The ultimate need for copper mining

L. Rattmann

TH Georg Agricola University, Germany

Would a future without copper mining be feasible and if so, for how long will we still need copper mining? These are the two questions addressed in this paper. Only material available in the economic cycle can be recycled. Thus, as a starting point, the total amount of copper in the so-called 'anthropogenic stock' is calculated first. Based on that figure, the current per-capita need for copper in low-, middle- and high-income countries is determined. Taking into account world population growth and a worldwide evenly distributed standard of living in the long term, an initial forecast for the need for primary copper can be generated. In addition, declining recycling losses, which could reach a zero level in the far future, are considered. As a result, the ultimate need for copper mining to fill the anthropogenic stock and to make it ready for a totally closed loop is calculated.

The aim of this paper is to find a justification for mining beyond pure profit and satisfaction of demand. This paper will not discuss whether zero recycling losses in the far future are possible or not. However, even if recycling losses become zero in the far future, the paper demonstrates that mining is essential for a sustainable future and a completely closed loop.

INTRODUCTION

World mineral resources are large but not infinite. Consequently, human society should at least aim for living concepts which are independent of primary mineral resources in the very far future. But would a future without mining be possible and if so, what are the requirements? A post mining future is only thinkable if the following requirements are met:

- a fully closed raw materials cycle
- no primary mineral resources are delivered into the human economic sphere
- a lossless recycling of raw materials
- a renewable energy for this purpose is available
- a stable plateau of world population with zero growth
-

Assuming that the current anthropogenic stock does not contain enough material for the future's world population, the basic scenario shown in Figure 1 can be developed.

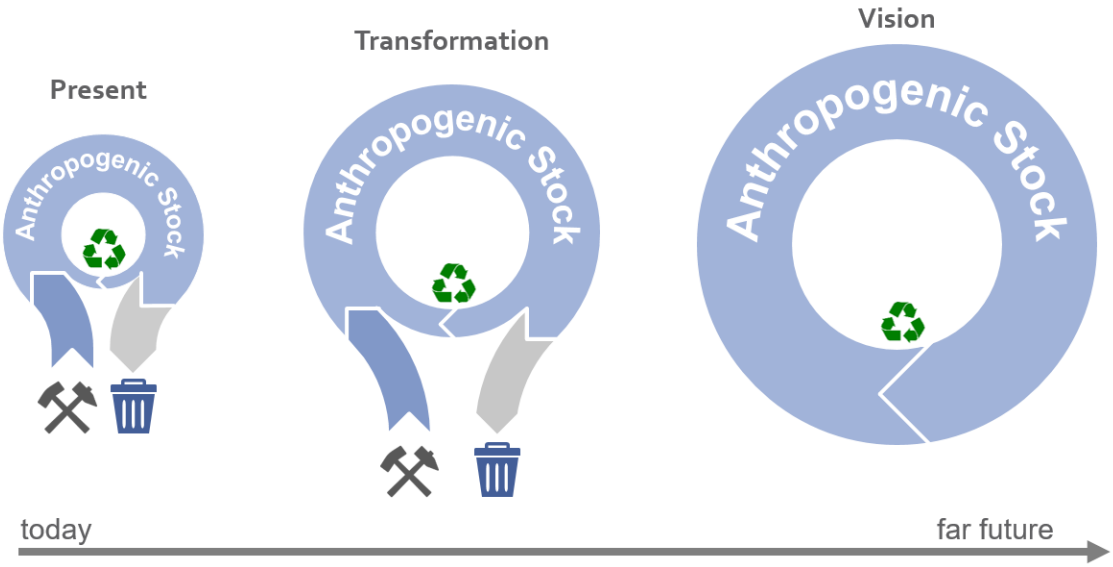

Figure 1. Scenario of closed anthropogenic loop in the far future.

At present a certain amount of raw materials are in the anthropogenic stock (AS), a certain amount of raw materials leave the AS, a certain amount is recycled and a certain amount of primary raw materials are delivered into the AS. The vision for the far future is a completely closed loop without any losses, and an AS large enough to serve the needs of the increased world population. The transformation stage is characterised by an increasing amount of recycled raw materials, and a growing anthropogenic stock due to the delivery of primary raw materials.

World population growth

The future total need of copper is dependent on the world population. According to the World Population Prospect 2019 (United Nations, 2019) the world population will grow to a size of 9.4 to 12.7 billion people by 2100 (Figure 2). By the end of this century, it is expected that the world population could cease to grow. For purposes of this study, it means that the world population will reach a plateau and there is no need for additional copper due to population growth. This also means that a post-mining future could become a reality in the far future.

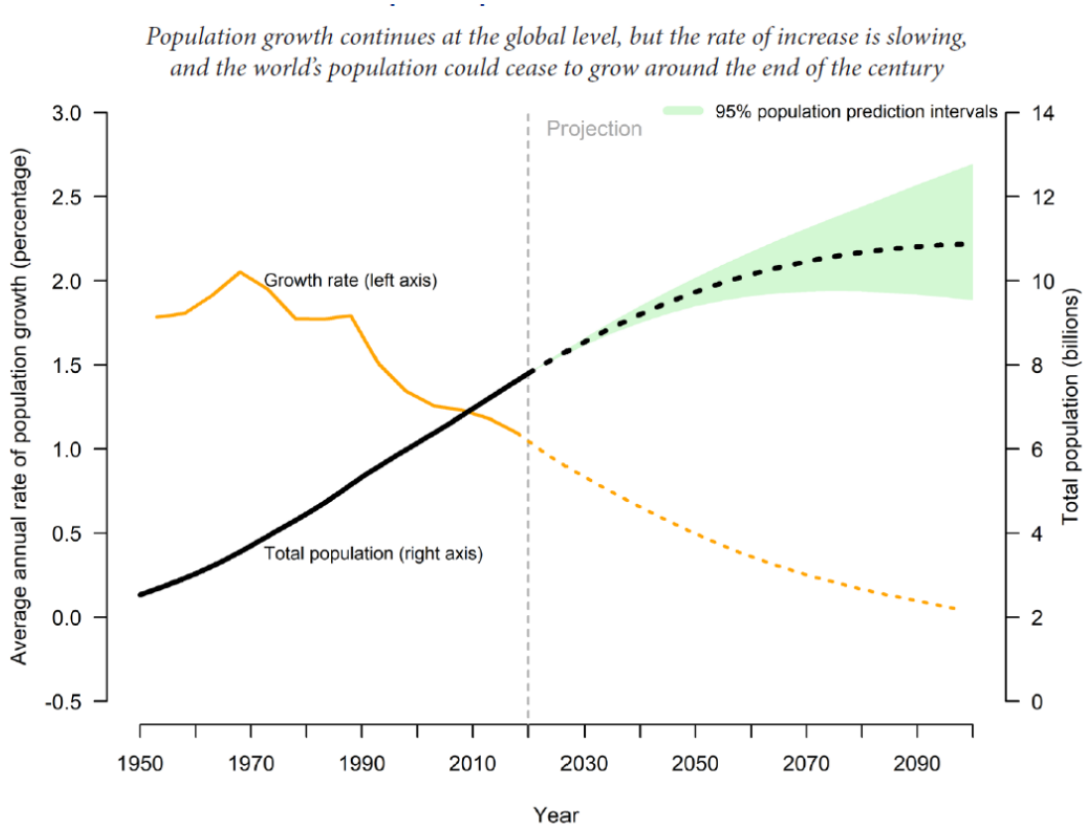

Figure 2. World population growth (United Nations, 2019).

Current per capita use of copper

Only raw materials can be recycled which are in the AS. Thus, the question arises as to how many raw materials have to be delivered into the AS of the future to enable a completely closed loop. The starting point to answer the question is the current use of copper. Lucas *et al.* (2008) argue that presumably 80% of the all-time copper production is still available in the AS. Based on the world copper mining figures since 1900 (Porter *et al.*, 2015; USGS, 2016 - 2022) plus an extra 20 million tonnes of copper mined before 1900, the total all-time mined copper amounts to 0.77 billion tonnes. Thus, the current AS of copper amounts to 0.62 billion tonnes of copper (Figure 3). Considering a 2020 World population of 7.8 billion people, the average AS per capita amounts to 0.079 tonnes of copper per person. To consider an uneven distribution of the AS per capita, this study assumes that the AS per capita at a high living standard is three times higher than the AS per capita at a medium living standard, which is three times higher than the AS per capita at a low living standard. Further, assuming that one third of the 2020 world population has a high living standard, one third has a medium living standard and one third has a low living standard, this leads to an AS per capita at a high living standard of 0.164 tonnes per person, 0.055 tonnes per person at a medium living standard and 0.018 tonnes per person at a low living standard. Extrapolation of the average AS per capita with the current anthropogenic stock of 0.62 billion tonnes at 10.9 billion people in 2100 would lead to a figure of 0.055 tonnes per person, significantly less than today's average. If the total world population had today's high living standard with an AS per capita of 0.164 tonnes per person, the total required AS would amount to 1.83 billion tonnes, which is 2.4 times the all-time mine production of copper until 2020.

As an intermediate conclusion, it can be stated that the current AS is not enough to serve future needs and therefore mining, as the only source for primary copper, is indispensable until the world population ceases to grow and lossless recycling is available.

Anthropogenic stock (AS) copper 2020		0.62 Bill. t
World population 2020		7.79 Bill. people
AS copper per capita living standard high	(1/3 of population use 9/13 of AS)	0.164 t/person
AS copper per capita living standard medium	(1/3 of population use 3/13 of AS)	0.055 t/person
AS copper per capita living standard low	(1/3 of population use 1/13 of AS)	0.018 t/person
AS copper per capita average		0.079 t/person
Today's AS copper per 11.2 Bill. People		0.055 t/person
Needed AS @ 11.2 Bill. People, living standard high		1.83 Bill. t

The current AS of copper is not enough to serve future needs!
We have to mine additional copper!

Figure 3. Current anthropogenic stock of copper.

The anthropogenic stock of copper in the far future and the transition
The previous chapter shows that we need to fill the AS to make a completely closed loop possible in the far future. The transition stage until the vision of a completely closed loop is available was modelled with the assumptions shown in Figure 4.

- World population growth ceases in 200 years, World population in 2220 11.2 Bill. people
- Ø standard of living in 200 years is evenly distributed worldwide
- Today 1/3 of World population uses 9/13 of AS, 1/3 uses 3/13, 1/3 uses 1/13
- Today's AS = 80% all-time mine production
  => all-time mine production 2020 approx. 770 Mill. t, AS 2020 approx. 620 Mill. t
- EoI Recycling Efficiency Rate (RER) increases constantly from 50% to 100%
- Substitution of copper not (yet) considered (shifting of need)
- Resource efficiency, new needs, acceptance of lower living standard not (yet) considered

Figure 4. Assumptions for the transition stage.

Based on the assumptions, the world population growth and the development of the living standards were modelled first. A nearly stable plateau of the world population will be reached in 2100; the growth rate will become zero in 2220 at a world population of 11.2 billion people. The share of people with a high living standard increases continuously. In 2220, the worldwide average living standard is expected to be high (Figure 5).

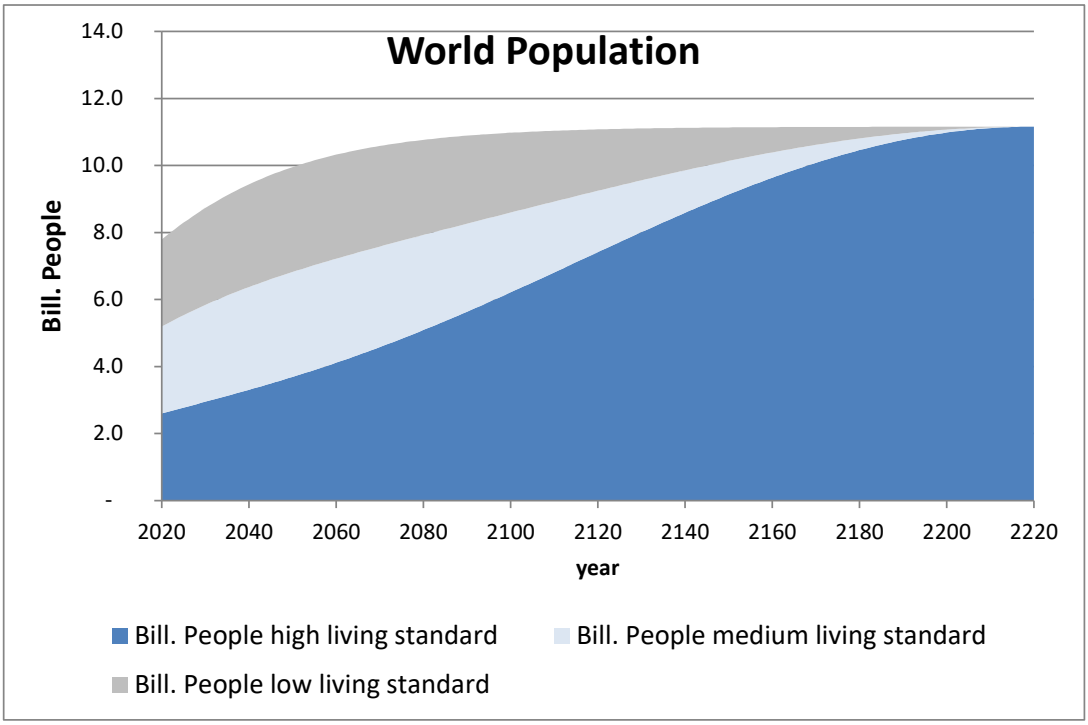

Figure 5. World population growth, development of living standards (Reference?).

Based on the modelled world population growth and the development of living standards, the needed anthropogenic stock was calculated with the current AS of copper per capita of 0.164 tonnes per person at a high living standard, 0.55 tonnes per person at a medium living standard and 0.18 tonnes per person at a low living standard (Figure 6). The AS totals at 1.83 billion tonnes of copper in the final year 2220. This leads to an additional need of some 1.2 billion tonnes of primary copper, which is roughly 1.6 times the all-time mine production.

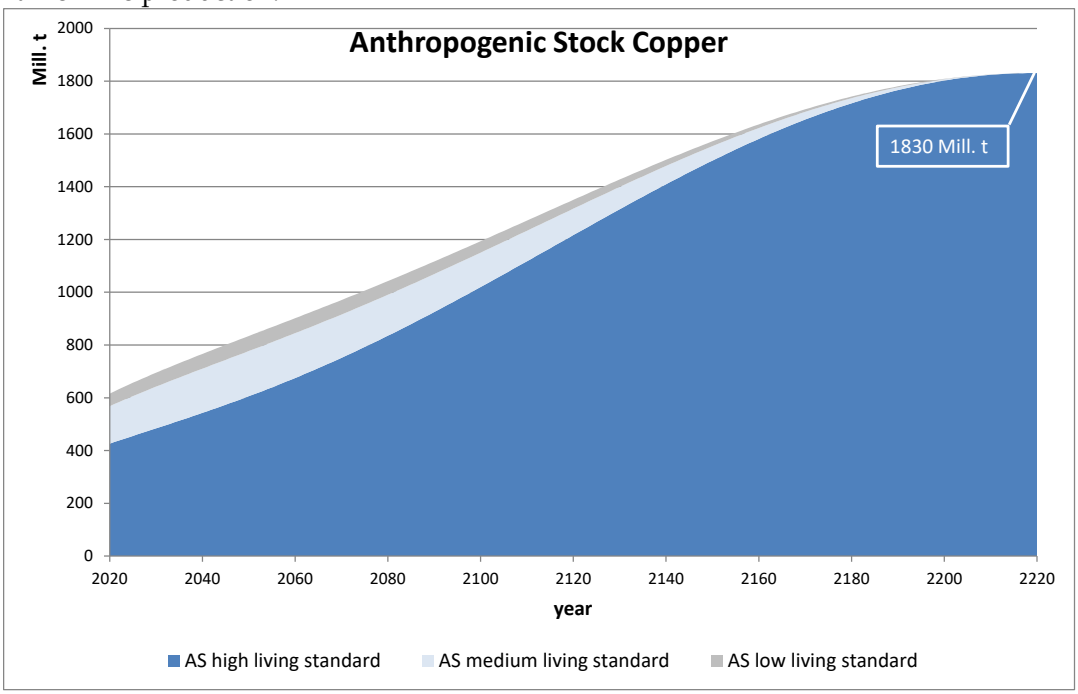

Figure 6. Anthropogenic stock of copper.

The ultimate need for copper

To make a completely closed loop possible under the given assumptions, the AS of copper has to be increased to 1.8 billion tonnes, which leads to an additional need of 1.2 billion tonnes of primary copper. Not yet considered are recycling losses on the way to the far future. Recycling losses are considered with continuously increasing end of life recycling rates, starting with 48% in 2020 and ending with 100% in 2220. Copper scrap amounts to 3% of the AS per year, which is equivalent to a 33 years average lifetime (residence time) of copper products. The modelling result is shown in Figure 7.

Based on the assumptions and the modelling results, the ultimate need for primary copper amounts to about 3 billion tonnes of primary copper, which is roughly four times the all-time primary copper production in 2020.

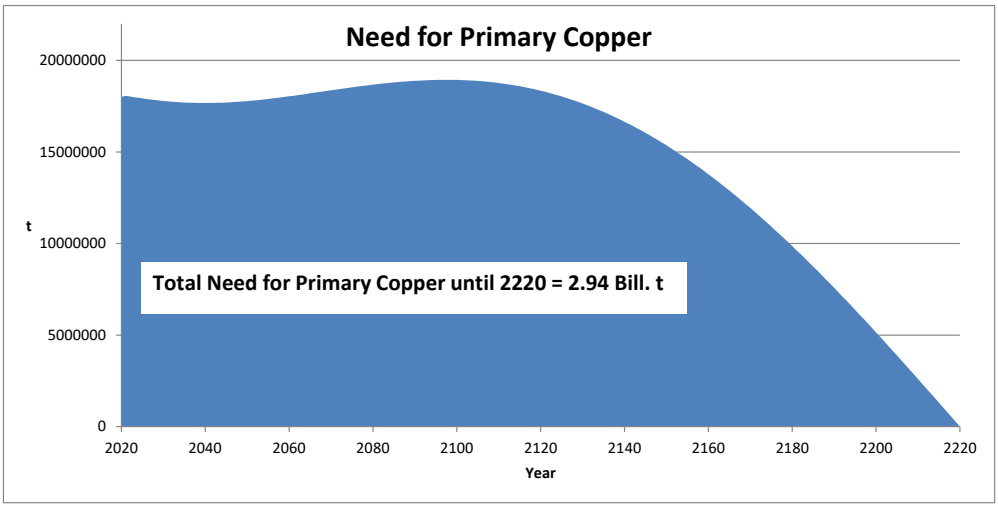

Figure 7. The ultimate need for primary copper.

When looking at the ultimate need for primary copper, the question arises whether it is possible to satisfy this need for primary copper. In the 2021 World Copper Fact Book (International Copper Study Group, 2021) the total world resources are estimated at 5.6 billion tonnes (Figure 8). Thus, the total world reserves of copper would be sufficient to satisfy the need for primary copper.

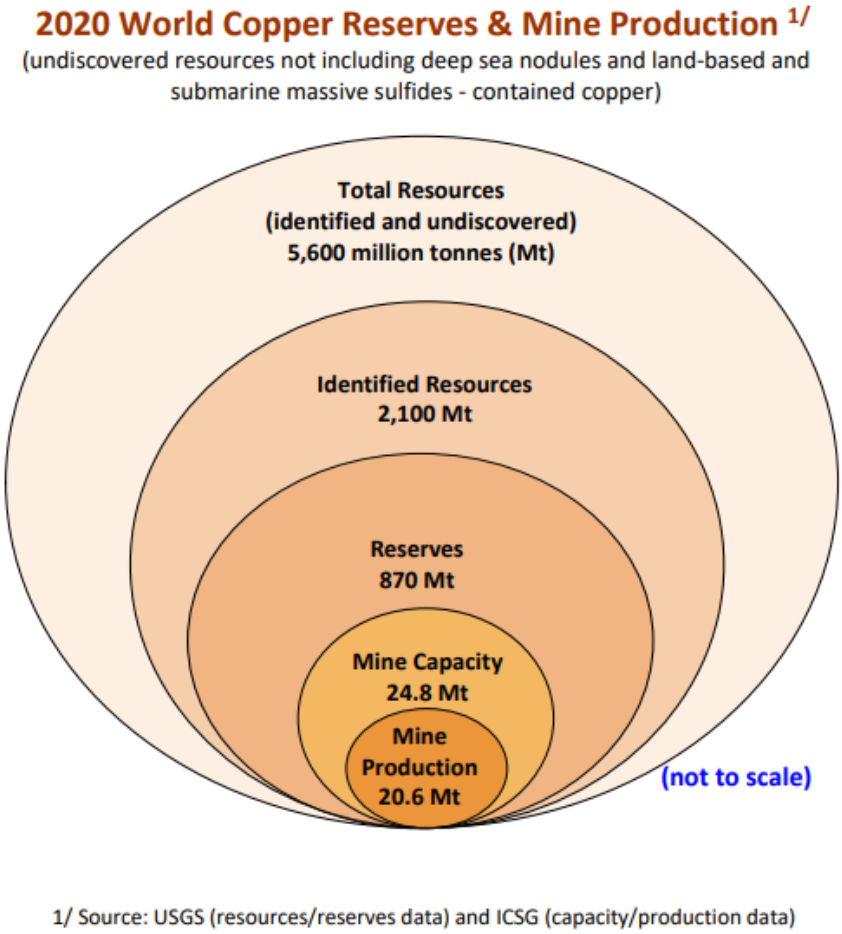

Figure 8. World copper resources (International Copper Study Group, 2021).

CONCLUSIONS

Based on the assumptions made in this paper, the ultimate need for copper mining can be calculated. The ultimate need for primary copper amounts to approximately 3 billion tonnes of primary copper, which is roughly four times the all-time primary copper production until 2020. The total world resources of 5.6 billion tonnes are sufficient to satisfy the ultimate need for copper.

A sustainable far future with a completely closed loop is unthinkable without mining to fill the AS and 100% recycling rates.

OUTLOOK

The current study is a first approach to predict the ultimate need for primary copper. The next steps include e.g., a more detailed analysis of the AS per capita, consideration of increased resource efficiency, consideration of the current predictable additional need for copper, different scenarios of the world population growth, substitution of copper and modelling of other metals.

REFERENCES

International Copper Study Group (2022). The World Copper Factbook 2021. https://icsg.org/wp-content/uploads/2021/11/ICSG-Factbook-2021.pdf (accessed on 18.05.2022).

Lucas, R., Bleischwitz, R., Krause, M., Stürmer, M., Scharpet, M. 2008. Kupfereffizienz - unerschlossene Potential, neue Perspektiven. Wuppertal Institut für Klima, Umwelt, Energie GmbH, Wuppertal (in German).

Porter, K.E., Edelstein, D.L. and Brininstool, M. 2015. Copper Statistics. U.S. Geological Survey.

United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019: Highlights (ST/ESA/SER.A/423).

USGS (2022). Mineral Commodity Summaries 2016 -2022. U.S. Geological Survey.

Ludger Rattmann

Mining Professor (since 2016)
TH Georg Agricola University, Bochum, Germany

Academic qualifications

1985 –1991	Studies in mining engineering at the RWTH Aachen University, Germany, Dipl.-Ing. Degree
1991 – 1997	Doctorate at RWTH Aachen University, Germany

Professional experience

1991 – 1995	Research and Teaching Assistant, Institute of Mining Engineering I, RWTH Aachen University
1995 - 1997	Senior Engineer, Institute of Mining Engineering I, RWTH Aachen University
1997 - 2016	Deputy Head of Institute of Mining Engineering I (since 2015 Institute of Mineral Resources Engineering), RWTH Aachen University
Since April 2016	Professor in Mining Engineering, TH Georg Agricola University, Bochum