

Advancing copper decarbonization and the role of recycling





1. Why decarbonizing copper is crucial

According to an analysis of the **International Copper Association (ICA)**, the production of copper contributes to approximately 0.2% of total global greenhouse gas (GHG) emissions, totaling around 97 million tons annually (ICA, 2018). **Copper is essential for a vast array of decarbonizing technologies.** When taken together, these technologies have the potential to account for two-thirds of global GHG emissions' abatement by 2050. Between 2018 and 2050, the demand for copper is expected to double due to population growth, economic development, and the growth of decarbonization technologies.

The International Energy Agency (IEA) highlights that the grid length is expected to double by more than 80 million kilometers until 2040 (IEA, 2023), driving **increased demand for copper in grid technologies such as transformers.** Copper plays a crucial role in the energy transition due to its exceptional conductivity and importance in grid technologies. However, the production of copper can generate adverse environmental impacts, including carbon emissions. Through responsible mining practices, these impacts can be managed, supporting an energy transition that is not only effective but also environmentally performant. The decarbonization of copper production is a process that has already started.

However, **decarbonizing copper production entails time-consuming as well as cost-intensive challenges** across the whole copper value chain. These include moving away from fossil fuels in heavy mining equipment, the procurement of carbon-free electricity at scale, the substi-

tution of carbon-based fuels and reagents in smelting and refining processes, and challenges with efficient recycling. Fostering technological innovation and collaborating among stakeholders can help unlock these improvements.

1.1 Getting to the bottom of it: sources of GHG emissions in copper production

Of the earlier mentioned 97 million tons of CO₂e emitted, approximately 70% are generated by mining sites, 23% originate from smelting and refining, and the remaining 7% come from upstream and downstream transport and end-of-life (EoL) treatment of products (ICA, 2018). In mining, the largest contributors to GHG emissions are the fossil fuels used in mining equipment and the electricity used in material concentration processes.

From its extraction in mines to its use in finished products, copper goes through several processing stages, but there are two distinct production pathways. **Primary copper** is extracted from ores through mining, followed by concentration and treatment in smelters using pyrometallurgical methods. Alternatively, a hydrometallurgical route may be used to leach copper from the ores and extract it through electro-winning, depending on the ore's nature. **Secondary copper** sources use recycled copper, including scrap from manufacturing processes and EoL products. High purity scrap can be directly remelted, while less pure scrap requires additional processing. This can occur in dedicated secondary smelters or in primary smelters with a certain percentage of added scrap. Primary and secondary sources



Figure 1 Close-up of a copper coil

are often combined to produce high-quality copper metal. While secondary copper has, in average, lower embedded emissions than primary copper, it will be crucial to focus on reducing the impacts of primary routes going forward.

1.2 To decarbonize copper means to pull the right levers

The copper industry has identified four key levers for decarbonization. In order of impact potential, starting with the biggest lever: decarbonized electricity; equipment electrification, like trolley or battery-driven haulage trucks; alternative fuels, such as hydrotreated vegetable oil and green hydrogen; and efficiency gains in various processes. By combining these levers, the copper sector aims to bring Scope 1 and 2 GHG emissions to net zero by 2050.

For practical industry examples, **Boliden**, a Swedish mining company, introduced electric trolley assistance in its hauling trucks in 2018, saving significant amounts of diesel fuel (Boliden, 2018). The electrification of fleets has spread to other truck types and to underground mining machinery. "Innovation for Cleaner and Safer Vehicles", an initiative by the International Council of Mining and Metals, brings mining companies together with many of the world's largest mining truck manufacturers in a non-competitive space with the aim to accelerate the decarbonization of mining fleets.

An **Aurubis** initiative pulls another lever at the Hamburg plant by using hydrogen instead of natural gas for the reduction process in its anode furnaces; from this, the German copper producer expects to reduce CO₂ emission by around 5 thousand tons per year (Aurubis, 2023).

1.3 How recycling contributes to the decarbonization of copper production

The availability of secondary material is a key limiting factor. Over the period from 2000 to 2020, the EoL recycling input rates averaged around 15%. In its Pathway to Net Zero, the ICA estimates that the EoL recycling input rate could increase up to 23% over the next 30 years. Recycling copper can offer significant environmental benefits, such as energy savings, reduced emissions of GHG and other pollutants, preservation of natural resources, and the prevention of valuable land from being used for landfills. Production using recycled content avoids all the impacts from the mining step detailed above.

However, as recycled copper rates are not expected to exceed 23%, recycling alone cannot be sufficient to cope with the growing global demand until 2050. For the same reason, it cannot be the main lever for copper decarbonization at a global scale. That being said, capturing and processing the cleanest scrap could serve as a closed loop example to minimize emissions. **Recyc-Câbles**, a joint venture between SUEZ and Nexans, was founded with the aim of

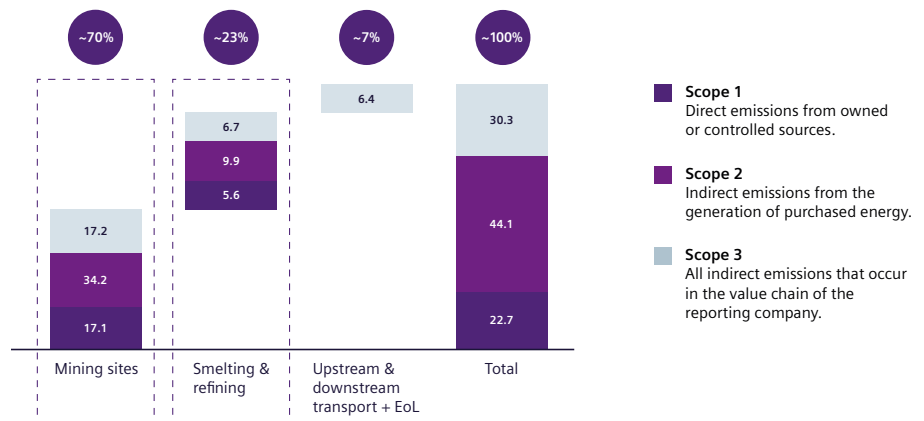


Figure 2 Global Scope 1, 2 and 3 copper CO₂e emissions, 2018 (million tons). Adapted figure from ICA.

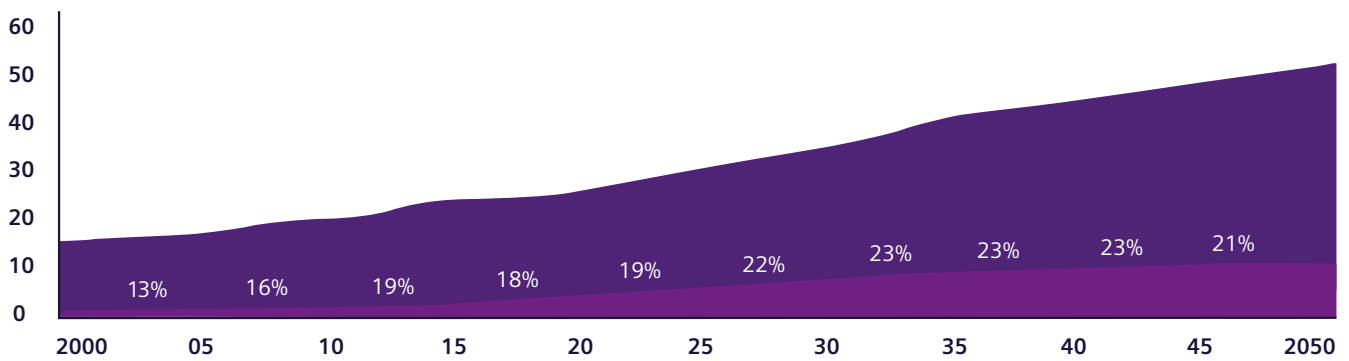


Figure 3 Global copper demand, scrap, 2000 – 2050 (thousand tons). Adapted figure from ICA.

■ Primary demand ■ Scrap

collecting, recovering, and processing materials from used cables, including copper. Ensuring a closed loop business model, this already resulted in new cables with 99.9 % pure copper (SUEZ, 2024).

Despite efforts to increase the input rate of recycled scrap in the copper production process, the World Bank Group has calculated that even a 100% EoL recycling rate would only reduce the demand for copper from primary sources by 26% by 2050 (The World Bank Group, 2020). This is mainly due to the fact that copper consumption has been growing since a century (practically doubling every 30 years) and lifespan of products using copper is, on average, very long (25-30 years). What is recovered today is what was put into the market a few decades ago, when the demand was approximately half of what it is today. Additionally, no process is 100% efficient, and losses in the collection, separation, and re-processing of copper scrap will always exist. Therefore, copper produced from mineral ores will continue to play a decisive role in fulfilling the growing global needs.

2. Copper as a significant component at Siemens Energy Grid Technologies

At Siemens Energy Grid Technologies, copper plays a pivotal role in our commitment to reducing GHG emissions and advancing sustainability within our supply chain. It is a major contributor to the GHG balance of transformers, accounting for a minimum of 15% of its total GHG emissions, and depending on the design and copper content, this can increase to over one quarter of the GHG emissions from raw materials. Evidently, addressing the Global Warming Potential (GWP) of copper is essential in our overall decarbonization efforts.

Recognizing that long-term decarbonization commitments, roadmaps, and actionable plans are essential for sustainable progress, our collaborative efforts with our partners

such as the ICA and our copper suppliers are aimed at creating a common understanding within our industry, driving impactful decarbonization results, and fostering widespread acceptance of sustainable practices. As we navigate the copper transition, our dedication lies in promoting closed-loop models to enhance circular efficiencies and, consequently, reduce the CO2 footprint within the copper supply chain. We are committed to advocating for the development of market conditions necessary for a successful green copper transition.

Together with Ørsted, Siemens Gamesa, and Circular, we at Siemens Energy Grid Technologies have supported the end-to-end copper traceability used in transformers for wind turbines. This initiative involves engagement across five tiers of the supply chain to identify component makers and material processors, as well as mine sites. Implemented with Circular's blockchain technology for material traceability, this cross-value chain project enables full visibility of the copper material journey, promoting more responsible supply chains for climate and human rights, including the mining extraction of Responsible Minerals.

In this context, we are geared towards overcoming technological and economic challenges, further emphasizing the importance of collaboration and concerted efforts to create a more climate-responsive and human rights respecting economy. Through our dedication and collaborative approach, we are committed to advancing the decarbonization of copper, driving sustainability, and contributing to a greener, more environmentally responsible future.

Even though this article mainly focuses on the decarbonization of copper production and GHG emissions are an important environmental indicator, other impact factors such as pollution and biodiversity as well as social and governance aspects must not be neglected.

This article is written with the support and review of the International Copper Association Europe.

3. Sources

Aurubis (2023). H2-ready: Aurubis investing in hydrogen-capable anode furnaces in the Hamburg plant. URL: <https://www.aurubis.com/en/media/press-releases/press-releases-2023/h2-ready-aurubis-investing-in-hydrogen-capable-anode-furnaces-in-the-hamburg-plant> (Retrieved 3 July 2024).

Boliden (2018). Boliden launches electric mine-truck pilot project in Aitik. URL: <https://investors.boliden.com/en/press/boliden-launches-electric-mine-truck-pilot-project-aitik-1553771> (Retrieved 3 July 2024).

ICA (2023). Copper - the pathway to net zero. URL: <https://internationalcopper.org/wp-content/uploads/2023/02/ICA-GlobalDecarbonization-202301-Final-singlepgs.pdf> (Retrieved 3 July 2024).

IEA (2023). Electricity Grids and Secure Energy Transitions. URL: <https://iea.blob.core.windows.net/assets/70f2de45-6d84-4e07-bfd0-93833e205c81/ElectricityGridsandSecureEnergyTransitions.pdf> (Retrieved 3 July 2024).

SUEZ (2024). RECYCABLES, the leading provider of cable waste recovery. URL: <https://www.suez.com/en/our-offering/success-stories/ourreferences/recycables-provider-of-waste-cable-recovery> (Retrieved 3 July 2024).

The World Bank Group (2020). Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition. (Retrieved 3 July 2024).

Published by

Siemens Energy Global GmbH & Co. KG
Grid Technologies
Siemenspromenade 9
91058 Erlangen
Germany

For more information, please visit our website:
siemens-energy.com/transmission

or contact us: support.energy@siemens-energy.com

© 2025 Siemens Energy

Subject to changes and errors. The information given in this document only contains general descriptions and/or performance features which may not always specifically reflect those described, or which may undergo modification in the course of further development of the products. The requested performance features are binding only when they are expressly agreed upon in the concluded contract. All product designations may be trademarks or product names of Siemens Energy Global GmbH & Co. KG or other companies whose use by third parties for their own purposes could violate the rights of the owners.

Siemens Energy is a trademark licensed by Siemens AG.

For the U.S. published by

Siemens Energy, Inc.
Grid Technologies
4912 Green Road
Raleigh, NC 27616
USA