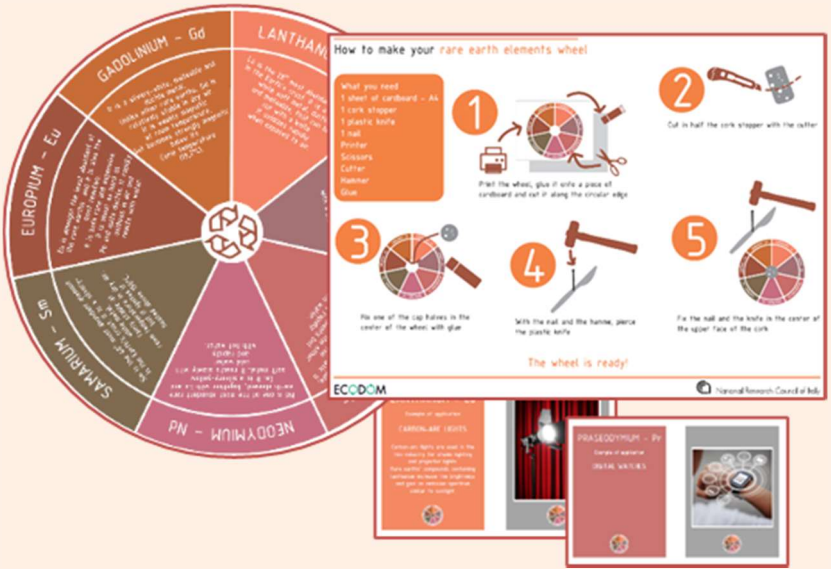
Teachers' Card

THE RARE EARTH ELEMENTS WHEEL



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General Introduction

This toolkit has the objective of bringing students' awareness to the importance of the content of metals, particularly the Rare Earth Elements, within EEE (Electrical and Electronic Equipment), and therefore, WEEE (Waste Electrical and Electronic Equipment). In a gameful way students will discover 7 Rare Earth Elements, which are "critical" metals, and learn their main characteristics and in which electronic appliance can be found.

A lot of electronic devices of daily usage, such as smartphones, computers or modern flat TVs, contain special metals named Rare Earth Elements (REEs). These metals are very important for their strategic applications, not only in the electronic devices, but also in the low-carbon energy technologies (e.g., wind turbines, energy-efficient lighting) and in the sustainable mobility (e.g., batteries of hybrid cars).

For this reason, in 2011, the European Commission drafted the first List of Critical Raw Materials (CRMs), being updated every three years.

Based on the last assessment published in 2017, the latest CRMs list includes 27 raw materials, comprising non-energy and non-agricultural raw materials. Their overall importance is related to both (i) high economic importance for the European Union and (ii) high risk of supply disruption. It follows that recycling is an important source of secondary raw materials, that can contribute to the security of raw materials supply and to advancing towards a more circular EU economy.

The toolkit will allow students:

- to discover the most utilized Rare Earth Elements in daily electronic devices;
- to think about the end of life of such devices and learn their properly disposal for a correct management and recycling. In this way, the Rare Earth Elements, together with other metals, can be recovered as secondary raw materials.

Before using this toolkit with students, teachers have to introduce the topic of the toolkit itself, giving a lesson on electronic wastes, their correct management and how recycling them, which is available in ***Appendix 1 – The WEEE Jungle Lesson*** and explained in the following section.

The target of this toolkit are students aged between 13-19 years old.

Key words:

WEEE (Waste Electrical and Electronic Equipment), EEE (Electrical and Electronic Equipment), Recycling, Critical Raw Materials (CRMs), Rare Earth Elements (REEs), Circular Economy

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Extended background information

The material explained in this section is the rationale behind and the necessary support for the toolkit **The Rare Earth Elements Wheel**.

Before using the toolkit, teachers are recommended to introduce the general topic to the students, showing **The WEEE Jungle Lesson** (***Appendix 1 – The WEEE Jungle Lesson***) whose focus is on WEEE topic.

WEEE is the word standing for waste from electrical and electronic equipment → also referred to as e-waste, and within WEEE there are the Rare Earth Elements → whose seven of them are part of the toolkit The Rare Earth Elements Wheel.

The presentation in ***Appendix 1 – The WEEE Jungle Lesson*** gives all the necessary information in order to understand the whole value chain concerning the importance of both the correct management and the treatment of WEEE.

The lesson has the following structure:

- Introduction (slide 2)
  - what WEEE are and where they come from
    → EEE (slide 3) vs WEEE (slide 4)
  - classification of WEEE in different streams: C&F, LHA, TV & Screens, SHA, Lamps (slide 5)
- The WEEE system (slide 6)
  - the legislation behind WEEE (slide 7)
  - WEEE and their disposal (slide 8)
    → two stories, the bad examples vs the good one, on different ways of disposing of a broken smartphone (slide 9-10)
    → how to properly dispose of WEEE (slide 11)
    → Compliance Schemes (slide 12)
- What can be achieved from WEEE recycling (slide 13)
  - overview on how WEEE treatment works (slide 14)
  - the issues linked to the electronic devices containing potentially harmful substances for the health and the environment (slide 15)
    → CFC/CH, oils, batteries, and PCB
  - what is recovered from WEEE treatment (slide 16)
    → plastics, aluminium, iron, copper, and CRMs (Critical Raw Materials)
  - meaning of RECOVERY / MATERIAL RECOVERY / ENERGY RECOVERY / REUSE AND RECYCLING (slide 17)
  - flow chart explaining the whole chain of the WEEE treatment (slide 18)
  - the thresholds to be reached by the WEEE treatment, as per Directive 2012/19/EU (slide 19)

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- 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 20)
- PRACTISING → EXERCISE TIME (slide 21-24)
  → at this moment of the lesson, it is possible to play with real numbers, in order to find out the figures in weight and percentage of what comes out from the treatment of two different streams of WEEE (R1=cooling and freezing equipment and R3=screens)

- CRMs, i.e., Critical Raw Materials in WEEE (slide 25)
  - what CRMs are (slide 26)
  - where CRMs are supplied from (slide 27)
  - the CRMs in the periodic table and a focus on the Rare Earth Elements=REEs (slide 28)
  - location of REEs deposits (slide 29)
  - the supply history of REEs (slide 30)
  - CRMs within WEEE (slide 31)

- A case study: the smartphone (slide 32)
  - the main constituents of a smartphone (slide 33)
    → casing, screen, electronics, and battery
  - SCREEN: the content of metals and other elements (slide 34)
  - ELECTRONICS and BATTERY: the content of metals and other elements (slide 35)
  - what do we get if we blend a smartphone?
    → the experiment of Plymouth University (slide 36)

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

1. INTRODUCTION (slide 2-5)

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;
- 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 7)

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;
- in Greece there is the Decision 133480 that is about the rules, terms, and conditions for the alternative management of WEEE, in compliance with the European Directive, and the Ministerial Decision 23675/651/E.103 that transposes the European Directive into the Greek legislation.

3. TWO WEEE DISPOSAL SCENARIOS (slide 9-10)

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

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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 12-20)

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.

5. EXERCISE SESSION (slide 21-24)

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Through simple math calculations, starting from material fractions obtained by the treatment of two different categories of WEEE (R1 → Cooling and freezing equipment and R3 → Screens) students can answer simple questions/statements made by different fictional WEEE actors, in order to get the percentages of materials recovered, energy recovered, incineration and landfill disposal.

The final purpose of the activity is getting handy with this matter and compare the output of treatment between two different groups of electronic waste.

The text of the exercise is given in documents ***Appendix 2.1 – Exercise activity on R1 stream*** *and* ***Appendix 2.2 – Exercise activity on R3 stream***, and the solutions are in slide 23 and 24, respectively.

To facilitate students, a blank table as the one showed below can be provided, to allow them to write down the answers (see ***Appendix 3 – Blank tables*** file).

R1 STREAM			Weight [kg]				Percentages [%]			
Components	Total weight [kg]		Material Recovery	Energy Recovery	Incineration	Landfill disposal	Material Recovery	Energy Recovery	Incineration	Landfill disposal
Aluminum	1,148,166	of which:								
Other metals	97,927	of which:								
CFC/HC	225,557	of which:								
Capacitors	8,267	of which:								
Wood	143,522	of which:								
Oils	132,351	of which:								
Plastics	5,484,440	of which:								
Polyurethane	5,121,150	of which:								
Copper	856,712	of which:								
Glass	437,920	of which:								
Non-hazardous wastes	1,113,831	of which:								
Ferrous metals	22,373,682	of which:								
Hazardous wastes	11,833	of which:								
TOTAL	**37,155,358**	of which:								

For example, ***Appendix 2.1 – Exercise activity on R1 stream*** document, which refers to the output of the treatment of cooling and freezing equipment, includes the following material:

- at page 1 there is the table with the outputs of the treatment process → all fractions of material are expressed in kilos;

Components	Total (kg)
Aluminum	1,148,166
Other metals	97,927
CFC/HC	225,557
Capacitors	8,267
Wood	143,522
Ferrous metals	22,373,682
Oils	132,351
Plastics	5,484,440
Polyurethane	5,121,150
Copper	856,712
Non-hazardous wastes	1,113,831
Hazardous wastes	11,833
Glass	437,920
Total	37,155,358

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- then, there are 16 pages explaining simple requests/statements to be given to students to find out material or energy recovery, incineration, and landfill disposal rates. Students can work in small groups.
  At page 2, the actor *Aluminium Smelter S.A.* states that 100 % of the aluminium received was processed to produce new bars.
  ANSWER: this means that, going back to the table at page 1, we look for the aluminium fraction, and we find that the whole output of the treatment plant, **1,148,166 kg**, was reused to produce new products → this is the expression of **material recovery**. Dividing the result by the total output of the treatment process, we obtain the corresponding percentage: 1,148,166 kg / 37,155,358 kg x100 = **3.1 %**.

Cooling and freezing R1

Aluminum Smelter S.A.

Dear ESEE Education,

Hereby it is stated that 100% of the aluminum we received from you was processed for the production of aluminum bars.

Best Regards

/CEO

Aluminum Smelter S.A.

At page 12, the actor *Polyurethane and Plastics S.A.* states the following:

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Cooling and freezing R1

Polyurethane and Plastics S.A.

Dear ESEE Education,

We hereby declare that we received 799,004 kg of polyurethane.

This polyurethane has been processed in our plant, producing 682,621 kg of scrap.

The remaining material has been recovered producing an absorbing system for oils that has been put on the market and sold to car repair shops.

Best Regards

/CEO

Polyurethane and Plastics S.A.

ANSWER: **682,621 kg** of polyurethane are scraps, meaning that they will go to **landfill disposal** (in percentage is 682,621 kg / 37,155,358 kg x100 = **1.84 %**). The remaining quantity, indeed, was reused to produce an absorbing system → 799,004 kg – 682,621 kg = **116,383 kg** is the fraction that went to **material recovery** (and in percentage is 116,383 kg / 37,155,358 kg x100 = **0.31 %**).

- Once all questions/statements are solved, the whole table will be completed, and it is possible to make general observations on the results.

6. CRMs IN WEEE (slide 25-31)

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:

- Lanthanum-La;
- Cerium-Ce;
- Praseodymium-Pr;
- Neodymium-Nd;

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- 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.

7. THE SMARTPHONE CASE STUDY (slide 32-36)

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.

All supporting materials abovementioned are available in the following Appendixes:

Appendix 1 – The WEEE Jungle Lesson

Appendix 2.1 – Exercise activity on R1 stream

Appendix 2.2 – Exercise activity on R3 stream

Appendix 3 – Blank tables

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Learning Outcomes

By the end of the lesson the students will have learnt:

- what are WEEE (Waste Electrical and Electronic Equipment), i.e., electronic waste, and how are classified;
- the correct WEEE management;
- the main concepts of linear and circular economy;
- an overview of the WEEE treatment;
- meaning of recovery and recycling, incineration and landfill disposal referred to WEEE;
- the main aspects related to Critical Raw Materials (what they are, where they come from, and the differences between virgin raw materials and secondary raw materials), and CRMs within WEEE;
- a focus on a family of CRMs, i.e., the Rare Earth Elements (REEs) to which is related The Rare Earth Elements Wheel toolkit;
- the case study on 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
S3. Ability to interpret the world and relate to others
S4. Ability to interact in an appropriate and creative way in any situation
Multilingual 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 oral and written form
S3. Ability to interpret the world and relate to others
S4. Ability to interact in an appropriate and creative way in any situation
S5. Knowledge of vocabulary, grammar and language
S6. Appreciation of cultural diversity
S7. Ability to use technical language accordingly to the field of work
Mathematical competence and competence in science, technology and engineering
S1. Ability to use constructed thinking in order to solve a problem in every situation
S2. Understanding of mathematical term and concept and know how to apply it

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S4. Readiness to address new problems from new areas
S5. Capacity for quantitative thinking
S6. Ability to extract qualitative information from quantitative data
Digital competence
S2. Basic skills in ICT
S3. Understanding the role, opportunity and risks related to ICT in everyday life
Personal, social and learning to learn competence
S1. Ability to pursue and persist in different kinds of learning
S2. Identifying available opportunities
S3. Ability to gain process and assimilate new knowledge, skills and qualification required for career goals
Citizen competence
S1. Ability to effective interaction with other people
S2. Ability to adapt to the changing situation, being flexible and work under pressure
S3. Ability to work effectively and collaborate with other team members
Entrepreneurship competence
S1. Awareness of local, national, European culture heritage and their place in the world
S2. Basic knowledge of contemporary culture
S3. Understanding of cultural diversity
Cultural awareness and expression competence
S1. Ability to turn idea into action
S2. Creativity/innovation
S3. Ability to plan and manage tasks
S4. Independence, Motivation and Determination

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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.

The goals linked to this activity are:

	1 NO POVERTY, 2 ZERO HUNGER — Enable access to basic services		10 REDUCED INEQUALITIES — Equal access to global expertise
	3 GOOD HEALTH AND WELL-BEING — Safe medical devices		11 SUSTAINABLE CITIES AND COMMUNITIES — Sustainable urbanization
✓	4 QUALITY EDUCATION — Access to education	✓	12 RESPONSIBLE CONSUMPTION AND PRODUCTION — Responsible consumption and production
	5 GENDER EQUALITY — Less hardship, more opportunities		13 CLIMATE ACTION — Strengthen resilience, reduce disaster impact
	6 CLEAN WATER AND SANITATION — Safe and affordable water		14 LIFE BELOW WATER — Reduce marine pollution
	7 AFFORDABLE AND CLEAN ENERGY — Energy – the golden thread		15 LIFE ON LAND — Sustainable use of terrestrial ecosystems
	8 DECENT WORK AND ECONOMIC GROWTH — Safety of workers and economic growth		16 PEACE, JUSTICE AND STRONG INSTITUTIONS — Promote peaceful and inclusive societies
✓	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE — Resilient infrastructure and sustainable industrialization	✓	17 PARTNERSHIPS FOR THE GOALS — Better access to technology and innovation

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Contents – Theoretical principles

This toolkit is a way for students and teachers, on one hand, to discover the most utilized Rare Earth Elements (REEs) within the electronic devices (i.e., EEE-Electrical and Electronic Equipment) that are used every day, and, on the other hand, to reflect on the end of life of such electronic devices, learning also the correct value chain for the management of these equipment. In this way, thanks to the collection, logistics and treatment of WEEE, it is possible to perform a correct recycling of WEEE and to recover the secondary raw materials within them, such as aluminium, copper, iron or plastics, but also to give the way to establish new technologies for a future recovery of Critical Raw Materials, such as the Rare Earth Elements that compose this toolkit.

The toolkit is made of two packages:

- the first package is composed of the instructions to follow to make the wheel and the file **The wheel_to be printed** where there is the wheel to be printed
  → **Students' Card_Module 1_THE RARE EARTH ELEMENTS WHEEL**
- the second package consists of seven cards needed to play with the wheel
  → **Cards_to be printed**

The target of this toolkit are students aged between 13-19 years old.

Students can build by their own the wheel, following the instructions given in ***Students'*** **Card_Module 1_THE RARE EARTH ELEMENTS WHEEL,** printing and cutting the wheel contained in **The wheel_to be printed.**

Then, students can play with the wheel in small groups, reading what comes out rotating the knife/pointer on the wheel and guessing in which electrical appliance is contained that Rare Earth Element amongst the cards showed by the teacher.

Additionally, the effectiveness of this toolkit can be strengthened by using other materials such as:

- the *Teacher Card* of the ***RawMatCards toolkit***, available on the Virtual Center of RM@Schools website, under the section "Exploration & Mining".

Activity

The activity of the teacher consists in:

- preparing the learning background of the students, showing the presentation explained in section **Extended background information** and available in ***Appendix 1 – The WEEE Jungle Lesson***;
- preparing the 7 cards associated to the wheel of the toolkit (***Cards_to be printed***);

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- Finally, the teacher has to give to students the instructions to build the wheel, available in the ***Students' Card_Module 1_THE RARE EARTH ELEMENTS WHEEL*** file;
- Students can also play with the wheel through interactions with their teachers.

Learning Pathway

Step 1- Time & Activity*: i.e.* 1,30 h - Teachers do a short introduction with the PowerPoint presentation available in ***Appendix 1 – The WEEE Jungle Lesson***. Teachers can find the structure of the contents of the lesson in this document, in **Extended background information**. During the lesson teachers do the exercises reported, related to WEEE recycling and disposal (support materials ***Appendix 2.1 – Exercise activity on R1 stream***, ***Appendix 2.2 – Exercise activity on R3 stream***, ***Appendix 3 – Blank tables***).

Step 2 – Time & Activity*: i.e.,* 30 minutes - Students are divided into groups (preferably the number of students in one group is 3-4). Each group has to prepare its wheel following these steps:

- print the wheel contained in ***The wheel_to be printed***, glue it onto a piece of cardboard and cut it along the circular edge;
- cut in half the cork stopper with the cutter;
- fix one of the cap halves in the middle of the wheel with the glue;
- with the nail and the hammer, pierce the plastic knife/pointer;
- fix the nail and the knife/rotating pointer in the middle of the upper face of the cork.

While students are preparing the wheel, teachers have to prepare the cards, cutting them and gluing the element with the corresponding picture.

Step 3 – Time& Activity*: i.e.,* 1 h – In each group, one student per time is asked to launch the rotation of the knife/pointer and read out the description of the selected Rare Earth Element. Then, the teacher shows to the group the different cards, asking the student who run the wheel, helped by his/her classmates, to guess in which electrical appliance is contained that Rare Earth Element, considering its characteristics. Teacher, using the *Teacher Fact Sheets*, can provide more information about the Rare Earth Element selected.

Evaluation

Below some questions are proposed: teachers can propose these questions at the end of the activity, in order to verify the learning of the key concepts.
Correct answers are also reported.

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1. **What are WEEE?**
   They are Waste Electrical and Electronic Equipment.
2. **How many Rare Earth Elements (REEs) exist?**
   The REEs are 15 elements known as "lanthanides", plus two additional elements (scandium and yttrium).
3. **What are CRMs?**
   CRMs stand for Critical Raw Materials.
4. **Who is the subject responsible for the correct WEEE management?**
   Producers who put on the market electronic devices.
5. **Which is the Italian Legislative Decree acknowledging the European WEEE Directive?**
   In Italy there is the Italian Legislative Decree n. 49/2014 and related Ministerial Decrees that acknowledge the EU WEEE Directive.
6. **What is the name for any operation by which products or components that are not waste are used again for the same purpose for which they were created?**
   The answer is REUSE.
7. **What kind of equipment do the categories R1 and R3 represent?**
   R1 stands for Cooling and Freezing equipment while R3 stands for Screens.
8. **Where can we find CRMs?**
   CRMs can be found in the screens, in the electronics and in the batteries.
9. **Which is the country that dominates the production and supply of REEs?**
   China dominates the production and supply of the REEs with a consequent international dependence for the majority of the world's REEs supply.
10. **How would you outline the main phases of the circular economy?**
    Circular economy stands for *manufacturing-consumption & use-recycling.*

Description of Students' Card

Students' Card is materials that can be printed and directly distributed to students before the activity.

Students' Card is composed of two documents:

- The document **Students' Card_Module 1_THE RARE EARTH ELEMENTS WHEEL** containing the instructions for students on how to build the wheel;
- The wheel, attached to the file ***The wheel_to be printed.***

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Students can build the wheel of Rare Earth Elements individually or in groups, following the instructions in the ***Students' Card_Module 1_THE RARE EARTH ELEMENTS WHEEL,*** printing and cutting the wheel in an A4 or A3 format, gluing it on a support (i.e. cardboard).

Teachers have to print and cut the linked cards.

When the wheel and the cards are ready, students can play with the wheel in small groups, reading what comes out rotating the knife on the wheel and guessing in which cards of the teacher, representing 7 different electrical appliances, is contained the specific Rare Earth Element.

Sources

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- USGS, THE RARE-EARTH ELEMENTS – VITAL TO MODERN TECHNOLOGIES AND LIFESTYLES, 2014 → USGS REEs
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- UNIVERSITY OF PLYMOUTH: AN EXPERIMENT. SCIENTISTS USE A BLENDER TO REVEAL WHAT'S IN OUR SMARTPHONES
  → Experiment of the University of Plymouth
  → Youtube video about the experiment
- NOVA ELEMENTS WEBSTORE → Set of Rare Earth Elements

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