



Greening the grid: How sustainable practices are reshaping energy infrastructure

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The global energy landscape is undergoing a significant transformation characterized by an unprecedented expansion of energy grids. According to the International Energy Agency (IEA), the global energy grid must double its capacity by 2040 to accommodate the increasing demand for electricity driven by the energy transition, electrification, and population growth. Additionally, in Europe and the USA, over 40% of the grid is over 20 years old, necessitating urgent upgrades.

This surge in demand for energy infrastructure presents a unique opportunity to shape the future of the grid sustainably. Christina Iosifidou, Head of Sustainability at Siemens Energy's Grid Technologies business, explains that the energy sector must adapt to meet ambitious climate goals while adopting sustainable practices in the entire supply chain and life cycle of its products.

The imperative for sustainable practices

As countries commit to ambitious climate goals, the demand for sustainable

practices in the energy sector has become critical. Recognizing that sustainability in the supply chain is integral to minimizing the environmental impact of operations and products, companies like Siemens Energy are taking proactive steps.

Siemens Energy covers the entire electricity transmission chain with its comprehensive portfolio, approaching sustainability holistically. This means focusing not only on the end products but also on the raw materials and manufacturing processes that underpin energy infrastructure.

High-voltage, high emissions?

High-voltage products, such as transformers, switchgear, and high-voltage direct current (HVDC) systems, are essential for the transmission and distribution of electricity. However, their production and operation can contribute to greenhouse gas emissions. A report by the IEA, "The Role of Critical Minerals in Clean Energy Transitions," highlights

that these products can account for over 30% of emissions in the electricity supply chain.

The energy transition needs transformers

One area experiencing massive growth is the large power transformer market. The IEA states that global transformer capacity will reach 28 terawatts (TW) by 2040. Transformers are critical components in the energy grid, and their production involves substantial use of raw materials such as steel and copper. To put this into perspective, at Siemens Energy, we expect that over hundreds of thousands of transformers will be needed in the next few years, requiring double-digit million tons of steel and copper. The rising demand for transformers illustrates the challenge faced, as raw materials contribute to a significant proportion of a transformer's total emissions, depending on the design.

Decarbonizing the supply chain: Step by step

To effectively address these challenges, Siemens Energy has embarked on a strategic initiative to identify and leverage decarbonization opportunities within its supply chain. The company has committed to reducing the greenhouse gas (GHG) emissions associated with its purchased goods and services by 30% by 2030. Central to this effort

Contributing > 80% of embodied CO₂ emissions, low emission raw materials offer the largest decarbonization opportunity

Decarbonized raw material upgrade options

Oil

Bio-based, biodegradable and regenerated oils

Electrical steel

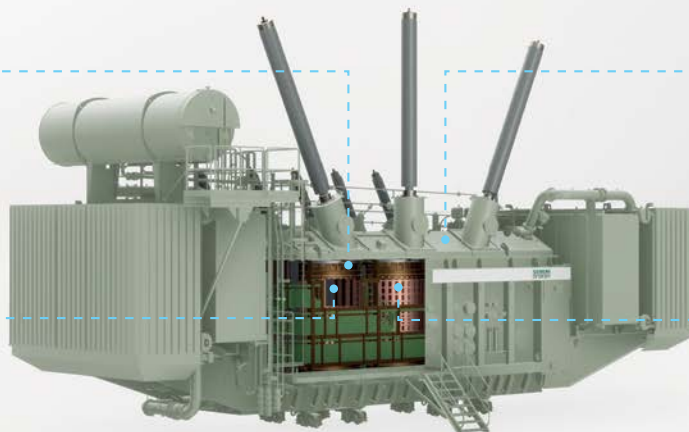
Recycled and CO₂-reduced options

Steel (tank)

High recycled content >95% options

Copper

Recycled and CO₂-reduced copper options





is the Supply Chain Decarbonization Program launched by the Siemens Energy Grid Technology business, which emphasizes enhancing transparency in supply chain sustainability and fostering collaboration with key suppliers. This program promotes the use of low-emission materials and components while working closely with suppliers to identify and implement effective strategies for reducing grid supply chain emissions.

In addition, Siemens Energy's Grid Technology business has formed partnerships with industry leaders to initiate Joint Industry Projects (JIPs) focused on enhancing sustainability across the sector, particularly in transformer production. These projects aim to establish standardized boundaries and key performance indicators, develop best practices for life cycle assessment (LCA) and environmental product declaration (EPD) reports.

By improving transparency in sustainability efforts, Siemens Energy enables customers to access comprehensive information about the environmental impact of their products, empowering them to make informed decisions and support sustainable practices. A key area of focus for advancing sustainabil-

Siemens Energy and TenneT have partnered to advance copper decarbonization and promote recycling

ity in the supply chain is a comprehensive analysis of the raw commodities market. As demand for raw materials continues to rise and costs escalate, it is increasingly important to ensure that these materials are sourced and produced in a sustainable and responsible manner.

Copper: Decarbonization efforts

Copper is a vital component in electrical systems, particularly in transformers. However, its production is energy-intensive and often relies on fossil fuels. Up to 90% of copper emissions result from copper cathodes, which are mainly a result of mining activities.

Today, there is huge potential to reduce emissions through recycled content and decarbonized electricity, but in the longer term the focus will be on electrification and the use of alternative fuels in the mining process. There are already low-emission options available today

ranging between 0.7 and 1.5 kg CO₂eq per kg copper cathode, depending on the supplier and levers used, and these are expected to reduce further to 0.3-0.4 kg CO₂eq per kg copper cathode in the future.

The journey of recycled copper from scrap to transformer windings is essential for decarbonizing supply chains in grid technology. Siemens Energy and TenneT, a Transmission System Operator operating in the Netherlands and Germany, have partnered to advance copper decarbonization and promote recycling, minimizing the environmental impact of copper production. The collaboration focuses on improving recycling efficiency and increasing the use of recycled copper in new transformers. Siemens Energy is supplying transformers made from 100 percent recycled copper, having recently completed a successful pilot. Together, they have identified around ten joint initiatives to enhance sustainability across their supply chain.

By collaborating with steel manufacturers committed to sustainable practices, Siemens Energy aims to significantly lower the emissions associated with steel in its supply chain

Steel: Transitioning to green steel

Steel is another major contributor to the carbon footprint of transformers. Up to 75% of emissions come from crude steel, which mainly results from blast furnaces running on coal. Today, the energy sector is focusing on the transition to greener steel. Emission reductions in steel production are already achieved by including a higher share of scrap, decarbonized electricity, and other efficiency improvements. In the long term, however, the production process must be converted to hydrogen-fired Direct Reduced Iron (DRI) and Electric Arc Furnace (EAF) technology.

These intermediary improvements are reflected through the introduction of low-emission steel or greener steel product lines using the mass balance

approach. This approach allocates overall emission reductions to CO₂-reduced steel products, ensuring they match the quality and properties of fossil-based alternatives. However, the mass balance approach comes with its fair share of criticism, highlighting the need for long-term transition technologies in steel production.

By collaborating with steel manufacturers committed to sustainable practices, Siemens Energy aims to significantly lower the emissions associated with steel in its supply chain. In this context, Siemens Energy is part of the cross-value chain project “Lead markets for CO₂-reduced steel in power grids”, which was initiated in the form of an open working group. Its aim is to lead the energy transition by fostering a green lead market for CO₂-reduced steel, providing policymakers

with insights and proposals that will enable the growth of such a market.

Aluminium: Enhancing transparency and sustainability

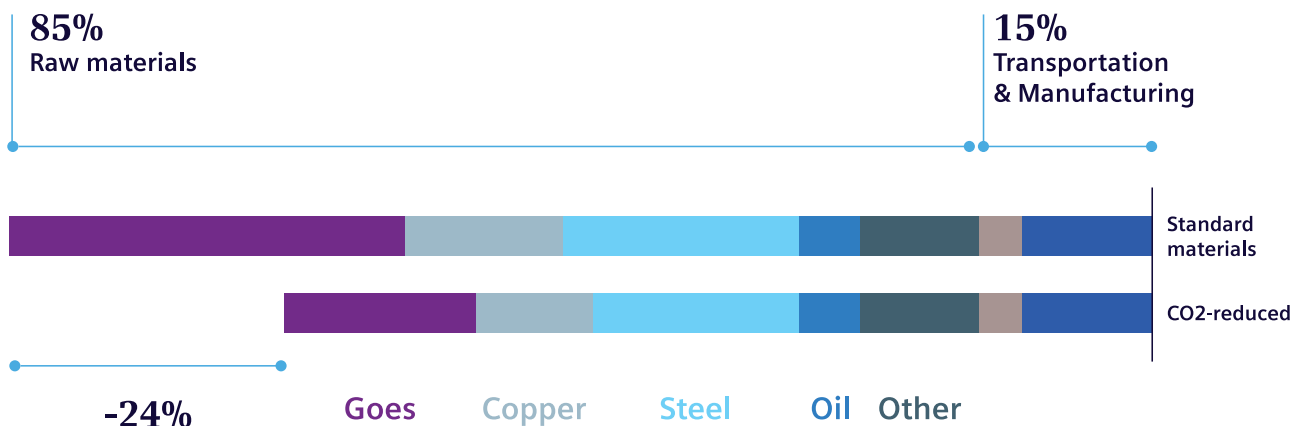
Finally, we have aluminium, which is another critical material. Aluminium is used less so in the production of transformers but is crucial for Siemens Energy Grid Technology's switchgear portfolio. Like steel, aluminium production is energy-intensive and contributes significantly to GHG emissions. The main GHG emissions from aluminium casting parts for switching products stem from the aluminium ingot, approximately 70%, of which are mainly generated in the smelting process. The most important levers for decarbonizing aluminium production in the future will be a higher proportion of recycled material and innovations such as inert anode technology. In Europe, the carbon footprint of aluminium has already been significantly reduced, with suppliers on the market offering aluminium ingots at 4.9 CO₂eq.

Together with Thoni Alutec, a key aluminium supplier, and We Don't Need

Combining material and factory decarbonization to achieve grid supply chain GHG reductions for our customers

Life cycle assessment: cradle-to-gate scope e.g. HVDC transformer 512MVA, 400kV

Life cycle phases*



*Figures vary depending on equipment rating and size

In steel products, up to 75%¹ of GHG emissions result from the production of crude steel, due to its reliance on coal

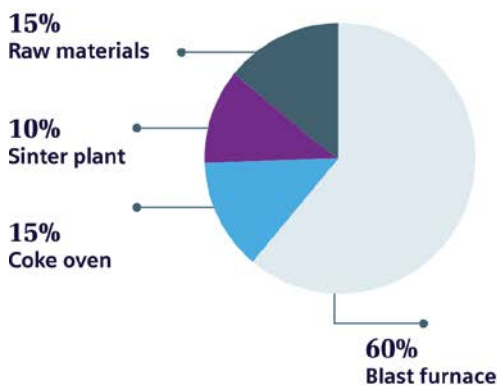


Figure: GHG emissions in the EU iron & steel industry²

In the production of copper products, up to 90%¹ of GHG emissions result from the use of copper cathode

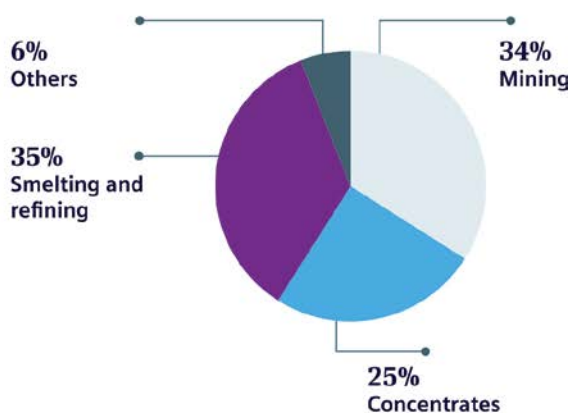


Figure: GHG emissions in the EU copper production²

Sources: 1 Ecoinvent v3.10 | 2 EU Joint Research Center. (2020)

Roads, an external sustainability consultancy, Siemens Energy Grid Technologies co-initiated a cross-collaboration project. As part of this project, a comprehensive LCA was conducted to assess the environmental impacts of the switching product's aluminium casting parts. As a result, key emission hotspots in Thoni Alutec's production process were highlighted, opportunities for improvements were identified, and recommendations to support further decarbonization efforts were provided.

Decarbonizing factory operations

Raw material consumption is only one side of the coin when it comes to greening the grid supply chain; the decarbonization of manufacturing operations must also be considered. Siemens Energy is not only setting expectations throughout its supply chain to decarbonize but is also setting the benchmark to become climate-neutral in its own operations by 2030.

The Siemens Energy transformer factory in Nuremberg, Germany, serves as a prime example of how industrial operations can be decarbonized. The factory

The whole grid sector is experiencing a boom. With that boom comes an increased responsibility to reduce its carbon footprint and green the grid through the supply chain

has successfully implemented several initiatives, including the electrification of its fleet and forklifts, as well as the construction of large Power-to-Heat drying ovens to replace gas-powered dryers. These measures collectively save up to 1,600 tons of CO₂eq per year.

The energy sector is booming so we must set the benchmark

Transformers are just one area in the energy landscape that experiences unprecedented demand and growth. In reality, the whole grid sector is experiencing a boom. With that boom comes an increased responsibility to reduce its carbon footprint and green the grid through the supply chain as well as through the deployment of technolo-

gy. Through initiatives to optimize raw material consumption, decarbonize raw materials and factory operations, and enhance sustainability transparency, the industry is taking significant steps to drive sustainability in the power grid.

As the demand for energy infrastructure continues to grow, these efforts will play a vital role in ensuring that the transition to a greener grid is both sustainable and economically viable. By leveraging this unprecedented opportunity for grid expansion, Siemens Energy is not only shaping a more sustainable energy landscape but also setting a benchmark for the industry as a whole. The focus on sustainable supply chains will be essential in meeting the challenges of the future while contributing to global climate goals.