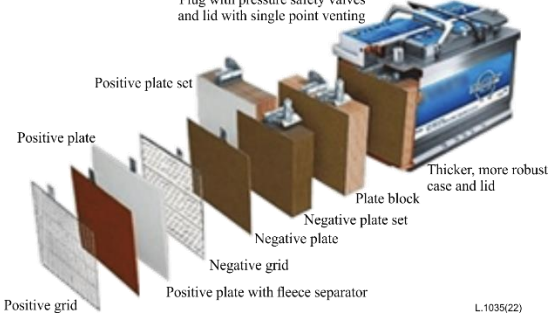
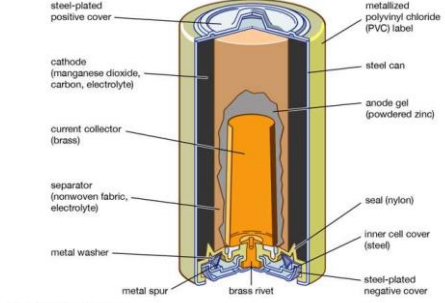
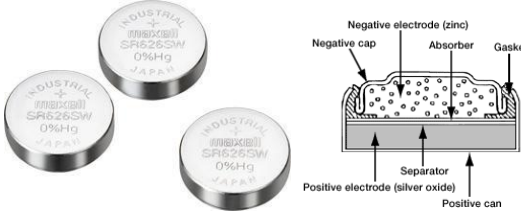
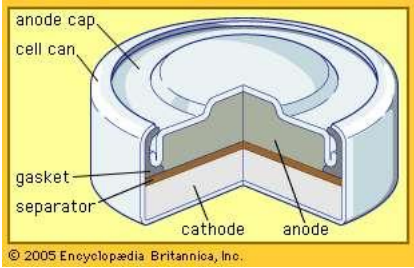
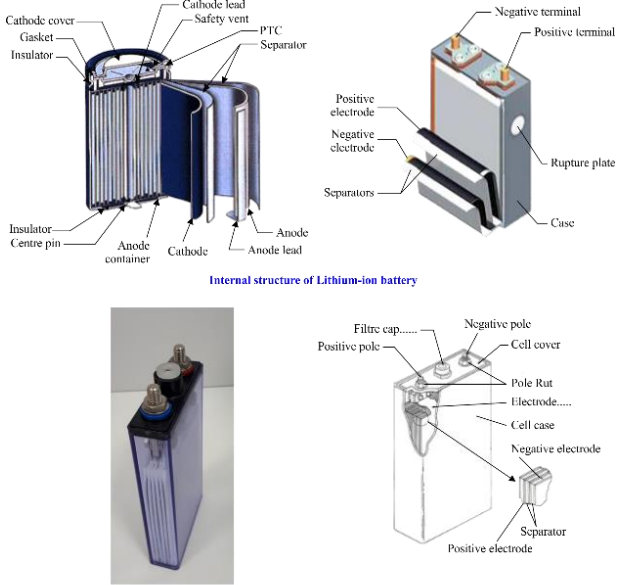
No.	Type of battery	Composition
1	Plug with pressure safety valves and lid with single point venting  Figure 1 – Content of a rechargeable lead-acid battery	Consists of toxic lead plates, and an electrolyte that is a mixture of water and sulphuric acid (H_2SO_4), plastic. Applications: Uninterruptable power supply (UPS), mobile boosting stations and other electronic setups. Hazardous substances Lead, sulphuric acid
2	 Figure 2 – Rechargeable nickel-cadmium battery	Consists of nickel(II) hydroxide ($Ni(OH)_2$) in the positive and cadmium in the negative electrode, which is a non-spillable toxic heavy metal. Applications: Telephones (corded/cordless). Hazardous substances Cadmium
3	 Figure 3 – Smart phone lithium-ion battery Figure 4 – Laptop lithium-ion battery	Consists of lithium, nickel, iron, manganese cobalt, aluminium and plastic. Applications: Smart mobile phones, laptops and other portable electrical and electronic ICT devices. Hazardous substances Cobalt oxides, depending on the battery chemistry: hydrogen fluoride, lithium-ion
4	 Figure 5 – Components of alkaline battery	Mainly consists of manganese(IV) oxide (MnO_2) in the positive electrode, zinc in the negative electrode and an alkaline electrolyte of potassium hydroxide (KOH). Applications: MP3 players, CD players, digital cameras, toys, lights, and radios

Table 1 – Composition of batteries

No.	Type of battery	Composition
	 Figure 6 – Alkaline batteries	
5	 Figure 7 – Silver-oxide batteries	This button cell battery mainly consists of silver oxide in the positive electrode, zinc in the negative electrode and an alkaline electrolyte. This electrolyte is usually sodium hydroxide (NaOH) or potassium hydroxide. Applications: Watches and calculators
6	 Figure 8 – Mercuric oxide-zinc cell battery	These non-rechargeable button cell batteries mainly consist of mercury oxide in the positive electrode, zinc in the negative electrode and an alkaline electrolyte. This electrolyte is usually sodium hydroxide or potassium hydroxide. Applications: Watches, hearing aids, cameras and calculators. Hazardous substance Mercury
7	 Figure 9 – Rechargeable lithium-ion battery	These rechargeable batteries are based on different chemical composition: lithium-ion (LCO, lithium manganese oxide (LMO), lithium nickel cobalt aluminium oxide (NCA), NMC, LFP, lithium titanium oxide (LTO; Li_2TiO_3)) Typical applications are as follows: – telecom rectifier-battery DC systems; – AC UPS; – renewable energy systems with charge-controller between generator, battery and hybrid engine generator set with battery; – power supply with back-up for fixed terminals; – peak power shaving; – Customer premises equipment back-up network in a safety extra low voltage (SELV) circuit

Source: [b-BAT/BEP Egypt] and for entry 7 the text is derived from [b-ITU-T L.1221] with some editorial modifications.

7 Steps in the environmentally sound management of waste batteries

This clause provides guidance on the following topics:

- a) the general process of collecting and managing wasted batteries;
- b) the safety requirements for handling waste batteries by recyclers and workers;
- c) the best technology for recycling waste batteries based on their types.

The purpose of the collection and recycling of batteries of various types is to recover residual metals that are toxic, scarce, of economic value or battery components (acids and plastic, in particular).

Its purpose is also to reduce the number of batteries found in household waste – even where waste sorting exists – and the public is informed and reminded that they should not dispose of them in that way.

Batteries are one source of certain heavy metals and other hazardous chemical substances that accumulate in the environment and can lead to soil contamination and water pollution.

The process of recycling waste batteries can be very polluting and can endanger human health and the environment if sound practices for the recycling of non-ferrous metals are not followed.

The environmentally sound management (ESM) of waste batteries of various types is best achieved by the following activities. These activities are divided into different stages and sub-activities within each stage, see Figure 10.

Pre-processing:

- collection and transport from collection sites to temporary storage and pre-treatment facilities;
- reception, sorting and weighing;
- storage at the recycling site.

Processing (recycling):

- manual or mechanical dismantling;
- sorting by type of equipment and storage by type of material;
- recovery and resale of materials and components;
- treatment and final disposal.

7.1 Pre-processing

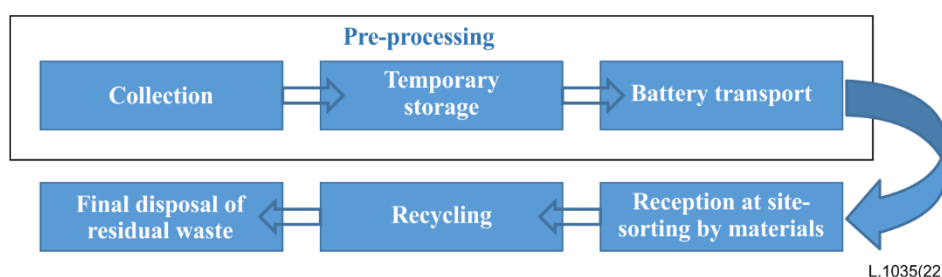


Figure 10 – Steps for the environmentally sound management of waste batteries

7.1.1 Collection and transport from collection sites to temporary storage and pre-treatment facilities

Batteries are collected in many different ways, depending on the type of batteries. Some countries have a collection and deposit system or take back procedures in place. Some countries apply extended producer responsibility policies, whereby a fee is collected for each battery sold, so that retailers and collectors can take back the batteries and deliver them to authorized recyclers. Small and family businesses also informally collect batteries Especially for WLABs and others containing hazardous