Teachers' Card

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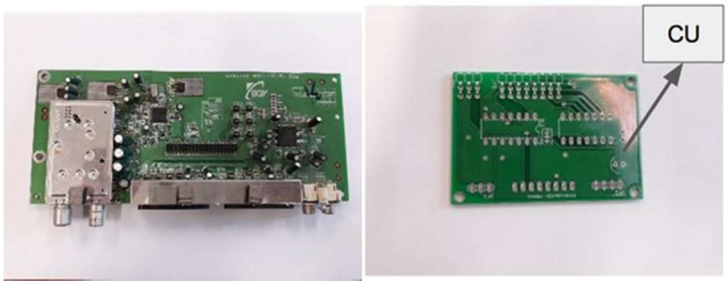
General Introduction

This toolkit is designed to help you and your students begin learning more about copper's essentiality to the modern world.

It is intended to understand copper attributes, its benefits particularly regarding environment, circular economy, recycling and sustainable development.

Through a webquest and a lab activity they learn what e-waste is and how to recover copper from electrical circuits.



Key words:

Copper, e-waste, recycle, redox

Extended background information

What are Critical Raw materials?

Critical Raw Materials (CRMs) are those raw materials which are economically and strategically important for the European economy, but have a high-risk associated with their supply. Used in environmental technologies, consumer electronics, health, steel-making, defense, space exploration, and aviation, these materials are not only 'critical' for key industry sectors and future applications, but also for the sustainable functioning of the European economy.

It is important to note that these materials are not classified as "critical" because these materials are considered scarce, rather because:

1. ***they have a significant economic importance for key sectors in the European economy**, such as consumer electronics, environmental technologies, automotive, aerospace, defense, health and industry.*

AND

2. ***they have a high-supply risk** due to the very-high import dependence and high level of concentration of set critical raw materials in particular countries and **there is a lack of (viable) substitutes,** due to the very unique and reliable properties of these materials for existing, as well as future, applications.*

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Why CRMs are so important?

Modern technology - technological progress and quality of life rely on access to a growing number of raw materials. For example, a smartphone might contain up to 50 different kinds of metals, all of which contribute to its small size, light weight and functionality.

Environment – raw materials are closely linked to clean technologies. They are irreplaceable in solar panels, wind turbines, electric vehicles, and energy-efficient lighting

Link to industry - non-energy raw materials are linked to all industries across all supply chain stages.

Where can we find CRMs?

The EU's industry and economy are reliant on international markets to provide access to many important raw materials since they are produced and supplied by external countries. Although the domestic production of certain critical raw materials exists in the EU, notably hafnium, in most cases the EU is dependent on imports from non-EU countries.

China is the major supplier of critical raw materials, accounting for 70% of their global supply and 62% of their supply to the EU (e.g. rare earth elements, magnesium, antimony, natural graphite, etc.). Brazil (niobium), USA (beryllium and helium), Russia (palladium) and South Africa (iridium, platinum, rhodium and ruthenium) are also important producers of critical raw materials. The risks associated with the concentration of production are in many cases compounded by low substitution and low recycling rates.

Within Europe, the largest known deposits are in Russia and Poland. Economic mines are also operating in Bulgaria, Finland, Portugal, Spain and Sweden. In 2010, EU mine production totaled 855,316 tons of copper (source: BGS), around 5.3% of world production.

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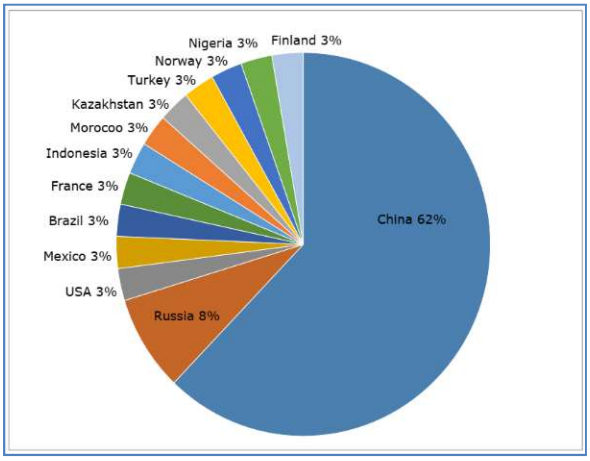
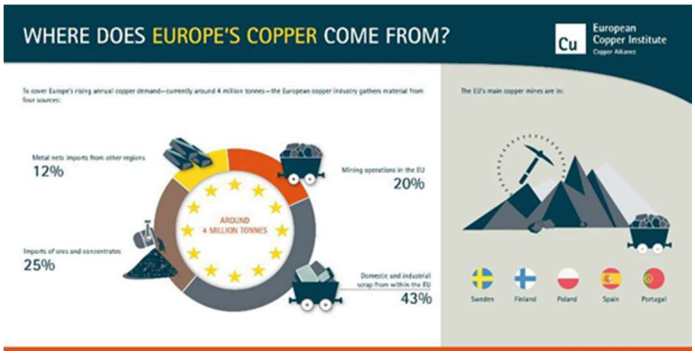


Main EU suppliers of CRMs (based on number of CRMs supplied out of 37), average from 2010-2014

Source: Deloitte Sustainability et al., *Study on the Review of the List of Critical Raw Materials*, cit., p. 16.

The Main Copper Producing Countries

While current and future exploration will increase both reserves and resources, we must not forget that supplies will also be sourced from the substantial amount of copper that is already in use today. The recovery of end of life products, so-called 'urban mining', is one of the reasons why, today, 41% of the EU27's copper demand is sourced recycling.



E-waste and Copper

Electronic waste, commonly known as e-scrap and e-waste, is the trash we generate from surplus, broken and obsolete electronic devices. E-waste or electronics recycling is the process of recovering material from old devices to use in new products.

Frequently replaced electronics

We are creating e-waste at a rapid rate. With such a very short useful life, these electronics transition into e-waste at a rapid pace. In fact, it was estimated that there were 422 million unused and unwanted cell phones accumulating in people's homes by the end of 2015.

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Globally, a cell phone is sold to around one of every four people on an annual basis. Every year millions of electronic devices such as mobile phones, TVs, computers, laptops, and tablets reach the end of their useful life.

What happens to devices at the end of their useful life?

Unfortunately, the majority of these electronic products end up in landfills and just a tiny percentage comes back as/in new electronic devices. According to a UN study, in 2014 alone, 41.8 million tons of electronic waste (e-waste) was discarded worldwide, with only 10 to 40 percent of disposal done properly.

Electronics are full of valuable materials including copper, tin, iron, aluminum, fossil fuels, titanium, gold, and silver. Many of the materials used in making these electronic devices can be recovered, reused and recycled, including plastics, metals, and glass. In a report, Apple revealed that it recovered 2,204 pounds of gold —worth $40 million—from recycled iPhones, Macs and iPads in 2015.

Copper: enabling innovation

Here, we explore the role of copper products in meeting present and future societal needs such as renewable energy, healthcare, more energy efficient transportation and modern communications.

Such copper innovations are critical to support the European Commission's goal of reestablishing industry as the source of 20% of Europe's GDP by 2020. The future-facing campaign reveals the multitude of ways in which copper alloys provide added value to our industries and our lives. By delivering safe electricity and water, and enabling the continued development of electrical applications and electronic devices, copper has never been more important to our society.

The copper industry's ongoing research and testing of new concepts deliver a steady stream of innovations that can dramatically transform how things are made and how they work. These innovations may make processes more cost-efficient, minimize their environmental impact, lower their energy consumption, or reduce their use of precious natural resources in the future.

Copper and the Circular Economy

Copper can be 100% recycled without any loss in performance. As such, copper is a sustainable material that is pivotal to building the circular economy.

Appendix 1 – Theoretical principles

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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.
S4. Ability to interact in an appropriate and creative way in any situation.
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
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.
S3. Ability to model mathematically a situation from the real world and to transfer mathematical expertise to non mathematical contexts.
S5. Capacity for quantitative thinking.
S6. Ability to extract qualitative information from quantitative data
Digital competence
S2. Basic skills in ICT
S4. Ability to use and handle technological tools and machines
Personal, social and learning to learn competence
S1. Ability to pursue and persist in different kinds of learning.
S2. Identifying available opportunities.

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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
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
Cultural awareness and expression competence
S3. Ability to plan and manage tasks

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.

	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

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

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	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

Contents – Theoretical principles

Electronic waste, commonly known as e-scrap and e-waste, is the trash we generate from surplus, broken and obsolete electronic devices.

Electronics are full of valuable materials including copper, tin, iron, aluminum, fossil fuels, titanium, gold, and silver. Many of the materials used in making these electronic devices can be recovered, reused and recycled, including copper.

E-waste or electronics recycling is the process of recovering material from old devices to use in new products.

Copper is a metal that is extracted from the earth, is essential to the development of all forms of life and has been vital in the progress of civilization, contributing to both social and technological development for more than 10,000 years.

The valuable properties of copper which were evident at the dawn of civilization were an attractive color, excellent ductility and malleability, and a capability of being hardened by working. In modern times, further properties have been appreciated and exploited across a wide range of applications: high thermal and electrical conductivities, excellent corrosion and hygienic properties.

In addition to their many uses in agriculture and biology, copper salts have an astonishing variety of industrial uses, chiefly of a specialized nature, and there is hardly an industry which does not have some small use for them. The following activity briefly describes a few of the more important copper compounds and reactions.

Appendix 1 – Theoretical principles

Lab Procedure/Activity

We suggest to divide this module in two activities: firstly through a webquest (an inquiry-oriented activity in which students get all information from the web) students learn more about copper, e-waste and

relevance of recycle for raw materials, then with a lab experience they discover chemical properties of copper and the possibility of recover it from an old electric circuit.

Module 1 - WebQuest

Module 2 – Lab Activity

Learning Pathway

Step 1- Time & Activity: 30 minute - Teachers do a short introduction with a prepared PowerPoint presentation

Step 2 – Time & Activity: 1 hour - Webquest. Students are divided into groups (preferably the number of students in one group is 3-4). Each group, putting into the shoes of researchers, should find information in the web about copper and its properties.

Step 3 – Time & Activity: 2 hours - students work in groups in the chemistry lab

Step 4 – Time & Activity: 45 minutes - evaluation

Evaluation

Lab questions

1) Percentage of Copper Recovered

A student performing this experiment started with a 0.3769 g sample of copper turnings, which was dissolved in concentrated nitric acid. After completing the series of reactions, the student isolated 0.3492 g of copper. Calculate the percent copper recovered by the student. Show your work.

Answer

Percent recovered = $\frac{Mass\ of\ final\ Copper}{Mass\ of\ initial\ Copper} x100 = \frac{0{,}3492\ g}{0{,}3769\ g} x100 = 92,6505\ \%$

2) Indicate whether the following procedural errors would result in an **incorrectly high** or **incorrectly low** percent recovery. **Circle and explain your answer.**

a. The solution was not basic before being heated in step II.
High **Low**

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b. In step III, the solution was poured into the funnel until it went above the top of the filter paper, and some black solid was disposed of with the filtrate.
High **Low**

c. The solution decanted in step V was slightly blue in color.
High **Low**

d. In step V, the copper metal was weighed while it was still damp.
High Low

3) In this lab, you observed that metals being heated in air will produce oxides. Predict what would happen if you heated a metal in an atmosphere of argon.

Answer: Nothing except heating, and that's the best part! Argon is a noble gas and is therefore nearly un-reactive due to its full valence electron shell. For this reason argon is often used as an environment for reactions, storage of air sensitive materials and compounds.

4) List two sources of error that could have resulted in higher than expected yields of copper.

Answers will vary but may include overheating of the copper recovered in the last step to CuO; failure to completely dry the copper in the last step; if all of the magnesium did not react in the final step, there could be some excess Mg mixed in with the copper.

5) List two sources of error that could result in lower than expected yields of copper.

Answers will vary but may include copper may have been lost during the decanting process; the original solution may not have been exactly 1.0M $CuSO_4$ so the starting amount may have been less than theoretical;

6) What observations did you make that indicated a chemical reaction was taking place?

Answer: Color changes, precipitates, evolution of gases.

7) Define percent yield in general terms.

Answer: Percent yield is a measure of how well the reaction proceeded to completion. The formula for percent yield is the experimental yield divided by the calculated (theoretical yield).

8) If your percent yield of copper was greater than 100%, what are two plausible errors you may have made?

Answer: Sample was not fully dried and still contained water. Impurities were mixed in with copper causing it to weigh more than it should.

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Description of Student's Cards

This toolkit is designed to help you and your students begin learning more about copper's essentiality to the modern world.
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Through a webquest and a lab activity the students learn what e-waste is and how to recover copper from electrical circuits.

Student's Card 1 – WebQuest

Student's Card 2 – Lab activity

Acknowledgement

CNR thanks the *I.S. A. Sobrero - Casale Monferrato (Alessandria), Italy* , for the precious collaboration in developing and testing this toolkit.

I.S. "A. SOBRERO"