Teachers' Card

Index

EIT RawMaterials is supported by the EIT, a body of the European Union

General Introduction

This toolkit shows students the content in terms of metals, Critical Raw Materials, Rare Earths, present in EEE (Electrical and Electronic Equipment) and Batteries and Accumulators, thus in WEEE (Waste EEE) and WBA (Waste Batteries and Accumulators). The students will learn, in a playful way, about the components of electronic equipment and their characteristics, why they are important and how to handle equipment once it reaches the end of its life.

Many electronic devices in everyday use, such as smartphones, televisions, lamps, printers contain specific materials and metals that need to be recovered and recycled once the equipment stops being used. Other materials, on the other hand, are extremely hazardous and only proper disposal of EEE at end-of-life prevents them from being released into the environment. Many metals are crucial for various applications, not only in electronic devices, but also in low-carbon energy technologies (e.g. wind turbines, low-energy lighting) and sustainable mobility (e.g. hybrid car batteries).

Certain components, necessary for the creation of electronic devices, are defined as Critical Raw Materials, which are of strategic economic importance and characterised by a high supply risk. For this reason, in 2011, the European Commission drew up the first list of Critical Raw Materials (CRM), which is updated every three years. It follows that recycling is an important source of secondary raw materials that can contribute to the security of supply of Critical Raw Materials and to a more circular European economy.

Based on the last evaluation published in 2020, the latest CRM list includes 30 Critical Raw Materials.

The toolkit will enable students to

- discover the most commonly used components in everyday electronic devices;
- think about the end-of-life of such devices and learn their correct disposal to improve their handling and recycling. In this way, metals, Critical Raw Materials, Rare Earths, can be recovered as secondary raw materials.

Before using the toolkit with students, teachers can introduce the topic through the e-waste lesson in which their proper handling and recycling is addressed, which is available in **The WEEE Jungle_Lesson** and explained in the following section.

Key words:

EIT RawMaterials is supported by the EIT, a body of the European Union

WEEE (Waste Electrical and Electronic Equipment), EEE (Electrical and Electronic Equipment), WBA (Waste Batteries and Accumulators), B&A (Batteries and Accumulators), Recycling, Critical Raw Materials (CRM), Rare Earths (REE), Circular Economy, Sustainability

Extended background information

The material explained in this section is the basis and support needed to use the **MemoRAEE toolkit**.

Before using the toolkit, teachers should introduce their students to the general topic provided in the lesson **The WEEE Jungle (The WEEE Jungle_Lesson)** which focuses on WEEE and WBA.

WEEE stands for Waste Electrical and Electronic Equipment and sometimes the English term e-waste is also used.

The presentation in **The WEEE Jungle_Lesson** provides all the information needed to understand the entire value chain regarding the importance of both the proper handling and treatment of WEEE and WBA.

The lesson has the following structure:

- Introduction (slide 2)
  - what WEEE is and where it comes from EEE (slide 3) vs WEEE (slide 4)
    - classification of WEEE into different streams: R1-Cool and Climate, R2-Great Whites, R3-TV and screens, R4-Small household appliances, ICT and IT equipment, lighting equipment, R5-Light sources (e.g. fluorescent tubes) (slide 5)
    - what are B&A and WBA (slide 6 and 7)

- The WEEE and WBA system (slide 8)
  - The legislation behind WEEE (slide 9)
  - The legislation behind WBA (slide 10)
  - WEEE and its disposal (slide 11)
    - → two stories, examples of two ways, bad vs good, of disposing of a smartphone (slide 12-13)
    - → how to properly dispose of WEEE (slide 14)
    - → how to manage WBA (slide 15)
    - → Collective Schemes (slide 16)

- What can be achieved from WEEE recycling (slide 17)
  - overview on how WEEE treatment works (slide 18)
  - the issues linked to the electronic devices containing potentially harmful substances for the health and the environment (slide 19)

EIT RawMaterials is supported by the EIT, a body of the European Union

→ CFC/CH, oils, batteries, and PCB
- what is recovered from WEEE treatment (slide 20)
  → plastics, aluminium, iron, copper, and CRMs (Critical Raw Materials)
- meaning of RECOVERY / MATERIAL RECOVERY / ENERGY RECOVERY / REUSE AND RECYCLING (slide 21)
- flow chart explaining the whole chain of the WEEE treatment (slide 22)
- the thresholds to be reached by the WEEE treatment, as per Directive 2012/19/EU (slide 23)
- an example showing the shares of material recovery, energy recovery, incineration and landfill disposal obtained by the treatment of the R1 WEEE stream, i.e., C&F (slide 24)
- Treatment and recycling of WBA (slide 25)
  → portable batteries and accumulators (slide 25)
  → lithium-ion batteries (slide 26)
  → treatment risks (slide 28)

- CRMs, i.e., Critical Raw Materials in WEEE (slide 29)
  - what CRMs are (slide 30)
  - where CRMs are supplied from (slide 31)
  - the CRMs in the periodic table and a focus on the Rare Earth Elements=REEs (slide 32)
  - location of REEs deposits (slide 33)
  - the supply history of REEs (slide 34)
  - CRMs within WEEE (slide 35)

- A case study: the smartphone (slide 36)
  - the main constituents of a smartphone (slide 37)
    → casing, screen, electronics, and battery
  - SCREEN: the content of metals and other elements (slide 38)
  - ELECTRONICS and BATTERY: the content of metals and other elements (slide 39)
  - what do we get if we blend a smartphone?
    → the experiment of Plymouth University (slide 40)

It follows an explanation of the main aspects included in the lesson.

1. INTRODUCTION (slide 2-7)

It describes what are EEE=Electrical and Electronic Equipment, and, therefore, WEEE=Waste Electrical and Electronic Equipment, and their classification. EEE are equipment working thanks to electric currents and/or electromagnetic fields, while WEEE are the abovementioned EEE that have reached their end of life, turning into e-waste. WEEE are grouped in macro-categories defined by law:

- C&F → cooling and freezing equipment, i.e., refrigerators, air-conditioning systems, freezers;
- LHA → large household appliances, i.e., washing machines, dishwasher, ovens, hoods;
- TV & screens → televisions, monitors, laptops;

EIT RawMaterials is supported by the EIT, a body of the European Union

- SHA and ICT→ small household appliances, and IT and telecommunication equipment and consumer electronics, i.e. vacuum cleaners, toasters, headphones, smartphones, printers, radios, video cameras, desktop PCs;
- Lamps.

2. LEGISLATIVE FRAMEWORK (slide 9-10)

It defines the background information regulating the down measures to deal with WEEE. The most important directive is the WEEE Directive 2012/19/EU. It sets the requirements to protect the environment and the human health by preventing or reducing the adverse impacts of the generation and management of WEEE, by reducing the overall impacts of resource use, improving the efficiency and contributing to a more sustainable development. Member States shall encourage cooperation between producers and recyclers and measures to promote the design and the production of EEE, in view of facilitating re-use, dismantling and recovery of WEEE. Summarizing, the primary purposes of the EU Directive are:

- preventing the generation of WEEE;
- promoting the reuse, recycling and recovery of WEEE;
- improving, from an environmental perspective, the environmental performance of all operators involved in the life cycle of such equipment;
- reducing the use of hazardous substances in electrical and electronic equipment.

This EU Directive has been adopted by Member States with national laws, for example:

- in Italy there is the Italian Legislative Decree n. 49/2014 and related Ministerial Decrees that govern the implementation aspects of the EU Directive. The D.Lgs. 49/2014 is aimed at reducing and avoiding negative impacts related to production of EEE and management of WEEE, and it defines the Italian WEEE Clearing House (i.e., CDCRAEE) setting also the recovery rates;

As far as the legislative framework for WBAs is concerned, there is the European Directive 2006/66/EC whose primary objective is to minimise the negative environmental impact of batteries and accumulators and their waste.

In order to achieve a high level of recycling of all waste batteries and accumulators, Member States shall take the necessary measures to promote and optimise the separate collection of waste batteries and accumulators, thus preventing batteries and accumulators from being disposed of as mixed municipal waste. States must set up schemes so that spent batteries and accumulators can be deposited at collection points in the vicinity of users and can be recovered free of charge by producers.

In 2020, the European Commission launched a proposal for a regulation on batteries and accumulators and their waste to replace the historic 2006 Directive with a "more circular" approach. In this comprehensive proposal, the mandatory requirements for all batteries placed on the EU market are highlighted. The requirements will cover the use of responsibly sourced materials with limited use of hazardous substances, a minimum content of recycled

EIT RawMaterials is supported by the EIT, a body of the European Union

materials, carbon footprint, performance and durability, and labelling, as well as compliance with collection and recycling targets.

3. TWO WEEE DISPOSAL SCENARIOS (slide 12-13)

Thanks to the common issue of disposing a broken smartphone, two stories involving a young person are presented.

- The first story tells about Remo, a young guy who decides to throw away his broken smartphone in the undifferentiated bin or put it somewhere at home in a drawer. In the first case, the action implies that the smartphone will die in a landfill together with other mixed wastes, while the second action implies collecting waste/stuff unused/broken at home and forgetting them. In any scenario, for manufacturing new smartphones, in order to get new metals and raw materials, it will be necessary mining the subsurface more and more, entailing, if not correctly managed, negative effects on our planet, such as damage of the environment, pollution and contamination of water bodies and lands, and similar, and, in some cases, child labour exploitation too.

This story highlights the concept of linear economy that stands for *take-make-dispose*: *take* resources from the world, *make* products for the industry sector, and *dispose* of them when reaching their end of life. This concept stresses a lot the environment and the planet, playing a role in the constant and fast depletion of our resources.

- The second story tells about Romolo, a young guy who correctly throws away his broken smartphone, bringing it to the municipal collection point where it is collected in a dedicated bin/container, together with similar objects. From here, the WEEE management system, represented by actors named *take-back schemes* (or *compliance schemes*, i.e., ERION), take care about the logistics and the treatment of the e-waste appliances (WEEE) collected at the municipal points. These WEEE are delivered to *treatment plants* where are disassembled/crushed, complying with safety and environmental rules, in order to correctly manage the depollution and recycle the raw materials (i.e. obtaining fractions of plastics, ferrous metals, non-ferrous metals, glass and others named secondary raw materials). Afterwards, for example, the metal fractions recovered go to final treatment plants, i.e. smelters, where metals are reshaped, giving them new life and, consequently, being used in new electrical appliances. These new products can finally be bought by everyone, and also by Romolo.

This second story highlights the concept of circular economy that stands for *manufacturing-consumption & use-recycling*: *manufacturing* products using resources from the environment, *consuming/using* these products up to their end of life, and *recycling* them in order to get secondary raw materials and limit the production of waste. This results in less pollution of the environment and limits the resources consumption.

4. COMPLIANCE SCHEMES AND WEEE TREATMENT (slide 17-28)

EIT RawMaterials is supported by the EIT, a body of the European Union

This section is an overview of what are compliance schemes, i.e., household appliances recovery and recycling consortia, and how e-waste treatment works. Consortia were born by European law to handle the electronic wastes, acting for and on behalf of manufacturers. It is, in fact, Producers' responsibility the management of their electronic products turned into e-waste. The correct WEEE treatment allows to recover materials such as plastics, aluminium, iron, copper and potentially, Critical Raw Materials (CRMs). Other fractions not being recycled can be burnt into incineration plants for energy recovery or disposed of in landfills. The threshold values to be reached for each WEEE macro-category are defined by law in the EU Directive.

For example, electrical appliances falling in the 1st category have to reach:

- 85% of recovery → i.e., material and/or energy recovery;
- 80% of reuse and recycling → i.e., only material recovery.

REUSE: means any operation by which products or components that are not waste are used again for the same purpose for which they were created.

RECOVERY: means any operation whose principal result is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function.

RECYCLING: means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes and does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

The correct treatment and recycling of batteries and accumulators varies depending on the type of battery and is necessary to ensure the recovery of reusable materials and to prevent polluting components from being released into the environment. The types of treatment vary depending on the battery: ported batteries or accumulators need specific procedures, while others are suitable for lithium-ion batteries.

5. CRMs IN WEEE (slide 29-35)

This section deals with the Critical Raw Materials (CRMs) topic. These materials are non-energy and non-agricultural raw materials, defined critical by the EU Commission for two reasons: their high economic importance for the European economy/market and the high risk associated with their supply. In 2011 the Commission drafted the first list of CRMs, listing 14 materials; this list is being revised every three years. The latest version, published in 2017, is the third list counting 27 materials, a great number of which are supplied to the European Union by Countries subjected to geopolitical instability.

The Rare Earth Elements (REEs) are part of the Critical Raw Materials (REEs). The REEs are 15 elements known as "lanthanides", plus two additional elements (scandium and yttrium) for similarity of their properties. Amongst REEs, the most widespread, due to their usage in the modern electronic devices, are the first seven ones:

EIT RawMaterials is supported by the EIT, a body of the European Union

- Lanthanum-La;
- Cerium-Ce;
- Praseodymium-Pr;
- Neodymium-Nd;
- Samarium-Sm;
- Europium-Eu;
- Gadolinium-Gd.

In the 21st century, REEs have gained visibility because the public has recognized their critical and specialized properties and the fact that REEs contribute to modern technology. China dominates in production and supply of the REEs with a consequent international dependence for the majority of the world's REEs supply. Since the late 1990s, China, in fact, has provided 85-95% of the world's Rare Earth Elements. In 2010, when China had announced its intention to reduce REEs exports, it caused great concern not only in the European Union, but also in Japan and the United States, whose economies rely on REEs.

6. THE SMARTPHONE CASE STUDY (slide 36-40)

The last section addresses a specific case study, the smartphone: this device is a suitable example showing the importance of Rare Earth Elements and other Critical Raw Materials utilized in its manufacturing.

CRMs are found in the screen, in the electronics and in the battery, and each element has a specific function (slides 34 and 35 are self-explanatory). In the end, this example shows that a mobile phone, owned by everyone, can be considered as a pocket mine, a source of precious metals.

Finally, it is showed the result of an experiment made by the University of Plymouth, which is available at the following link Plymouth University experiment: this short video concludes the topic giving the quantities of metals and other materials necessary to produce a single smartphone, how many smartphones are produced in a year, and the total amount of materials used each year for producing smartphones.

All these figures can be used to reflect on the quantity of metals, either precious or rare, or even more common serves for manufacturing the year production of one of the most common and spread out electronic device that everybody owns.

Learning Outcomes

At the end of the lesson, students will be able to know

- what a WEEE (Waste Electrical and Electronic Equipment) is - electronic waste - and how it is classified;

EIT RawMaterials is supported by the EIT, a body of the European Union

- what WBA is;
- the proper management of WEEE and WBA;
- the main concepts of linear economy and circular economy;
- an overview of the treatment of WEEE and WBA;
- meaning of recovery and recycling, incineration and landfilling with reference to WEEE;
- the main aspects related to Critical Raw Materials (CRM) and Rare Earths (REE),
- the case study of the smartphone.

Key Competence European Framework

Literacy competence
S1. Ability to understand and interpret concepts, feelings, facts or opinions in oral and written form.
S2. Ability to express concepts, feelings, facts or opinion in written and oral form.
Multilingual competence
S5. Knowledge of vocabulary, grammar and language.
S7. Ability to use technical language accordingly to the field of work.
Mathematical competence and competence in science, technology and engineering
S2. Understanding of mathematical term and concept and know how to apply it.
S4. Readiness to address new problems from new areas.
S6. Ability to extract qualitative information from quantitative data
Digital competence
S1. Critical use of information technology for work
Personal, social and learning to learn competence
S3. Ability to gain process and assimilate new knowledge, skills and qualification required for career goals.
Citizen competence
S2. Ability to adapt to the changing situation, being flexible and work under pressure

United Nations' Sustainable Development Goals

The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate change, environmental degradation, peace and justice.

EIT RawMaterials is supported by the EIT, a body of the European Union

Teachers' Card

	Enable access to basic services		Equal access to global expertise
	Safe medical devices		Sustainable urbanization
✓	Access to education	✓	Responsible consumption and production
	Less hardship, more opportunities	✓	Strengthen resilience, reduce disaster impact
	Safe and affordable water		Reduce marine pollution
	Energy – the golden thread	✓	Sustainable use of terrestrial ecosystems
	Safety of workers and economic growth		Promote peaceful and inclusive societies
	Resilient infrastructure and sustainable industrialization		Better access to technology and innovation

Contents – Theoretical principles

This toolkit is a way for both students and teachers to discover the materials contained in the electronic devices (EEE-Electrical and Electronic Equipment) that are used every day, to reflect on the end-of-life of these electronic devices, and to learn the correct value chain related to the management of these devices. In this way, through the collection, logistics and treatment of WEEE and WBAs, it is possible to achieve proper recycling of waste, recover secondary raw materials contained within them, such as aluminium, copper, iron or plastics, but also to reflect on new technologies that will enable the recovery of the Critical Raw Materials and Rare Earths in the future, as presented in this toolkit.

EIT RawMaterials is supported by the EIT, a body of the European Union

Teachers' Card

The toolkit consists of:

- Teachers' Card
- Students' Card (instructions for playing with cards)
- Summary
- Cards needed to play MemoRAEE and questions (**CARDS and QUESTIONS to print**)
- Teacher's lesson slides - **The WEEE Jungle_Lesson;**

The target audience of this toolkit are students aged between 11 and 16.

- The Teachers' Card of the **toolkit**, available on the Virtual Centre of the **RM@Schools** website in the "Exploration & Mining" section.

Lab Procedure/Activity

The teacher's activity consists of:

- provide students with basic knowledge of the subject by showing the presentation explained in the **Extended background information** section and available in **_The WEEE Jungle_Lesson;**
- preparing the cards and questions **CARDS and QUESTIONS to be print**;
- The teacher must give the students instructions on how to play, available in the **Students' Card_MemoRAEE** file;
- Students can play the cards by interacting with the teacher.

Learning Pathway

- **Step 1- Time & Activity: 1.30 h**: Teachers introduce the topic of the activity through a short PowerPoint presentation, available in **_The WEEE Jungle_Lesson**. Teachers have an outline of the lesson content in this document, under **Extended background information**.
- **Step 2 - Time& Activity: 20 minutes**: Students together with teachers prepare the material by following the steps below:

  - print the cards contained in **CARDS_to print**;

  - print the questions for the teacher, contained in **QUESTIONS_to be printed**, to be played during the MemoRAEE game;

  - collect the cards in one or more packs and shuffle them to obtain the card mix;

EIT RawMaterials is supported by the EIT, a body of the European Union

- **Step 3 - Time& Activity: 1 h**: Students divide into teams of 4 or 5 students to start the game.

Description of Student's Cards

The Students' Card is the material that can be printed and distributed directly to the students prior to the activity.

The Students' Card consists of two documents:

- The **Students' Card_MemoRAEE** document containing instructions for students on how to use the toolkit;
- The cards and quiz questions, attached to the file **CARDS_to_print** and **QUESTIONS_to_print**.

Students can construct the cards individually or in groups or with the help of the teacher, following the instructions in **Students' Card_MemoRAEE**.

Sources

- EUROPEAN DIRECTIVE 2012/19/EU ON WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE) → WEEE EU Directive
- EUROPEAN DIRECTIVE 2006/66/EC ON WASTE BATTERIES AND ACCUMULATORS →European Directive
- PROPOSAL AF NEW EUROPEAN DIRECTIVE ON WASTE BATTERIES AND ACCUMULATORS →Proposal European Directive
- ERION, SUSTAINABILITY REPORT 2020 → ERION SUSTAINABILITY REPORT 2020
- JRC SCIENCE FOR POLICY REPORT: CRITICAL RAW MATERIALS AND THE CIRCULAR ECONOMY, 2017→ Study of the JRC on CRMs 2017
- EUROPEAN COMMISSION: CRITICAL RAW MATERIALS→ EU Portal on CRMs
- EUROPEAN COMMISSION: STUDY ON THE REVIEW OF THE LIST OF CRITICAL RAW MATERIALS. CRITICAL RAW MATERIALS FACTSHEETS→ CRMs Fact Sheets
- USGS, THE RARE-EARTH ELEMENTS – VITAL TO MODERN TECHNOLOGIES AND LIFESTYLES, 2014
  → USGS REEs
- GEOLOGY.COM: RARE EARTH ELEMENTS AND THEIR USAGE→ REEs and their usage
- UNIVERSITY OF PLYMOUTH: AN EXPERIMENT. SCIENTISTS USE A BLENDER TO REVEAL WHAT'S IN OUR SMARTPHONES

EIT RawMaterials is supported by the EIT, a body of the European Union

→ Experiment of the University of Plymouth
→ Youtube video about the experiment

- NOVA ELEMENTS WEBSTORE→ Set of Rare Earth Elements

EIT RawMaterials is supported by the EIT, a body of the European Union