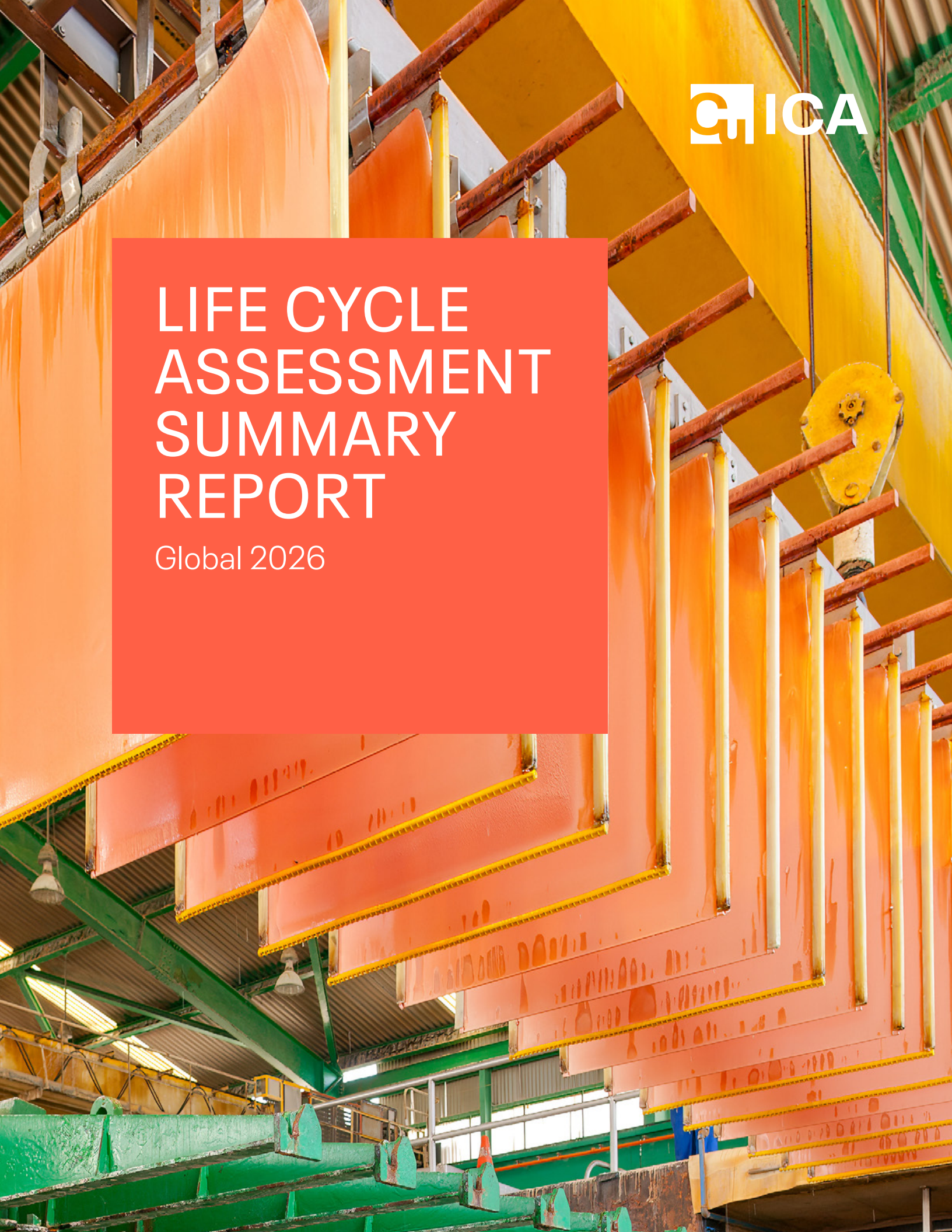


LIFE CYCLE ASSESSMENT SUMMARY REPORT

Global 2026

EXECUTIVE SUMMARY

This study is a global, cradle-to-gate copper life cycle assessment (LCA) for public communication and presents an update to the average life cycle data of global copper concentrate and copper cathode. The previous study was completed in 2022 and was based on production data from 2019. The current study utilizes 2023 production data from participating ICA member sites.

Participating member companies include: Anglo American, Antofagasta, Aurubis, BHP Group, Boliden, Codelco, Freeport-McMoRan, Glencore, Grupo Mexico, KGHM, Rio Tinto, Sumitomo, Teck, and Vale. In total, this LCA includes primary data from 30 mines and 40 smelters, representing mining and smelting operations in North America, South America, Europe, Asia, and Africa. Both pyrometallurgical and hydrometallurgical processing route are included, with a representation of 66% and 34% respectively.

The total volume covers 4.3 million metric tons of mined copper and 5.6 million metric tons of produced copper cathode, respectively.

This study considers the production of one (1) metric tonne of copper concentrate, which has an average concentration of 24.06% wt. Cu, wet basis (with assumed 8 % water content resulting in 25.98% wt. Cu, dry basis). It also considers the production of one (1) metric tonne of copper cathode with purity of at least 99.99% copper.

The assessment identified electricity consumption and direct operational emissions as the primary drivers of environmental impacts across the copper production system. Climate change impacts are largely associated with mining, concentrate production, and metallurgical processing activities, with electricity use representing a significant share of total greenhouse gas emissions. As a result, the environmental profile of copper production is strongly influenced by regional energy mixes, fuel use, and emissions control technologies.

Additional impacts, including acidification and eutrophication, are primarily linked to fuel combustion, sulfur dioxide emissions, wastewater management, and industrial processing activities occurring throughout the copper value chain. The study also found that results can vary between operations due to differences in ore grade, production methods, transportation distances, and regional infrastructure and energy systems. The results are averages that seek to be representative to identify trends and areas for improvement, but not absolute values of specific operations. Caution is advised when comparing with other studies or sectors, ensuring compatible methodologies and considering variability. Values should not be used for comparative claims in marketing without additional analysis in accordance with ISO standards; for that, the specific LCA results of each individual company are recommended.

Copper plays a critical role in electrification, renewable energy systems, modern infrastructure, and emerging technologies. As demand for copper continues to grow, transparent environmental data is increasingly important to support informed decision-making across the value chain.

INTRODUCTION

The International Copper Association (ICA) promotes, protects, and defends copper and copper markets through advocacy, technical leadership, and collaboration across the copper value chain.

As part of its commitment to advancing sustainable practices and supporting informed decision-making, ICA works to develop and share transparent, science-based environmental data for copper production. This report provides life cycle assessment (LCA) results for copper products, offering stakeholders consistent and credible information to better understand environmental performance and identify opportunities for continuous improvement across the value chain.

WHAT IS COPPER AND WHERE DOES IT COME FROM?

Copper is a naturally occurring element (Cu) found throughout the earth's crust, oceans, and living systems. It is present at average concentrations of approximately 0.006% (60-70 mg/kg) in the earth's crust, though this varies depending on geological conditions (USGS, 2024). Copper is found in a range of mineral forms and is widely distributed, but only a small fraction is concentrated into deposits that can be economically extracted.

Copper resources are formed through geological processes that concentrate the metal into ore deposits over millions of years. These deposits are typically classified into two main types based on their mineral composition: sulfidic and oxidic ores. Sulfidic ores contain copper primarily in sulfide minerals such as chalcopyrite and are generally found in deeper, primary (unweathered) deposits. Oxidic ores, by contrast, form near the earth's surface through the weathering and oxidation of sulfide deposits and contain copper in oxide or carbonate minerals. These differences reflect the geological history of the deposit and influence how copper is distributed in the natural environment (USGS, 2024).

Copper deposits are found globally, with significant resources located in regions such as South America, Central Africa, North America, Asia, and Australia. Today, major copper-producing countries include Chile, the Democratic Republic of the Congo, Peru, China, the United States, Indonesia, Russia, Kazakhstan, and Australia, reflecting both the natural distribution of resources and the development of mining operations (ICSG, 2025).

In addition to primary resources from mined ore, copper is also sourced from secondary materials through recycling. Copper can be recovered and reused repeatedly without degradation in its intrinsic properties (physical and chemical), meaning that both primary and secondary sources contribute to the overall supply of copper.

Globally, more than 26 million tonnes of copper are used annually.

Figure 1:
Copper Usage
[ICSG, 2025; IEA, 2023]

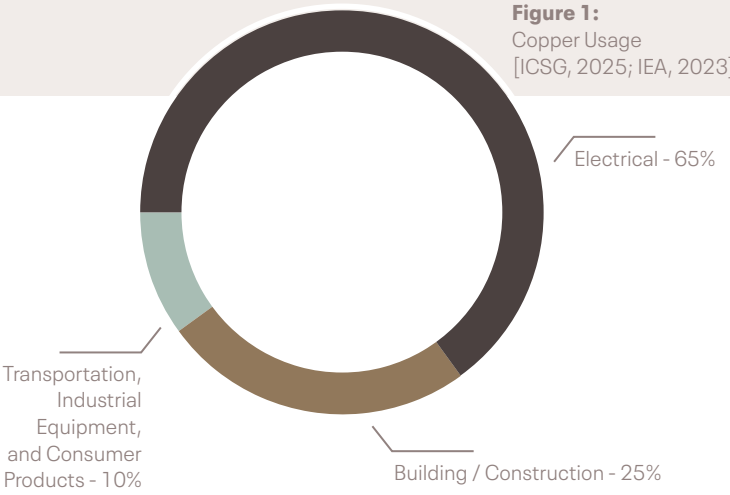
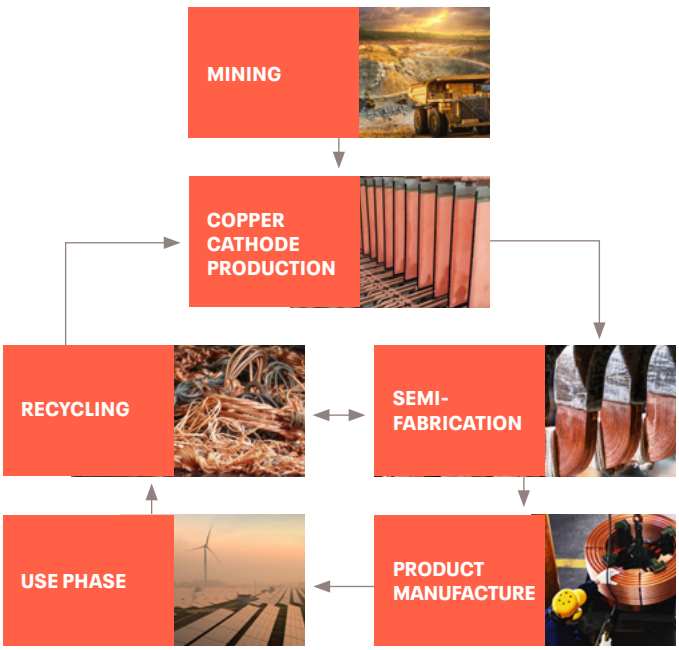


Figure 2:
Copper Life Cycle



HOW IS COPPER USED?

Globally, more than 26 million tonnes of copper are used annually, with demand increasingly driven by the global energy transition (ICSG, 2025). Copper's high electrical and thermal conductivity, durability, and corrosion resistance make it an essential material for the generation, transmission, and use of electricity which places it at the center of efforts to decarbonize energy systems.

Electrical applications account for the majority of copper use, representing approximately 65% of global demand. This includes power generation, transmission and distribution infrastructure, and wiring in buildings, electronics, and telecommunications systems. As energy systems shift toward renewable sources and expanded electrification, the need for reliable and efficient electrical infrastructure is expected to increase significantly, reinforcing copper's critical role. (ICSG, 2025; IEA, 2023).

The building and construction sector accounts for roughly 25% of global copper use, where copper is used in electrical systems, plumbing, roofing, and cladding. As buildings become more electrified and energy-efficient, copper demand in this sector is also expected to grow (ICSG, 2025).

The transport sector represents a growing share of copper demand, particularly as part of the broader transition to low emission mobility. Electric vehicles (EVs) require significantly more copper than conventional vehicles due to their use in batteries, electric motors, and charging infrastructure. As EV adoption accelerates globally, this is expected to be a key contributor to increased copper demand (IEA, 2023).

The remaining share of copper use is distributed across industrial equipment and consumer products, including machinery, appliances, and smaller-scale applications.

THE COPPER LIFE CYCLE

Copper is produced, used, and reused within a highly integrated life cycle that spans from resource extraction to end-of-life recovery. Understanding this life cycle is essential for evaluating environmental performance using LCA, which considers impacts across all stages of a product system.

The copper life cycle begins with mining, where copper-containing resources are extracted from the earth. The material then moves through processing and fabrication, where it is transformed into usable forms for incorporation into products and systems. These products enter the use phase, often over long service lifetimes, particularly in infrastructure and energy systems.

At the end of use, copper can be collected and returned to the system through recycling, where it re-enters the production cycle and reduces the need for new primary material. Because copper can be recycled repeatedly without the loss of its intrinsic properties (as mentioned above), both primary and secondary sources contribute to the overall supply. This ability to retain its intrinsic properties through repeated recycling enables copper to remain in productive use for generations and contributes to the material's role in supporting a more circular economy.

Rather than a linear sequence, the copper life cycle is best understood as a continuous loop, where material flows are maintained within the economy for as long as possible. This circularity is a key characteristic of copper.

HOW COPPER IS PRODUCED

From its origin in mined resources to its use in finished products, copper undergoes several stages of production. Primary copper production begins with the extraction of copper-bearing ores through open-pit or underground mining, depending on the depth and characteristics of the deposit. Because copper is typically present at relatively low concentrations, large volumes of ore must be processed.

Current global average copper ore grade for mining is around 0.6% copper content (Schlesinger, Klein and Vengosh, 2022), with the remainder comprising gangue minerals. The deposits also contain economically significant by-products (gold and silver), which may be processed alongside copper. Notably, oxidic ores tend to have lower copper concentrations compared to sulfidic varieties, and the precise copper content depends on the specific geological layer being mined.

After mining, production follows one of two main pathways depending on ore type: pyrometallurgy or hydrometallurgy.

Pyrometallurgy (high-temperature processing) is primarily used for sulfidic ores. Following mining, ores are crushed and milled. The material is then concentrated, most commonly through flotation, producing a copper concentrate that typically contains around 20-30% copper (ICSG, 2025). The copper concentrate is heated in furnaces during smelting to produce a molten intermediate known as matte, which contains approximately 50-70% copper. Intermediate-grade copper scrap (85-98% copper) is added during this step as a cooling agent for the furnace. The matte is further processed to produce blister copper, with a purity of about 98-99%. The blister is further processed to copper anode with 99.5% purity. The copper anode is then refined through electro-refining, where an electric current is used to remove remaining impurities, producing high-purity copper cathodes of approximately 99.99% copper.

Hydrometallurgy (aqueous, or solution-based processing) is typically used for oxidic ores and some low-grade materials. In this route, copper is dissolved from the ore using a leaching solution. The dissolved copper is then concentrated through solvent extraction and recovered through electrowinning (SX-EW), where an electric current is used to deposit copper onto cathodes. This process also produces high-purity copper cathodes of 99.99% purity without the need for high-temperature smelting.

In addition to primary production, copper is also produced from secondary sources through recycling. Scrap materials from manufacturing processes and end-of-life products are collected and reprocessed. Depending on their quality, these materials may be directly remelted into copper semi-fabricated products or refined to produce copper cathodes at the same purity standard of primary production.

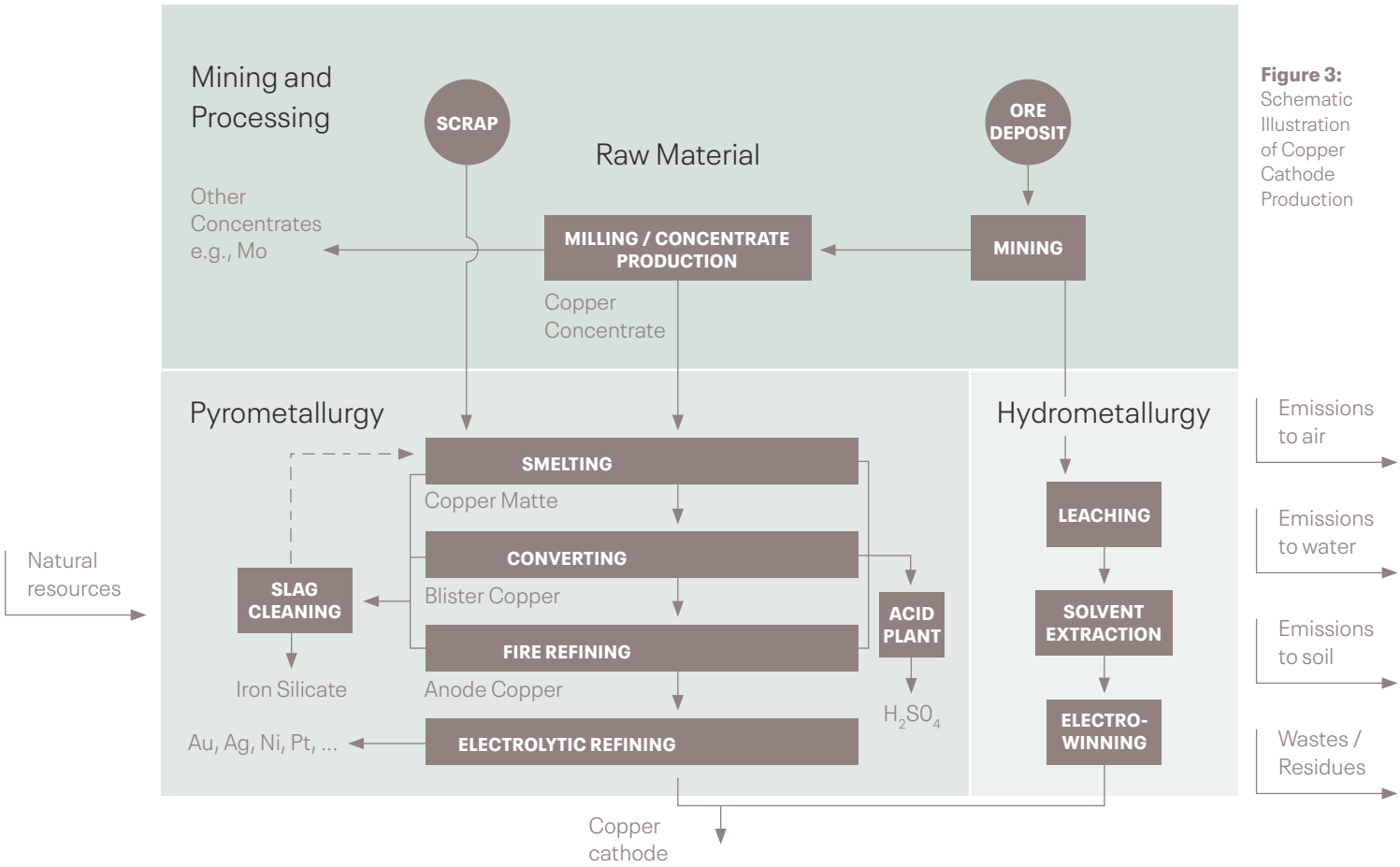


Figure 3: Schematic Illustration of Copper Cathode Production

LIFE CYCLE ASSESSMENT

GOAL AND SCOPE DEFINITION

The objective of this study is to revise and enhance the aggregated cradle-to-gate Life Cycle Inventory (LCI) for copper concentrate and copper cathode, based on the most recent production data available across participating member company sites of the International Copper Association (ICA). This update reflects annual data for 2023 in operational realities, including technological advancements at production facilities, changes in by-product management, and updated background datasets – particularly those related to energy inputs such as electricity, heat, and fuel.

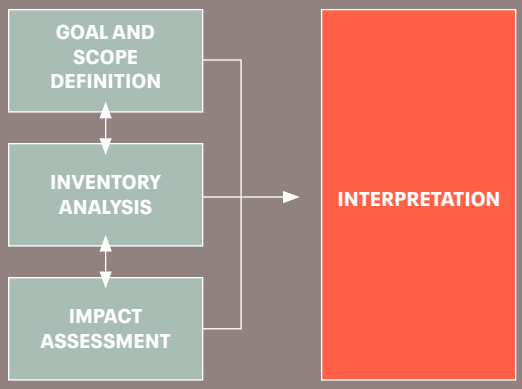
In addition to updating the dataset, the study seeks to identify areas for improvement within the copper industry. This is achieved through hotspot analysis, whereby individual company results are also compared internally by each participant against the aggregated LCI average. These comparisons are not part of the public report. The benchmarking process is designed to support internal sustainability initiatives and encourage similar efforts among both participating and non-participating ICA member companies, as well as prospective members, while maintaining strict confidentiality of proprietary information.

The system boundary of the study included a cradle-to-gate LCI from the extraction at the mine to the production of copper cathode, from both primary and secondary sources. The LCA study documented in this report was conducted in accordance with the International Standards ISO 14040:2006 and ISO 14044:2006. A critical review was conducted by independent expert, Manfred Russ LCA-Consulting, Germany, in accordance with ISO/TS 14071. The review statement is available on request.

Participating member companies include: Anglo American, Antofagasta, Aurubis, BHP Group, Boliden, Codelco, Freeport-McMoRan, Glencore, Grupo Mexico, KGHM, Rio Tinto, Sumitomo, Teck, and Vale. In total, this LCA includes primary data from 30 mines and 40 smelters, representing mining and smelting operations in North America, South America, Europe, Asia, and Africa. Both pyrometallurgical and hydrometallurgical processing route are included, with a representation of 66% and 34% respectively. In 2023, global copper mine production and global refined copper production were around 22.3M tonnes and 26.5M tonnes respectively.

Previous studies were carried out in 2022 (based on the year 2019), 2017 (based on the year 2013), and 2011 (based on the year 2005). This report is intended to provide an update of the environmental impacts from copper concentrate and cathode production, calculated using the most recent activity data available. It is not intended to be compared to previous study results as participating sites and companies as well as global ratios vary between studies.

Figure 4: Life Cycle Assessment Framework*



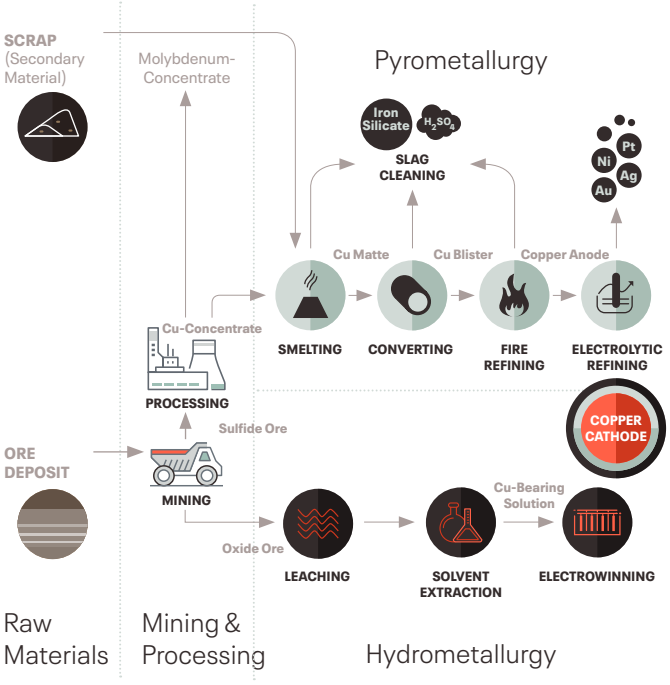
*ISO. (2006). ISO 14044. Environmental management – Life cycle assessment – Requirements and guidelines. International Organization for Standardization, Geneva

FUNCTIONAL UNIT

Given that the scope of this assessment includes both ore extraction and the processing of secondary inputs into refined copper cathode, the primary study functional unit is the production of 1 kilogram of copper cathode at the factory gate, containing at least 99.99% pure copper.

Two functional units are applied for copper concentrate. The first is the production of one metric tonne of copper concentrate (wet basis), with an average copper content of 24.06%. The second is the production of one metric tonne of copper contained within the concentrate, which accounts for the actual copper content of the concentrate. This corresponds to approximately 3.85 metric tonnes of concentrate based on the average concentrate grade.

Figure 5: The copper production system covered in the scope of this study.



LIFE CYCLE INVENTORY

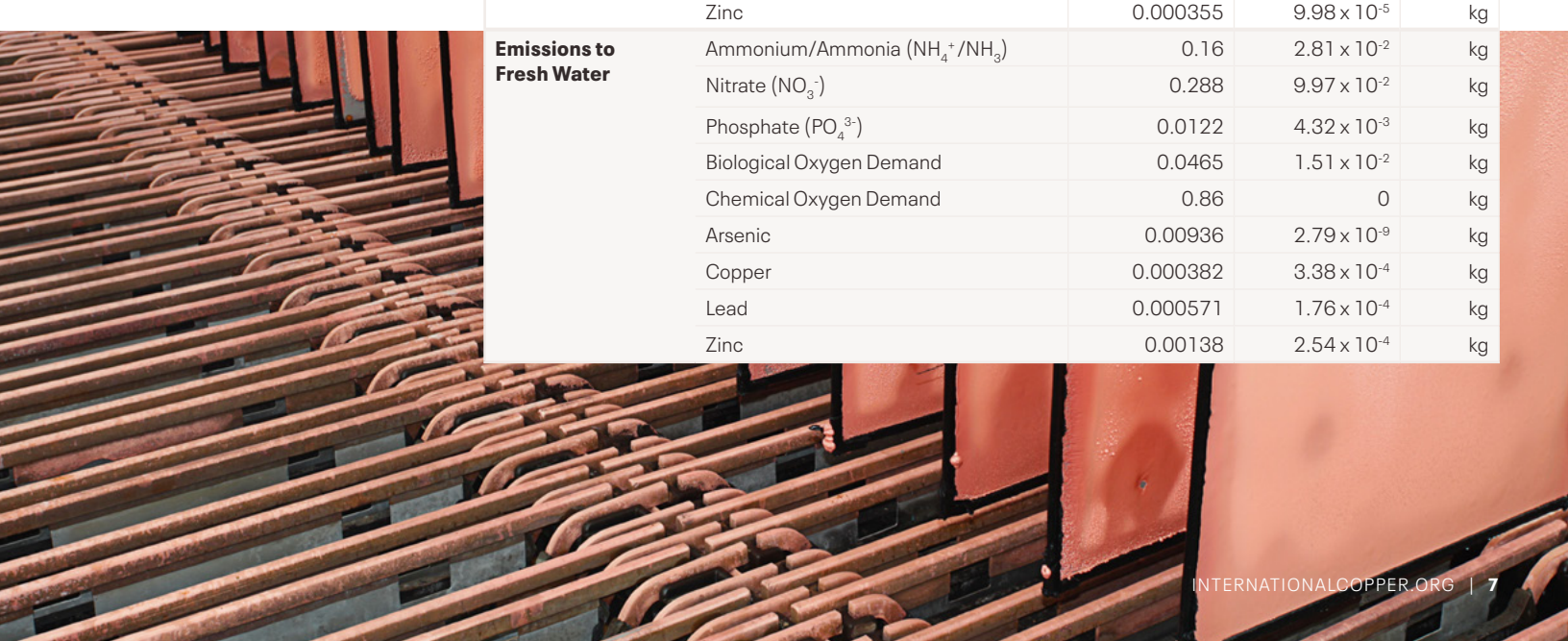
The Life Cycle Inventory (LCI) is the phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its lifecycle (ISO 14040:2006 section 3.3). This is a critical step in the Life Cycle Assessment as it forms the quantitative foundation for all subsequent impact assessment results. A robust LCI requires clearly defined system boundaries, consistent and complete data collection on material and energy inputs, product outputs, emissions, waste flows, and adherence to data quality standards which are outlined below.

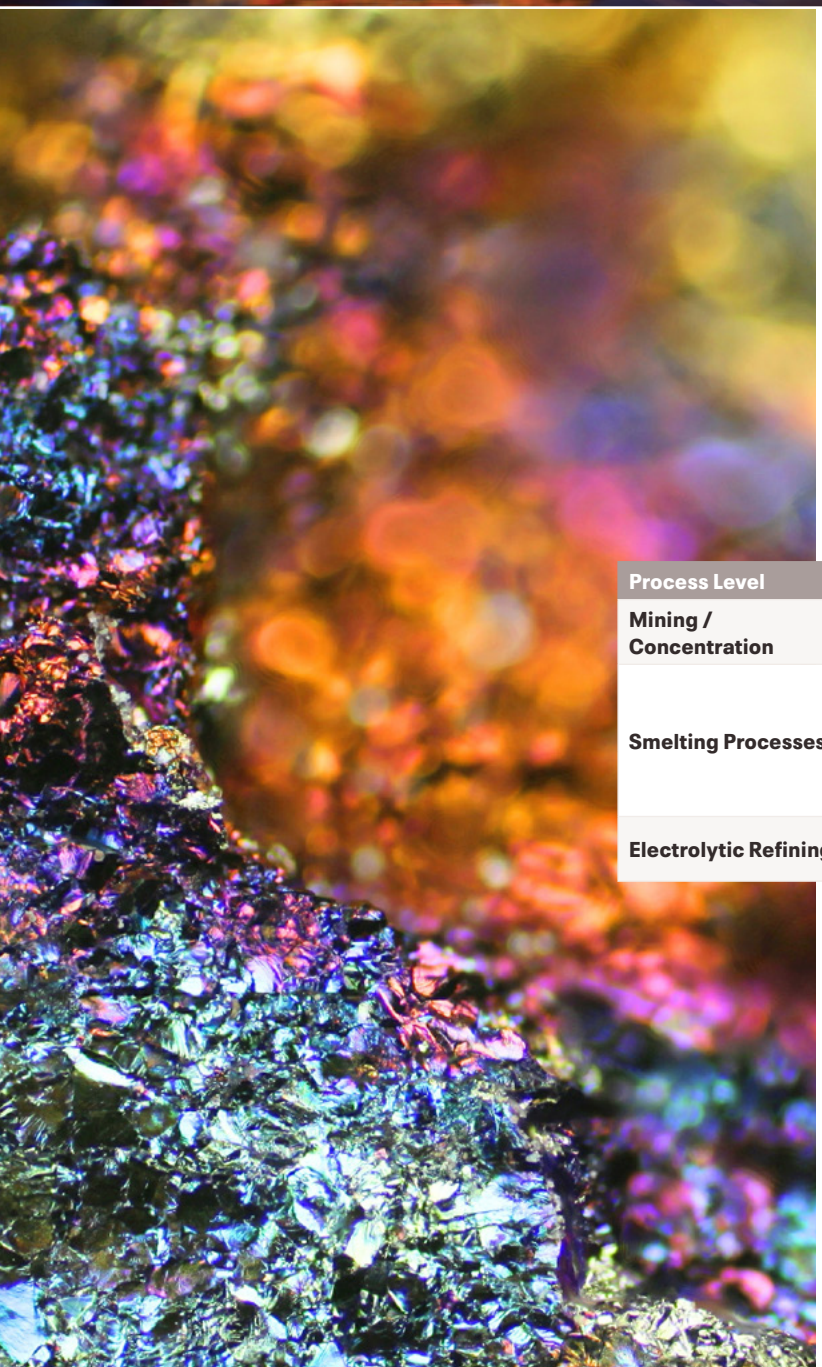
A data quality assessment was performed assessing the technological, geographical, time-related representativeness, and precision.

As the complete inventory comprises hundreds of flows, the table below displays a selection of flows based on their relevance to the subsequent impact assessment in order to provide a transparent link between the inventory and impact assessment results.

Table 1: LCI results of 1 tonne Cu concentrate (24.06% wt, wet basis) and 1 tonne of Cu cathode

Type	Flow	1 Tonne Cu Concentrate	1 Tonne Cu Cathode	Unit
Energy Resources *(Net Calorific Value)*	Crude Oil (Resource)	4191	1427	MJ
	Hard Coal (Resource)	1904	871	MJ
	Lignite (Resource)	317	163	MJ
	Natural Gas (Resource)	2059	1410	MJ
	Peat (Resource)	2.83	1.34	MJ
	Uranium (Resource)	697	297	MJ
	Primary Energy from Hydro Power	2694	786.8	MJ
	Primary Energy from Solar Energy	4579	1391	MJ
	Primary Energy from Wind Power	1238	375	MJ
Material Resources	Ore (Mined)/Ore (Oxidic, 0.56%-wt Cu)	84736	5324	kg
	Cu Concentrate (24% wt Cu)	-	178	kg
	Limestone (Calcium Carbonate)	93	25.26	kg
	Sand	-	14.16	kg
	Water Use (Input)	221907	914800	kg
	Secondary Materials (100% wt Cu)	-	8.98	kg
Deposited Goods	Overburden (Deposited)	7869	1375	kg
	Tailings (Deposited)	40144	8127	kg
Emissions to Air	CO_2	771	322	kg
	CH_4	1.83	0.714	kg
	N_2O	4.52	1.69	kg
	NO_x	0.0731	4.50×10^{-3}	kg
	SO_2	1.36	2.46	kg
	NMVOC	0.775	1.45×10^{-3}	kg
	CO	2.27	0.754	kg
	Dust (>PM10)	0.117	6.55×10^{-2}	kg
	Dust (PM10)	0.0328	6.21×10^{-2}	kg
	Dust (PM2.5 - PM10)	0.262	0.126	kg
	Dust (PM2.5)	0.0967	5.02×10^{-2}	kg
	Arsenic	0.0000428	1.62×10^{-6}	kg
	Copper	0.000207	2.59×10^{-4}	kg
	Lead	0.000114	3.01×10^{-4}	kg
	Zinc	0.000355	9.98×10^{-5}	kg
Emissions to Fresh Water	Ammonium/Ammonia (NH_4^+/NH_3)	0.16	2.81×10^{-2}	kg
	Nitrate (NO_3^-)	0.288	9.97×10^{-2}	kg
	Phosphate (PO_4^{3-})	0.0122	4.32×10^{-3}	kg
	Biological Oxygen Demand	0.0465	1.51×10^{-2}	kg
	Chemical Oxygen Demand	0.86	0	kg
	Arsenic	0.00936	2.79×10^{-9}	kg
	Copper	0.000382	3.38×10^{-4}	kg
	Lead	0.000571	1.76×10^{-4}	kg
	Zinc	0.00138	2.54×10^{-4}	kg





Copper production and recycling enable the recovery of many valuable metal and non-metal co-products from the primary and secondary raw materials. These can include precious metals (e.g., gold and silver), nickel sulphate, zinc, lead, tin, sulfuric acid, and iron silicate. The burden needs to be shared across these co-products. The treatment of each co-product varies, and a summary of the allocation treatment method can be found in the table below.

Table 2: Summary of Co-Product Treatment Methods

Process Level	Co-Products	Treatment Method
Mining / Concentration	Molybdenum concentrate Copper concentrate types	Mass of metal content
Smelting Processes	Steam Sulfuric acid	System expansion
	Lead/Tin	Economic (10-years average price)
Electrolytic Refining	Precious metals (via anode sludge)	Economic (10-years average price)

LIFE CYCLE IMPACT ASSESSMENT (LCIA)

Following the LCI, a LCIA was completed to help ICA and its members determine which process or processes contribute the most to the potential environmental impacts. LCIA helps the copper industry pinpoint opportunities for improvement within its operations.

The following categories were chosen to remain aligned with previous publications of this study. These impact categories are considered relevant to climate change, energy efficiency, and nature, which are all topics of high public and institutional interest.

Table 3: Definitions of LCIA Impact Categories

Impact Category	Description	Unit
Climate Change (Global warming potential)	A measure of greenhouse gas emissions, such as CO_2 and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may in turn have adverse impacts on ecosystem health, human health, and material welfare.	kg CO_2 equivalent
Acidification Potential	A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline, and the deterioration of building materials.	Moles H+ equivalent
Eutrophication (Terrestrial, Fresh water, Marine)	Eutrophication covers all potential impacts of excessively high levels of macronutrients, the most important of which nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems increased biomass production may lead to depressed oxygen levels, because of the additional consumption of oxygen in biomass decomposition.	Terrestrial: moles N equivalent Fresh water: kg P equivalent Marine: kg N equivalent
Photochemical Ozone Formation	A measure of emissions of precursors that contribute to ground level smog formation (mainly ozone O_3), produced by the reaction of VOC and carbon monoxide in the presence of nitrogen oxides under the influence of UV light. Ground level ozone may be injurious to human health and ecosystems and may also damage crops.	kg NMVOC equivalent
Water Use*	An assessment of water scarcity accounting for the net intake and release of fresh water across the life of the product system considering the availability of water in different regions.	m^3 world equivalent
Ozone Depletion	A measure of air emissions that contribute to the depletion of the stratospheric ozone layer, causing higher levels of UVB ultraviolet rays to reach the earth's surface.	kg CFC -11 equivalent
Resource Use, Fossil	A measure of the total amount of fossil resources non-renewable (e.g., petroleum, natural gas, etc.) extracted from the earth used for the primary energy production.	MJ

The reported impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit. LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

*Results should be interpreted with consideration of current data availability and remaining data gaps. ICA is continuing to improve the water use metric by strengthening the underlying dataset for future assessment.

STUDY RESULTS

The study found that:

- **Direct emissions** associated with fuel combustion and industrial processing activities represent a significant contributor to the overall climate change impacts of copper production. These emissions are primarily linked to diesel use in mining equipment, transportation activities, and metallurgical operations required throughout the production system.
- **Electricity consumption** represents the single largest contributor to climate change impacts across the assessed copper production system, accounting for more than 30% of total GHG emissions. As a result, the environmental profile of copper production is strongly influenced by regional electricity grid composition and the share of fossil fuels, renewable energy, and other generation technologies supplying electricity to operations.
- For the environmental impact category of **Climate change**, the mining and processing stage is the most impactful, with concentrate production representing the dominant contributor. Direct fuel combustion and industrial processing activities remain key contributors to overall GHG emissions throughout the copper production system.
- For the environmental impact category of **Eutrophication**, marine and terrestrial impacts are driven primarily by NOx emissions associated with diesel combustion during mining activities and, for some operations, the intermediate transport of concentrate. Freshwater impacts are driven primarily by phosphorus and phosphate emissions to water which are mainly associated with wastewater treatment and diesel combustion. More broadly, these impacts are linked to combustion-related emissions, upstream energy production, and material and wastewater management activities occurring throughout the copper production system.
- For the environmental impact category of **Acidification Potential**, sulfur dioxide (SO_2) emissions associated with metallurgical processing and energy generation remain significant contributors. The magnitude of these impacts is influenced by sulfur capture and treatment systems, regional emissions regulations, and installed desulfurization technologies. Electricity consumption also contributes substantially to acidification impacts, particularly in regions where electricity generation relies heavily on fossil fuel-based power systems.

Individual operations may report results above or below the aggregated industry average due to differences in ore grade, geographic conditions, mining methods, transport distances, energy mix, and operational practices. These variations are expected within a global copper production system and do not inherently indicate better or worse performance without consideration of site-specific conditions and system boundaries.

The results identify key environmental impact drivers across the copper production system and provide insight into areas where continued technological innovation, operational improvements, and broader infrastructure developments may contribute to future reductions.

Table 4: Categories of results

Direct Emissions	All reported emissions of elementary flows from processes, specifically from the mining and concentration processes, diesel combustion, use of reductants, and water when not specified at the site-level; also includes any elementary flow inputs such as ground water or elementary metals
Electricity	Production of electricity, including transmission and distribution losses
Explosives	Upstream production
Production of Fuels	Diesel, natural gas, gasoline, propane, or fuel oil upstream production and combustion of all above mentioned fuels except diesel, which combustion emissions are grouped in the direct emissions
Auxiliaries	Auxiliary materials such as limestone, sulfuric acid, etc.
Transport	Inbound transport of auxiliary, external raw materials to site, and intermediate concentrate transport as applicable
Waste	Upstream production
Water	Site-level inputs and outputs of water; waste water treatment (including energy or process materials needed); any municipal waste water treatment included
Lubricants	Upstream production
Material – Credit	Credit for other non-metal co-products

Table 5: Results of the LCIA for Copper Concentrate and Copper Cathode according to EF 3.1 Method

Impact Category	Results per metric tonne of Copper Concentrate (24% Cu)	Results per metric tonne of Copper Contained in Concentrate	Results per metric tonne of Copper Cathode (99.99% Cu)	Unit
EF 3.1 Climate Change - Fossil	848.97	3529	3515.23	kg CO_2 eq.
EF 3.1 Climate Change - Total	879.68	3657.71	3638.01	kg CO_2 eq.
EF 3.1 Eutrophication, Fresh Water	0.007	0.03	0.0248	kg P eq.
EF 3.1 Eutrophication, Marine	2.086	8.69	9.489	kg N eq.
EF 3.1 Eutrophication, Terrestrial	21.32	88.66	81.41	Mole of N eq.
EF 3.1 Acidification	5.56	23.12	46.88	Mole of H^+ eq.
EF 3.1 Photochemical Ozone Formation, Human Health	5.30	22.05	22.10	kg NMVOC eq.
EF 3.1 Ozone Depletion	1.54×10^{-8}	6.39×10^{-8}	4.5×10^{-8}	kg CFC-11 eq.
EF 3.1 Water Use	1853.17	7705.47	5607.77	m^3 world equiv.
EF 3.1 Resource Use, Fossils	10409.99	43284.76	41840.09	MJ

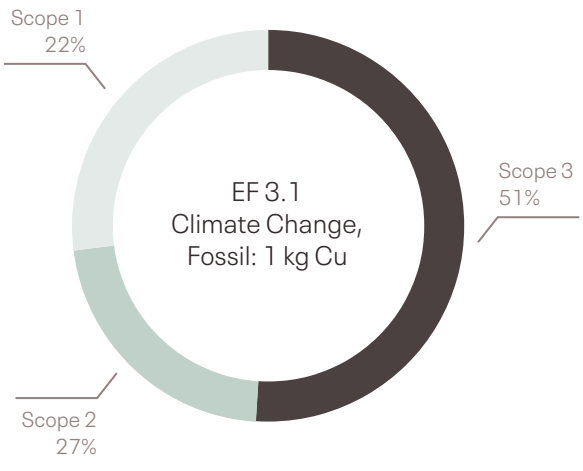
Copper production and recycling enable the recovery of many valuable metal and non-metal co-products from the primary and secondary raw materials.

SCOPE BREAKDOWN

GHG emissions associated with copper production can broadly be grouped into Scope 1, Scope 2, and Scope 3 emissions categories. Scope 1 emissions represent direct emissions from owned or controlled operations, including fuel combustion from mining equipment, transportation activities, and industrial processing. Scope 2 emissions result from the generation of purchased electricity consumed throughout mining, concentration, and refining activities. Scope 3 emissions include indirect upstream and downstream emissions occurring outside direct operations, such as purchased materials, fuels, transportation, and other supply chain activities.

While all three emissions scopes contribute to the overall cradle-to-gate environmental profile of copper production, Scope 3 emissions account for more than half of the total GHG emissions within the assessed system. This reflects the significant influence of purchased materials, transportation, and other supply chain activities on the overall environmental profile of copper production. Scope 1 and Scope 2 emissions together represent the remaining share and are associated primarily with direct operational activities and purchased electricity consumption. Scope 1 and Scope 2 emissions are generally the areas over which copper producers have the greatest direct operational influence, while Scope 3 emissions require collaboration across the broader value chain.

Figure 6: Relative GWP results for 1 kg Cu Cathode by scope 1, 2 and 3



3.52 [kg CO_2 eq./kg Cu Cathode]

HOW TO USE OR INTERPRET THESE RESULTS

The results presented in this report are intended to provide a robust, science-based understanding of life cycle performance at a system level. They are most appropriately used to identify key impact drivers and inform opportunities for improvement across the value chain.

These are representative averages, and not precise values for a specific end-use product, facility, or region. Variations in technology, geography, energy mix, and operational practices can lead to differences in environmental performance at the site or company level.

Comparison of results within the same or other sectors should only be done when able to verify identical methodologies (system boundary, allocation, data quality, assessment and interpretation). LCA results reflect a modeled representation of reality, based on the data and assumptions described in this report. While the findings are robust for identifying trends and relative contributions, they should not be used for comparative assertions, without making sure all requirements according to ISO rules are taken into account.

It is important to note that individual results will fall above or below the reported industry average. This variation is expected and reflects differences in production routes, geographic conditions, energy sources, technology configurations, and operational efficiencies across sites. The industry average represents an aggregated benchmark rather than a prescriptive through single technology calculated value and therefore should be used as a point of reference rather than a target. Results that deviate from the average do not inherently indicate better or worse performance without considering the underlying drivers and external conditions.

Finally, these results are not intended to support comparative assertions for marketing purposes without further analysis in accordance with relevant standards, including ISO 14044.

KEY DRIVERS OF FUTURE IMPROVEMENT

Continued reductions in the environmental impacts associated with copper production will depend on a combination of operational improvements, technological innovation, and broader systems level changes occurring across energy, transportation, and industrial infrastructure. While copper producers can directly influence certain operational emissions, many environmental impact drivers are also shaped by external factors such as electricity grid composition, fuel availability, transportation infrastructure, and upstream supply chain activities. At the same time, the copper industry is working in collaboration with OEMs and NGOs in advancing initiatives aimed at reducing environmental impacts across the value chain.

Ongoing efforts and future improvement pathways include:

- Continued decarbonization of regional electricity grids
- Improvements in energy efficiency, operational optimization, sulfur capture systems, and emissions control technologies
- Development and scaling of lower carbon heavy-duty mining equipment, including battery-electric haul trucks, trolley-assist systems, hydrogen fuel technologies, and autonomous mining equipment
- Increased availability of renewable electricity, lower-carbon industrial fuels, and supporting infrastructure
- With Scope 3 emissions accounting for over half of the total GHG emissions in this study, expanded collaboration across the value chain, including energy providers, suppliers, transportation systems, technology developers, equipment manufacturers, and mid to downstream users

These findings highlight both the complexity of copper production systems and the importance of evaluating environmental performance within the broader context of regional infrastructure, technology availability, and supply chain dynamics. As global demand for copper continues to grow alongside the energy transition, life cycle assessment remains an important tool for identifying key impact drivers, informing improvement efforts, and supporting transparent communication across the value chain.

FOR MORE INFORMATION, PLEASE CONTACT:

Bethany Perkins
Bethany.Perkins@internationalcopper.org

Ladji Tikana
Ladji.Tikana@internationalcopper.org

Louise Assem
Louise.Assem@internationalcopper.org

INTERNATIONALCOPPER.ORG

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