Trends in global copper mining – a review

S Pietrzyk¹ and B Tora²

¹ Department of Non Ferrous Metals, AGH University of Science and Technology, Krakow, Poland

² Department of Mining and Geoengineering, AGH University of Science and Technology, Krakow, Poland
tora@agh.edu.pl

Abstract Copper and its alloys are used for diverse applications that are required for us to attain a specific standard of life. Continuous copper production and use are needed for the development of the society. Future copper demand will be covered mainly by the discovery of new deposits and mining. However, technological improvements and efficient designs intended to limit copper consumption will be equally important, similarly to recycling, as part of the activities associated with circular economy. Current data indicate that the global extraction of copper reached 20.2 million tons in 2016, while the output from metallurgical plants attained the level of 19.0 million tons in the same year. However, the refined copper production output increased to 23.3 million tons in 2016, including 3.9 million tons obtained from recycling. One can ask the question: Can we run short of copper, considering the present 6% increase and projected further increase of copper extraction and use? This paper is trying to find an answer to this question, based on such factors as copper resources and their long-term availability, global distribution of identified and projected copper resources, global extraction rates, and the trends in copper extraction capabilities.

1. Global copper resources

Usually, the projection of the availability of a given metal in the future is based on the evaluation of the existing resources in comparison to mining capabilities.

International classifications (United Nations Framework Classification (UNFC)) distinguish [1,2] the extractable and non-extractable resources, comprising non-industrial and subeconomic ones, as well as economic ones that have not been included in industrial or non-industrial resources (figure 1).

The class of “Reserves” includes the resources that can be extracted in an economically feasible manner, omitting losses or waste, and taking into account depletion. The term “Resources” includes geological assets, excluding the “Reserves”. According to the United States Geological Survey (USGS), the global copper reserves are presently estimated at ca. 720 Mt, while the remaining resources are estimated at ca. 5.600 Mt (figure 4). The latter figure contains the identified and undiscovered quantities that are estimated at ca. 2.100 Mt and 3.500 Mt, respectively [3].
The estimation of the undiscovered copper resources, based on the status of geological knowledge, was provided by USGS in 2013. Undiscovered copper resources were estimated, assuming two basic forms of occurrence, being so typical that they constitute 80% of identified resources. Those are porphyry deposits (60%) and sedimentary ore deposits (20%) [4]. The distribution of such resources is presented in figure 2 [4].

The estimated average amounts of undiscovered porphyry and sedimentary resources amount to 3.100 and 400 Mt, respectively, giving 3.500 Mt of copper on the global scale (not qualified as...
extractable deposits or resources). In total, the copper resources (both undiscovered and identified) are estimated at 5.600 Mt (figures 3, 4, and 5) [3, 5].

![Diagram](image)

**Figure 3.** Global resources and mining output [3].

![Pie chart](image)

**Figure 4.** Distribution of identified copper resources [3].
The latter value excludes the copper resources occurring at sea bottom. The geological recognition of such resources will increase the figures in both groups: reserves and resources. We should also take into account the average Cu content in the earth’s crust down to the depth of 3.3 km (estimated as a limit of future mining operations), and that amounts to ca. 85 ppm. This parameter additionally increases the resource content to the astronomical figure of 300.000 Mt [6].

2. Global copper mining

Pure copper, in the form of natural copper, is rarely found and it constitutes about 1% of all copper compounds. The remaining copper resources occur in the form of sulphide ores in about 90% and oxide ores in about 9%. Copper is recovered from the metallic minerals occurring in more than 160 compounds. The main copper minerals are the following: chalcosine, bornite, chalcopryrite, digenite, covellite, cuprite, malachite, djurleite, anilite, and idaite. The basic production of original copper starts with the extraction of natural copper ores in copper mines. There are three basic methods of copper ore extraction: open-pit, underground, and leaching mining. Open-pit mining is a dominating form on a global scale.

Figure 6 presents the global trends in copper mining in 1900-2016. As we can notice, the output reached 20.2 Mt in 2016 and showed more than a 3% increase. We also witnessed the appearance of a new copper production technology in the 1970’s, consisting in copper extraction and leaching in heaps, with the delivery of the mineral in the form of electrolyte (the so-called solvent extraction and electrowinning, or the SX-EW method).
Figure 6. Global copper mining [3].

Figure 7 presents the changes of continental shares in copper ore mining.

We can observe a fast increase of copper production in South America, mainly in Chile and Peru, with a 41% of share in global copper production. A strong increase from 6 to 18% also occurred in Asia, mainly in China. A drop was noted in North America, from 36 to 15%. Chile is the largest copper ore producer, representing the level of 5.5 Mt in 2016 (figure 8). The Escondida Chile is the largest copper mine, with the output of 1.270 Mt (applying the concentration and SX-EW methods).
3. Global metallurgical copper production and copper applications

The original copper production consists in obtaining the metal from natural ores. We can distinguish two production methods: pyro- and hydrometallurgical processes. The former consists in high-temperature melting of copper concentrates, containing 20-40% of Cu, obtained by ore enrichment. Copper is melted into the form of cake, or an alloy of sulphides, mainly CuS2 and FeS, containing 50-75% of Cu. The next stage involves converting processes, changing melted cake into the so-called blister copper (with 98.5-99.5% of Cu). Subsequent stages include fire refining and casting in the form of ingots or anodes designed for further electrowinning copper processes. Copper cathodes are the final product, with high 99.99% purity.

There is an alternative method of copper production called the SX-EW method. It is applied to poor oxide ores, with low copper content, as well as some sulphide ores. The method includes leaching (Solvent Extraction, SX) and electrowinning (EW).

Refined copper is the output product of both methods, with a comparable purity class. It is estimated that the SX-EW method was used to produce 16% of the total global refined copper output in 2016, and the remaining proportion originated from the pyro-metallurgical processes.

However, there is still another source of raw material available for the production of copper: copper scrap. That resource is subject to recycling. Scrap is divided into new (post-production scrap), occurring as a result of ore processing, and old scrap (post-consumer scrap) collected from scrapped products. Scrap constitutes valuable and increasingly significant raw-material in the recycled copper production, in the times of circulation economy implementation. It was estimated that recycled copper constituted about 17% of the global refined copper output in 2016 (figure 9).

Figure 8. The largest global copper mining countries [3].
The production of blister copper reached the level of about 19 Mt in 2016. China was the largest producing country of blister copper and anodes in 2016 (7.2 Mt). The total refined copper output amounted to 23.3 Mt in that year, including 3.9 Mt obtained from recycling (recycled refined copper).

Copper consumption is continually increasing, together with the development of global economy, and it is expected that the trend will continue because more and more people and societies will aspire to a higher standard of life, with the access to electricity, sewage systems, and modern appliances.

Wide-ranging copper applications rely mainly on the metal’s properties, e.g. high electrical and thermal conductivity, high workability and ductility, resistance to corrosion, and antibacterial effect. The latter feature is becoming more and more significant.

Nearly 90% of the global copper output is used in electrical devices and communication systems. Copper represents the highest electrical conductivity after silver, and that causes that it is widely used (40%) in electricity generation and electricity distribution systems by both industrial and individual consumers, in an efficient and safe manner. 12.5% of copper is used for the construction of electric and electronic equipment (electric circuits, cables, contacts etc.) [10,11]. Another 12.5% is used in the transportation industry (e.g. in the form of copper cable bundles with the highest purity, applied in trains, airplanes, trucks etc., conducting current from batteries to various control devices, lighting, onboard computers, or satellite navigation systems).

Another 20% of the whole copper output is used in the building industry (sewage systems inside the buildings, roof decking, or facade panels). Copper allows to produce light and durable structures that do not require maintenance, since the material is natural, nicely looking, and recyclable. The remaining 10% of copper output is designed for coins, sculptures, jewellery, musical instruments, kitchen utensils, and other consumer products [11].

Besides, a different application is coming back to copper consumption, with anti-microbiological touch surfaces designed for hospitals or public facilities.
4. Projections of the development of copper mine capabilities

It is estimated that copper extraction will reach 25.9 Mt in 2020 of which 19% will be obtained by the SX-EW method. That will be equivalent to a 10% increase in comparison to 2016 when the global extraction capability reached 23.5 Mt.

It is envisaged that the mining capabilities will be increasing by 2.9% a year, with the implementation of new capabilities in the existing mines (figure 11).

What is a good indication of copper mining trends is the relationship between mining output and mining capabilities, called the proportion of using production capabilities. The global indicators of using copper mine production capabilities amounted to about 86% in 2016, and that shows some reserves, allowing for extraction increase.

Another good indicator of the status of copper resources, in comparison to copper extraction capabilities, is the comparison of the figures relating to resources and mining output (figure 12) [8].
5. Conclusions

Based on the data presented above, we can conclude that there are very promising trends in the development of copper mining. The current copper resources and ore mines’ capabilities, as well as the technologies of the production of primary and refined copper provide good prospects for further regular increase of copper production in the future.

However, certain limitations exist as well. Those can affect the growing trends. One of the reasons of such an option is the fact that the high-quality copper ores become rare and difficult to discover. The success of the resource exploration requires long-term and continued capital investments at the initial stages of resource evaluation which is charged with a high risk of losses. The presently operated copper mines struggle with a number of problems, starting with the exhaustion of quality ores and the necessity to extract deeper and deeper deposits and ending with the growing expectations of the governments, regulatory authorities, and the local communities.

The Wood Mackenzie consulting agency expects that a possible drop in ore mining can reach even 17% [9]. The analysts estimate that the mining output may be dropping by 230 kt a year after 2019. The global increase of demand for copper is estimated at 2.1% a year, or 521 kt of new supply. Consequently, the deficit can increase in case of ore mining decrease.

New high-class copper ore deposits are required to meet the growing global demand for copper. The increase of copper ore extraction can be enforced in the coming decades by such new industries as electric car production, power generation from renewable resources, or infrastructure development in growing and emerging economies.

The electric car production is increasing fast. Hybrid cars consume 40 kg of copper each: twice as much in comparison to conventionally or natural gas-powered cars. Electric cars use 90 or more kilograms of copper, which is three or four times more than in the case of traditional cars. It is expected that the global fleet of electric cars will increase from the present one million vehicles to about 140 million by 2035 [11].

The increase of primary copper production can be greatly supported by renewable energy. Renewable technologies, based on wind or solar energy displayed a nearly 50 time increase in the recent decade. The share of solar energy in global energy generation increased more than twice in only three years, although it still constitutes a small part of the total energy balance. From now up to 2040, 8 billion dollars will be spent on the global renewable resources, or about two thirds of all the expenditures for energy. The renewable energy systems require 4 to 12 times more copper than the
traditional energy generation plants using fossil fuels. The growing demand for solar energy will require from 7 to 10 million tons of copper until 2030 [11].

Another hope of copper mining is associated with the growing economies that create new demand for copper. It is expected that the technological development and the positive demographic growth only in Asia will create an additional demand for more than 30 million tons of copper by 2030.

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