SCRREEN2

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FACTSHEETS UPDATES **BASED ON THE EU FACTSHEETS 2020**

COPPER

AUTHOR(S):

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COPPER

OVERVIEW

Copper (chemical symbol Cu; from Latin “cuprum”) is a ductile, reddish metal, used since the early days of human history. It is an important trace element for many living organisms, including humans (Lossin, 2001). There are over 150 identified copper minerals, but only around ten of them are of economic importance. About half of world’s copper production is mined from chalcopyrite ($CuFeS_2$) (BGS, 2007). Copper does not react with water, but slowly reacts with atmospheric oxygen. This oxidation forms a thin protective layer of brown-black copper oxide that prevents the bulk of the copper from being oxidised. In the absence of air copper is also resistant to many acids such as hydrochloric acid, sulphuric acid or acetic acid (Römpp, 2006).

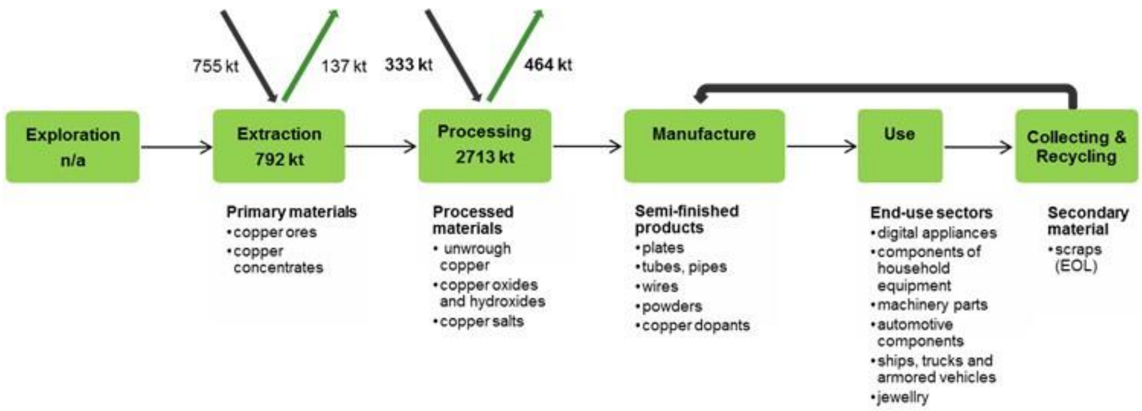

Figure 1. Simplified value chain for copper in the EU[1]

Table 1. Copper supply and demand in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
20,538,727.2	Chile 28% Peru 12% China 8% Congo,D.R, USA 6% Australia, Zambia, Russia, Mexico 4% Canada, Indonesia, Kazakhstan 3%	2,054,007.3	10.0%	Poland 20% Chile 15% Brazil 10% Peru 10% Spain 9% Bulgaria 5% Sweden 5% Canada 4%	48%

[1] JRC elaboration on multiple sources (see next sections)

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Prices: The reference price refers to the cathode standard LME Grade A (≥ 99.99 % Cu). Copper is the industry metal that is considered being traded most intense. In general, the copper price is determined by the copper supply and copper demand. In addition, speculative activities, exchange rates and market news about production losses have an impact on the price (DERA, 2020). Copper reached its higher price en 2010, after recovering from the 2008 financial crises, when it was at its lowest. The price decreased again until 2015 to reach a new peak in 2017 and then again in 2020, with a highest since 2010.

Primary supply: Most of the copper is produced as the main product from copper mines. In addition, a significant amount of copper comes as a co-product from zinc, lead, nickel, and gold mines, and in minor volumes as a by-product from gold, silver, and molybdenum mines. Global mine production of copper between 2010 and 2020 showed gradual increase until 2016, then flattening out, and amounted between 16,100,000 and 20,800,000 tons per year (WMD 2022). Within the EU, 760,000 to 960,000 tons of copper was produced from the mines in the same period, with the peak in 2016. In 2020, the main EU producers were from Poland (45 % of the EU production), Spain (23 %), Bulgaria (13 %), and Sweden (12 %) (WMD 2022).

Secondary supply: Copper is one of the most recycled of all metals. Thus, nearly all copper products can be recycled over and over again without loss in product properties (DKI, 2016) (ICSC, 2021). Copper scrap derives from metal discarded in semi-final products fabrication or finished product manufacturing processes (new scrap) and end-of-life products (old scrap). Refined copper production attributable to recycled scrap feed is classified as secondary copper production. Secondary producers use similar processes to primary production. (ICSG, 2021). The International Copper Study Group (ISGS) estimates that in 2019, 30% of global copper use come from recycled copper and the 10-year average (2008-2018) recycling input rate (RIR) for copper is 32%. Globally, 9,500 kt of copper were recycled in 2019, including secondary refined production and scrap direct melt (ICSG, 2021).

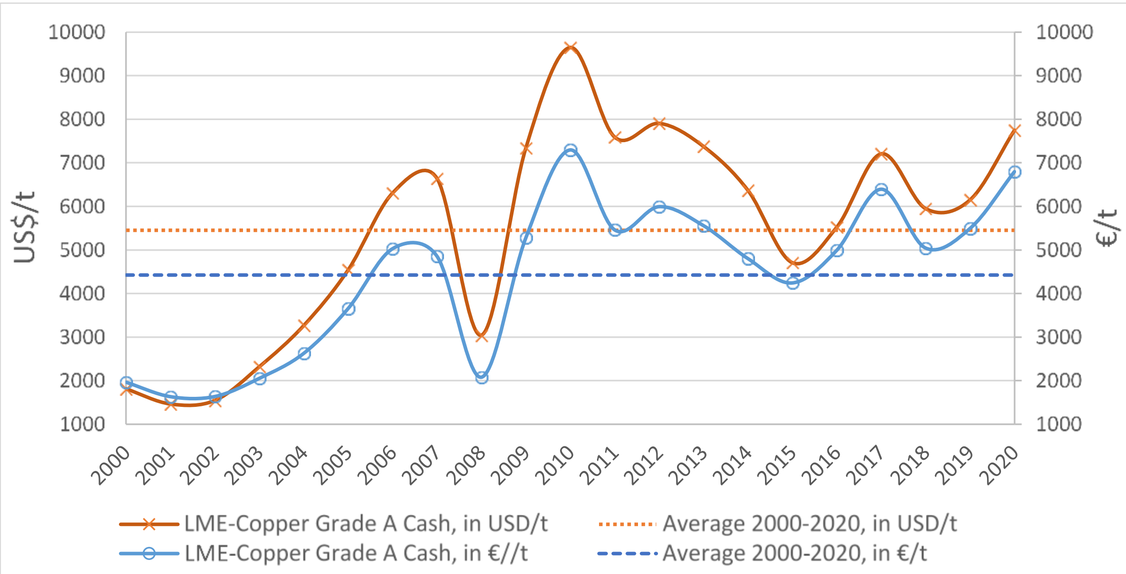

Figure 2. Annual average price of copper between 2000 and 2020 (USGS, 2021)[2].

[2] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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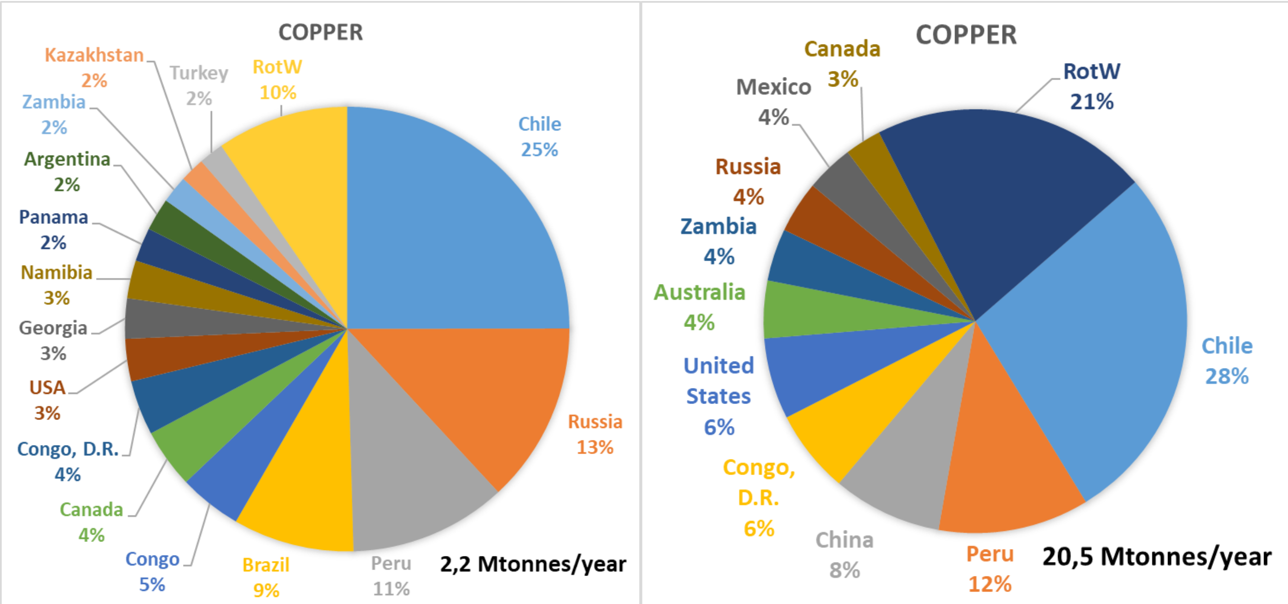

Figure 3. EU sourcing of copper and global mine production (average 2016-2020)

Uses: Copper is crucial for several applications due to its unique properties. It is the best electrical conductor after silver. Additionally, copper is corrosion resistant, ductile and malleable. These properties make copper to one main material for electrically conductive components in a wide variety of applications. The copper uses have been quite stable along the last 10 years and the EU uses are close to the global uses.

Substitution: The unique properties of copper make it difficult to substitute it in various applications, especially due to its thermal and electrical conductivity. Nevertheless substitution options exist and are described in Table 2.

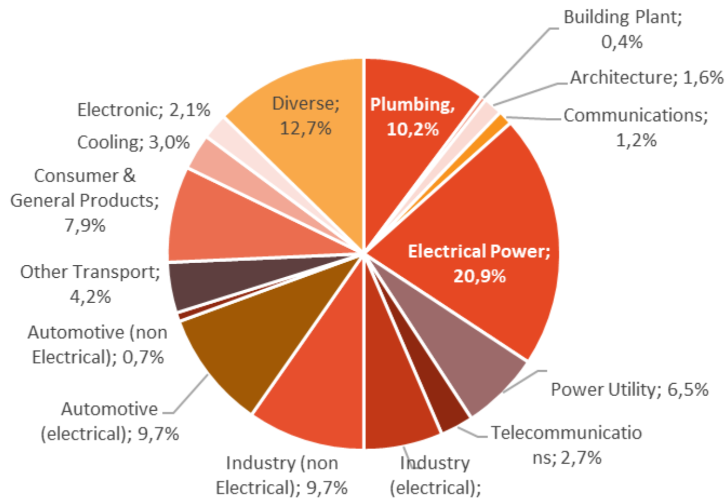

Figure 4: EU uses of copper. Average figure for 2016-2020 (IWCC; ICA, 2022a)

Other issues: Copper is classified as a heavy metal (German Environment Agency, 2020; Tchounwou et al., 2022). Copper is a nutrient that is essential for many biochemical and physiological functions. In particular, it intervenes in some enzymatic reactions due to its ability to cycle between an oxidized Cu(II) and reduced state Cu(I). This property makes it also potentially toxic especially in case of excessive exposure (Tchounwou et al.,

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2014; Gaetke and Chow 2003). At high concentrations, copper is mainly toxic to aquatic organisms with long lasting effects (ECHA, 2022a; US EPA 2022), which is also reflected in the CLP (Classification, Labelling and Packaging) notifications. Human exposures to copper are mainly linked to anthropospheric activities such as smelting, mining, industrial activities, domestic waste emissions and application as fertilizers, sewage sludge, algicides, fungicides or molluscicides (Flemming and Trevors, 1989; Tchounwou et al., 2014). The environmental impacts of copper production are well assessed, especially using life cycle assessment (LCA). Globally it could be said that from extraction to refining, copper production is highly energy intensive leading to important emissions of GHG (greenhouse gases). Water consumption is also important in the copper life cycle, moreover this life cycle occurs in countries where the water stress is relatively high (Chile or Peru for example). Some of the copper mines are open pit mines, leading to potentially high land use impacts. However, impacts from copper extraction and copper production are site-specific and mainly depend on the type of mining (open pit vs. underground mining), the type of ores exploited (oxidized vs. sulphuric as well as the grade of the exploited ore) and the type of metal processing technology (pyrometallurgy vs hydrometallurgy) (Northey et al. 2012; Sanjuan-Delmás et al., 2022).

Table 2: Substitution options for copper by application.

Use	Percentage*	Substitute	Comment on substitute
Electrical applications	>46	Aluminium, silver	Trade-off between conductivity and costs
Telecommunication	2.7	Optical fibres (silicon)	Slightly higher costs, similar performance**
Pipes and plumbing	10.2	Plastics, aluminium	Similar or lower costs; reduced performance**
Heat exchanger	unknown	Titanium, stainless steel, aluminium and plastics	In the main, Similar or lower costs; reduced performance**

*Average European end use share for 2016-2020 (IWCC; ICA, 2022)
** EC CRM Data 2023

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MARKET ANALYSIS, TRADE AND PRICES

GLOBAL MARKET

Table 3: Copper (extraction) supply and demand in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
20,538,727.2	Chile 28% Peru 12% China 8% Congo,D.R, USA 6% Australia, Zambia, Russia, Mexico 4% Canada, Indonesia, Kazakhstan 3% Others 16%	2,054,007.3	10.0%	Poland 20% Chile 15% Brazil 10% Peru 10% Spain 9% Bulgaria 5% Sweden 5% Canada 4% Portugal 3% Georgia 3% US 3%	48%

Table 4: Copper (processing) supply and demand in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
24,132,631.0	China 38% Chile 10% Japan 6% Congo, D.R. 4% Russia 4% UMI 4% Germany 3% India 3% South Korea 3%	3688055.5	15%	Germany 18% Poland 15% Spain 11% Belgium 10% Russia 8% China 7% Sweden 6% Bulgaria 6% Finland 4% Austria 3% Congo 3%	17%

Copper trading takes place predominantly in three commodity exchanges: The London Metal Exchange (LME), the Commodity Exchange Division of the New York Mercantile Exchange (COMEX/NYMEX) and the Shanghai Futures Exchange (SHFE). On the LME, copper is traded in 25 tonne lots and quoted in US dollars per tonne; on COMEX, copper is traded in lots of 25,000 pounds and quoted in US cents per pound; and on the SHFE, copper is traded in lots of 5 tonnes and quoted in Renminbi per tonne. More recently, mini contracts of smaller lots sizes have been introduced at the exchanges (ICSG, 2019a) The exchanges facilitate to hedge, store and to a limited degree also trade copper.

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With 28% of global mine production, Chile is the top copper producer by worldwide, followed by Peru with 12% and China with 8%. China is the biggest processed copper producer with a 38% share followed by Chile with 10% and then other countries with a share lower than 6%. Most reserves are in Chile (about 23% of the world's reserves). Other significant reserves are located in Australia, Peru, Russia, Mexico, and the US.

The copper market is partially consolidated, with a few major players dominating a significant portion of the market. The top 5 biggest copper miners are Codelco, Freeport McMoRan, Glencore, BHP and Southern Copper. The copper market size is projected to grow by a CAGR of 3.26% between 2021 and 2026 with Asia-Pacific expected to experience the fastest growth. Increasing demand from construction, electrical and electronic industries is boosting the market's growth (Technavio, 2022).

Due to its unique properties, copper is crucial for many applications. Copper is the best electrical conductor after silver and is used in the production of energy-efficient power circuits. As it is also corrosion resistant, ductile and malleable, it is mainly applied in all types of wiring; from electric energy supply from the power plant to the wall socket, through motor windings for electrical motors, to connectors in computers. Copper is used in many forms in buildings including wiring, pipes and fittings, electrical outlets, switches and locks. It is corrosion resistant, antibacterial and impermeable and thus has been used in the production of water pipes for at least 4500 years (ECI, 2016a). Copper roofing is another common application where it is used for its functionality and architectural characteristics (ECI, 2016a).

Copper and its alloys, mainly brass and bronze, are important raw materials for many kinds of mechanical parts such as sleeve bearings and other forged parts (CDA, 2016). In the automotive and transport sector, copper is an essential metal; there is an average 25 kg copper in every car. Aside from its use in electrical parts, copper is used in heat exchangers and radiators due to its high thermal conductivity. The development of modern hybrid cars – in which an electrical motor supports the combustion engine - leads to an even higher copper consumption in cars (ECI, 2016a).

For the main applications possible substitutes are as follows (Glöser et al., 2013b; BGS, 2007):

- in electrical applications, aluminium can replace copper wiring, though it is prone to conduction loss through corrosion
- in telecommunications, cables made from optical fibres can substitute for copper wire
- for pipes and plumbing fixtures, plastics can replace copper
- for heat exchangers, titanium, stainless steel, aluminium or plastics can substitute for copper, depending on the requirements of the application (temperature, aggressive fluids, etc.).

Copper is essential for low-carbon technologies in the broad areas of transport (energy infrastructure, hybrid & electric vehicles and associated charging infrastructure); wind power (cabling and temperature control within wind turbines); solar power (heat exchangers of solar thermal systems, photovoltaic panels), tidal generation (ECI, 2012; Euromines, 2019a)

EU TRADE

Copper metal is assessed at Mining and processing/refining stage. Once processed, copper is traded in numerous forms, pure or alloyed, under the trade cope family 74. For this assessment, the list has been limited to the main products. The following table lists relevant Eurostat CN trade codes selected for Copper.

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Table 5. Relevant Eurostat CN trade codes for Copper

Mining		Processing/refining	
CN trade code	**title**	**CN trade code**	**title**
26030000	Copper ores and concentrates (Cu content 30%)	**74031100**	Refined copper (Cu content 100%)
		74010000	Copper mattes; cement copper "precipitated copper" (Cu content 75%)
		74020000	Copper, unrefined; copper anodes for electrolytic refining (Cu content 100%)

Figure 5 shows the import and export trend of copper ores and concentrates in Cu content (30% of the ores and concentrates). The EU is a net importer of copper ores and concentrates. The import increased from 630 thousand tonnes in 2000 to 1.2 million tonnes in 2017-2018. The import has increased continuously in past 20 years with a slight decline 2009 with obvious reason of slowing down the demand due to financial crisis. EU also export considerable quantity of copper ores and concentrate. The export grew from 66164 tonnes in in 2000 to 280000 tonnes in 2020.

The high volume of ores import shows EU has considerable capacity to process these materials to finished copper products and other value add activities.

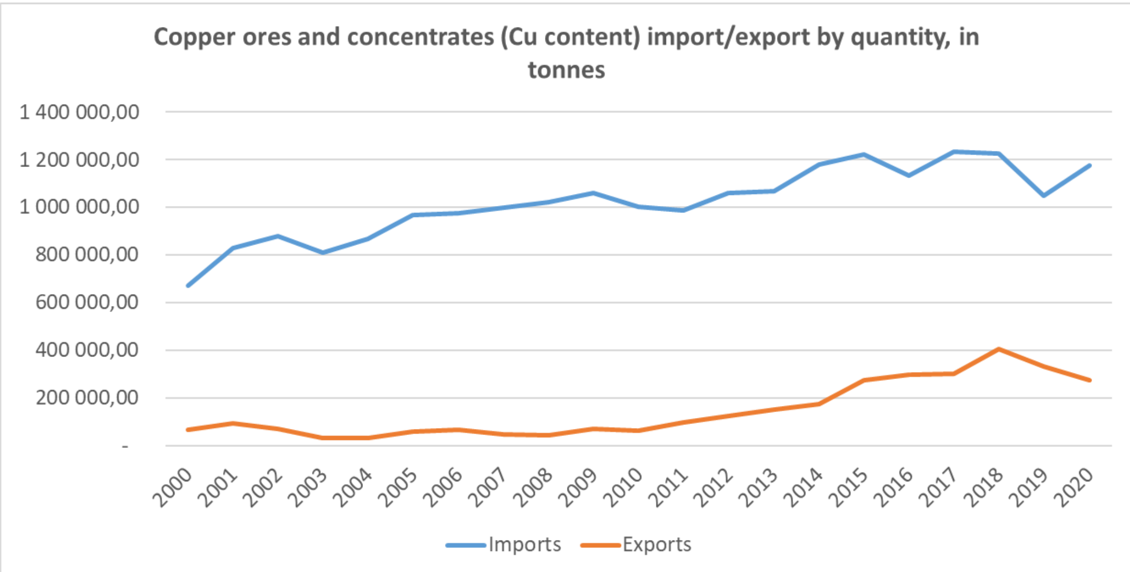

Figure 5. EU trade flows of Copper containing Copper ores and concentrates (Cu content, CN 26030000) from 2000 to 2020 (Eurostat, 2022)

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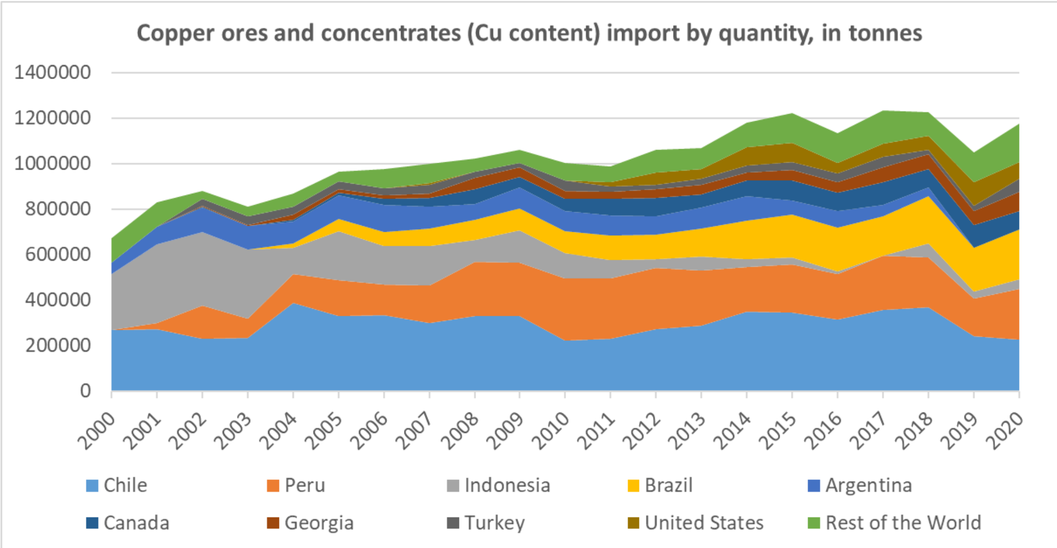

Figure 6 illustrates the share of import of EU for Copper ores and concentrates from various countries. The main supplier to EU in the past two decades (2000-2020) was Chile (28% of share), followed by Peru, Indonesia, Brazil and Argentina (18%, 12%, 11% and 7%, respectively).

Figure 7 presents the import and export trend of refined copper. During the year 2000-2020, the EU export of refined copper had a gradual increase with some fluctuations while the import decreased from 1.8 million tonnes to 0.8 tonnes in 2021. During 2019 to 2020, the export of Refined Copper increased while the import decreased.

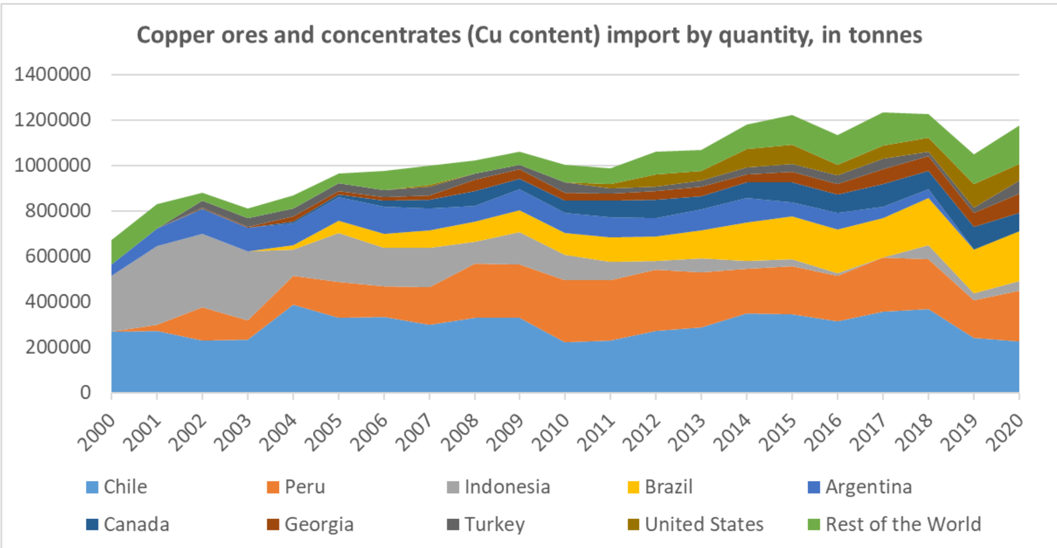

Figure 6. EU imports of Copper containing Copper ores and concentrates (Cu content, CN 26030000) from 2000 to 2020 (Eurostat, 2022)

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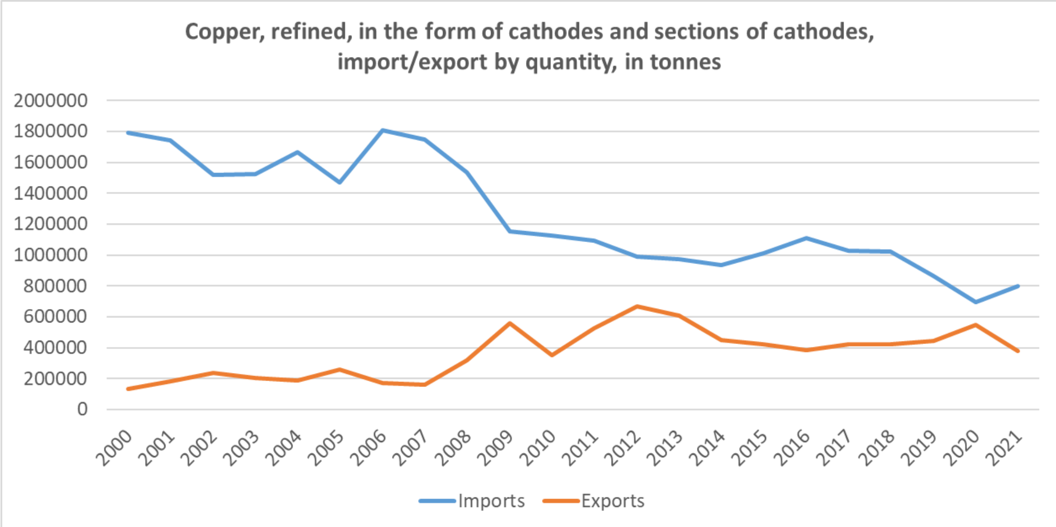

Figure 7. EU Trade flows of Refined copper (CN 74031100) from 2000 to 2020 (Eurostat, 2022)

Figure 8 shows the share of import for refined Copper from various countries. The main import partners of EU for refined Copper are Chile (47%), Russia (24%), Peru (5%), Kazakhstan (4%) and Republic of Congo (3%). Chile is the main supplier of all times (2000-2020). The import of Refined Copper from Republic of Congo increased from 40 tonnes in 2004 to 118000 tonnes in 2013 and increased by 17 times from 2011 to 2013 (from 7,012 tonnes to 118000 tonnes). It reached to 880,914 tonnes in 2021. Another important change is related to the import from Chile which gently reduced from 1,015,389 tonnes in 2007 to about 190000 tonnes in 2020.

Figure 9 shows the import and export trend of Copper mattes; cement copper "precipitated copper". Data are only available since 2007. During the year 2007-2020, the EU import and export showed several fluctuations, with almost no import in 2013-2015. Until 2012, exports were lower than imports but the trend changed in 2012. Exports doubles between 2018 and 2020.

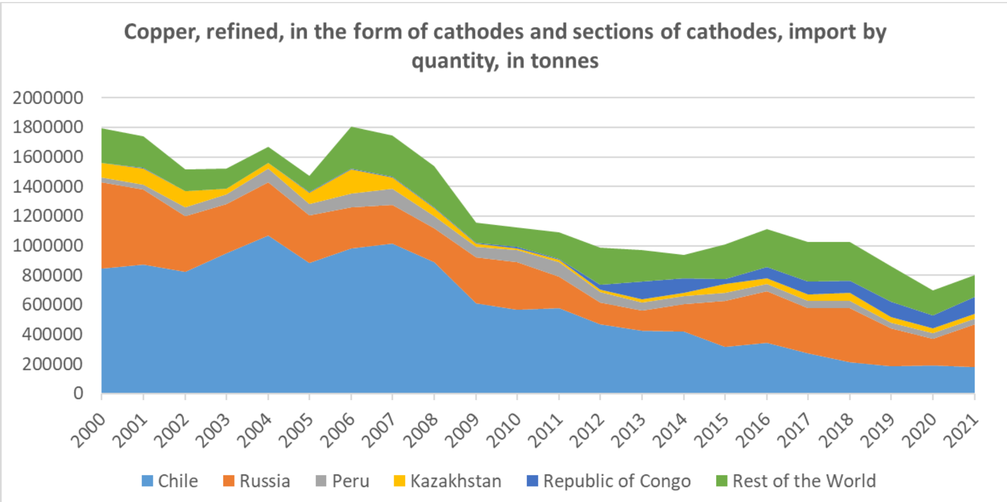

Figure 8. EU imports of Refined copper (CN 74031100) by country from 2000 to 2020 (Eurostat, 2022)

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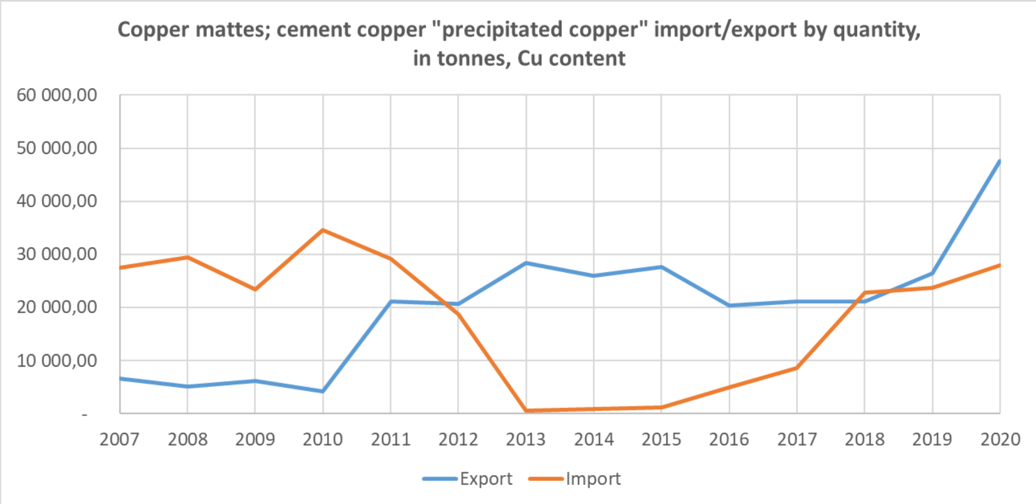

Figure 9. EU trade flow of Copper mattes (CN 74010000) from 2007 to 2020 (Eurostat, 2022)

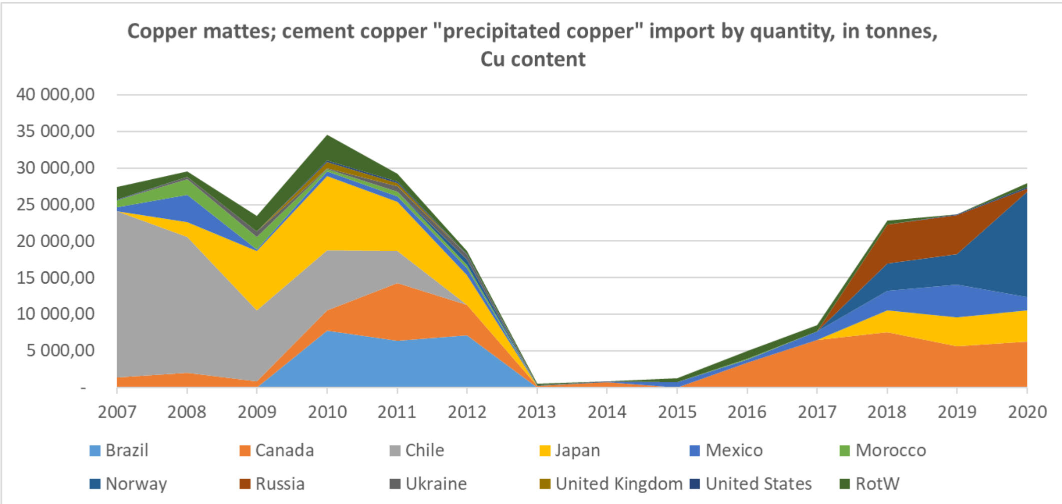

Figure 10. EU imports of Copper mattes (CN 74010000) by country from 2007 to 2020 (Eurostat, 2022)

Figure 10 illustrates the share of Copper mattes; cement copper "precipitated copper" from various countries. The main supplier to EU in 2007-2009 was Chile but the market diversified with Brazil, Canada and Japan until 2013. Since 2016, the main EU suppliers are Canada, Japan, Mexico, Norway and Russia.

Figure 11 indicates the import and export trend of Copper, unrefined; copper anodes for electrolytic refining. The import and export of Copper Articles have been fluctuating a lot (factor of 3 for imports and 15 for exports). Export were always lower than imports but in 2020.

Figure 12 shows the share of import in EU for Copper Articles from various countries. The main import partners of EU are Chile (30%), Russia (15%), UK (10%), Switzerland (4%) and Turkey (4%). Chile used to be the main supplier until 2016 but Russia has overtaken others as the main import partner in last five years. The import quantity of Copper Article from Turkey increased twice from 2016 and reached to 155,951 tonnes in 2021.

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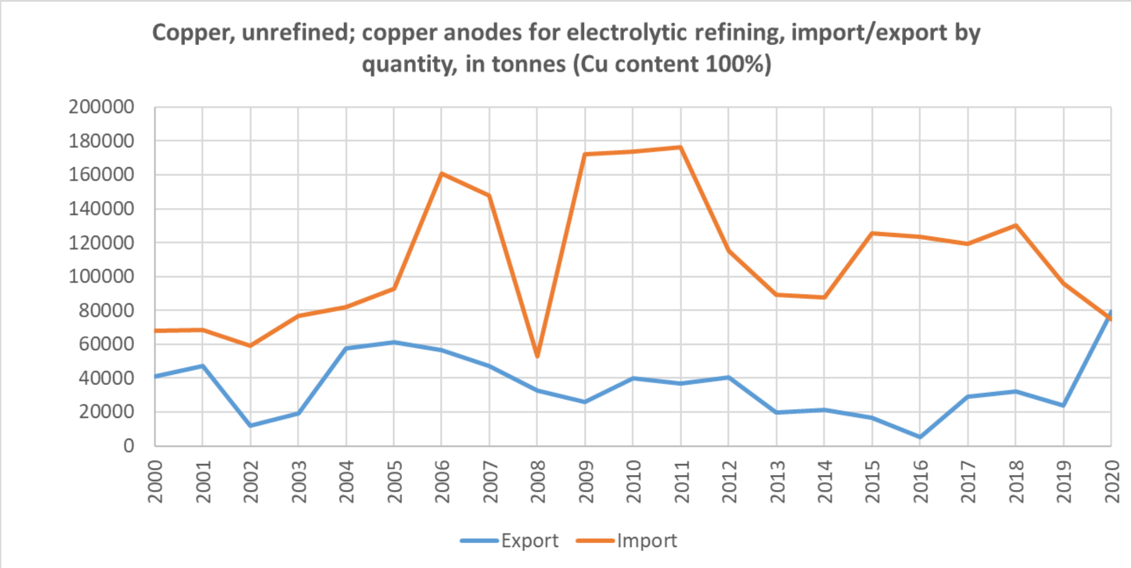

Figure 11. EU trade flow of Copper, unrefined (CN 74020000) from 2000 to 2021 (Eurostat, 2022)

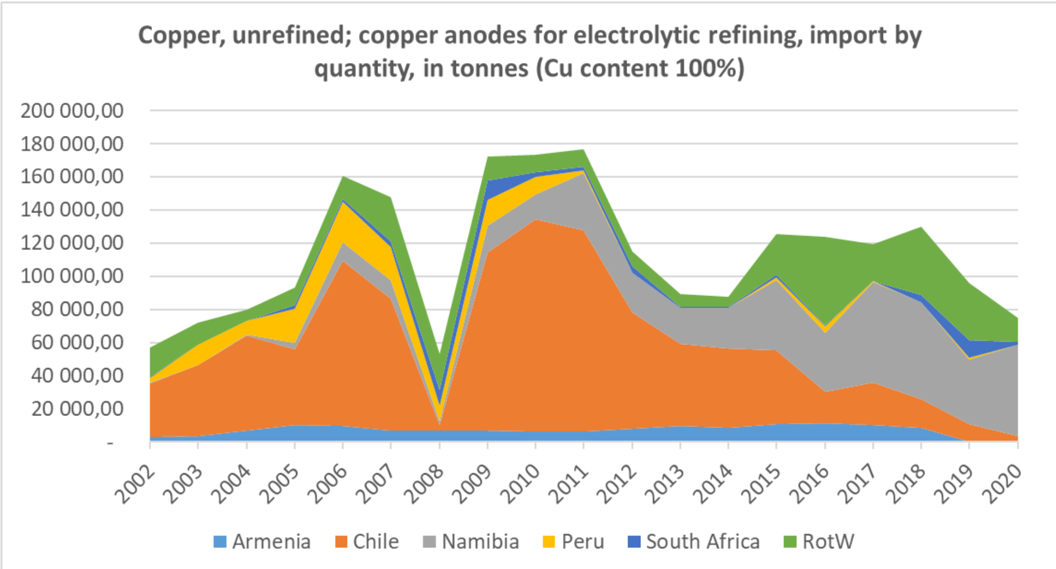

Figure 12. EU imports of Copper, unrefined (CN 74020000) by country from 2000 to 2020 (Eurostat, 2022)

3.3. PRICE AND PRICE VOLATILITY

The reference price refers to the cathode standard LME Grade A (≥ 99.99 % Cu). Copper is the industry metal that is considered being traded most intense. In general, the copper price is determined by the copper supply and copper demand. In addition, speculative activities, exchange rates and market news about production losses have an impact on the price (DERA, 2020).

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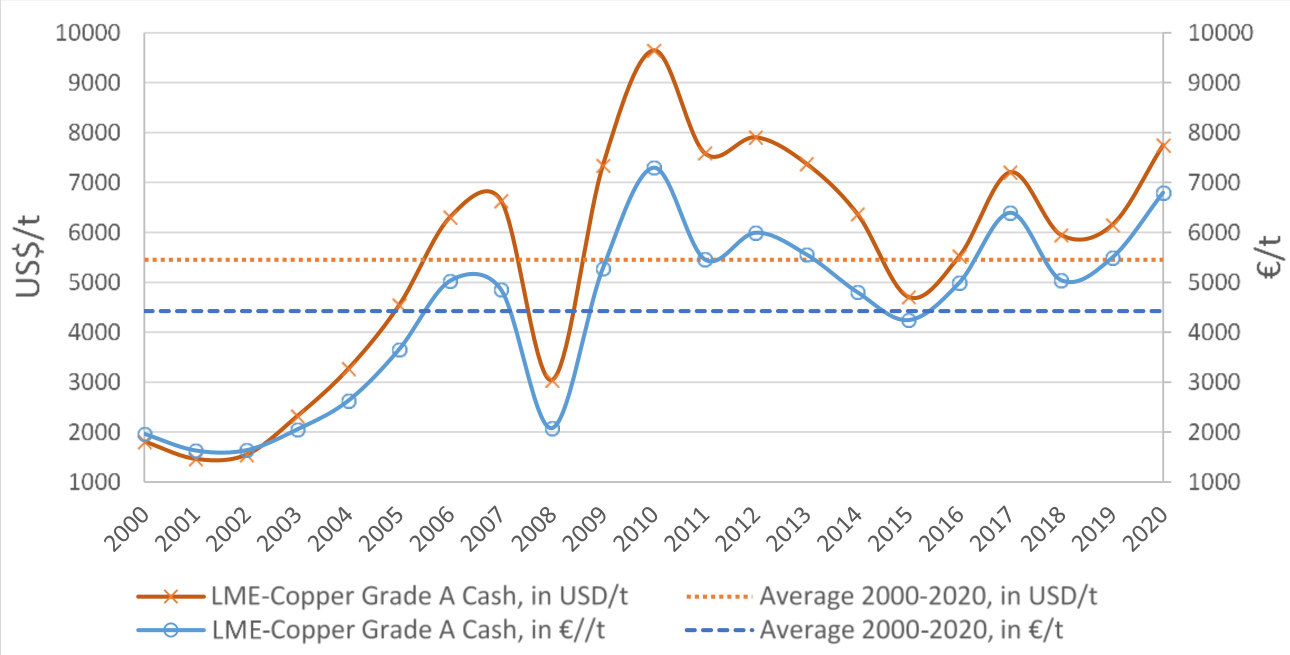

Figure 9. Annual average price of LME copper between 2000 and 2020, in US$/t and €/t[3]. Dash lines indicate average price for 2000-2020 (S&P Global, 2022a)

With the strengthening of China as an emerging economic power, the copper price rose until the financial market crisis in 2008. The price managed to recover once the global economy in 2009 and 2010 recovered. Since 2011, the price experienced a downward trend due to previously built-up overcapacities and a downward GDP growth in China which ended in mid-2016. By the end of 2016, copper was trading at its lowest price in 7 years. The copper price experienced remarkable growth in 2017 due to a combination of supply and demand factors. The surge was largely due to structural changes implemented in the Chinese economy, which consumes around half of the global copper production. Production from the two largest copper mines was interrupted which tightened global supply. Furthermore, a decrease in the dollar index also supported global copper prices because a weaker US dollar makes copper more affordable with respect to other currencies (Nasdaq, 2017). In the first half of 2018, prices surged amid expectations of labour strikes at copper mines in Chile and Peru in conjunction with strong copper demand from electric vehicle manufacturers. In the second half of the year, prices plunged on the back of failed strikes and the intensification of US-China trade tensions which caused concerns about lower demand (Nornickel, 2018). The fear of global economic slowdown linked to US-China trade war drove the copper price for most of 2019 instead of the metal's demand-supply balance. These fears dampened the global industrial demand. Copper began the year of 2019 at USD 6,075 per tonne, dipped to as low as USD 5,757 per tonne in October and ended the year at USD 6,077 per tonne (Televisory, 2020). Slower copper production in recent years has led to a shortage with demand rising. Copper prices followed China's pace of growth, which recovered in the second half of 2020 and the first half of 2021. Copper

[3] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

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prices have been among the commodities that have reached record high prices since the COVID-19 pandemic began (Institutional Investor, 2022).

OUTLOOK FOR SUPPLY AND DEMAND

Various factors including bills, multiyear plans and other forms of government stimulus directed toward decarbonization, electrification, renewables development, and infrastructure and technology will sustain copper demand in the long term. Despite several new projects and ramp-ups announced to be in the supply pipeline, robust demand will keep the refined market in deficit and sustain prices by the middle of the decade (Cecil, Sumangil, & Marjolin, 2022). According to Goldman Sachs, the copper market as it currently stands is not prepared for the expected demand. Green electrification-associated demand will have a substantial tightening effect on the global copper balance over the next decade. A long-term supply gap of 8.2Mt by 2030 is expected (Goldman Sachs, 2022). An average three-month copper price of USD 8,990 per tonne and USD 9,570 per tonne is estimated in 2025 and 2026 (S&P Global, 2022).

DEMAND

GLOBAL AND EU DEMAND AND CONSUMPTION

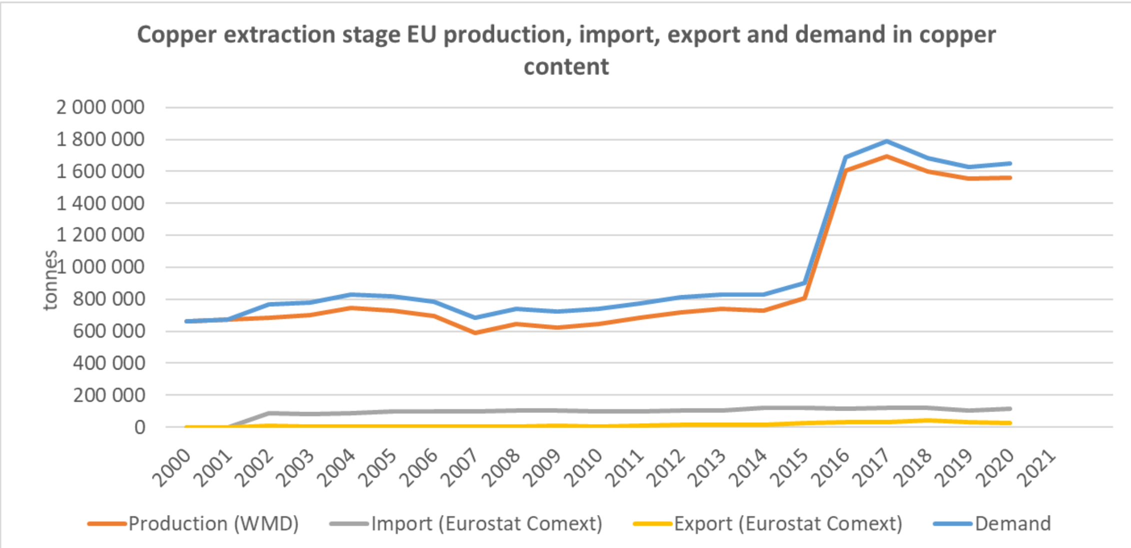

Figure 13.Copper (CN 26030000) extraction stage apparent EU consumption. Production data is available from WMD (2022). Consumption is calculated in copper content (EU production+import-export).

In 2021, the global apparent consumption of copper reached 25.3 Mtonnes per year (ICSG, 2022). The International Copper Study Group suggests European consumption of refined copper as 4.0 Mtonnes in 2021 (ibid.).

Copper extraction stage EU consumption is presented by HS code CN 26030000 Copper ores and concentrates. Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from WMD (2022).

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Copper processing stage EU consumption is presented by HS codes CN 74031300 Copper, Refined, in the form of billets, CN 74031100 Copper, Refined, in the form of cathodes and sections of cathodes, CN 74020000 Copper, unrefined; Copper anodes for electrolytic refining and CN 74010000 Copper mattes; Cement copper "precipitated copper". Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from BGS (2021).

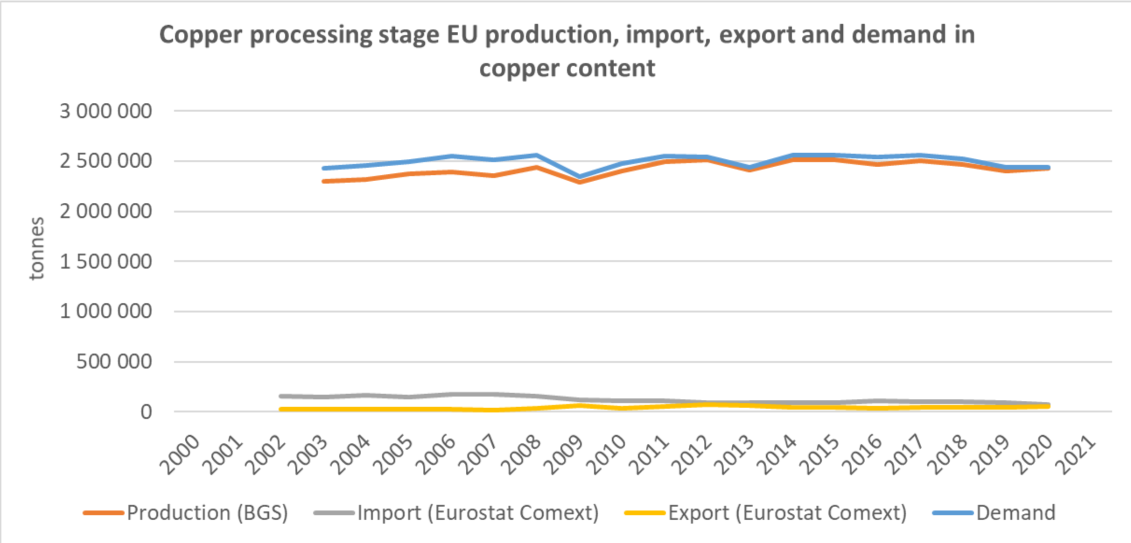

Figure 14. Copper (CN 74031300, 74031100, 74020000 and 74010000) processing stage apparent EU consumption. Production data is available from (BGS, 2021). Import and export data is available for 2002-2020. Consumption is calculated in copper content (EU production+import-export).

Average import reliance of copper is at extraction stage 5.0 % and at processing stage 1.9 % for 2016-2020.

GLOBAL AND EU USES AND END-USES

Copper is crucial for several applications due to its unique properties.

It is the best electrical conductor after silver. Additionally, copper is corrosion resistant, ductile and malleable. These properties make copper to one main material for electrically conductive components in a wide variety of applications.

The European end uses of copper are shown in Figure 15, while Figure 16 and Figure 17 show the global end use sectors for 2021 and 2011, respectively.

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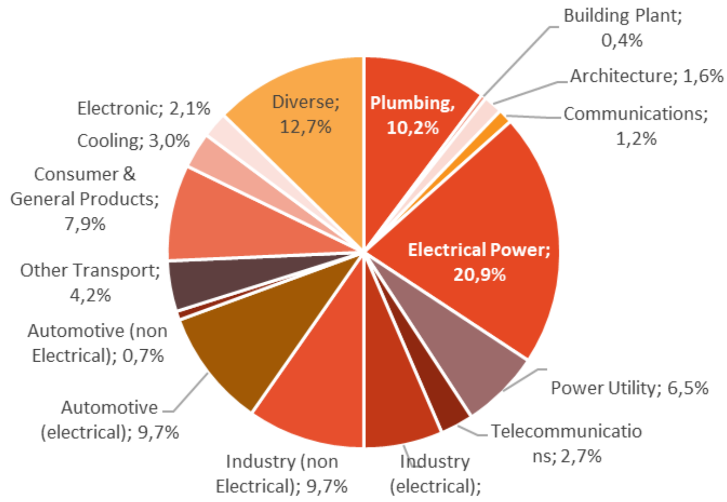

Figure 15: European end uses of copper. Average figure for 2016-2020 (IWCC; ICA, 2022a)

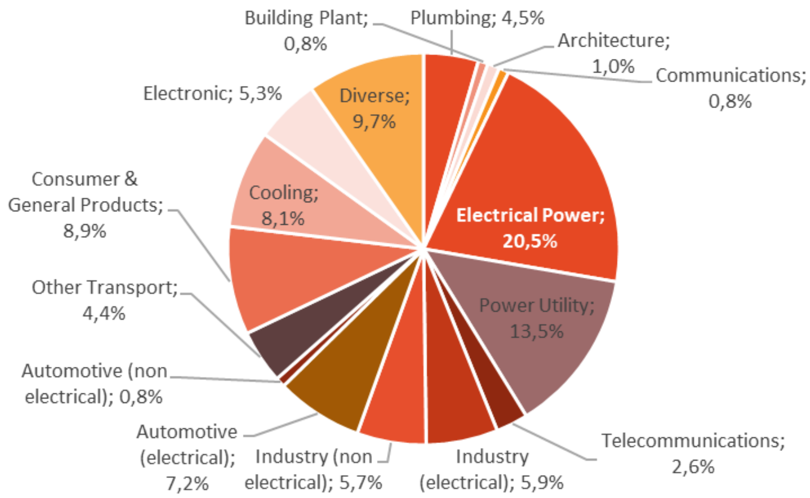

Figure 16: Global end use sectors of copper for 2021 (IWCC; ICA, 2022b).

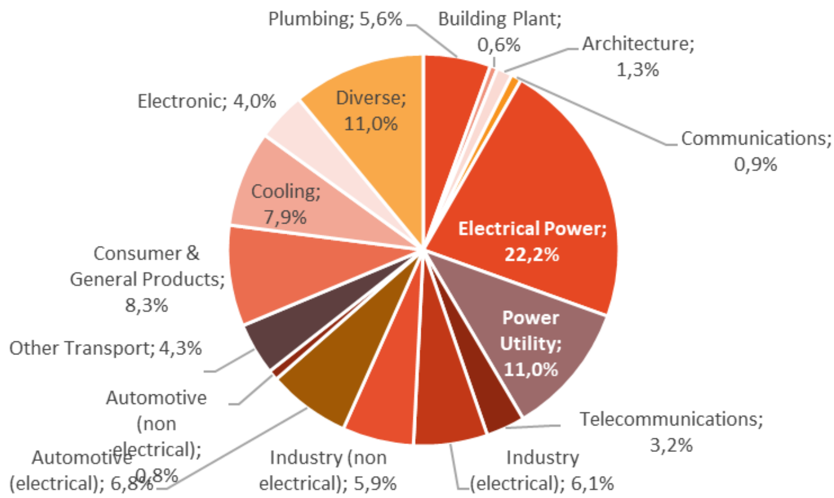

Figure 17: Global end use sectors of copper for 2011 (IWCC; ICA, 2022b).

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Table 6: Copper applications, 2-digit and examples of associated 4-digit NACE sectors, and value-added per sector for 2018 (Eurostat, 2021).

Applications	2-digit NACE sector	Value added of NACE 2 sector (M€)	4-digit CPA
Oxides and dopants	C20 - Manufacture of chemicals and chemical products	117,093*	C20.13 - Manufacture of other inorganic basic chemicals
Electrolytic refined copper	C24 - Manufacture of basic metals	71,391	C24.20 -Manufacture of tubes, pipes, hollow profiles and related fittings, of steel
Tubes, plates, wire	C25 - Manufacture of fabricated metal products, except machinery and equipment	183,016	C25.91 - Forging, pressing, stamping and roll-forming of metal; powder metallurgy
Digital appliances	C26 - Manufacture of computer, electronic and optical products	84,021	C26.11 - Manufacture of electronic components
Components and household	C27 - Manufacture of electrical equipment	98,417	C27.32 -Manufacture of other electronic and electric wires and cables
Machinery	C28 - Manufacture of machinery and equipment n.e.c.	200,030	C28.15 -Manufacture of bearings, gears, gearing and driving elements
Automotive parts	C29 - Manufacture of motor vehicles, trailers and semi-trailers	234,941	C29.20 - Manufacture of bodies (coachwork) for motor vehicle
Ships, trucks and armoured vehicles	C30 - Manufacture of other transport equipment	49,098	C30.20 -Manufacture of railway locomotives and rolling stock
Subparts of interior	C31 - Manufacture of furniture	76,795**	C31.01 -Manufacture of office and shop furniture
Jewellery	C32 - Other manufacturing	76,795**	C32.11 - Manufacture of jewellery and related articles

* for 2014
** C31 plus C32

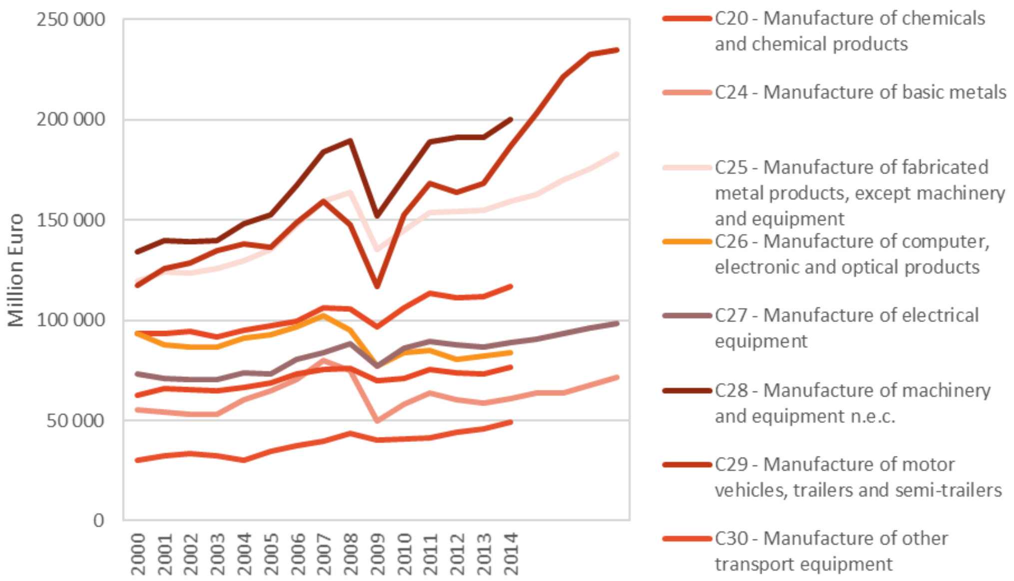

Figure 18: Value added per 2-digit NACE sector over time (Eurostat, 2021).

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Relevant industry sectors are described using the NACE sector codes (Eurostat, 2021). The calculation of economic importance is based on the use of the NACE 2-digit codes and the value added at factor cost for the identified sectors (Table 6 and Figure 18).

APPLICATIONS OF COPPER

ELECTRIC AND ELECTRONIC APPLICATIONS

- Copper is used in the production of energy-efficient power circuits.
- Copper wires are used for electric energy supply from the power plant to the wall socket, motor windings for electrical motors, and connectors in computers.

MECHANICAL EQUIPMENT

- Copper and its alloys, mainly brass and bronze, are important raw materials for many kinds of mechanical parts such as sleeve bearings and other forged parts (CDA, 2016).

BUILDINGS

- Copper is used in many forms in buildings including as wiring, pipes and fittings, electrical outlets, switches and locks.
- It is corrosion resistant, antibacterial and impermeable and thus has been used in the production of water pipes for at least 4,500 years (ECI, 2016a).
- Copper roofing is another common application where it is used for its functionality and architectural characteristics (ECI, 2016a).

AUTOMOTIVE

- In the automotive and transport sector, copper is an essential metal.
- On average there are 25 kg copper in every car. The development of modern hybrid and full electric cars leads to an even higher copper consumption in cars (ECI, 2016a).

HEAT EXCHANGER

- Due to its high thermal conductivity, copper is used in heat exchangers and radiators.
-

SUBSTITUTION

The unique properties of copper make it difficult to substitute it in various applications, especially due to its thermal and electrical conductivity. Nevertheless substitution options exist and are described in Table 7 and in more detail below (Glöser et al., 2013; BGS, 2007; USGS, 2019).

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Table 7: Substitution options for copper by application.

Use	Percentage*	Substitute	Comment on substitute
Electrical applications	>46	Aluminium, silver	Trade-off between conductivity and costs
Telecommunication	2.7	Optical fibres (silicon)	Slightly higher costs, similar performance**
Pipes and plumbing	10.2	Plastics, aluminium	Similar or lower costs; reduced performance**
Heat exchanger	unknown	Titanium, stainless steel, aluminium and plastics	In the main, Similar or lower costs; reduced performance**

*Average European end use share for 2016-2020 (IWCC; ICA, 2022)
** EC CRM Data 2023

ELECTRICAL APPLICATIONS

Aluminium can replace copper in electrical equipment like wiring or power cables though it is prone to conduction loss through corrosion. Silver has a higher electrical conductivity than copper, but comes with higher material costs (BGS, 2007).

TELECOMMUNICATION

In telecommunication applications, cables made from optical fibres can substitute copper wire.

PIPES AND PLUMBING

Plastics and aluminium can replace copper, for example in and water pipes, plumbing fixtures, and drain pipes (BGS, 2007).

HEAT EXCHANGER

Titanium, stainless steel, aluminium and plastics can serve as a substitute for copper in heat exchanging applications. The substitution depends on the requirements of the application (temperature, aggressive fluids, etc.) (BGS, 2007).

OTHER APPLICATIONS

Aluminium can substitute copper-containing brass in automobile radiators as well as in cooling and refrigeration tubes.

Steel substitutes copper in artillery shell castings (BGS, 2007).

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SUPPLY

EU SUPPLY CHAIN

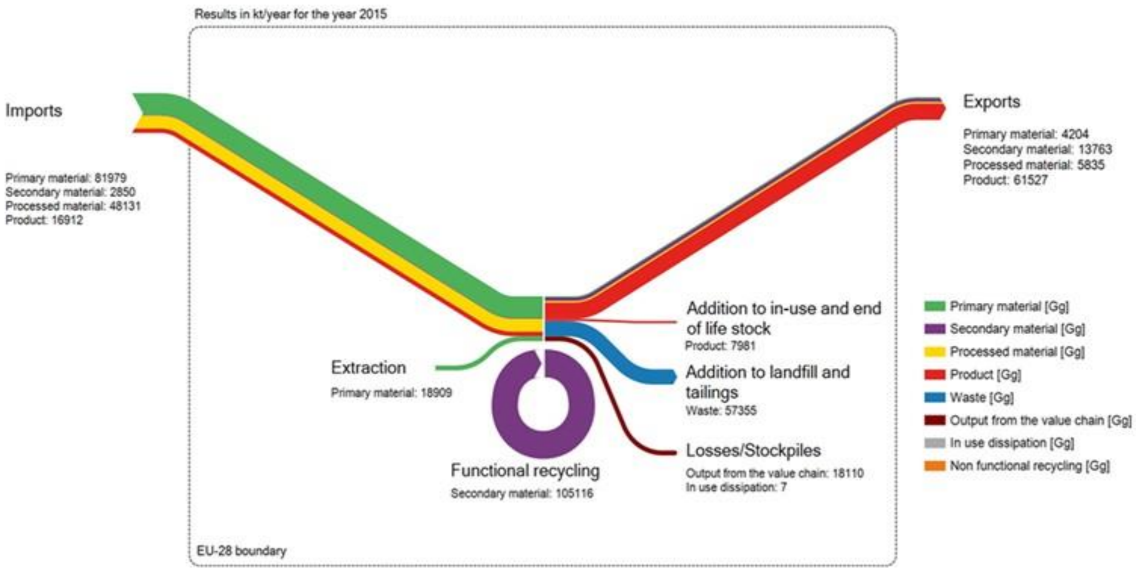

Figure 19: Simplified MSA of copper flows in the EU in 2014 (Passarini et al., 2018)

About 1 million tonnes of copper concentrates were annually produced in EU during the period 2016-2020. Poland, Spain, Bulgaria, and Sweden are the main producers at the production stage (Eurostat, 2021). The EU refinery production of copper in the same year was 2,654,800 tons; of that, 24 % was produced in Germany, 21 % in Poland, 15 % in Spain, 12 % in Belgium, and the rest (28 %) in Austria, Bulgaria, Finland, Italy, and Sweden (Iodine et al. 2022). EU imported 4.95 million tonnes of copper under various forms including: concentrates with 30% Cu concentration, copper mattes with 75% Cu content and metallic Cu. The majority of copper amount is imported by Chile, Peru and Brazil. At the same period 1.6 million tonnes of various copper products (including concentrates, mattes and metallic copper) were extracted to third countries. China, Namibia and Turkey are the major partners. The copper recycling rate in EU is estimated at 17%, however this value is not updated and it is referred in the period 2012-2016 (Eurostat, 2021).

The final products from smelting and refining (copper cathodes) in EU are made through electrolytic processes. These are either sold directly into the market, or melted and cast into shapes, typically referred to as billets and cakes, for easier processing by downstream users (ECI, 2016b). Further downstream in the EU, many companies operate in the semi-fabricated products sector. About 80 companies, employing some 35,000 people throughout the EU-28, produce copper and copper alloy rods, bars, wires, sections, tubes, sheet and strip. Around 30 companies have integrated foundries, for the in-house production of cakes, billets and other shapes while the others purchase their requirements on the merchant market (ECI, 2016b).

Several countries have restrictions concerning trade with copper ores and concentrated (OECD, 2016). According to the OECD´s inventory on export restrictions, Indonesia and Mongolia show export taxes bigger than 25%. Further countries with export taxes on ores and concentrates are Zambia (15%), China (10%), Democratic Republic of Congo (DRC) (10%), and Argentina (10%). Several of these countries also require a

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licensing agreement. Indonesia has shifted its export tax in 2012 several times (even prohibited exports temporarily), only to remove restrictions afterwards. Indonesia has issued an export ban for a couple of months in 2014, with partial lifts of the bans after that time. Less countries have restrictions in place concerning trade with refined copper: China, Russia and DRC apply export taxes below 25% on refined copper, of which only China and Russia exported to the EU in the period 2012-2016. There is also a wide range of other countries imposing trade restrictions on products with a high percentage of copper content.

SUPPLY FROM PRIMARY MATERIALS

Most of the copper is produced as the main product from copper mines. In addition, a significant amount of copper comes as a co-product from zinc, lead, nickel, and gold mines, and in minor volumes as a by-product from gold, silver, and molybdenum mines.

GEOLOGY, RESOURCES AND RESERVES OF COPPER

GEOLOGY

The presence of copper in the earth's crust ranks it as a moderately present element, with 28 parts per million (ppm) upper crustal abundance (Rudnick & Gao, 2014). Copper combines with numerous elements and more than 150 copper minerals have been identified (BGS, 2007). The most important minerals for copper extraction are chalcopyrite ($CuFeS_2$) and chalcocite (Cu_2S). Further relevant copper minerals are chrysocolla ($Cu_4H_4[(OH)_8|Si_4O_{10}] \cdot nH_2O$) and malachite ($Cu_2[(OH)_2|CO_3]$) (MEC, 2019). Copper is one of the few metals that in some cases occur in nature in a directly usable metallic form, i.e., as native metal. Copper deposits are found worldwide in a variety of geological environments (e.g., BGS, 2007). Hydrothermal deposits are most significant on a global scale, although magmatic and supergene deposits are locally important. The porphyry copper deposits are currently the world's main source of copper (50–60% of world production), with copper grades generally from 0.2 % to >1 % (BGS, 2007). Globally significant deposits are known from occur in Canada, Chile, China, Indonesia, Peru, Philippines, and Papua New Guinea; within the EU, large porphyry copper deposits are known from Bulgaria, Greece, Hungary, Romania, and Sweden. Sediment-hosted deposits, mainly located in the Central African Copperbelt, but also, e.g., in Poland and Germany, are the world's second most important source of copper (about 20 % of current world production), grading about 1–2 % copper. In the entire Europe, the Polish sediment-hosted deposits are the largest source of mined copper (WMD 2022, PGI 2022). Volcanogenic massive sulphide (VMS) deposits are also important sources of copper, with grades at 0.1–3 % copper (BGS, 2007). Large Cu-rich VMS deposits currently mined within the EU include Cobre Las Cruces (Spain), Neves Corvo (Portugal), and Kristineberg (Sweden). Within the EU, copper is also produced from black shales (Terrafame, Finland), ultramafic-hosted nickel deposits (Kevitsa, Finland), and epithermal gold-silver deposits (e.g., Chelopech, Bulgaria).

GLOBAL RESOURCES AND RESERVES:

The world identified resources of copper in 2015 were about 2,100,000,000 tonnes, and additional assumed ("undiscovered") resources 3,500,000,000 tonnes jointly in porphyry and sediment-hosted types, and

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850,000,000 t Cu in other deposit types (USGS 2022). Some copper is typically recovered as a by-product or co-product, especially from nickel, zinc, molybdenum, silver and gold ores demonstrated world resources of the metal are not fully indicative of available supplies.

According to USGS (2022), the world known reserves of copper (metal content) are about 880,000,000 tonnes and are quite diversified (Table 2). About 23 % of the reserves are in Chile. Additional 26 % are in Australia (10.6 %), Peru (8.8 %), and Russia (7.0 %).

Table 8. Copper reserves by country (USGS, 2022).

Country	*Reserves (tonnes)*
Chile	200,000,000
Australia	93,000,000
Peru	77,000,000
Russia	62,000,000
Mexico	53,000,000
USA	48,000,000
Poland	31,000,000
DRC	31,000,000
China	26,000,000
Indonesia	24,000,000
Zambia	21,000,000
Kazakhstan	20,000,000
Canada	9,800,000
Rest of the world	180,000,000
Total, rounded	880,000,000
DRC = Democratic Republic of Congo	

EU RESOURCES AND RESERVES

The EU known copper resources are about 70–71 million tonnes (Mt) and reserves 26.5 Mt of copper (Tables 3 and 4). These are a meagre 3.5 and 3.0 % of the global known resources and reserves, respectively.

The largest copper reserve and resource in Europe is in the Kupferschiefer deposits (sediment-hosted Cu) in southern Poland and SE Germany. The Polish Kupferschiefer deposits cover about 52 % of the known EU resources and 76 % of the reserves (Tables 3 and 4). By deposit type, porphyry copper deposits contain 25 % of the EU resources and 13 % of the reserves, and VMS deposits 14 % of resources and 4 % of the reserves. Hence, very little of the total is covered for the other types of copper deposits. Among copper reserves per individual mines, the four largest are in Poland, and for the resources, the six largest deposits are in Poland, too. The largest porphyry-type deposit is the Aitik mine in Sweden, with 5th largest reserve and 13th largest resource in the EU. Resources larger than that for Aitik (i.e., >1.5 Mt of copper), but smaller in total copper endowment (Aitik total is 4.3 Mt Cu), i.e., without any reported reserve, include the Bucium-Tarnita, Moldova Noua, Roşia Poieni (Romania), Laver (Sweden), and Recsk (Hungary) porphyry type, KSL (Germany) Kupferschiefer type, and the MATSA (Spain) VMS deposits. These have a resource at 1.7–2.4 Mt Cu. The Skouries porphyry copper deposit in Greece and the black shale hosted Terrafame mine in Finland also go into

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this 2 Mt copper endowment category with 0.87 Mt and 0.74 Mt in reserves plus additional 1.4 Mt and 1.3 Mt in resources, respectively (Tables 3 and 4).

There also is a major potential for additional copper resources in all regions with active and closed copper mines and/or unexploited resources. For Finland, such "undiscovered" resources have been estimated at 50 % probability to contain 9,700,000 tons (9.7 Mt) of copper (Rasilainen et al., 2017). We have no knowledge of similar modern, numerical, estimates been done elsewhere in the EU. However, one should assume an "undiscovered" copper endowment of similar size, if not larger than that for Finland, also for Bulgaria, Poland, Portugal, Romania, Spain, and Sweden. Smaller additional endowment probably is, at least, in Cyprus, Czechia, France, Germany, Greece, Hungary, Ireland, Italy, and Slovakia. An additional caveat for the data comes from the fact that public updated information, or any resource information at all, seems to be missing for several deposits in, at least, Bulgaria, Germany, Hungary, Italy, and Romania. Especially stressing the issue is for Bulgaria, Hungary, and Romania where there is a significant potential for large porphyry-type deposits and wherefrom the public data for known deposits is old (Table 3).

Table 9: Copper resources data in the EU. Note that a large number of deposits in several countries, e.g., form Bulgaria, Finland, Romania, Spain, and Sweden, is not included, each of which containing 100 to 80,000 t copper, the estimates of which mostly (but not for all cases) are non-compliant with the CRIRSCO reporting codes (i.e., equal to UNFC categories 331 to 343, and dominantly 343). This omission of smaller deposits is done to shorten the table, to focus into the larger resources. All the Polish data are from PGI (2022).

Country	Classification	Quantity (Mt of ore)	Grade (% Cu)	Reporting code	Reporting date	Deposit, Source
Bulgaria	Measured	7.0	0.96	NI43-101	03/2022	Chelopech mine (Dundee 2022)
	Indicated	6.8	0.82			
	Inferred	2.9	0.82			
	[3]All resource	143	0.43	Historic	2013	Assarel mine (Mudd & Jowitt 2018)
	[3]All resource	244	0.37	Historic	2013	Medet mine (Mudd & Jowitt 2018)
	[3]All resource	350	0.39	Historic	2013	Elatsite mine (Mudd & Jowitt 2018)
Cyprus	Inferred	9.5	0.65	JORC	2020	Magellan mine project (Venus Minerals 2020)
	All resource	15	3.8	Historic	2006	Mavrovouni (Mudd & Jowitt 2018)
Finland	Measured + indicated + inferred	932.8	0.14	JORC	12/2020	Terrafame mine (Mineral Deposit Database of Finland 2022)
	Measured	50.0	0.33	PERC	12/2021	Kevitsa mine (Boliden 2022)
	Indicated	88.0	0.36		12/2021	
	Inferred	0.2	0.19		12/2021	
	Indicated	3.5	3.45	NI43-101	2017	Sakatti mine project (Anglo American 2017)
	Inferred	40.9	1.77		2017	
	Measured	38.197	0.161	NI43-101	2007	Ahmavaara mine project (Purich et al. 2007)
	Indicated	114.816	0.181		2007	
	Inferred	34.757	0.17		2007	

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Country	Classification	Quantity (Mt of ore)	Grade (% Cu)	Reporting code	Reporting date	Deposit, Source
	Measured + Indicated + Inferred	6.84	0.39	PERC	12/2019	Kylylahti closed mine (Boliden 2019)
	Measured + Indicated + Inferred	12.7	0.17	JORC	09/2022	Hautalampi mine project (Eurobattery 2022)
	Measured	26.031	0.1	NI43-101	2007	Konttijärvi mine project (Purich et al. 2007)
	Indicated	37.571	0.095		2007	
	Inferred	11.638	0.097		2007	
	Measured + Indicated + Inferred	221	0.17	NI43-101	01/2014	Hannukainen mine project (SRK 2014)
	Indicated + Inferred	43	0.19	NI43-101	01/2014	Kuervitikko deposit (SRK 2014)
	Indicated + Inferred	32.0	0.2	NI43-101	2011	Vaaralampi deposit (Holland 2011)
	Indicated + Inferred	43.575	0.13	NI43-101	09/2021	Haukiaho deposit (Palladium One 2021)
France	All resource	100	0.6	Historic	2006	Rouez deposit (Mudd & Jowitt 2018)
Germany	Indicated	115.195	1.47	NI43-101	5/2011	KSL mine project (KSL Mining 2011)
	Inferred	14.468	1.46			
Greece	Measured[2]	90.714	0.51	NI43-101	09/2021	Skouries mine project (Eldorado Gold 2022)
	Indicated[2]	149.260	0.44			
	Inferred	67.657	0.40			
Hungary	All resource	159	1.14	Historic	2013	Recsk deposit (Mudd & Jowitt 2018)
Ireland	Indicated	2.656	0.3	NI43-101	01/2019	Kilbricken deposit (Hannan Metals 2019)
	Inferred	1.681	0.2			
Poland[1]	C2+D+ 'Anticipated subeconomic' categories	169.551	1.93	Polish standard	12/2021	Bytom Odrzański deposit
		276.951	1.73	Polish standard	12/2021	Głogów deposit
		0.608	0.82	Polish standard	12/2021	Lubin-Małomice mine
		233.176	1.97	Polish standard	12/2021	Mozów deposit
		848.481	1.25	Polish standard	12/2021	Nowa Sól deposit
		17.476	0.78	Polish standard	12/2021	Radwanice-Gaworzyce mine
		339.019	1.54	Polish standard	12/2021	Retkow deposit
		0.232	1.72	Polish standard	12/2021	Runa mine
		0.199	2.01	Polish standard	12/2021	Sieroszowice Mine
		296.043	1.91	Polish standard	12/2021	Sulmierzyce Północ deposit

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Country	Classification	Quantity (Mt of ore)	Grade (% Cu)	Reporting code	Reporting date	Deposit, Source
		76.688	1.66	Polish standard	12/2021	Żary deposit
		2.205	1.36	Polish standard	12/2021	Niecka Grodziecka deposit
		23.651	0.70	Polish standard	12/2021	Nowy Kościół deposit
		49.890	1.20	Polish standard	12/2021	Wartowice deposit
Portugal	Measured[2]	8.985	3.6	NI43-101	06/2021	Neves-Corvo mine (Lundin 2022)
	Indicated[2]	51.023	2.1			
	Inferred	12.681	1.8			
	Inferred	7.807	2.9	NI43-101	06/2021	Semblana deposit (Lundin 2022)
	Measured + Indicated	14.378	0.38	NI43-101	06/2021	Lagoa Salgada mine project (Ascent 2021)
	Inferred	13.329	0.29			
Romania	Measured[2]	62.2	0.21	NI43-101	04/2021	Colnic & Rovina mine projects (Eurosun 2021)
	Indicated[2]	175.6	0.15			
	Measured	28.5	0.16	NI43-101	02/2019	Ciresata mine project (Eurosun 2021)
	Indicated	125.9	0.15			
	All resource	355	0.50	Historic	2008	Bucium-Tarnita deposit (Mudd & Jowitt 2018)
	All resource	500	0.35	Historic	2013	Moldova Noua deposit (Mudd & Jowitt 2018)
	All resource	431	0.55	Historic	2013	Roşia Poieni deposit (Mudd & Jowitt 2018)
	All resource	150	0.35	Historic	2013	Talagiu deposit (Mudd & Jowitt 2018)
	All resource	100	0.25	Historic	2008	Valea Morii deposit (Mudd & Jowitt 2018)
Slovakia	All resource	29	1	Historic	2006	Lubietova-Orsblie deposit (Mudd & Jowitt 2018)
Spain	Measured	18.32	1.27	JORC	12/2021	Las Cruces Mine, primary sulphide (FQM 2022)
	Indicated	17.92	1.24			
	Inferred	7.09	1.23			
	Indicated stockpiles	5.0	1.19			
	Measured	0.86	6.23	JORC	12/2021	Las Cruces Mine, secondary sulphide (FQM 2022)
	Indicated	0.06	2.51			
	Inferred	10.66	0.45	NI43-101	2022	Lomero-Poyatos deposit (Denarius 2022)
	Measured	4.767	0.59	NI43-101	09/2021	El Valle mine (Orvana 2021)
	Indicated	5.572	0.37			
	Inferred	3.684	0.46			
	Measured	152.1	0.39	NI43-101	06/2018	Riotinto mine project (Atalaya 2018b)
	Indicated	106.1	0.40			
	Inferred	18.1	0.50			
	Indicated	7.76	0.66	NI43-101	10/2017	Alconchel deposit (Atalaya 2021)
	Inferred	15.03	0.47			
	Measured	69.258	0.42	NI43-101	04/2018	

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Country	Classification	Quantity (Mt of ore)	Grade (% Cu)	Reporting code	Reporting date	Deposit, Source
	Indicated	60.592	0.36			Touro mine project (Atalaya 2018a)
	Inferred	46.521	0.37			
	Measured[2] + Indicated[2] + Inferred	147.2	1.4	JORC	07/2022	MATSA mine project (Sandfire 2022b)
	Indicated + Inferred	73.4	0.61	NI43-101	03/2022	Masa Valverde mine project (Atalaya 2022)
	All resource	71	0.34	Historic	2013	Aznacollar mine project (Emerita 2022)
Sweden	Measured	281	0.15	JORC	12/2021	Aitik mine (Boliden 2022)
	Indicated	621	0.17			
	Inferred	15	0.19			
	Measured	0.17	0.8	JORC	12/2021	Kristineberg mine (Boliden 2022)
	Indicated	3.9	0.6			
	Inferred	8.1	0.8			
	Indicated	0.36	1.6	JORC	12/2021	Petiknäs N deposit (Boliden 2022)
	Inferred	0.17	0.9			
	Indicated	0.8	2.1	JORC	12/2021	Rockliden deposit (Boliden 2022)
	Inferred	9.2	1.7			
	Indicated	1.5	0.5	JORC	12/2021	Renström mine (Boliden 2022)
	Inferred	0.93	0.5			
	Measured	0.07	0.03	JORC	12/2021	Garpenberg mine (Boliden 2022)
	Indicated	30.5	0.06			
	Inferred	48.4	0.06			
	Measured	1.1	0.20	JORC	12/2021	Laver deposit (Boliden 2022)
	Indicated	512.4	0.22			
	Inferred	550.6	0.21			
	Indicated	12.7	1.5	JORC	12/2021	Nautanen deposit (Boliden 2022)
	Inferred	8.7	1.4			
	All resource	26.1	0.77	NI43-101	2018	Dingelvik deposit (Eilu et al. 2022)
	Measured	3.526	2.2	NI43-101	06/2021	Zinkgruvan Mine (Lundin 2022)
	Indicated	0.486	2.0			
	Inferred	0.217	1.7			
	All resource	3062	0.012	NI43-101	2019	Myrviken deposit (Eilu et al. 2022)
	All resource	7.5	1.97	Historic	1992	Adakfältet closed mine (Eilu et al. 2022)
	All resource	45	0.25	Historic	1992	Tallberg closed mine (Eilu et al. 2022)
	All resource (three ore bodies)	52.4	1.0	JORC	2016	Viscaria mine project (Eilu et al. 2022)

1 Copper grade (%) calculated from ore and contained metal tonnage
2 Inclusive mineral reserves
3 The figures are not recent, and the remaining resource may be even significantly less now

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Table 10: Copper reserves data in the EU. All the Polish data are from PGI (2022). xxx and xxx tons, respectively, are not detailed, as only aggregated figures for these countries are known.

Country	Classification	Quantity (Mt of ore)	Grade (% Cu)	Cu content (t)	Reporting code	Reporting date	Source
Bulgaria	Proven	5.8	0.85	49,300	NI43-101	03/2022	Chelopech mine (Dundee 2022)
	Probable	13.6	0.78	106,080			
Finland	Proven + probable	525.2	0.14	735,280	JORC	12/2020	Terrafame mine (Mineral Deposit Database of Finland 2022)
	Proven	72.0	0.31	223,200	PERC	12/2021	Kevitsa mine (Boliden 2022)
	Probable	52.0	0.33	171,600			
Greece	Proven	73.101	0.52	380,125	NI43-101	09/2021	Skouries mine project (Eldorado Gold 2022)
	Probable	74.014	0.66	488,492			
Poland[1]	"Economic resources in place"	241.862	2.45	5,914,000	Polish standard	12/2021	Głogów Głęboki-Przemysłowy mine
		323.075	1.25	4.041,000	Polish standard	12/2021	Lubin-Małomice mine
		66.463	2.31	1,536,000	Polish standard	12/2021	Polkowice mine
		73.250	2.60	1,908,000	Polish standard	12/2021	Radwanice-Gaworzyce mine
		116.658	1.39	1,623,000	Polish standard	12/2021	Retków deposit
		209.576	1.63	3,419,000	Polish standard	12/2021	Rudna mine
		166.952	2.81	4,685,000	Polish standard	12/2021	Sieroszowice mine
		10.291	1.38	142,000	Polish standard	12/2021	Niecka Grodziecka closed mine
		5.705	0.93	53,000	Polish standard	12/2021	Nowy Kościół closed mine

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Country	Classification	Quantity (Mt of ore)	Grade (% Cu)	Cu content (t)	Reporting code	Reporting date	Source
		46.712	1.64	768,000	Polish standard	12/2021	Wartowice deposit
Portugal	Proven	3.801	0.3	11,403	NI43-101	06/2021	Neves-Corvo Mine (Lundin 2022)
	Probable	20.974	0.3	69,992			
Romania	Proven	48.28	0.20	96,560	NI43-101	04/2021	Colnic & Rovina mine projects (Eurosun 2021)
	Probable	85.11	0.13	110,643			
Spain	Proven + probable	3.324	0.34	11,342	NI43-101	09/2021	El Valle mine (Orvana 2021)
	Proven	56.769	0.44	249,784	NI43-101	04/2018	Touro mine project (Atalaya 2018a)
	Probable	34.137	0.41	139,962			
	Proven + Probable	37.1	1.6	593,600	JORC	07/2022	MATSA (Sandfire 2022a)
	Proven	154.0	0.19	292,600	JORC	12/2021	Aitik Mine (Boliden 2022)
Sweden	Probable	1,153.0	0.22	2,536,600			
	Proven	0.04	0.4	160	JORC	12/2021	Kristineberg Mine (Boliden 2022)
	Probable	4.4	0.8	32,200			
	Proven	0.44	0.5	2,200	JORC	12/2021	Renström Mine (Boliden 2022)
	Probable	4.0	0.3	12,000			
	Proven	7.7	0.03	2,310	JORC	12/2021	Garpenberg Mine (Boliden 2022)
	Probable	86.0	0.05	43,000			

1 Copper grade (%) calculated from ore and contained metal tonnage

GLOBAL AND EU MINE PRODUCTION

Global mine production of copper between 2010 and 2020 showed gradual increase until 2016, then flattening out, and amounted between 16,100,000 and 20,800,000 tons per year (WMD 2022). Within the EU, 760,000 to 960,000 tons of copper was produced from the mines in the same period, with the peak in 2016. In 2020, the main EU producers were from Poland (45 % of the EU production), Spain (23 %), Bulgaria (13 %), and Sweden (12 %) (WMD 2022).

The largest global producer of copper ores, with a 28 % share in 2020, is Chile; the second, third and fourth largest copper miners were Peru, China, and the Democratic Republic of Congo (DRC), at 10 %, 8.3 % and 8.2 %, respectively (USGS 2022, WMD 2022). Chile has been the largest copper miner for many decades. In

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absolute numbers, the largest changes from 2010 to 2020 in mine production for copper are increases in DRC (by 1,275,000 t), Peru (by 902,000 t), China (by 540,000 t), and Mexico (by 530,000 t), and the decrease in Indonesia (by 375,000 t).

For some countries, there is some discrepancy between the WMD and USGS statistics. These differences are significant for certain countries and should be taken into account when comparing Figures 1 and 2: There is lack of data for some countries in the USGS data shown in Figure 2 during 2014–2019. No clear reason appears from comparing the USGS and WMD statistics, as why there are gaps of variable length in the figures published by the USGS during that time for Canada, Indonesia, Kazakhstan, Poland, and Russia, as they all probably should have qualified into the USGS Mineral Commodity Summary reports for all these years. The EU share of the global mined copper was 4.2 % – nearly half of that is from Poland. Poland has been the largest EU producer for many decades (WMD 2022).

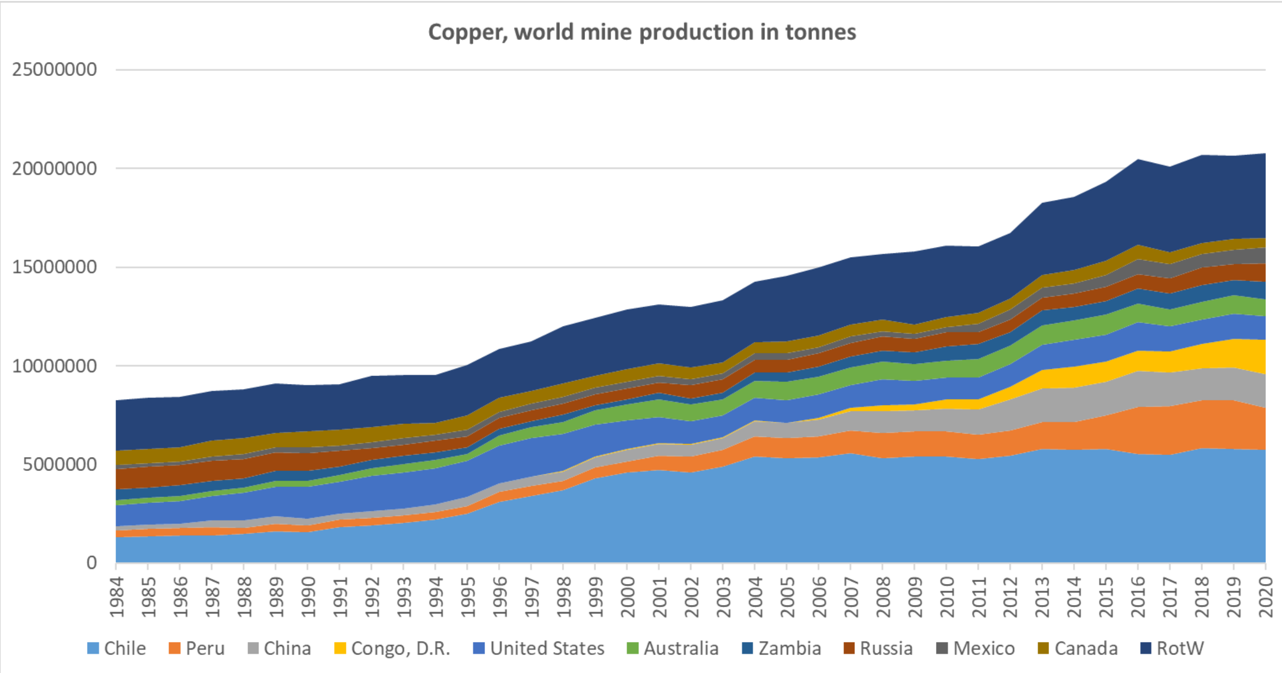

Figure 20: Global mine production of copper in tonnes, (WMD 2022). The largest producers (as of 2020) shown individually, in decreasing order. DRC = Democratic Republic of Congo (Zaire 1971– 1997), ROW = rest of the world.

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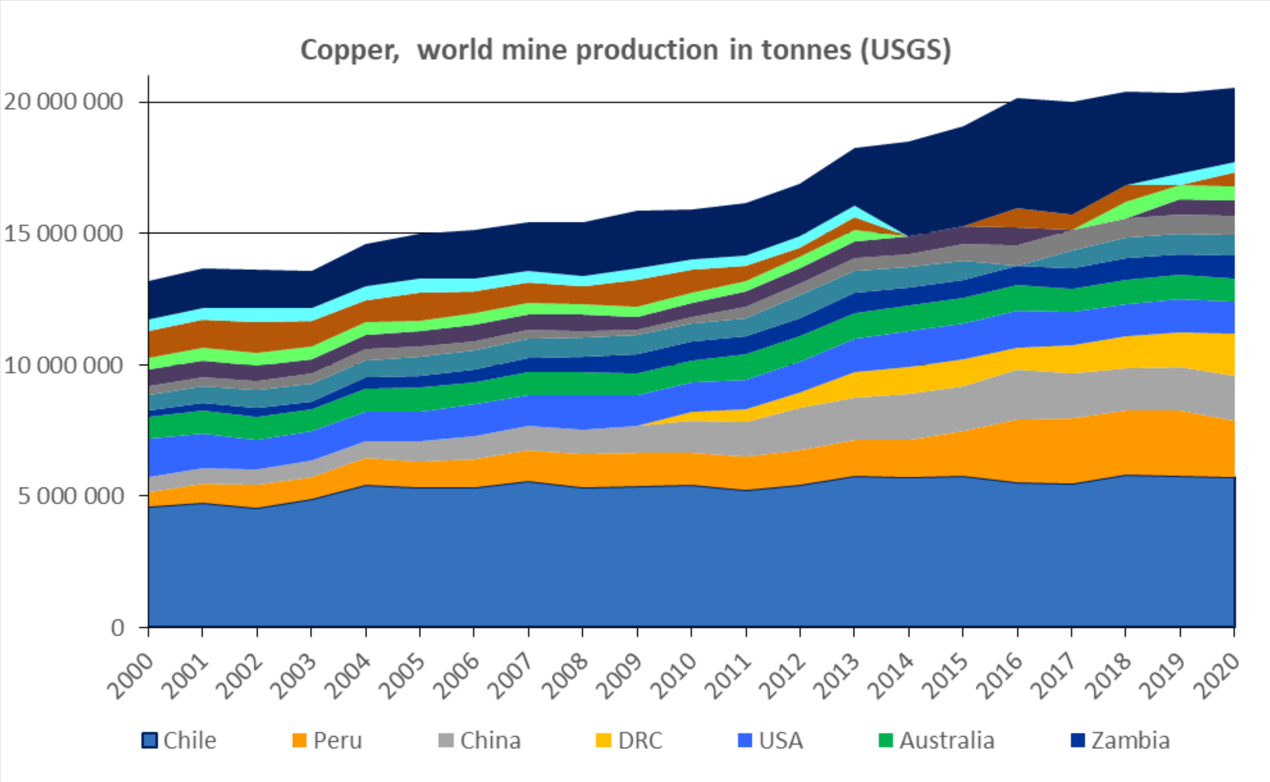

Figure 21: Global mine production of copper in tonnes (USGS Mineral Commodity Summaries 2002 to 2022). When comparing with Figure 1, note that pre-2000 data is not included in the USGS information. The largest producers (as of 2020) shown individually, in decreasing order. DRC = Democratic Republic of Congo, ROW = rest of the world.

OUTLOOK FOR SUPPLY

Copper demand is expected to significantly rise with the global energy transition aiming substantial decrease in CO_2 emissions in climate change mitigation (e.g., Hund et al. 2020, IEA 2021, Marscheider-Weidemann et al. 2021). For example, much more copper is needed for an electric vehicle than for an internal combustion engine-driven one, more resilient electric transmission becomes necessary, and large volumes of electricity storage facilities and electrolysis plants for hydrogen production need to be built (e.g., Marscheider-Weidemann et al. 2021). In power generation, it is the wind power that demand most copper per MW produced, 3–6 times the demand in coal and natural gas power plants (IEA 2021).

In this context, IEA (2021) and Marscheider-Weidemann et al. (2021) forecast that, by 2040, the climate mitigation and other emerging technologies would need, depending on scenario, 20–40 % of the copper currently annually mined, a majority of this would go into building electricity transmission and distribution networks. A recent forecast, by S&P Global (2022b), suggests that the demand of refined copper would roughly double by 2035 "with energy transition technologies accounting for about half of the growth in demand".

Obviously, recycling seems not to be possible to cover the demand gap. Currently, recycling covers 17 % of total world refined copper supply (S&P Global 2022b). It is forecasted that recycling, even when increased as

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much as possible, could only cover an additional 5–10 % of the cumulative demand of copper by 2050, in a scenario where the global warming is kept at 2 degrees (Hund et al. 2020, IEA 2021, S&P Global 2022). This partially comes from the fact that a lot of copper is already recycled, perhaps more than 70 % of end-of-life products, in one part explaining why there is little room for improvement (Marscheider-Weidemann et al. 2021). At the same time, there are no indications that copper demand for any other industrial sector would decrease.

Globally, the major issue is that there is not enough projected copper production to cover the demand in mid to long term (e.g., S&P Global 2022b). Investment in copper exploration is flat and the copper grade in new projects has been decreasing for decades, not showing any recent change. On the other hand, some see that a 'peak copper' won't come anytime soon. Singer (2017) argued that "Demand for copper is not driven by time, but rather by population and per capita income. Rates of population increases are slowing and incomes in many countries are increasing. The per capita consumption of copper will increase over the coming years as populous nations such as China and India develop increasing per capita incomes, but that the demand will likely level off as their economies improve." For example, Dobra & Dobra (2014), Meinert et al. (2016), and Arndt et al (2017) agree with the view of Singer (2017). The main issue that remains, is this: We know that there are very large resources but having in production all what is needed for the future demand in short to mid-term, at least, is uncertain. The S&P Global (2022b) report summarises: "While increasing mining capacity would certainly help close the supply gap, much would be required to lower the 16-year average that the IEA has estimated that it currently takes to move mining projects from discovery to production."

No major changes for copper production from the EU mines are expected for short to medium term. There appears no major mine projects in the pipeline that would significantly increase European total production, nor are the significant decreases, as major mine closures in the view before the 2030s do not exist.

SUPPLY FROM RECONDARY MATERIALS/RECYCLING

Most of the copper is used in its metallic form or in copper alloys. Copper is one of the most recycled of all metals. Thus, nearly all copper products can be recycled over and over again without loss in product properties (DKI, 2016) (ICSC, 2021). Copper scrap derives from metal discarded in semi-final products fabrication or finished product manufacturing processes (new scrap) and end-of-life products (old scrap). Refined copper production attributable to recycled scrap feed is classified as secondary copper production. Secondary producers use similar processes to primary production. (ICSG, 2021)

Secondary copper constitutes a significant input to the processing. The International Copper Study Group (ISGS) estimates that in 2019, 30% of global copper use come from recycled copper and the 10-year average (2008-2018) recycling input rate (RIR) for copper is 32%. Globally, 9,500 kt of copper were recycled in 2019, including secondary refined production and scrap direct melt (ICSG, 2021). As European mined copper is not sufficient to meet demand, the EU is highly dependent on refining and on smelting imported concentrates as well as on recycling production scrap and end-of-life products (BGS, 2007).

In the Europe, the amount of secondary copper constitutes only 40% of the demand. Reasons for that are increasing copper use, long lifetimes of its applications, societal, technological and economic constraints, and

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export of copper old scrap to other countries, mainly China. (Ciacci et al., 2020) Although the copper recycling industry is consolidated in the EU, the improvement of efficiencies at the end-of life will be needed to close the copper flows. According to the MFA study of copper flows (Passarini *et al.*, 2018), in the EU, copper old scrap generated at end-of life amounted 2,625kt in 2014 from which 1,603 kt were collected for recycling, resulting EOL-RR value of 61%. However, not all copper old scrap collected for recycling is processed in the EU, which reduces the EOL-RR value to 28%. The amount of secondary copper sent to domestic processing is supplemented by imports of copper waste and scrap but in absolute terms EU is a net-exporter of secondary copper. In the EU, the processing included 1,959 ktonnes of secondary copper in 2014, the majority of which originating from domestic EU manufacturing (47%) and end-of-life collection and recycling (37%) (Passarini *et al.*, 2018).

POST-CONSUMER RECYCLING (OLD SCRAP)

End-of-life recycling input rate (EoL-RIR) for copper is estimated at 17% for the criticality assessment, based on the results of the Material System Analysis on copper Table 5 (Passarini *et al.*, 2018). This value is used for the criticality assessment.

The global ten year-average (2008-2017) of the EoL-RIR is 17% and supports the order of magnitude also for the EU (ICSG, 2019a). ICSG estimates that in 2020, at the refinery level, secondary copper refined production reached 16% of total copper refined production globally (ICSG, 2021).

Table 11. Material flows relevant to the EoL-RIR of copper

MSA Flow	Value (t)
B.1.1 Production of primary material as main product in EU sent to processing in EU	356’215
B.1.2 Production of primary material as by product in EU sent to processing in EU	0
C.1.3 Imports to EU of primary material	2’621’444
C.1.4 Imports to EU of secondary material	305’484
D.1.3 Imports to EU of processed material	300’492
E.1.6 Products at end of life in EU collected for treatment	2’625’328
F.1.1 Exports from EU of manufactured products at end-of-life	595
F.1.2 Imports to EU of manufactured products at end-of-life	0
G.1.1 Production of secondary material from post consumer functional recycling in EU sent to processing in EU	729’568
G.1.2 Production of secondary material from post consumer functional recycling in EU sent to manufacture in EU	0

Values from primary material input, recycled end-of-life material, scrap used in fabrication (new and old scrap) and scrap used in production (new and old scrap), found in (UNEP, 2011), imply a much higher EoL-RIR (55%).

INDUSTRIAL RECYCLING (NEW SCRAP)

Most of the recycled copper originates from scrap different than end-of-life scrap (i.e. new scrap). Depending on its impurity content, the scrap must be conditioned and is then used for smelting and casting new products (Lossin, 2001).

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PROCESSING OF COPPER

Primary copper production starts with the extraction of copper-bearing ores. There are three main techniques for mining copper: open pit mining, underground mining and leaching operations (heap leaching, and to a minor extent also in-situ leaching) (Euromines, 2019b) (ICSG, 2021). Open pit mining is the most common form and appropriate for low grade ores that are close to the surface (< 100 m). For example, the open pit copper mines at Bingham Canyon in Utah, USA, and Chuquicamata in Antofagasta, Chile, belong to the largest man-made excavations in the world. Underground mining is suitable for higher grade ores and carried out for example in the Lubin mine, Poland. With in-situ leaching a weak sulphuric acid leach solution is pumped through lower grade ore bodies to dissolve copper. This technique is used for example in the Mufulira mine (Mopani Copper Mines) in the Zambian Copperbelt.

Mined ores generally contain 0.5 to 3% copper. After the ore has been mined, it is crushed and ground followed by a concentration by flotation. The first phase in processing the ore is concentration which increases the copper content to 25 to 35%. This is carried out at the mine site, involving crushing and grinding, followed by physical processing and separation stages. In the following smelting process, copper is transformed into "matte" containing 50-70% copper. The conversion into pure copper is done using two techniques: pyrometallurgical processes (including smelting and electrolytic refining) and hydrometallurgical processes (including leaching, solvent extraction and electro-winning). In the hydrometallurgical route, copper is extracted from mainly low-grade oxide ores and also some sulphide ores, through leaching (solvent extraction) and electrowinning (SX-EW process). Both processes (pyrometallurgical and hydrometallurgical) produce refined copper cathodes as output. (ICSG, 2021)

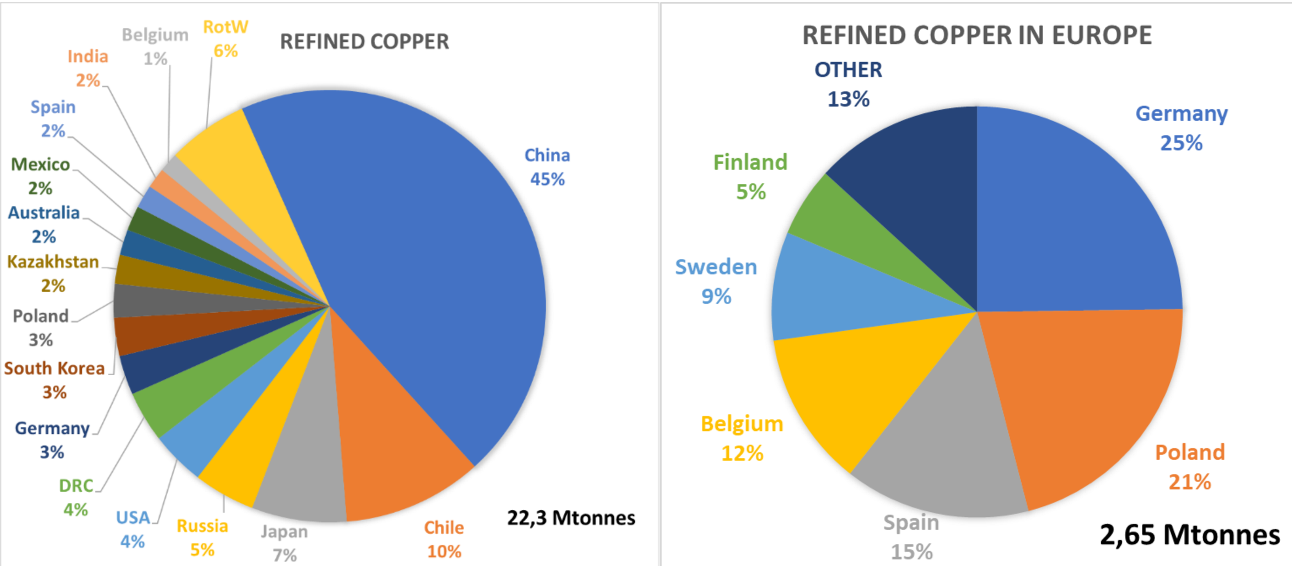

Figure 22. Estimation of global (left) and EU (right) production capacity of refined copper, in 2020 – (based on Statista 2023, Boliden 2023).

In 2020, world copper smelter production (pyrometallurgical process) reached 21.1 million tonnes copper. Primary smelters use mine concentrates as their main source of feed, but some use copper scrap as well. Secondary copper smelters use copper scrap as their feed. ICSG estimates that in 2020, refined copper

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production from SX-EW represented around 16% of total copper refined production. World total copper refined production was 24.5 million tonnes in 2020. (ICSG, 2021)

Figure 22 shows the production figures and the country shares of the global production and the EU production, respectively, of refined copper. The global production of refined copper is rising steadily since 2003, reaching an all-time high of 23.5 Mtonnes in 2017 (ICSG, 2019a).

OTHER CONSIDERATIONS

ACRONYMS AND DEFINITIONS

- CLP Classification, Labelling and Packaging
- ANSES Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail
- LCA Life Cycle Assessment
- ICA International Copper Alliance

HEALTH AND SAFETY ISSUES RELATED TO THE COPPER OR SPECIFIC/RELEVANT COMPOUNDS AT ANY STAGE OF THE LIFE CYCLE

Copper is classified as a heavy metal (German Environment Agency, 2020; Tchounwou et al., 2022). Copper is a nutrient that is essential for many biochemical and physiological functions. In particular, it intervenes in some enzymatic reactions due to its ability to cycle between an oxidized Cu(II) and reduced state Cu(I). This property makes it also potentially toxic especially in case of excessive exposure (Tchounwou et al., 2014; Gaetke and Chow 2003). At high concentrations, copper is mainly toxic to aquatic organisms with long lasting effects (ECHA, 2022a; US EPA 2022), which is also reflected in the CLP (Classification, Labelling and Packaging) notifications.

In Europe, the ECHA reports that to humans, effects can be harmful if the substance is swallowed or can cause eyes irritations in case of contact. Moreover, copper is approved to be used as a biocidal active substance and is under assessment regarding the Endocrine Disrupting list (ECHA, 2022b). Regarding compounds of copper, the CLP regulation (N°1272/2008) also considers cuprous chloride, copper hydroxide, cuprous oxide and cupric oxide (INERIS, 2019). Finally, in 2017 after a proposal from ANSES (Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail), the product “granulated copper; [particle length: from 0,9 mm to 6,0 mm; particle width: from 0,494 to 0,949 mm]” was added to the CLP regulation, again due to the aquatic chronic effects.

Human exposures to copper are mainly linked to anthropospheric activities such as smelting, mining, industrial activities, domestic waste emissions and application as fertilizers, sewage sludge, algicides, fungicides or molluscicides (Flemming and Trevors, 1989; Tchounwou et al., 2014).

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ENVIRONMENTAL ISSUES

The environmental impacts of copper production are well assessed, especially using life cycle assessment (LCA). Globally it could be said that from extraction to refining, copper production is highly energy intensive leading to important emissions of GHG (greenhouse gases). Water consumption is also important in the copper life cycle, moreover this life cycle occurs in countries where the water stress is relatively high (Chile or Peru for example). Some of the copper mines are open pit mines, leading to potentially high land use impacts.

However, impacts from copper extraction and copper production are site-specific and mainly depend on the type of mining (open pit vs. underground mining), the type of ores exploited (oxidized vs. sulphuric as well as the grade of the exploited ore) and the type of metal processing technology (pyrometallurgy vs hydrometallurgy) (Northey et al. 2012; Sanjuan-Delmás et al., 2022).

Based on the information available in some copper miners' and producers' sustainability reports, (Northey et al. 2012) assessed the environmental footprint of copper production regarding energy intensity, carbon footprint and water footprint. Their compiled results are the following:

- Energy intensity range [10 GJ/t Cu to 70 GJ/t Cu] with an average of 22.2 GJ/t Cu;
- GHG intensity range [1 t $CO_{2\,éq}$/t Cu to 9 t $CO_{2\,éq}$/t Cu] with an average of 2.6 t $CO_{2\,éq}$/t Cu
  - Large variations are due to the mined ore grade, the type of electricity and energy used at the mine site and at the processing site. The different methods used to declare GHGs emissions in such company reports could also explain these variations;
- Water intensity range [~1 kL/t Cu to 350 kL/t Cu] with an average of 74 kL/t Cu
  - The variations are mainly due to the location of the mine sites and mainly to the climatic conditions (arid regions such as Australia vs temperate cool regions such as Canada).

These results could be compared with a similar study conducted ten years later, in which the authors compiled LCA results for the cumulative energy demand and the global warming impacts indicators while looking at different characteristics of the mine site and the process used to produce metallic copper (Sanjuan-Delmás et al., 2022).

Table 1: Comparison of LCA results for the production of 1 ton of copper production

Case study	Country	Ore grade (%Cu)	Mining type	Process	Global warming (kg CO2 éq / t Cu)	Cumulative energy demand (MJ / t Cu)
1	Australia	2	Not specified	Hydrometallurgy	6200	64 000
2	Chile	0.71	Not specified	Pyrometallurgy	6000	Not specified
3	Chile	0.71	Not specified	Hydrometallurgy	4900	Not specified
4	Australia	0.1	In situ leaching	In situ leaching	4780	61 000
5	Sweden	0.18	Open pit	Pyrometallurgy	4750	168 000
6	Australia	3	Not specified	Pyrometallurgy	3300	33 000
7	China	1.02	Not specified	Hydrometallurgy	1910	Not specified

Source: Sanjuan-Delmás et al., 2022

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Regarding impact categories other than climate change and cumulative energy demand, (Sanjuan-Delmás et al. 2022) found in their study (in the case of open pit mining and pyrometallurgy processes) that they are mainly driven using explosives and SO_2 emissions occurring at the smelter (especially for the impacts relative to photochemical ozone formation and acidification).

The type of ore exploited has also a direct incidence on toxicity-related impact categories. Especially, the tailings associated to sulfidic deposits could have long-term effects on the natural emissions linked to acid mine drainage and the increase of heavy metals concentration in the environment if the tailings are poorly managed in the long-term. Depending on the assessed mine site, these impacts can vary from several CTUe / kg Cu to more than 10^4 CTUe / kg Cu regarding ecotoxicity impacts (Adrianto et al., 2022).
According to the German Environment Agency, almost 85% of copper ores mined are sulfidic ores leading to high pre-conditions for acid mine drainage, subsequently leading to potential environmental harms near these mine sites. The Agency also reports copper deposits where low exposure to radioactive elements can occur, more particularly in China, the United States and the Democratic Republic of Congo (German Environment Agency, 2020).

NORMATIVE REQUIREMENTS RELATED TO MINING/COPPER PRODUCTION, USE AND PROCESSING OF THE MATERIAL

The US EPA recently proposed the "National emission standards for hazardous air pollutants: primary copper smelting residual risk and technology review and primary copper smelting area source technology review" (EPA 2022). This proposal presents the results of the US EPA residual Risk and Technology Review (RTR) for the National Emission Standards for Hazardous Air Pollutants (NESHAP) for major source Primary Copper Smelters as required under the Clean Air Act. The EPA is proposing new emissions standards and to remove exemptions for periods of startup, shutdown, and malfunction (US EPA 2022b).

In addition, the Copper Mark – an association which group copper producers from all over the world – developed two Standards to set common expectations for responsible production practices. The first one is the Copper Mark criteria for responsible production, which uses the risk readiness assessment of the RMI as the basis to evaluate the performance of the participants. The second one is the Joint due diligence standard for copper, lead, nickel and zinc – which implementation is currently voluntary and is planned to become mandatory for Copper Mark members (Copper Mark 2022).

The International Copper Alliance developed a set of indicators to link the UN SDGs and the GRI Standards with regards to copper production in relation to CO2 equivalent emissions, energy intensity, water recycled and reused, total workforce, injury rate, the economic value distributed and the sustainability reporting (ICA 2022).

SOCIO-ECONOMIC AND ETHICAL ISSUES

ECONOMIC IMPORTANCE OF THE COPPER FOR EXPORTING COUNTRIES

The copper processing industry is a significant employer. On a global scale, the copper industry employs more than one million people and brings an added value of $144 bn to the global economy. (ICA, 2022). In the EU,

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many companies operate in the semi-fabricated products sector. The European Copper Institute represents an industry of €45 billion turnover and 50,000 jobs. (Metalsforbuilding, 2019).

Table 12 illustrates the high importance of copper exports are economicly for many countries. They represent more than 50 % of the total export values for Zambia (74 %), DRC (57 %) and Chile (52 %), and more than 20 % for Namibia, Peru, Mongolia, Armenia and Georgia. Many other countries generate considerably more than 1 % of their export value from copper exports.

Table 12. Share of the copper export market vs the total export market for the 25 most contributing countries

. Country	Export value (USD)	Share in total exports (%)
Zambia	5776737637	74.02%
Dem. Rep. of the Congo	8117466745	57.48%
Chile	3.8363E+10	51.78%
Namibia	1611591241	28.78%
Peru	1.1066E+10	28.55%
Mongolia	1837321308	24.25%
Armenia	559867777	24.01%
Georgia	781169277	23.36%
Lao People's Dem. Rep.	641736382	12.62%
Kazakhstan	3863887016	8.23%
Bulgaria	2496153679	7.82%
Mauritania	215806510	7.63%
Myanmar	924829443	5.46%
Uzbekistan	571760897	4.31%
Panama	252068091	2.91%
Philippines	1641306832	2.52%
Australia	5570001281	2.27%
Indonesia	3633519341	2.23%
Serbia	433196428	2.22%
Finland	1204539730	1.84%
Ecuador	322738888	1.59%
Russian Federation	5202508152	1.54%
Brazil	2537546298	1.21%
Canada	4436043064	1.14%
Tajikistan	7655234	1.07%

Source: (COMTRADE 2022), based on data from 2020

SOCIAL AND ETHICAL ASPECTS

Strikes of workers occasionally occur especially in Latin America, where some of the largest copper mines are located. The reasons are not only related to the mining business, but sometimes rooted deep in societal

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inequality (Jamasmie, 2019). For example, the Escondida mine, was hit in 2018 by the longest private sector mining strike in Chile (44-days). In addition, mines in Chile can also be affected by strikes in ports like in October 2019 when a strike in Escondida mine was superposed by strikes at various sea ports handling copper concentrates (including Iquique, Tocopilla, Antofagasta and Ventanas) (Bloomberg, 2019).

Within Europe, the price spikes after 2000 have infamously created theft of copper objects from the public space. Thieves stole copper parts and then sold the valuable scrap metal to recyclers. The lack of these copper objects then caused disruptions of infrastructure, in particular overhead contact lines of electricity driven trains, trams and trolleybuses, but also power cables. Similarly, copper claddings were stolen from public and non-public buildings (Europol 2018).

In 2020, ICA announced the creation of the "Copper Mark", a global standard to ensure responsible production and trading of copper inspired by the United Nations Sustainable Development Goals. ICA announced that "*The new measure seeks to monitor the performance of copper mines and refineries around the globe, assessed against responsible production criteria. Unlike other sustainability programs currently in place, the Mark targets copper specifically. As such, there is hope that it will lay the foundations for the ethical development of an industry so crucial in the creation of a green future*." (ICA 2020)

The DELVE database[4] reports that artisanal mining of copper ores can occur in the Democratic Republic of Congo. Despite the lack of official statistics, (Gerig et al. 2019) report that 10,000 tons of copper ore were extracted from artisanal production in two provinces in 2 months in 2019. Artisanal mining of copper also occurs in India (Lahiri-Dutt and McQuilken, 2019) as well as in Peru (where copper artisanal mining is linked to international copper prices) (Faulkner, 2019).

RESEARCH AND DEVELOPMENT TRENDS

RESEARCH AND DEVELOPMENT TRENDS FOR LOW-CARBON AND GREEN TECHNOLOGIES

- Copper-based flow batteries for energy storage renewables integration – CUBER project (EU, 2022 –2023)

The search for competitive energy storage is linked to the transition towards renewable energy solutions. The all-copper redox flow battery (CuRFB), based on RFB technology, is designed in a simple, modular, and scalable way and offers security and sustainability. The EU-funded CUBER project will prove that RFB technology can be integrated into Smart Cities and residential self-consumption market segments. Its development could allow more comprehensive applications, such as backup power systems in isolated areas, for energy management and grid balancing in renewable energy plants. The project coordinates a wide range of European actors to develop operating pilots to confirm and introduce innovative methods to produce and consume renewable energy in urban, rural, and industrial sites.

[4] A global platform for artisanal and small-scale mining data: https://delvedatabase.org/

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• Surface-functionalised nanocrystal catalysts for the electrochemical reduction of carbon dioxide – SURFCAT (EU, 2020 –2022)

Among the crucial ways to reduce atmospheric CO2 is its capture and catalytic conversion into valuable chemicals. The electrochemical reduction of CO2 can help us store excess renewable electricity in the bonds of carbon-based liquid fuels and industrially relevant chemicals. It is a win-win-win proposition, reducing CO2, generating useful chemicals, and relying on renewable energy sources. However, it faces challenges related to the low selectivity, activity, and stability of electrocatalysts in aqueous solutions. The EU-funded SURFCAT project is developing approaches to modify copper nanocrystals, the catalyst of choice, to surpass these obstacles and spur the commercialisation of this important process to close the carbon cycle, protect the environment and provide fuels and chemicals.

- Industrial Selective PLAting for Solar Heterojunction – iSPLASH (EU, 2022 –2024)

Despite the boom in the photovoltaics industry, there are still barriers to solar cell deployment. Costly and cumbersome manufacturing processes emitting high levels of greenhouse gas GHG constitute a significant hindrance. A critical step in cell manufacture is metallisation, representing over 30% of the cost of manufacture. Currently, heterojunction cell metallisation utilises silver paste, which has significant disadvantages in terms of price, efficiency, and environmental impact. Alternative metals, such as copper, can overcome these challenges; however, efficient process technology has not yet been brought to market. The iSPLASH project will cause a paradigm shift in heterojunction cell metallisation. Our technology will be the only processing technology on the market to cost-effectively exploit the low price of copper and facilitate the reliable and precise fine-line deposition of copper onto HJT cells, eliminating the use of silver. iSPLASH technology will reduce metallisation costs by 90% and carbon emissions.

OTHER RESEARCH AND DEVELOPMENT TRENDS

- TOMACOP: Copper homeostasis and the effects of copper deficiency on tomato plants and fruit quality (2019-2021)[5]

Copper (Cu) is a vital micronutrient but is toxic when in excess. In humans, Cu is acquired by diet. Plants are also sensitive to Cu bioavailability in soil and their nutritional deficiencies or excesses are transferred to consumers. Therefore, deciphering the regulatory mechanisms underlying Cu uptake and distribution to edible products is crucial to prevent deficient or toxic Cu levels in horticultural crops that may ultimately affect human health. Furthermore, in Europe, around 20 % of the arable land is classified as Cu deficient, which has been compensated by using Cu-enriched fertilizers. However, the EU warns that this practice implies high environmental costs and compromises food security for consumers. TOMACOP studied the effects of Cu deficiency on plant growth and development and on fruit nutritional status and quality by using tomato (Solanum lycopersicum), one of the most important crops worldwide. The characterization of Cu homeostasis components and the identification of tissue-specificities in the molecular mechanisms regulating Cu uptake provided important clues for future biotechnological improvements aimed to solve the challenge EU agriculture is facing.

[5] https://cordis.europa.eu/project/id/799712

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- Mapping China's copper cycle from 1950–2015: Role of international trade and secondary resources (Hao et al, 2023)

China's high copper demands and poor mineral endowments have led it to rely heavily on the international copper trade. However, the importance of the metal trade has not been adequately appreciated. This study explores the role of metal trade in copper security through a high-resolution material flow analysis of China's copper cycle from 1950 to 2015 that covers over 300 types of copper-containing products. We found that the annual inflow of copper has increased from 4.3 KT/yr to 14 MMT/yr from 1950 to 2015, which drove the increase of copper stocks accumulated in buildings, infrastructures, and products from 7 kg/cap to 56 kg/cap. The total copper in-use stocks in China were approximately 80 MMT in 2015. However, about 70% of all copper used in China in this period was imported from other nations. Thus, this study indicates that more attention should be paid to the importance of the copper waste trade in China.

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