Potentials for GHG emission reduction associated with the Circular Economy.
The anthropogenic copper cycle

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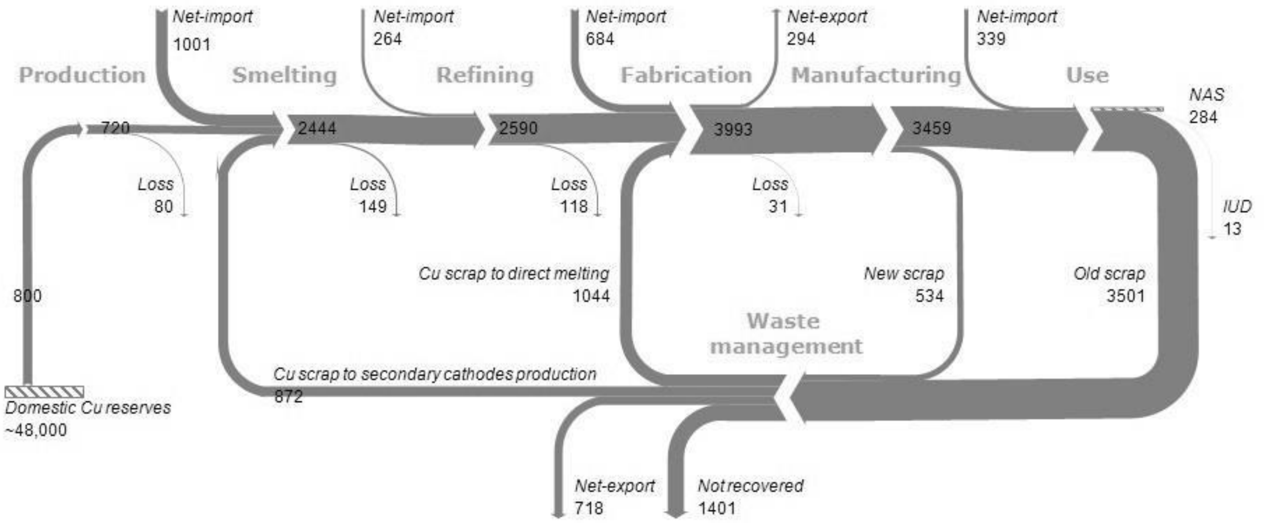
1. Introduction

Copper is widely used in modern society, being employed in traditional end-uses such as plumbing, power generation, power distribution, and transportation, but it is also an essential material in emerging green energy systems. A well-established industrial capability characterizes primary copper production in Europe. However, the amount of copper extracted annually from ores and minerals is generally not enough to meet the domestic demand so that the EU Member States rely on imports of copper forms from foreign trade partners. [1]
This import reliance determines a potential vulnerability to supply disruption in the value chain, which is magnified by the expected mine production peak and decreasing ore grade. [2-3]
From this perspective, end-of-life recycling is often adduced as a way to secure access to secondary resources while benefiting the environment. As copper recycling is generally less energy intensive than primary copper production, closing the elemental cycle through recycling would result in significant environmental benefits.
To this aim, material flow analysis (MFA), scenario analysis (SA), and life cycle assessment (LCA) were combined to explore the future copper demand and supply in the EU-28 and to determine to what extend the Circular Economy approach could reduce the associated greenhouse gas (GHG) emissions.



NAS – Net addition to in-use stock; IUD – In-use dissipation

Fig. 1 – *The anthropogenic copper cycle in the EU-28 (best estimate for 2014). Values in Gg copper metallic equivalent. Reproduced from [1]*

2. Results and Discussion

MFA is based on the principle of mass conservation so it enabled to identify and quantify copper flows and stocks in the EU-28 to 2014. [1] The anthropogenic copper cycle for the most recent year is displayed in Fig.

1. The historical demand for copper was used as a foundation for SA. More precisely, the copper flow into use by major end-use application segments was related by means of regression techniques to the main explanatory drivers for resource consumption such as gross domestic product, population, and the level of urbanization.
Extrapolation to 2050 was then carried out by applying growth rates for the set of the most significant explanatory variables as described by the storylines of two scenarios, namely a business-as-usual scenario (Scenario 1) and a scenario in which the sustainable development goals are priority (Scenario 2). The description of scenario storylines was previously reported. [3] The estimated future copper demand was then used to inform the MFA model and simulate the generation of copper waste and scrap at end-of-life. The fraction of the future domestic demand that could be met by secondary copper forms domestically supplied was then explored over time for different end-of-life recycling rates.
Based on these outcomes, LCA was modeled to determine the energy-related GHG emissions associated with total copper demand in the region. Global Warming Potential was selected as life cycle impact assessment indicator. Energy-related GHG emission factors were defined per unit of energy carriers. The modeling considered primary and final energy inputs from mining to refining both for primary (virgin) and secondary (recycled) copper production. For virgin copper, the resulting energy increase that could result from the mine production peak and the declining of ore grade was also part of consideration.
For recycled copper, energy inputs were compiled for collecting and sorting copper waste and scrap at end-of-life. Furthermore, the MFA model enabled to distinguish the energy demand on the basis of the recycling process followed, whether the flow of copper scrap goes to direct melting or to secondary refining for cathodes production. In addition, the possible evolution of the electricity production mix both for the EU-28 and the world was estimated on projections from the International Energy Agency. [4]
The results show that the business-as-usual scenario expects a huge increase in the future copper demand in Europe, which will likely determine GHG emissions to increase dramatically compared with the current levels. Even in the unlikely event that the end-of-life recycling performance improved to their maximum level, reliefs would still remain marginal. In contrast, making the sustainable development goals priority in the region (Scenario 2) requires to reduce the current demand for copper, providing recycling with the opportunity to meet a considerable fraction of copper supply. In this scenario, the resulting reduction of GHG emissions would also contribute positively to comply with the 2°C target.

3. Conclusions

The results demonstrated that copper recycling could significantly contribute to reduce the energy requirements and mitigate GHG emissions associated with the regional copper demand. However, the current recycling performance seems not to be enough to close the copper cycle. Fundamental constraints are likely to limit the implementation of the circular economy unless changing the current pattern of copper production, consumption and recycling at end-of-life.

References

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