Towards a sustainable and circular metals economy: the case of copper in China

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Summary

In-use stocks of products can be considered as intermediaries between human needs and the physical world. These stocks are regarded as an important indicator for society's metabolism. During use, they fulfil important functions, but they can also be seen as a source of materials for the future: when the products are discarded, the materials embedded in them become available to be used again: the production of secondary materials. Stocks of materials are therefore increasingly the subject of investigation.

This idea of an urban mine can be applied to all kinds of materials and resources, and applies at all scale levels, from the local to the global level. In this dissertation, the urban mine of copper in China is the subject. Consumption of diverse copper-containing products in China is increasing rapidly. The in-use copper stocks have become a large reservoir for urban mining. The aim of this research is therefore to explore how the stocks and flows related to the Chinese copper cycle can be transformed into a sustainable and circular economy.

The research was performed with four complementary and successive research questions:

1. How are copper demand, in-use stocks and waste generation expected to develop under the current Chinese policies related to development, energy transition and the circular economy? (Chapter 2)
2. How could China meet its future copper demand in the context of moving towards a circular economy, and how may this be affected by the import restrictions on copper scrap? (Chapter 3)
3. What are the environmental benefits and drawbacks related to future copper production in China, and how could the country's environmental performance be improved in the future? (Chapters 4 and 5)
4. What is the potential to close the copper cycle in China? (Chapters 2, 3 and 5)

The starting point of this thesis is the material resources use and the concurrent challenges for resource availability, waste generation and management and environmental impacts of material production. These challenges make it clear that there is a need for resource efficiency and transition to a circular economy for the copper cycle in China. A logical point of departure from this view was therefore to quantify the in-use stocks, as well as demand and waste generation for copper under the current Chinese policies (question 1). The findings indicate that copper demand in 2050 under the current Chinese policies related to development, energy transition and the circular economy cannot be met through the supply of secondary copper. More diverse circular economy strategies need to be employed to develop the copper cycle sustainably in China, especially given the expected restriction on the import of copper scrap (question 2). In the move towards sustainable development, the environmental performance of copper cycle is a crucial dimension. An LCA approach was used and up-scaled with several prospective changes related to copper production to understand what the environmental impacts are related to future copper production in China (question 3). Finally, combining the different scenarios assessed in this thesis, an overview was given of the potential to close the copper cycle in China (research question 4).

Chapter 2 presents the in-use stocks, as well as the demand for and waste generation of copper under the current Chinese policies. The main conclusion is that the in-use stocks and demand for copper in China are expected to increase significantly, albeit with different growth rates for different copper categories. The copper stocks for some copper-containing products like buildings are likely to have stabilized by 2050. For infrastructure and transportation, saturation will likely not have occurred yet by that time. Specifically, the copper stocks and demands of electricity infrastructure and new energy vehicles are expected to increase considerably up to 2050 as a result of the ongoing energy transition. Domestic waste generation has been increasing in recent years; however, most of China's copper products have not entered their retirement period at present, resulting in a growth of EoL copper recycled in China that is much slower than that of copper demand. For that reason, it is unlikely that copper demand in 2050 under the current Chinese policies could be met through the supply of secondary copper.

Chapter 3 answers question 2 and explores the potential of a number of more stringent circular economy strategies to close the Chinese copper cycle. A special point of attention is the effects of China's import restrictions on copper scrap. The main findings are that the Chinese copper cycle could benefit

considerably from these circular economy strategies, but that there still may be a substantial gap between the Chinese demand for copper and the amount of scrap available domestically. Extending the lifetimes of copper-containing products could lead to a reduction in the overall copper demand. The restriction or ban on imported copper waste will reduce the availability of scrap to be used for secondary copper production. Even with a growing amount of domestic scrap and assuming a high copper recycling rate, the share of secondary copper supply may not be more than 60% even in the more distant future. The substantial gap between Chinese copper demand and the amount of scrap available domestically needs to be closed, either by means of primary copper in the form of domestic mining, or through imports of concentrates and refined copper in the future. An alternative scenario could be to consider lifting the ban on import of copper scrap. In combination with the establishment of a state-of-the-art, efficient and environmentally friendly recycling industry, this could be an opportunity for China to transition to a more circular economy with regard to copper.

Chapter 4 assesses the future environmental impacts of pyrometallurgical, hydrometallurgical and secondary copper production in China, under influence of declining copper ore grade, energy efficiency improvement of production processes and energy transition on electricity supply. Potential options to improve the environmental performance of copper production are also identified in this chapter. Environmental impacts related to the production of 1 kg of copper could go down considerably. Nevertheless, the total environmental impact of copper production with these prospective changes will not be lower than that of the business-as-usual scenario. The energy transition by shifting from fossil fuels to more renewable energy will reduce CO2 emissions, but at the same time will increase copper demand compared to the business-as-usual scenario. The results also support the idea that the environmental impact of the production of 1 kg secondary copper is and will remain much lower than that of primary copper, which suggests that increasing the share of secondary copper production is the most environmental friendly option.

Chapter 5 takes a closer look at copper waste management. Circular economy and “Zero waste” strategies for the copper waste management system are investigated, and the potential to close the copper cycle based on an optimized

waste management system is explored in this chapter. In combination with the environmental impact of primary copper production in Chapter 4, the main conclusion is that under the present Chinese policies, the reuse and recycling of copper-containing products will lead to somewhat lower GHG emissions and reduced energy demand for total copper production. Maximizing such circular economy strategies may lead to a further reduction, but if applied too stringently can also be counter-productive. GHG emissions related to secondary copper production may become larger than those of primary copper production despite lower per kg GHG emissions of secondary production. The findings indicate that the copper waste management system should be improved to keep the utility and value of copper at the highest level. This requires actions across the full product lifecycle, including waste prevention and circular economy strategies for the EoL products as well as early-stage product design. In this way, the dematerialization and environmental sustainability of the copper cycle could be realized simultaneously in China.

Chapter 6 concludes that this thesis has contributed to the exploration on how to move toward a sustainable and circular economy of copper cycle in China, with respond to the challenges for the close cycle and environmental dimension. Several recommendations are provided to improve the existing analysis of copper cycle. The first one is to improve uncertainties with regard to data and model, such as obtaining more information on the changes of copper content over time. Second, the rebound effects and side effects should be considered in future research. The final one is the need to consider other models to comprehensively estimate the copper stocks and flows. Further step in this direction is to integrate the MFA and LCA with other models to include environmental, economic and social dimensions, such as economic models and spatial models. This, by the way, could realize the dynamic modeling of copper cycle and provide more reliable and comprehensive policy suggestions to move toward a sustainable development of copper cycle in the future.