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E-Mining@School CASE STUDY

Circular economy and E-waste management

INTRODUCTION

This work is aimed at raising awareness about a problem that urgently needs attention: a more efficient management of electronic waste (E-waste) that is created at an exponential rate due the fast expansion of new technologies. Rapid changes in technology, media (tapes, software, MP3), falling prices, and planned obsolescence are producing a fast-growing surplus of E-waste around the world.

Technical solutions are available, but in most cases legal frameworks, separate collection systems, logistics, and other services strongly need implementation.

Electronic waste includes discarded electrical or electronic devices (Waste Electrical and Electronic Equipment, WEEE). Used electronics which are destined for reuse, resale, conditioning, recycling, or disposal are also considered E-waste.

A part from discarding precious materials, informal processing of E-waste or dumping can lead to adverse human health effects and environmental pollution. Great care must be taken to avoid unsafe exposure in recycling operations and leaking of materials such as heavy metals from landfills and incinerator ashes. Properly disposing of or reusing electronics can help prevent health problems, reduce greenhouse-gas emissions, and create jobs. Reuse and refurbishing offer a more environmentally friendly and socially conscious alternative to downcycling processes.

Unfortunately, there is still little awareness about the variety and the increasing amounts of metals required by new technologies (Fig.1).

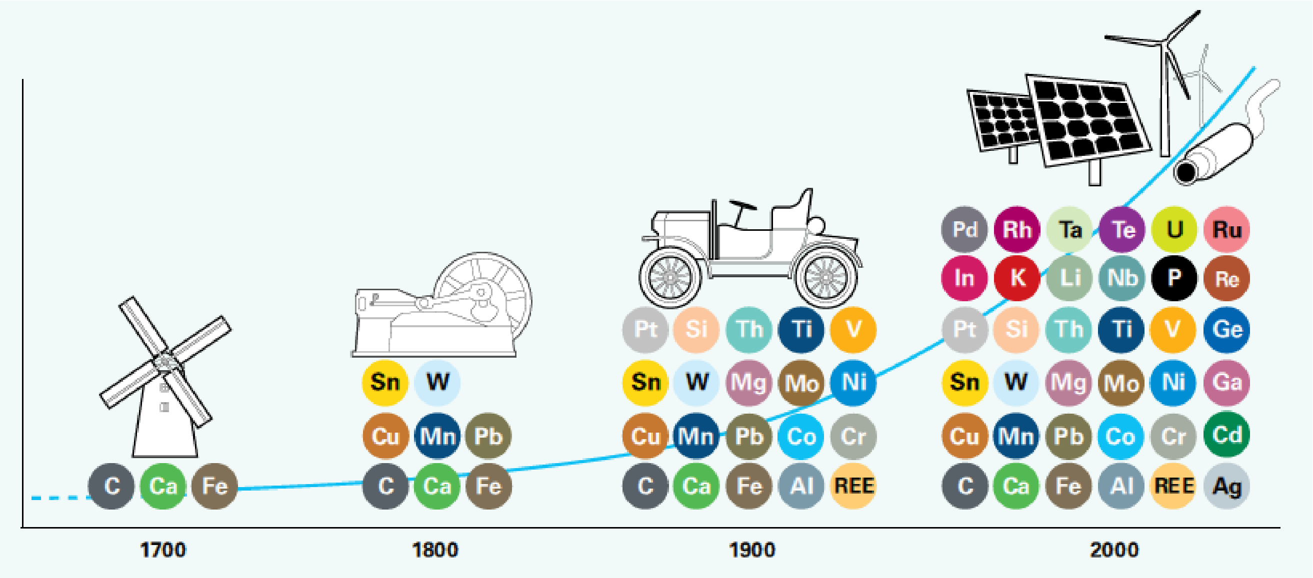


Figure 1. Timeline of metals required by technological advances

Furthermore, the recovery of several metals is becoming more and more strategic in view of their reduced supply in a more or less distant future (Fig.2). Therefore the future challenge will be the transformation of discarded materials in valuable resources.

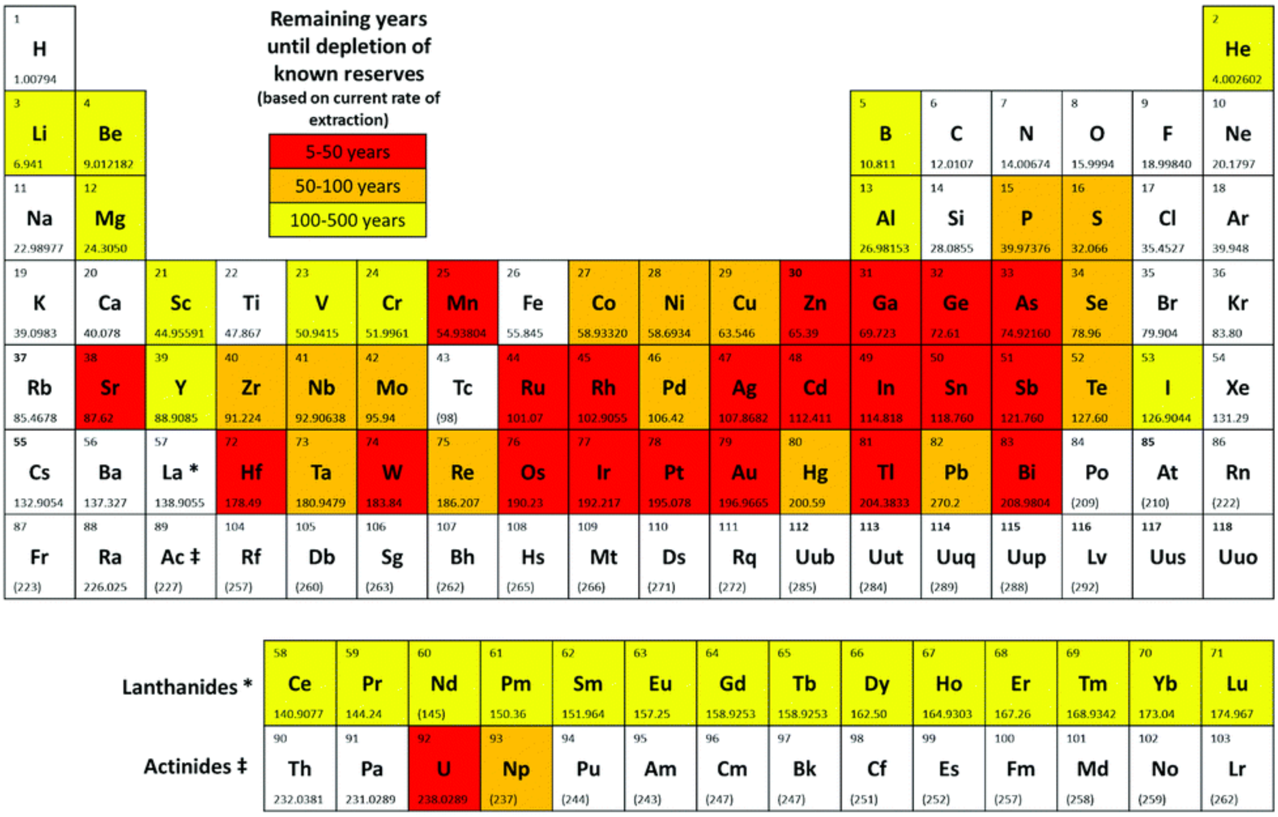


Figure 2. Expected remaining years until depletion of metals[1]

E-WASTE –STATE OF THE ART

According to UNEP[2] each year about 42 metric million tons of E-waste are produced in the world, for a value of intrinsic material estimated to be 48 billion euro.

In EU, historically, WEEE increases by 16-28% every five years, which is three times faster than average annual municipal solid waste generation. It is estimated that the total amount of WEEE generation in EU ranges from 5 to 7 million tons per annum or about 14-15 kg per capita, and is expected to grow at a rate of 3-5% per year.

CLASSIFICATION OF WEEE

European and Italian classifications of WEEE

EU directives identifies ten categories of electrical and electronic equipment:
1. Large household appliances
2. Small household appliances
3. IT and telecommunications equipment
4. Consumer equipment
5. Lighting equipment
6. Electrical and electronic tools (except large-scale stationary industrial tools)
7. Toys, leisure and sports equipment
8. Medical devices (except all implanted and infected products)

[1] from A.J. Hunt, A.S. Matharu, A.H. King, J.H. Clark, The importance of elemental sustainability and critical element recovery, Green Chem., 2015, 17, 1949-1950

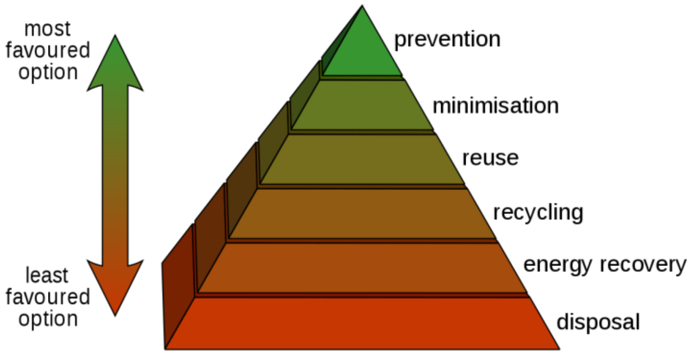
[2] http://web.unep.org/ietc/sites/unep.org.ietc/files/E-Waste-Summary-FINAL-%20WEB.pdf

9. Monitoring and control instruments
10. Automatic dispensers

In Italy WEEE are called RAEE (Rifiuti di Apparecchiature Elettriche ed Elettroniche) and their collection is differentiated according to the type of production and the use of EEE, and grouped according to the treatment necessary to recover the materials, and to prevent hazards in this operation.
The recovery treatment starts with the removal and proper disposal of the components containing materials dangerous to health or environment, followed by recovery of all reusable components and recyclable materials, and ends with the correct disposal of non-recyclable materials.
The supply of WEEE can be carried out by consumers at collection centers set up by the municipalities, or by withdrawal by retailers during the purchase of new products.
In Italy, separated collection of RAEE is regulated and organized according to five typological groups (Fig.3):

Figure 3. Italian classification of RAEE

In the sector of separated recovery, WEEE are still too neglected with respect to other materials (paper, plastic, glass, …) and it is urgent to invert the so-called pyramid of sustainability from



to

The research undertaken by the Countering WEEE Illegal Trade (CWIT) project[3], funded by European Commission, found that in Europe, only 35% (3.3 million tons) of all the e-waste discarded in 2012, ended up in officially collection and recycling systems. The other 65% (6.15 million tons) was either:

- exported (1.5 million tons)
- recycled under non-compliant conditions in Europe (3.15 million tons)
- scavenged for valuable parts (750,000 tons)
- or simply thrown in waste bins (750,000 tons).

E-WASTE AND CRITICAL RAW MATERIALS (CRM)

Raw materials are essential for the production of a broad range of goods and applications used in everyday life. The accelerating technological innovation and the rapid growth of emerging economies have led to a steadily increasing demand for a great numbers of metals and minerals. They are crucial for EU's growth and competitiveness, but for most of them Europe strongly depends on import from outer areas.
To address the growing concern of securing valuable raw materials for the EU economy, the Commission launched the European Raw Materials Initiative in 2008. In 2017 a review[4] identified 27 CRMs for an assessment of 61 raw materials (Fig.4).

Critical Raw Materials			
Antimony	Fluorspar	LREEs	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs	PGMs	Vanadium
Coking coal	Indium	Phosphate rock	

Figure 4: List of Critical Raw Materials to the EU (HREEs= Heavy Rare Earth Elements, LREEs= Light Rare Earth Elements, PGMs= Platinum Group Metals)

[3] https://www.cwitproject.eu/wp-content/uploads/2015/09/CWIT-Final-Report.pdf
[4] European Commission, Report on Critical Raw Materials and the Circular Economy, 16/01/2018

CRITERIA TO INDIVIDUATE CRITICAL RAW MATERIALS

Although the most obvious reason why a material can become difficult to retrieve is its scarcity on the earth's crust, the European Union has detected other important factors than can become even more important if considered all together. In the previous reviews EU assessed the criticality on the basis of the combination of two factors: economic importance and supply risk.
In the last one other more complex factors have been taken into account:

- Existence of critical points in the supply chain (mining/extracting and processing/refining)
- Import reliance and a trade-related parameters based on export restrictions and the EU trade agreements
- Actual sourcing of the material specifically to the EU (domestic production plus imports), not only the global supply in general (Fig.5)

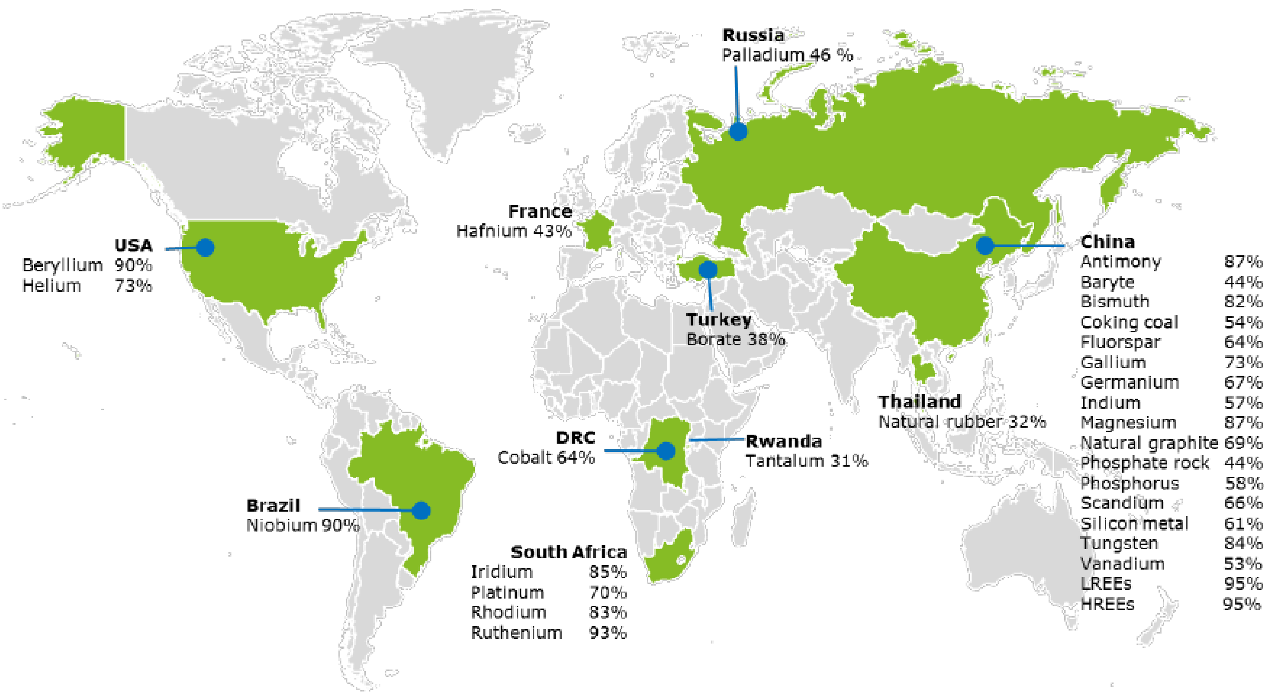


Figure 5: Contribution of primary global suppliers of critical raw materials, average from 2010-2014

- Possibility of substitution connected to supply risk and economic importance
- Specific allocation of raw materials to the relevant end-use applications and corresponding manufacturing sectors.

The recycling rate and efficiency should also be taken into account, because for several critical materials is very low or quite absent.
In Figure 6 (taken from the same document) are reported the End-of-life recycling input rates (EOL-RIR) in the EU-28 for a number of raw materials.
It shows that even for materials with a relatively high overall recycling rate, recycling’s contribution is not enough to meet the materials demand. In other cases, functional recycling is not economically feasible or it is technically difficult for small size objects and components.

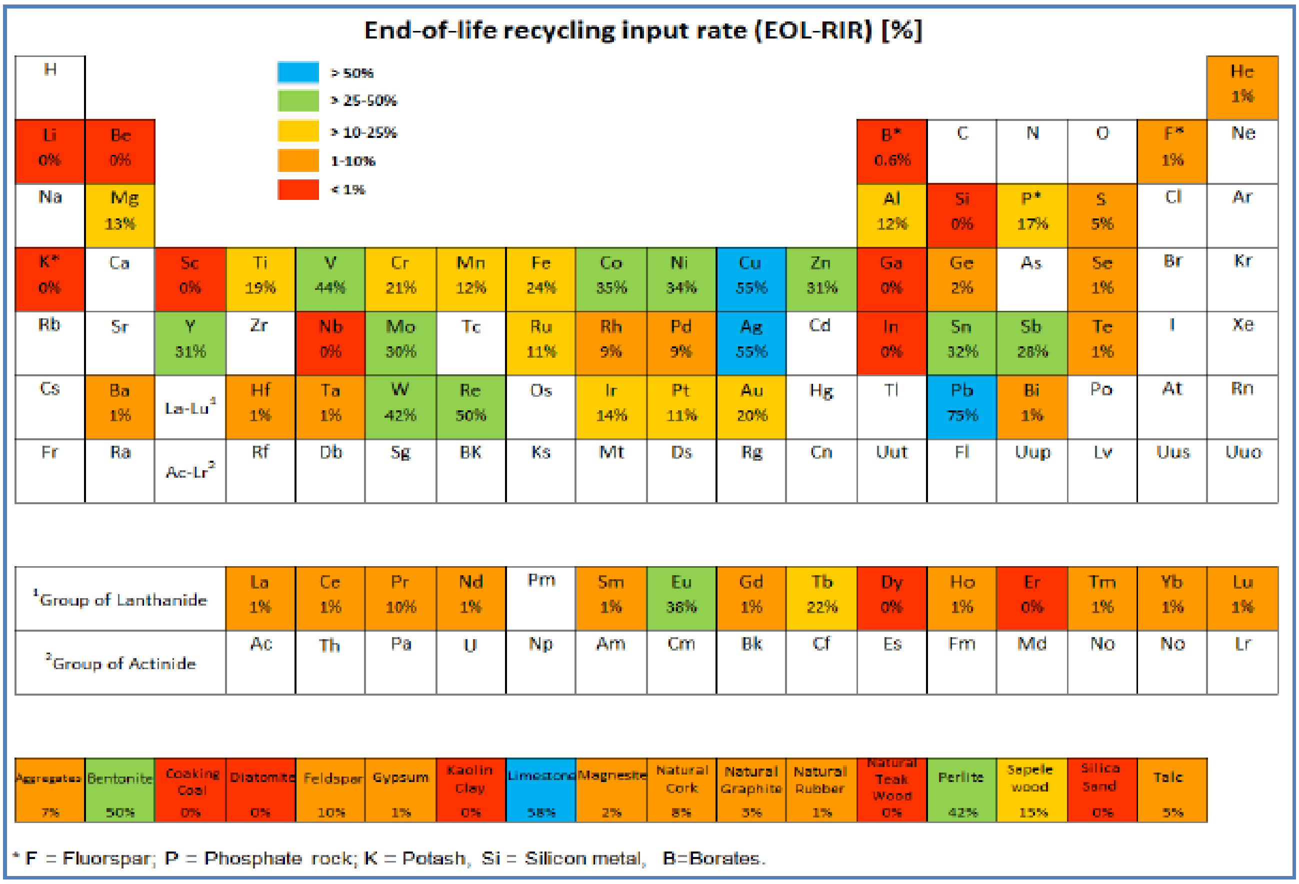


Figure 6. End-of-life recycling input rates (EOL-RIR) in the EU-28 for a number of raw materials (CRMs and non-CRMs).

ETHICAL ASPECTS

People should also be aware of the ethical aspects linked to a better management of natural resources.
First of all, there are *environmental problems* due to:

- dumping of WEEEs with release of toxic chemicals in land and in groundwater
- leaching of chemicals and release of corrosive and greenhouse gases during extraction and processing of metals and ores from mines
- illegal recovery of precious metals from WEEE in developing countries with abysmal working conditions regardless of elementary safety rules, child and women underpaid labor, and release of toxic chemicals and fumes in the environment during work-up and after crude extraction of the most lucrative metals.

Among critical materials there also several "*conflict minerals/metals*", that are natural resources extracted in a conflict zone and sold to perpetuate the fighting. The most notorious example is the Democratic Republic of the Congo (DRC), where various armies, rebel groups, and outside actors profit from mining while contributing to violence and exploitation during wars in the region. It has been estimated that to now at least eleven million people have been killed because of these minerals.

Figure 7 "Circular" trade movements for conflict minerals/metals[5]

The four most commonly mined conflict minerals are cassiterite (for tin), wolframite (for tungsten), coltan (for tantalum), and gold ore, which are extracted from the eastern Congo, and passed through a variety of intermediaries before being purchased. Therefore sellers are able to override the embargo imposed by ONU and make very difficult to trace the entire productive and commercial chain. These minerals are essential in the manufacture of a variety of devices, including consumer electronics such as mobile phones, laptops, and MP3 players.

POSSIBLE SOLUTIONS

The Waste Framework Directive[6] and the 7th Environment Action Programme set some priority objectives for waste policy in the EU:

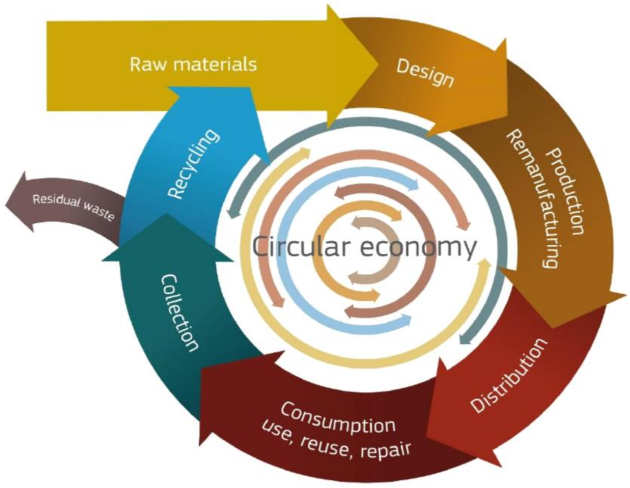
- Reduce the amount of waste generated
- Maximise recycling and re-use
- Limit incineration to non-recyclable materials
- Phase out landfilling to non-recyclable and non-recoverable waste
- Ensure full implementation of the waste policy targets in all Member States.

These objectives can be reached through:

- Implementation of circular economy strategies to reduce waste of precious materials and dependence from outer countries.

[5] Image from: http://www.usconverters.com/index.php?main_page=page&id=82&chapter=0

[6] Directive 2008/98/EC of the European Parliament and of the Council on waste



- When circular economy topics are addressed in public events or in schools, the problem of WEEE should more stressed, because people usually associate the topic of waste separate collection mainly to plastic, glass, paper, organic discards and aluminum cans.

- Search for new sources of CRM (find new mines, re-open old ones, recover them from urban waste, search the oceans, and in the future the moon, or the asteroids.

- Fostering scientific research in order to
  - ✓ find cheaper and more efficient substitutes for CRM
  - ✓ find better, more efficient and environmentally friendly extraction methods for minerals and metals
  - ✓ improve recovery from separated collection

- Promotion of industrial research in order to produce better designed products, when possible in a modular fashion (to ease the partial substitution of elements without throwing away the entire appliance), and to allow an easy recovery of precious materials.

- Diffusion of information about this problem among people, either in educational or informal events, in order to encourage more sustainable and aware behaviors when buying, using and disposing of electric and electronic devices.