SECTION 1 FACT CHECK COPPER

As a relatively soft and tough metal, copper is easy to shape. As an excellent conductor of heat and electricity, it has many uses. In addition, it also belongs to the group of coinage metals. As an important technology and functional metal, copper belongs to the group of semi-precious metals.

In nature, copper forms either in the form of "copper-red", metallic shiny nuggets or in branched structures, so-called dendrites. Copper is often associated with other metals in copper minerals and copper ores (cuprite, malachite, copper glance).

The most important copper producer worldwide is Chile, followed at a great distance by Peru and China. In Europe, Poland, Portugal and Sweden are worth mentioning.
The extraction of copper from the ores is a multi-step process: raw copper is first dissolved out of the mineral in a flash smelter with the addition of coking coal. In the following refining step, unwanted impurities are removed by oxidation. The resulting crude copper still contains 2 % iron, zinc and silver and gold. The pure metal is obtained through a final electrolytic refining process.

Copper is an all-round metal and belongs to the non-ferrous metals! It is the third most important metallic material after steel and aluminium. In addition to very good corrosion resistance, copper is the most important electrical conductor and has good thermal conductivity. It occurs in over 400 different alloys, which are themselves technically versatile materials. 2.1 million tons were produced worldwide in 2016. The price of copper remains high, hovering around the value of 6000 dollars per tonne (purity of 99.8%) on the world market in 2015. That is why copper is often stolen! Copper is 100% recyclable without any loss of quality.

TASKS
1. Research the material copper and its many uses.
2. Complete the table.

Area	**Used in / as...**
Medicine	
Arts and Crafts	
Missile/ Rocket Technology	
Construction, Functional Material	
Lightweight	
E-vehicle construction, Aerospace	
Thermal conductor	
Electrical conductor	
Metrology	

SECTION 2 INFO SHEET PRODUCTION OF COPPER

Mining using the example of the water-filled former Mamut Copper Mine in Malaysia. The crater has a diameter of 1.2 kilometres and is 500 metres deep. Worldwide, the extraction of copper has doubled about every 20 years since 1900 and increased 40-fold in the 120 years (about 15 million tons per year), mainly due to the demand of the electrical industry.

There are already very old copper mines worldwide whose copper grades are decreasing significantly over time, by about a third since the end of the 1990s. Since much more earth has to be moved to obtain the same amount of copper, the operation of existing mines is continuously becoming more expensive. The mining of copper ore takes up large areas of land that can only be used again after recultivation.

TASKS

3. Research conditions at the world's largest copper mine, ESCONDIDA, in Chile.
   Find out more about the processing and refining of copper on the websites
   https://www.copper.org/education/copper-production/ and
   https://commons.wikimedia.org/wiki/Category:Copper_electrowinning?uselang=de.
4. Use the DEMO-TOOL SimaPro5 and recapitulate the LCA. Use SECTION 3 + 4.
5. Create your own DATA-SET and prepare the data graphically. Pay attention to the scaling.

Recycling: In Germany the production of copper from secondary cycles is constantly about 45 %, worldwide about 35 %.

Copper can be recycled very well. Through urban mining (e.g. electrical equipment from recycling stations, metal processing, etc.), the metal-bearing scrap enters the secondary cycles. Various recycling processes are used to recover primarily the valuable metals (gold, silver, PGM, copper) and the so-called strategically important metals (which are important for e-mobility and digitalisation).

One possibility is multi-metal extraction, which is carried out by Aurubis AG in Hamburg, Germany, among others (see picture). In this process, several processes are connected in series in order to extract different elements. By combining mechanical, pyro- and hydrometallurgical processes, complex raw materials, such as the blanks, can be separated. Elemental copper can be extracted from crude copper by means of electrolytic refining. In addition, anode slimes consisting of precious metals precipitate. After multi-metal extraction, this is recovered in a precious metal treatment by electrolytic refining for maximum yield and purity of copper (as well as gold and elements of the platinum group PGM). Copper recycling requires only 10% of the amount of energy used in primary production.

SECTION 3 Pollutants and influencing parameters

Against a backdrop of increasing resource scarcity, environmental pollution and global climate change, sustainable production technologies and changes in consumer behaviour are becoming increasingly important to all economic, social and political sectors. Life Cycle Assessment (LCA) is a methodological framework to analyse products, materials and services to determine their impacts on health, environment and resource consumption.

The three influencing variables mentioned represent the endpoints of the LCA. They result from eleven damage categories, which consider the relevant environmental compartments (living organisms, soil, water, air) with the pollutant inputs (substances, radiation, noise) and their migration. Mineral and fossil resources as well as land and water requirements are taken into account, as is the emission load of all subsystems examined.

These damage categories are calculated in the LCA (Life Cycle Inventory; LCI) with the help of the material data, the applied processing steps, the energy inputs and the disposal route. By material flow analyses with the SimaPro5 tool in the DEMO version 9.4.0 an ECOBALANCE succeeds. Unfortunately, no LCA data for copper from ore (primary, virgin) are available in the DEMO version!

The table lists on the one hand the elements, substances and radiation responsible for a pollutant effect, and on the other hand further influencing factors relating to the consumption of raw materials and land areas. In some cases, pollutant classes affect more than one endpoint. For example, the gases carbon dioxide, methane and nitrous oxide affect both human health and the environment. Heavy metals are toxic to all living organisms.

TASK

6. Using the metal copper as an example, the environmental impact is to be determined for the quantity of 1 kg if the metal is extracted from the sludges (copper cakes; here (4)) or 100% recycled copper e-scrap or (6) 100% from metal processing scrap (5) is calculated.

The impact categories are colour-coded. They are reflected in the two staggered bars of the diagram.

Schadenskategorie Impact Categories	COPPER RAW Data for 1 kg Material					
	1	2	3	4	5	6
	Cu cathode	Cu, cathode , solvent extraction / electrowinning	Cu anode	Cu rich material	Cu Scrap	Cu electronic scrap, anode
in mPt	3240	4734	3669	**2884**	**0.0014**	**0.0320**
Carcinogens/Toxicity	9.37E-05	0.0001	0.000121	0.000063	3.6E-07	0.000012
Resp. Organics/Inorganic	9.06E-06	9.19E-06	8.06E-06	6.91E-06	2.41E-08	1.95E-06
Climate Change	5.13E-08	5.2E-08	4.56E-08	3.91E-08	1.36E-10	1.1E-08
Radiation	1.2E-08	9.27E-09	9.58E-09	2.58E-08	4.88E-12	9.41E-10
Ozone Layer	4E-09	5.33E-09	4.34E-09	2.48E-09	8.13E-12	1.03E-10
	8.09E-10	9.53E-10	7.18E-10	1.04E-09	1.04E-09	2.29E-10
	3.32E-05	1.27E-05	4.48E-05	2.52E-08	1.37E-08	3.14E-07
Ecotoxicity	1.88E-09	5.3E-09	1.56E-09	8.1E-09	6.97E-08	1.89E-11
	3.46E-09	9.36E-09	2.98E-09	1.54E-09	1.23E-08	3.65E-11
	2.27E-09	3.16E-10	3.47E-09	3.21E-09	6.77E-13	1.16E-11
Acidification	2.47E-09	7.63E-10	3.34E-09	1.78E-10	4.84E-13	1.54E-11
Eutrophication	1.95E-09	5.3E-09	1.63E-09	2.1E-09	1.4E-13	2.79E-12
Land Use	5.5E-09	1.05E-08	4.39E-09	3.21E-09	7.16E-12	9.2E-11
	2.72E-08	1.55E-08	3.87E-08	2.09E-08	5.55E-11	4.15E-10
	9.52E-09	6.79E-09	1.28E-08	7.57E-09	-5.58E-11	1.62E-10
Metal depletion	2.96	4.46	3.42	2.63	0.000208	0.00092
Fossile Fuels	0.28	0.274	0.249	0.254	0.00121	0.0311

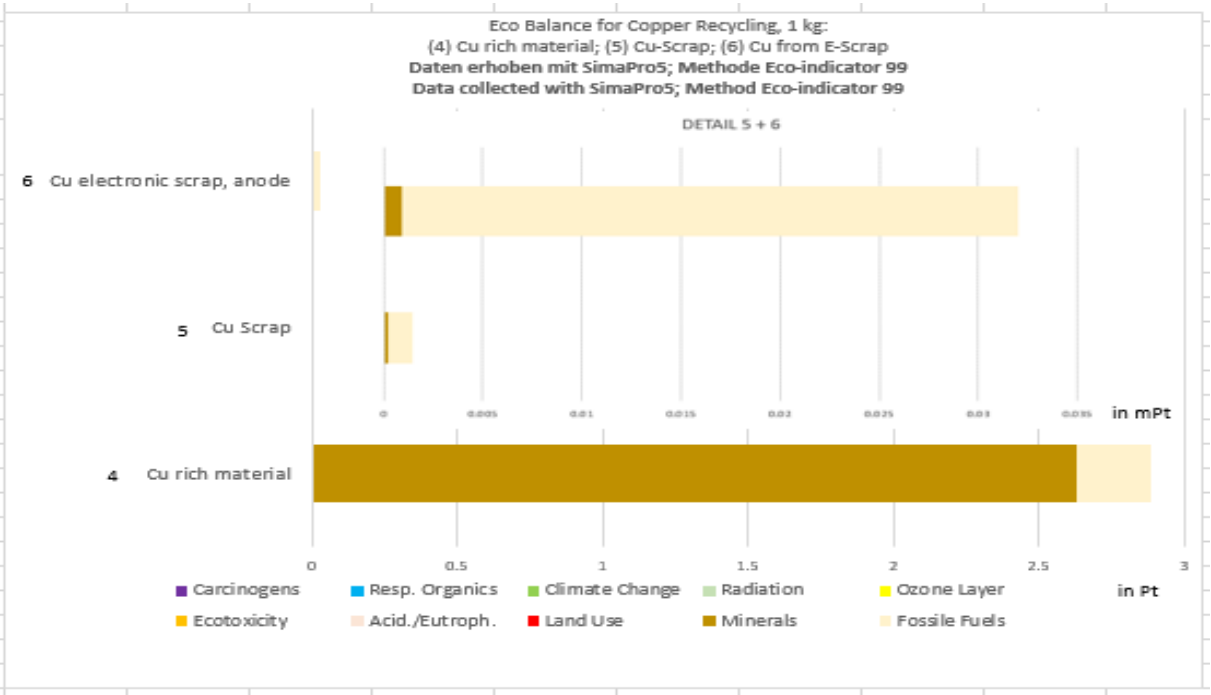
The data collected were compiled using the Eco-indicator 99 method. The unit is expressed in Eco-Point **Pt.** 1 Pt is 1/1000th of the annual environmental impact of an average European.

SECTION 4 Interpretation of the results

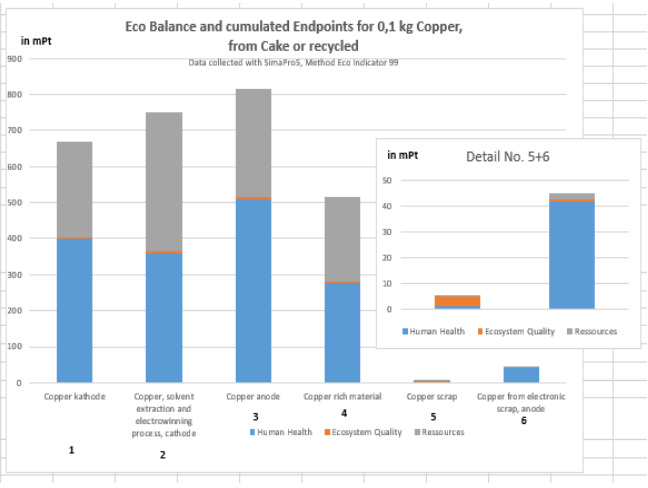
The consumption of mineral and energy resources is also clearly visible in the recycling of copper cakes. Depending on its origin, it still contains considerable proportions of other metals, which have to be separated in a complex electrolytic process. Therefore, the energetic expenditure is about 10 times higher than for scrap recycling. The higher the proportion of recyclables recovered, the better the eco-balance.

TASK

7. The negative health effects are lost in the scaling. Prepare the data in the DATA-SET in such a way that a graphical interpretation becomes possible.



The manual pre-sorting and complex processing of the e-scrap (6) entails considerable health risks, particularly due to the dust load, as it contains further metal components, some of which are toxic. In contrast, the scrap (5) from metal processing is only contaminated with cutting oils and cooling lubricants, which play hardly any role in electrolysis. The end-point consideration now for each 100 g of processed copper material illustrates this.



Cu 0.1 kg	1 Copper kathode	2 Copper, solvent extraction and electrowinning process,	3 Copper anode	4 Copper rich material	5 Copper scrap	6 Copper from electronic scrap, anode
	mPt	mPt	mPt	mPt	mPt	mPt
Human Health	399	358	510	276	1.17	41.9
Ecosystem Quality	5.34	6.69	5.99	3.71	3.58	0.521
Ressources	264	387	300	235	0.115	2.61
Summe mPt	**668**	**752**	**816**	**515**	**4.86**	**45**

CONCLUSION: The best way to recycle almost unmixed waste from the metal processing industry is to return it to the secondary copper cycle! But urban mining with the processing of even complex e-scrap is very worthwhile!