ABSTRACT

The carbon footprint of transformers during the life cycle, including raw materials, production, and operation stages, has been analyzed. First, primary raw materials are discussed regarding their contribution to the carbon footprint. Then, as the largest contributor to carbon footprint, the steel industry is discussed in detail. The current investments and commercial offerings for green steel are presented. The enormous challenges the steel industry faces to reach carbon neutral status in 2050 and the revolutionary changes in steel making process are discussed. The same points are also presented for the copper, aluminium, and oil industries. Some sample carbon footprints of different transformer types (LPT, SPT, DT with copper or aluminium) are also included. It is also explained that the transport industry is a major contributor to global emissions, and the transport of transformers creates a significant carbon footprint. As the last point, it is discussed how the transformer industry could contribute to decarbonization efforts in their factories and during the operation stage of the transformers, and some suggestions have been made.

KEYWORDS:

raw materials, steel, copper, aluminium, fluids, transportation, decarbonization, supply chain, supply chain management

Ufuk KIVRAK

Green supply chains for the transformer industry

Transformer operation has a major impact on the carbon footprint, assuming 40 years of the transformer's lifetime

The carbon footprint of transformers during the life cycle, including raw materials, production and operation stages has been analysed.

1. Transformer lifecycle

The following graph shows the carbon footprint contribution of 3 stages of the transformer lifecycle in proportion:

The figures are index values (raw materials assigned as 100) and are intended to show the relative magnitudes as an average.

The average load of the transformer during operation is taken as 50 %, and the lifetime is assumed as 40 years.

For transformer producers, raw materials are defined as Scope 3 and usually not reported (Scope 3 reporting is voluntary). The absolute values of the figures may show some variations depending on several assumptions made during the calculation, however, the proportions will not change.

This graph clearly shows that the dominant part of the carbon emissions takes place during the operation of the transformer. The consequences one may derive from this graph will be discussed in a later part of this article.

2. Raw materials

2.1. Steel

The iron and steel industry accounts for 7.2 % of global carbon emissions, which makes it one of the largest contributors in the world.

Steel has the largest share of carbon emissions among the raw materials of a transformer (60–70 %)

Raw materials	Tr. Production	Operation (40 years)
100	2	8,000

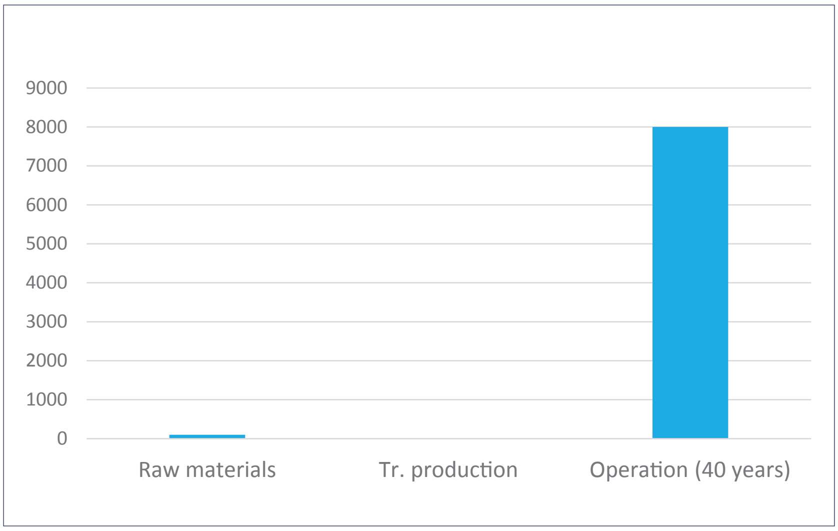


Fig. 1. Carbon footprint of transformer lifecycle (index values)

Steel has the largest share of carbon emissions among the raw materials of a transformer (60–70 %)

The transformer tank, conservator, and radiators are made of steel, and the core is made of electrical steel.

1 tonne of crude steel emits 2 tonnes of CO_2.

Mining of iron ore and coal is the upstream industry for steel production. The steel industry is energy, capital, and technology-intensive.

All major steel companies have confirmed their 2030 and 2050 targets to eventually reach carbon-free status in 2050.

A short explanation may help understand the steelmaking process. There are two major technologies. One is blast furnace technology. In this case, the iron ore (iron oxide) and the coking coal (carbon) are brought together in the blast furnace, and the iron is reduced for downstream operations. This process generates high levels of a by-product by combining carbon and oxygen, which is carbon dioxide. The blast furnace is the largest contributor to the carbon emissions from steel. And the environmental impact is high. The other technology is electric arc furnaces, and they typically work with steel scrap. They don't use iron ore. This is good in two aspects. First, it doesn't produce the same amount of carbon dioxide as a blast furnace. Secondly, steel scrap is recycled, which is also good for circularity and environmental aspects, but the dominant technology is blast furnace because although the capital investment is very high compared to the electric arc furnace, the operational costs are much lower.

There are several efforts to produce "green steel." The announced investments to produce green steel will be briefly reviewed. (All the information is taken from the websites of the relevant companies).

2.1.1. SSAB (Sweden) HYBRIT Project

In 2016, SSAB, LKAB, and Vattenfall joined forces to create HYBRIT – a joint venture project that endeavours to revolutionize steelmaking. HYBRIT aims to replace coking coal, traditionally needed for ore-based steel making, with hydrogen. The result will be unique: the world's first fossil-free steelmaking technology, with virtually no carbon footprint. The goal is to have a solution for fossil-free steel by 2026.

The first stage was the development of hydrogen steelmaking using a newly built direct reduction plant (7,000 t/yr) in Lulea, with a €150 million investment.

The planned production capacity is 1.3 million tonnes/year from 2026.

Volvo Group reveals the first vehicle made of fossil-free steel produced by SSAB, a load carrier for use in mining and quarrying (13 October 2021).

SSAB is teaming up with Faurecia to jointly explore the development of fossil-free advanced high-strength steel for use in the automotive seating business (2 September 2021). The investment is supported by Swedish Energy Agency.

2.1.2. BAOWU

On 18 November 2021, the **Global Low-Carbon Metallurgical Innovation (GLCMI) Alliance**, initiated by China Baowu and co-sponsored by the global steel industry and ecosystem partners, was announced in Shanghai.

The Global Low-Carbon Metallurgical Innovation Alliance is jointly established by 62 companies, universities, and scientific research institutions from 15 countries in the world. Its members include internationally renowned companies such as ArcelorMittal, ThyssenKrupp, Tata, BHP, Rio Tinto, Vale, and FMG, as well as scientific research institutes and engineering companies, among them, are *RWTH* Aachen University, Ukrainian Metallurgical Research Institute, Danieli and Pratt.

The alliance positions itself as a technology exchange platform in the field of low-carbon metallurgical innovation to gather R&D resources of the global steel industry, upstream and downstream companies, universities, and research institutions to collaborate in the development of basic as well as forward-looking low-carbon metallurgical technology, to promote technology cooperation, exchange, and transformation, advancing the engineering and industrialization of low-carbon technologies, forming a low-carbon value innovation chain and promoting the low-carbon transformation in the steel industry. Members of the alliance will follow the principles of openness, vision sharing, and intellectual property protection, actively respond to climate change, and work together for the future of the steel industry and the benefit of mankind. They started research on the industrialization of hydrogen steelmaking using the existing 400 m3 test BF in Xinjiang.

2.1.3. Thyssen-Krupp

Thyssen-Krupp launched **bluemint®** steel with a reduced carbon footprint in 2022. It is also available for GOES grades from TKES, and it is the first commercial GOES product with low carbon emissions.

bluemint® pure

- Measure: use of HBI in the blast furnace, also hydrogen in the long run
- CO_2 reductions at the Duisburg production site and in a global context
- Allocated CO_2 reductions lead to reduced product-related carbon intensity
- CO_2 reduction of 1.5 tonnes of CO_2 per tonne of hot strip
- Residual carbon intensity of 0.6 tonnes of CO_2 per tonne of hot strip

bluemint® recycled

- Measure: use of scrap in the blast furnace
- CO_2 reductions at the Duisburg production site
- Balance-sheet CO_2-neutral recycling product
- CO_2 reduction of 1.35 tonnes of CO_2 per tonne of hot strip
- Specific CO_2 emissions of 0.75 tonnes of CO_2 per tonne of hot strip

2.1.4. Arcelor Mittal

Arcelor Mittal announced the development of hydrogen use in an existing commercial natural gas DRI plant (100,000 tonnes/year).

ArcelorMittal has received a German state funding pledge for half the €110 million ($131 million) it plans to invest in a demonstration steel plant that will use hydrogen produced with renewable electricity.

Environment Minister Svenja Schultze said Berlin would pay €55 million -- subject to EU approval -- for the direct reduced iron (DRI) plant that will use green hydrogen to reduce iron ore in a CO_2-free steelmaking process, ArcelorMittal said in a statement on Tuesday.

The company aims to produce "green" steel from 2025 onwards, obtaining it from clean DRI derived from a yet-to-be-built 50-megawatt electrolyzer and melted with steel scrap in an electric arc furnace, which itself will be fuelled by green power.

Uwe Braun, CEO of ArcelorMittal Hamburg, said the plant would enable his company to produce 100,000 tonnes of DRI for steelmaking with green hydrogen by 2025. FRANKFURT, 7 September 2021 (Reuters)

2.1.5. Salzgitter SALCOS®

13 July 2022 | Press release of Salzgitter AG

Salzgitter AG's Supervisory Board approves funds of **€723 million** for implementing the first stage of the SALCOS® - Salzgitter Low CO_2. SALCOS® is aimed at converting the integrated steelworks into low-carbon crude steel production in three stages over the period up until 2033. As part of the transformation, direct reduction plants and electric arc furnaces will be built and will then replace the blast furnaces and converters in stages. The transformation will enable the process that was formerly based on coking coal to be replaced by a new hydrogen-based route. Emissions savings of around 95 % a year are to be subsequently achieved, thereby avoiding approximately 1 % of Germany's carbon emissions.

Major steel production companies are focusing their efforts on the production of environmentally friendly "green steel" that causes lower CO_2 emissions in the manufacturing process

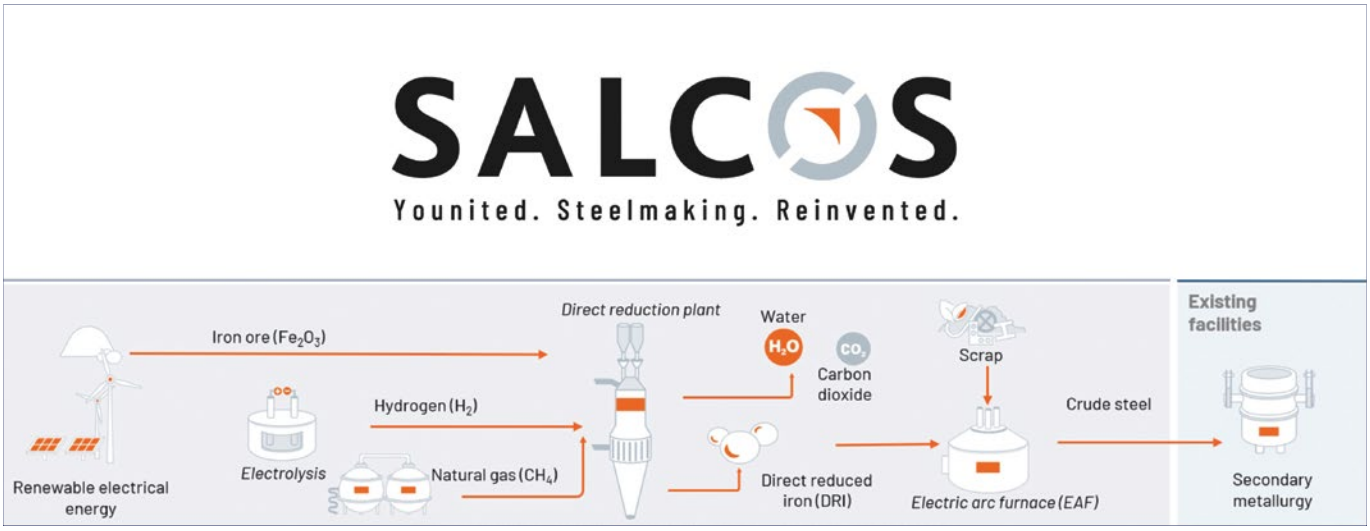


Fig. 2. Salcos steelmaking process of Salzgitter

Nippon Steel Corporation has launched sales of "NSCarbolexTM Neutral," a steel product that is certified as reducing CO_2 emissions in the steelmaking process, in the first half of fiscal 2023

Production launch is planned for the end of 2025.

The new facilities will enable us to produce **1.9 million tonnes** of green steel a year. Customers from a range of industries are already expressing keen interest. As a result, the Salzgitter Group has already agreed on possible deliveries in recent weeks with customers from various sectors, including household appliance manufacturers, the automotive industry, and re-rollers.

2.1.6. GravitHY

30 June 2022 | Press release

A company composed of EIT InnoEnergy, the innovation engine for sustainable energy supported by the European Institute of Innovation & Technology, a body of the European Union (EU), Engie New Ventures, Plug, FORVIA, GROUPE IDEC through GROUPE IDEC INVEST INNOVATION and Primetals Technologies, today launch GravitHy – a future market leader in green iron.

The project will build its first plant in the area of Fos sur Mer, Southern France, with construction commencing in 2024. The company aims for the plant to be fully operational by 2027, subject to the required regulatory approvals. GravitHy has the ambition to produce an annual throughput of **2 million tonnes** of Direct Reduced Iron (DRI) and to create over 3,000 direct and indirect jobs for the region.

The scheme will involve the installation of some 650 MW of electrolyzer capacity, which will be one of Europe's largest by the time it comes online, to produce 110,000 tonnes of hydrogen per year.

2.1.7. NSCarbolex™ Neutral by Nippon Steel C

Nippon Steel Corporation ("Nippon Steel") has launched sales of "NSCarbolex™ Neutral," a steel product that is certified as reducing CO_2 emissions in the steelmaking process, in the first half of fiscal 2023.

As a certification method of reducing CO_2 emissions, Nippon Steel is considering adopting a method (the mass balance method) in which the total amount of CO_2 emissions that Nippon Steel has actually reduced by reforming and improving manufacturing processes, etc., is determined and allocated to any given steel product.

All steel products manufactured by Nippon Steel (including GOES) can be supplied as NSCarbolex™ Neutral, which makes it the second commercial GOES product with a low-carbon footprint in the market.

Supply volume in fiscal 2023 is expected to be about 300,000 tonnes per year, calculated by basic unit conversion of steel products certified with virtually zero CO_2 emissions.

In addition to the CO_2 emission reduction certificate issued by Nippon Steel, NSCarbolex™ Neutral will be provided with a third-party certificate to ensure impartiality.

2.1.8. Vision by 2050 for the steel industry

Based on a report from Wood MacKenzie (15 September 2022)

Decarbonizing the steel and iron ore industry by 2050, in line with the Paris Climate Agreement, will require US$1.4 trillion of investment and revolution across every stage of the value chain.

Wood Mackenzie's analysis shows US$800-900 billion will be essential to remove carbon from existing steelmaking infrastructure, such as setting up new hydrogen-based direct reduced iron (DRI) and electric arc furnaces.

Mining companies will need to play an active role in cutting their operational emissions as well as invest in new high-grade mines and green pellet capacities to feed green steel. In turn, this will require five times the current supply of high-grade pellet feed, an equivalent to 750 million tonnes, translating into an investment of US$250-300 billion.

Switching to clean energy will also require around 2,000 GW of dedicated renewable generation capacity, equivalent to two-thirds of current global renewable generation capacity."

A hydrogen ecosystem will also need to be developed for green steel, as decarbonization will require around 50 million tonnes per annum of competitively priced green hydrogen, with commercial viability versus conventional steelmaking routes requiring green hydrogen supply at US$2/kg.

Decarbonizing the steel and iron ore industry by 2050, in line with the Paris Climate Agreement, will require US$1.4 trillion of investment and revolution across every stage of the value chain

The report warns that these measures will still fall short of emissions targets, necessitating an incremental US$200-250 billion investment in carbon offset measures, such as Carbon Capture, Utilisation, and Storage (CCUS), as the industry will need to capture and store 470 million tonnes of carbon to reach its emission target in 2050.

Green premiums are also inevitable, given new technologies and low-carbon feedstocks are likely to inflate steel production costs by 15-20 %

The transition to net zero calls for collaborative action globally and a unified approach across the value chain.

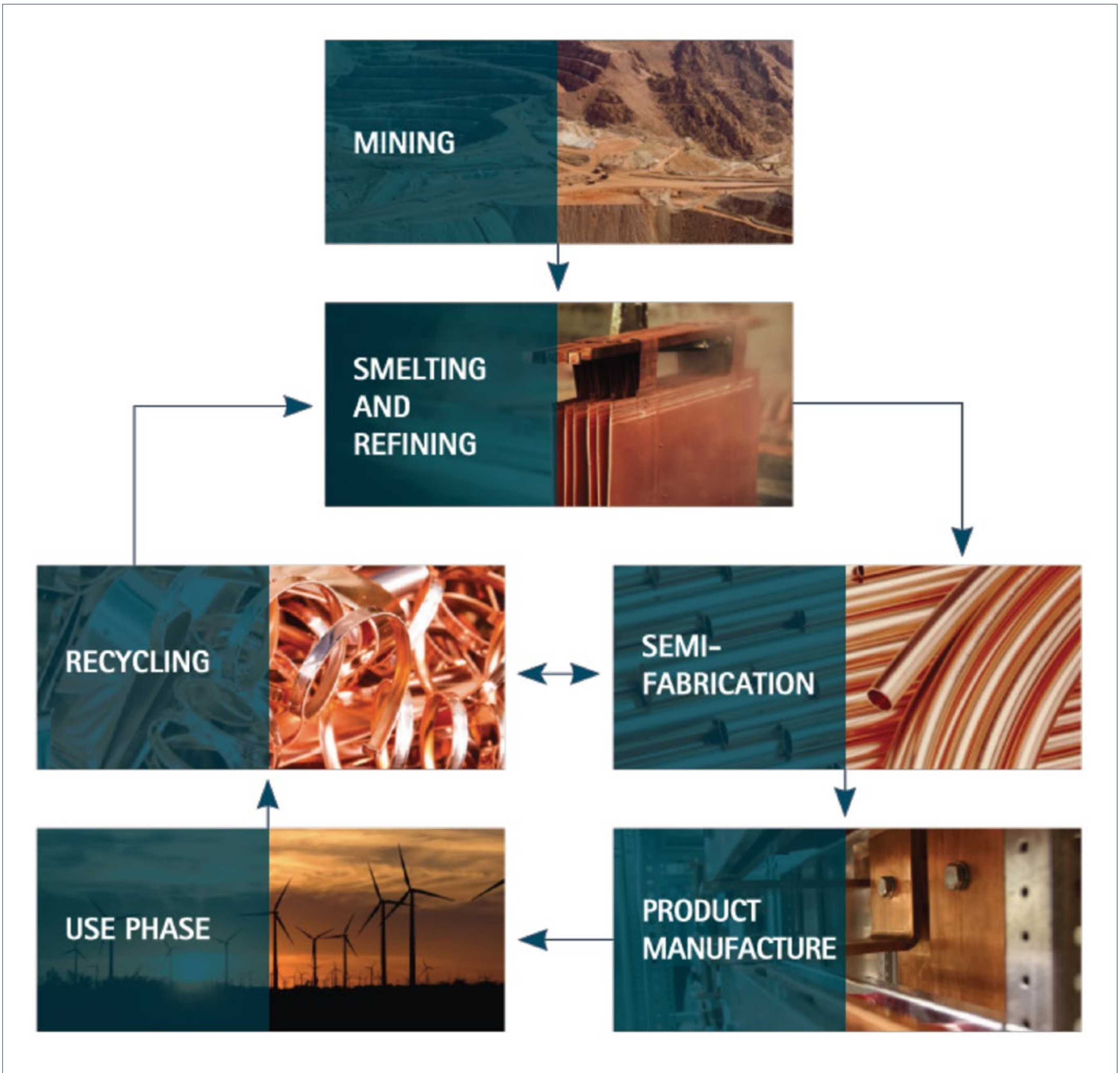


Fig. 3. Copper value chain

Report by Hydrogen Europe:

Decarbonizing the average primary steel plant in the EU would require 1.2-1.3 GW of renewables-powered electrolyzers running at full load to produce enough green hydrogen to extract iron from iron ore.

The required Capex ranges from €3.3bn to €7.0bn for a single plant of average capacity. And that does not include the renewable energy that would be needed to power the electric arc furnaces that make the steel.

2.1.9. Conclusion

Decarbonization of the steel industry is a mammoth task with the following challenges:

1. Huge R&D investments are needed: many aspects of the new steelmaking technology are not fully solved yet.
2. A huge Capex is required for implementation (government involvement will be needed).
3. Strong collaboration among stakeholders is necessary.
4. The whole value chain and logistics have to be re-established.
5. The industry will face higher operating costs.

This transition is an ultra-marathon, and it will not follow a straight path.

However, there are already a few commercial offerings, and they will grow significantly after 2025.

The transformer industry could partner with green steel initiatives and start applications already today.

3. Copper

3.1. Copper value chain

There is a long value chain in copper conductors for the transformer industry.

Copper miners and smelters serve a wide range of industries, and transformers represent only a tiny portion of their portfolio. They are tier 2 and tier 3 suppliers to the transformer industry, and usually, there is no direct business relation.

Copper has the second largest share of carbon emissions among the raw

Copper mining emits 2.3–2.5 tonnes of carbon per tonne of metal, while smelting adds another 1.65 tonnes

Fig. 4. Power-agnostic truck from Komatsu

materials, after steel, in a transformer (20–25 %).

Copper mining emits **2.3–2.5 tonnes of carbon per tonne of metal**, while smelting adds another 1.65 tonnes. In comparison, most of the fabrication processes have a much lower carbon footprint. There are also newer efforts to produce green copper.

3.2. Green copper from Boliden

Boliden AB is a Swedish multinational metals, mining, and smelting company headquartered in Stockholm. The company produces zinc, copper, lead, nickel, silver, and gold with operations in Sweden, Finland, Norway, and Ireland, and they have reported group revenues as $6.3 B in 2021.

Boliden offers low-carbon copper as a commercial product, and it has less than 1.5 kg CO_2EQ/kg of copper

Boliden offers low-carbon copper as a commercial product, and it has less than 1.5 kg CO_2EQ/kg of copper. Boliden's low-carbon copper is produced from copper mined in their mines in the north of Sweden, using clean energy. Boliden also offers 100 % recycled copper with the same carbon footprint value. The primary raw material for Boliden's recycled copper is the used electronics.

3.3. Elcowire group low carbon copper / ASTA low carbon CTC

Elcowire Group (Sweden) manufactures copper wire rods and further-processed aluminium and copper wire. The group is offering low-carbon copper, which is made possible through production that has undergone a substantial transformation due to electrification and automation of various stages of the process. It has also been possible by a very efficient ore concentration process and an energy mix, including a high share of renewables. Elcowire is also offering a recycled version.

The carbon emission value for Elcowire low carbon copper and the recycled rod is 1.7 kg CO_2EQ/kg copper.

ASTA is collaborating with Elcowire to produce low-carbon CTC for transformers.

3.4. Zero-emission mining

Komatsu announces collaborative customer alliance to advance zero-emission equipment solutions (2 August 2021). Rio Tinto, BHP, and other mining firms have partnered with manufacturing company Komatsu to develop zero-emission mining equipment and infrastructure. The collaboration will form part of the Komatsu Greenhouse Gas (GHG) alliance, which also includes Codelco and Boliden as founding members. Members of the alliance will collaborate with Komatsu on the planning, development, testing, and commissioning of the next generation of zero-emission mining. This alliance's initial work will aim to advance Komatsu's power-agnostic truck concept for a haulage vehicle. The vehicle will be designed to run on different power sources, including diesel-electric, electric, trolley (wired), battery power, and hydrogen fuel cells.

4. Aluminium

Aluminium, in the form of foil or wire, is widely used in distribution transformers. Aluminium has the highest CO_2 emission ratio among all transformer materials. 1 tonne of primary aluminium emits 16 tonnes of CO_2, and out of this 80 % comes from the electrolysis process, which is very energy intensive. Different forms of aluminium products emit 18–20 tonnes of CO_2.

Hydro offers 2 new "greener" aluminium products

1. Hydro CIRCAL recycled aluminium: produced with a minimum of 75 % recycled aluminium and 2.3 MT of CO_2 per tonne of the product is guaranteed.
2. Hydro REDUXA low-carbon aluminium: uses renewable energy in produc-

Aluminium has the highest CO_2 emission ratio among all transformer materials. 1 tonne of primary aluminium emits 16 tonnes of CO_2, and out of this 80 % comes from the electrolysis process

The transport of power transformers may generate emissions of 10–25 % of the total emissions of raw materials depending on weight and distance

tion and has a carbon footprint of 4 tonnes per tonne of product.

5. Insulating fluids

Insulating fluid typically accounts for 10–15 % of carbon emissions linked to raw materials in a transformer.

1 tonne of mineral oil emits 1.21 tonnes of CO_2.

Mineral oil is not biodegradable, and it is inflammable. Other than carbon footprint, mineral oil imposes environmental risks like fire or contamination through leaks or spillage.

There is already a wide range of alternatives to mineral oil, which are biodegradable.

Cargill

- FR3: Biodegradable soybean oil
- Envirotemp 360 Fluid: Synthtic ester transformer oil

M&I

- Midel 7131: Synthetic ester fluids
- Midel eN: Natural ester fluid in 2 versions (from soybean and rapeseed/canola oil)

Nynas

- Nytro Bio 300X: Bio-based transformer fluid

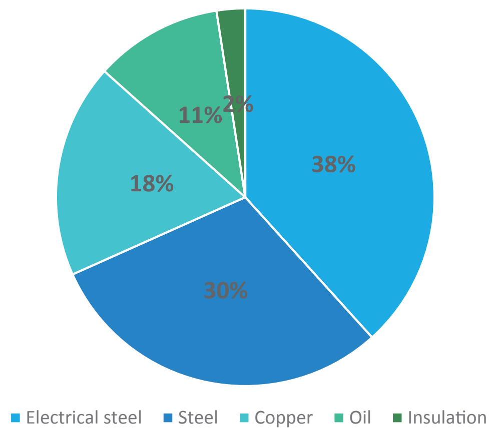
Ergon

- HyVolt NE: renewable soy vegetable oil-based ester fluid
- HyVolt SE: synthetic ester fluid

Shell

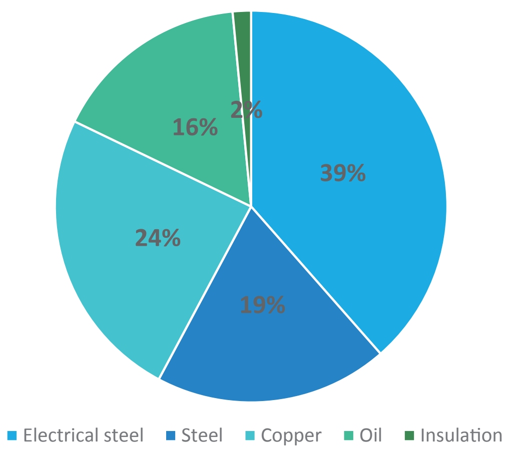
- Diala S5 BD: biodegradable oil

Another alternative product is recycled oil, which has a much lower carbon footprint. Until recently, this was only avail-



765 KV, 500 MVA 1 Ph autotransformer				
	Quantity(MT)	CO2/MT	CO2 (MT)	Share
Electrical steel	99	3.00	297	38%
Steel	93	2.50	233	30%
Copper	30	4.74	142	18%
Oil	70	1.21	85	11%
Insulation	16	1.18	19	2%
Transformer weight	339	2.29	775	

Fig. 5. Carbon footprint of an LPT



110 kv, 25 MVA				
	Quantity (MT)	CO2/MT	CO2 (MT)	Share
Electrical steel	20	3.00	60	39%
Steel	12	2.50	30	19%
Copper	8	4.74	38	24%
Oil	21	1.21	25	16%
Insulation	2	1.18	2	2%
Transformer weight	70	2.22	156	

Fig. 6. Carbon footprint of an SPT

able from smaller companies in limited quantities. Recently, (31 August 2022) Nynas launched NYTRO® RR 900X, which is a recycled product.

6. Sample carbon footprints of different transformer types

The carbon footprints of several types of transformers are calculated as examples to illustrate the impact coming from different materials.

As the graphs show, if the conductor is copper, there are no major changes in emission shares of materials in different types of transformers. However, when aluminium is used as the conductor, it contributes to the major share of emissions.

Transformer production is not energy intensive, and the carbon footprint is a tiny fraction of the emission of raw materials (only 2%)

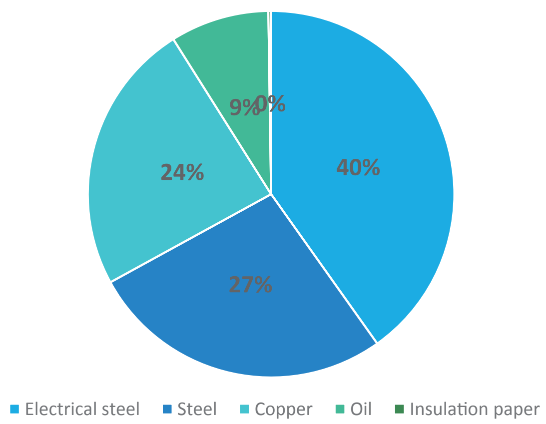
7. Transportation

The transportation sector is responsible for 16.2 % of the global CO_2 emissions. It is one of the most significant contributors. Out of this, industrial transport (road freight + shipping) is 6.5 %

Transportation carbon footprint comparison:

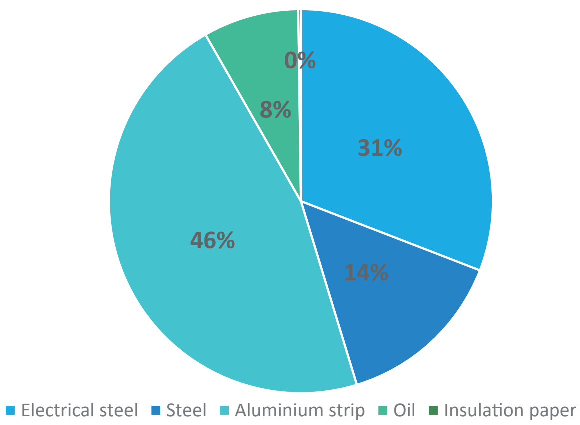
- Air: 8X
- Road: 1X
- Rail: 4X
- Sea: 8X

Especially large power transformers are heavy and bulky and occasionally transported over long distances, sometimes intercontinental. This is a very carbon-intensive process. The transport of power transformers may generate emissions of 10–25 % of the total emissions of raw materials depending on weight and distance. This ratio may be 5-10% for distribution transformers.



12 kv, 250 kVA distribution transformer				
	Quantity (MT)	CO2/MT	CO2 (MT)	Share
Electrical steel	0.42	3.00	1.3	40%
Steel	0.337	2.50	0.8	27%
Copper	0.159	4.74	0.8	24%
Oil	0.226	1.21	0.3	9%
Insulation paper	0.009	0.82	0.0	0%
Transformer weight	1.266	2.48	3.1	

Fig. 7. Carbon footprint of a DT with copper



36 kv, 1000 kVA distribution transformer				
	Quantity (MT)	CO2/MT	CO2 (MT)	Share
Electrical steel	1.161	3.00	3.5	31%
Steel	0.651	2.50	1.6	14%
Aluminium strip	0.291	18	5.2	46%
Oil	0.752	1.21	0.9	8%
Insulation paper	0.03	0.82	0.0	0%
Transformer weight	3.174	3.55	11.3	

Fig. 8. Carbon footprint of a DT with aluminium

The lowest GOES grade in the market is M5, with core loss values of 1.30 W/kg, and the best available grade has a core loss value of 0.65 W/kg

Table 1. Global emission share of transport modes

Mode of transport	CO_2 share
Passenger travel	7.1 %
Road freight	4.8 %
Aviation	1.9 %
Shipping	1.7 %
Rail	0.4 %
Pipeline	0.3 %
Total transport	**16.2 %**

8. Transformer production

Transformer production is not energy intensive, and the carbon footprint is a tiny fraction of the emission of raw materials (only 2%).

Energy-saving efforts in a transformer factory will not generate a significant impact on emissions of the whole transformer life cycle, although cost reduction out of this effort can be significant.

A larger impact can be achieved if the factory can switch to renewable energy (Scope 2 becomes zero).

Much larger emission reductions could be achieved through 2 actions:

1. Waste reduction: This will have a very high impact on carbon emissions. If all scrap rates can be reduced by 1 percentage point, this will generate a reduction in the carbon footprint, which is equal to half of the total production emissions. Especially conductors have a high potential for scrap reduction. Due to MOQ and quantity tolerance stacking (design + ordering + supplier) typically transformer factories generate high scrap for conductors.

2. Recycling: Recycling uses significantly less energy, 80–90 % less for copper, for example, than mining and smelting primary metal. The recycling process of aluminium requires a lot less energy than primary aluminium production and thus emits less CO_2 - approximately 0.5 tonnes per tonne of aluminium (95 % less). Steel, copper, aluminium, paper, and pressboard scraps should be accumulated and returned to the original suppliers whenever possible. Special deals could be discussed with the suppliers to receive recycled products whenever feasible.

9. Transformer operation

In the whole lifecycle of transformers, by far the largest share of CO_2 emissions are generated during the operation stage. The average life of a transformer is assumed to be around 40 years, which is pushing up the share of emissions at this stage. The main driver of the emissions during the transformer operation is no load losses and load losses. No load losses depend on the choice of electrical steel grade. The lowest GOES grade in the market is M5, with core loss values of 1.30 W/kg, and the best available grade has a core loss value of 0.65 W/kg, although very limited in quantity. The choice of the grade will depend on the customer's specifications. If there is no demand for the core loss performance of the transformer, the designer will select M5. And for very high loss capitalization, the choice would be the best available grade.

Load losses are strongly influenced by the choice of conductor. Aluminium is cheaper but will generate higher losses. We have also seen that aluminium has a higher CO_2 footprint as a raw material as well. Copper will perform better, but the cost is higher. This choice is also typically made by the customer.

Transformer producers should try to convince the customer to adopt the TCO concept and specify higher performance for the transformer. This will have a significant impact on the emissions during the operation stage. With the right choices, emissions during operation can be reduced by 30–40 %.

10. Last words

Transformer producers can collaborate with raw material suppliers to utilize emerging "green" options. In transformer factories, the efforts should focus on switching to renewable energy, reducing scrap, and recycling.

The biggest impact on reducing the carbon footprint of transformers can be achieved by reducing no-load and load losses by convincing the end customers to change their specifications and to require the best performance, which will also reduce their TCO.

Author

Ufuk Kivrak has BS and MS degrees in mechanical engineering. He has more than 25 years of industrial experience in transformers and power grid industries. He has worked for ABB in several management positions in Turkey, Thailand, and Switzerland. He led the Supply Chain Management organisation of ABB transformer business globally from 2003 to 2015, which included explosive growth of the transformer market from 2003 to 2008, followed by a market collapse in 2009 and onwards. In 2015, he joined Alstom Grid as VP-Strategic Sourcing and continued as Head of Strategic Sourcing in GE Grid Solutions after Alstom was acquired by GE. Currently, he is the Managing Director of SCM Consulting GmbH.