LIFE CYCLE ASSESSMENT FOR THE PRODUCTION OF PRECIOUS METALS

MONTANWERKE BRIXLEGG

GOAL OF THE STUDY

Montanwerke Brixlegg AG, hereinafter referred to as MWB, aims to calculate a product specific carbon footprint and additional environmental impact categories for its precious metals production for the reference year 2023. The goal of this study focuses on conducting a product life cycle assessment (LCA). The target audience for the LCA study includes MWB and its customers and stakeholders. This study is conducted with the help of Sphera Solutions, Inc.

SCOPE OF THE STUDY

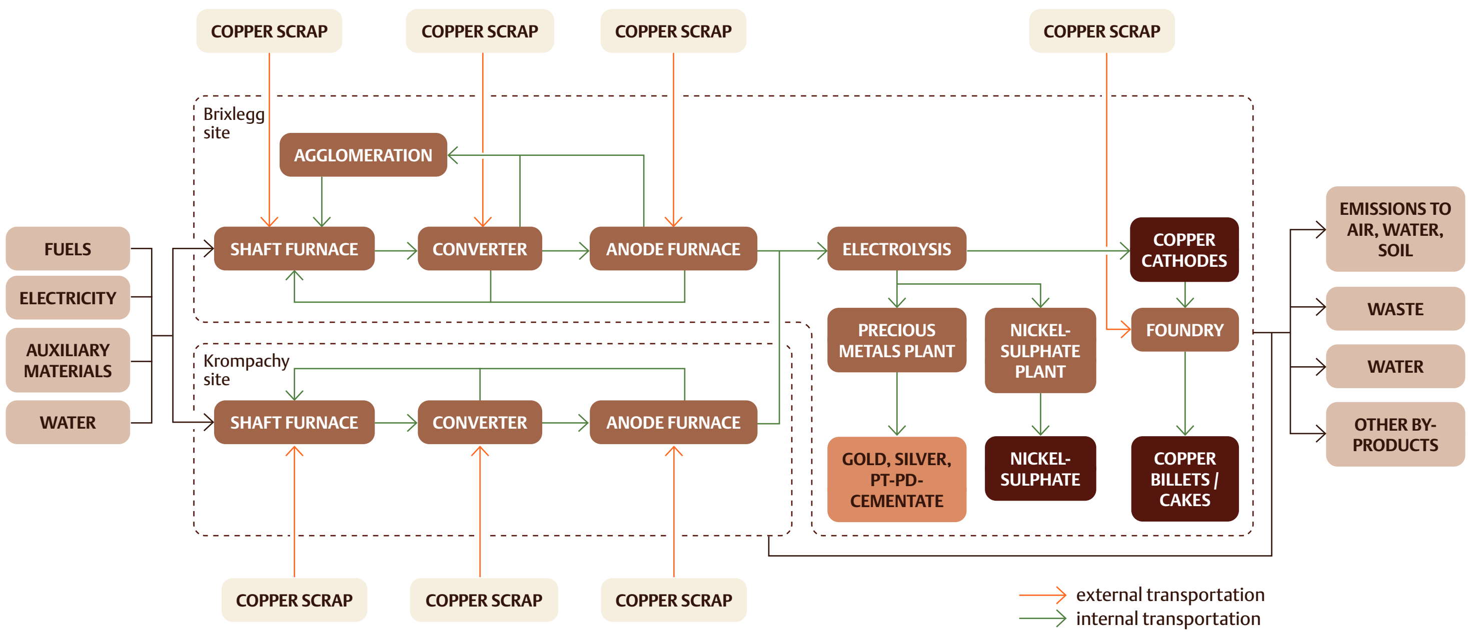
This study ist performed in accordance with ISO 14040:2006 and ISO 14044:2006. The product carbon footprint is calculated in compliance with ISO 14067 and verified according to ISO 14064-3. The impact categories are selected and calculated in accordance with EN 15804:2012+A2:2019+AC:2021 and critically reviewed according to ISO/TS 14071:2014. The study focuses on the production of precious metals at MWB. The declared functional units for the assessed products in this life cycle assessment are as follows:

- 1 kg precious metal: silver granules
- 1 kg precious metal: gold granules

This study considers a "cradle-to-gate" LCA, covering all production steps from raw materials to finished products ready to be shipped. The assessment includes Scope 1, 2 and 3 emissions. The global warming potential based on IPCC AR6 and climate change category as defined in EN 15804+A2 (EF3.1) do not directly correspond. While both describe the potential contribution to climate change in terms of CO_2-equivalents, they are calculated according to different impact assessment methodologies and include slightly different factors and conversions. As a result, the numerical values may differ for the same product.

In the study the infrastructure, use and end of life phase are excluded and cut-off criteria have been applied, where mass and energy flows with less than 1% product mass and cumulative energy are excluded. The time reference for the study is the calendar year 2023.

When allocation becomes necessary the most suitable kind is applied. Mass allocation is used with base metals, while economic allocation is applied when both base metals and precious metals occur together. In the case of the precious metals plant, allocation was based on the recovery of gold and silver. For filter dust and anode slime, a multi-output allocation approach was used.



The impact categories are assessed based on the 100-year time frame (GWP100) as this is currently the most used metric. In this calculation the global warming potential also includes biogenic carbon.

PROCESS DESCRIPTION

The process flow is illustrated in the Figure above. At both smelter sites, MWB and KK, only secondary raw materials from recycling are treated. Materials delivered by metal recyclers are sampled and analyzed by the sampling department. At both smelter sites there are three furnaces to treat copper scraps according to their quality, low grade in the shaft furnace, medium grade in the converter and high grade in the anode furnace. In the shaft furnace also internal recirculating materials from other process steps are treated, including agglomerated fines as pellets. The black copper metal product from the shaft furnaces is converted to blister copper which is further refined in the anode furnace. Anodes from both sites are electro-refined in the electrolysis in MWB to grade A cathodes. Precious metals are recovered from the anode slime which is processed through multiple precipitation and filtration steps before the solid components are separated. Afterwards, the precious metals are selectively separated, followed by refining to produce pure precious metals.

LIFE CYCLE INVENTORY ANALYSIS

The LCA model was created using the LCA for Experts 10 Software system for life cycle engineering. The data used for this assessment is taken from measured primary data at MWB and KK. The primary data was collected based on the International Copper Association approach. Secondary data was taken from the MLC database version 2024.2. It provides life cycle inventory data for several of the raw and process materials as well as fuel inputs and electricity grid mixtures. At MWB the entire electricity consumption stems from renewable energy sources. MWB owns hydropower plants in a nearby valley with a direct electrical connection to the production site.

DATA QUALITY

Inventory data quality is judged by its precision (whether data is measured, calculated or estimated), completeness (including unreported emissions), consistency (uniformity of the applied methodology) and representativeness (covering geographical, temporal and technological aspects). To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the MLC database 2024.2 were used. The study did not include any major assumptions outside of the data provided by plant operators. The LCI datasets from MLC database 2024.2 are widely distributed and reviewed by Dekra4 and used with the LCA FE Software of Sphera Solutions, Inc. The datasets have been used in LCA models worldwide in industrial and scientific applications in internal as well as in many critically reviewed and published studies. In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

All relevant process steps for each product system were considered and modelled to represent each specific situation. The process chain is considered sufficiently complete and detailed with regards to the goal and scope of this study.

All assumptions, methods and data are consistent with each other and with the study's goal and scope. Differences in background data quality were minimised by predominantly using LCI data from the MLC 2024.2 databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

The transportation of KK anodes to MWB and the transportation of scrap was modelled using the MLC database global transportation processes that consider the different modes of transport and the specified distances. It should be noted that the diesel consumption was not reported for specific process stages but rather as an overall consumption figure therefore it was modelled as a separate process stage. Additionally, water consumed at KK is also provided as an overall figure as opposed to process specific figures. Lastly, the compressed air is accounted for in the electricity consumption data of the site.

LIFE CYCLE IMPACT ASSESSMENT RESULTS

This chapter contains the results of the impact categories. The impact categories represent impact potentials, they are approximations of environmental impacts that could occur if the emissions follow the impact pathway and meet certain conditions in the receiving environment while doing so. The inventory only captures the fraction of the total environmental load that corresponds to the chosen declared unit.

The impact sources are divided into 3 categories:

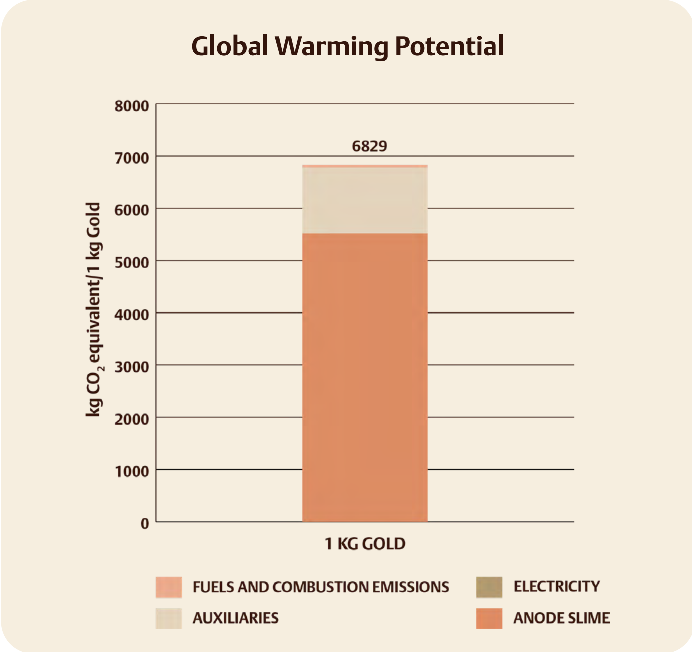
- Scope 1: Direct GHG emissions from sources that are owned or controlled by the company.
- Scope 2: GHG emissions from the generation of purchased electricity consumed by the company.
- Scope 3: Emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company.

PRECIOUS METALS

Gold granules are associated with an impact of 6829 kg CO_2 eq per kg and silver granules with an impact of 92 kg CO_2eq per kg. Most of the environmental impacts of the precious metals stem from the anode slime which includes upstream emissions from copper refining that are allocated to the anode slime in the electrolysis. Although gold granules are produced in much smaller quantities compared to silver granules, their respective impacts per kg precious metal are considerably higher. This is because the allocation is based on economic value, reflecting their higher market price.

In addition to the global warming potential the impact categories which are listed in the table below have been determined.

IMPACT CATEGORY	DESCRIPTION
Global warming potential	Measures the greenhouse gas emissions which contribute to trapping heat in the Earth's atmosphere. These gases enhance the greenhouse gas effect by absorbing more of the radiation emitted from the earth's surface. As a result, this affects ecosystems, economic resources and human health.
Energy use	Amount of renewable and non-renewable energy consumed
Photochemical ozone formation	A measure of air pollutants like VOCs, CO and NO_x which react in the presence of sunlight and form ground level ozone. This process is also known as photochemical smog formation.
Acidification	A measure of air pollutants like SO_2, NO_x and NH_3 released into the atmosphere that cause acidifying effects. These substances increase hydrogen ion (H^+) concentration when reacting with water, resulting in a lower pH and causing harmful environmental effects.
Eutrophication	Eutrophication refers to the impacts caused by excessive nutrients, mainly nitrogen and phosphorus that lead to overgrowth of plants and algae. This nutrient enrichment can alter species balance and increase biomass, often resulting in lower oxygen levels in water bodies which harms aquatic life.



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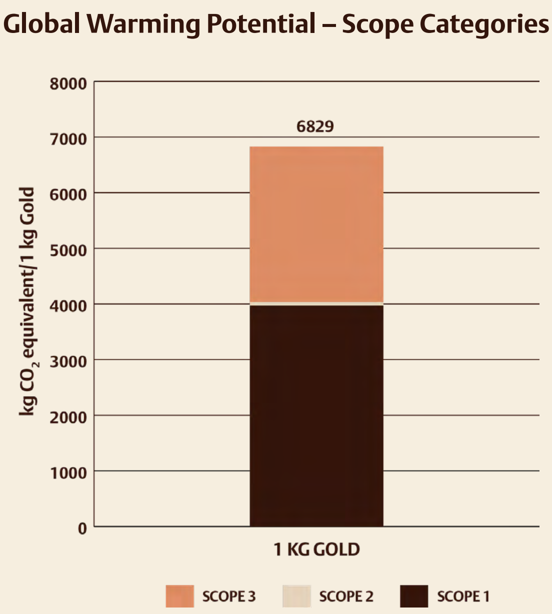

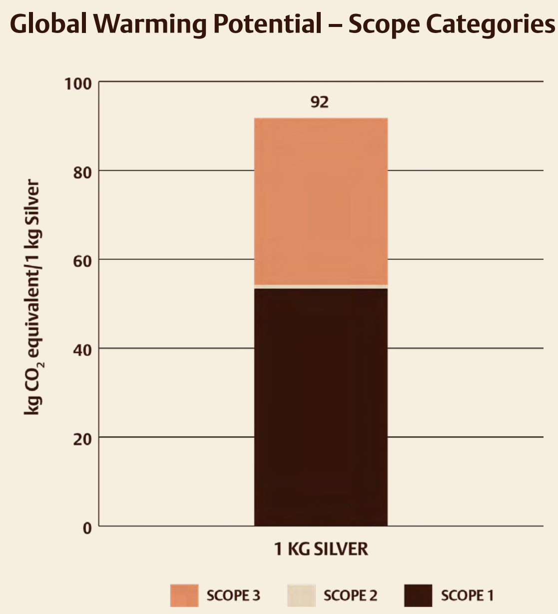

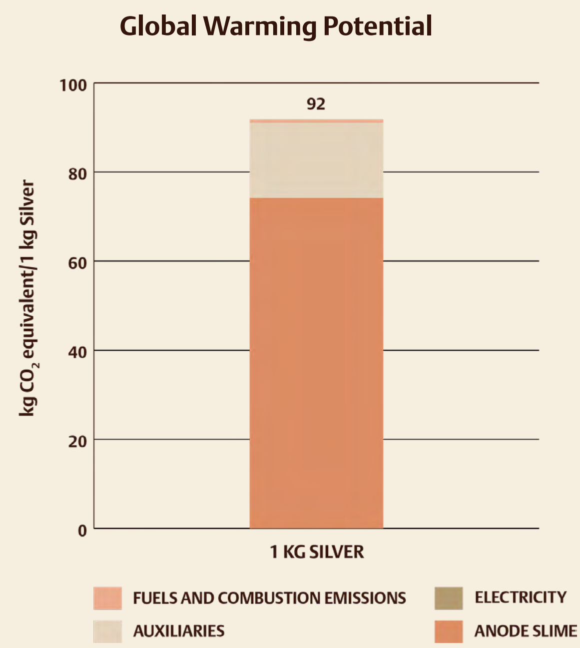

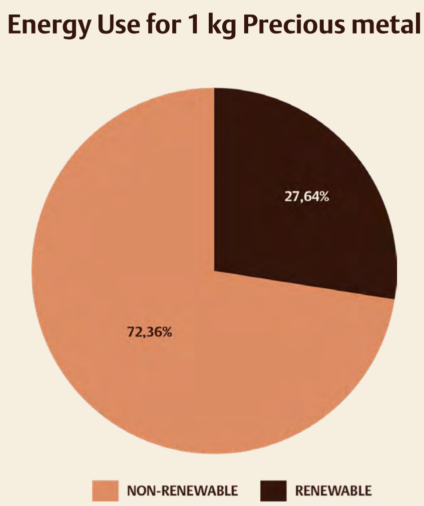

Results for Impact Categories and Indicators according to EN15804+A2 (EF3.1)

	STANDARD	IMPACT CATEGORIES	UNIT	SILVER	GOLD
1. Environmental impact indicators	01 EN15804+A2 (EF 3.1)	Climate change - total	kg CO_2 eq.	92	6823
	02 EN15804+A2 (EF 3.1)	Climate change, fossil	kg CO_2 eq.	90	6724
	03 EN15804+A2 (EF 3.1)	Climate change, biogenic	kg CO_2 eq.	1	96
	04 EN15804+A2 (EF 3.1)	Climate change, land use and land use change	kg CO_2 eq.	0,03	2,06
	05 EN15804+A2 (EF 3.1)	Ozone depletion	kg CFC-11 eq.	4E-10	3E-08
	06 EN15804+A2 (EF 3.1)	Acidification	Mole of H^+ eq.	0,3	24,0
	07 EN15804+A2 (EF 3.1)	Eutrophication, freshwater	kg P eq.	1E-03	1E-02
	08 EN15804+A2 (EF 3.1)	Eutrophication, marine	kg N eq.	0,12	8,65
	09 EN15804+A2 (EF 3.1)	Eutrophication, terrestrial	Mole of N eq.	1,27	94,27
	10 EN15804+A2 (EF 3.1)	Photochemical ozone formation, human health	kg NMVOC eq.	0,32	23,99
	11 EN15804+A2 (EF 3.1)	Resource use, mineral and metals	kg Sb eq.	1E-03	8E-02
	12 EN15804+A2 (EF 3.1)	Resource use, fossils	MJ	1193	88565
	13 EN15804+A2 (EF 3.1)	Water use	m^3 world eq.	7	509
2. Resource use indicators	01 EN15804+A2	Use of renewable primary energy (PERE)	MJ	455	33832
	03 EN15804+A2	Total use of renewable primary energy resources (PERT)	MJ	455	33832
	04 EN15804+A2	Use of non-renewable primary energy (PENRE)	MJ	1193	88565
	06 EN15804+A2	Total use of non-renewable primary energy resources (PENRT)	MJ	1193	88565
	10 EN15804+A2	Use of net fresh water (FW)	m^3	0,5	38
3. Output flows and waste categories	01 EN15804+A2	Hazardous waste disposed (HWD)	kg	4E-07	3E-05
	02 EN15804+A2	Non-hazardous waste disposed (NHWD)	kg	0,5	35
	03 EN15804+A2	Radioactive waste disposed (RWD)	kg	0,03	2,22

INTERPRETATION

The anode slime shows the highest environmental impact in the precious metals production, mainly due to the upstream emissions it inherits from previous process stages during electrolysis. The second largest contribution comes from the auxiliaries used in the process. During the processing of the anode slime steam is required. For this reason waste heat recovery projects were realised to reduce the environmental impact considerably. Today 61% of the demand is met through waste heat recovery. The remaining steam is produced by high-efficient gas-fired boilers.

CONCLUSION

In conclusion, the goal of the study has been achieved by illustrating the global warming potential for the production of 1 kg gold and silver and identifying the main process hotspots. The main impact stems from the required steam for anode slime processing. As was highlighted, Scope 1 emissions form the largest share of total emissions followed by Scope 3 emissions. Still, the environmental impacts of MWB are considerably lower compared to the global industry average reported by the International Copper Association[1]. MWB continues its efforts to reduce emissions by expanding the use of photovoltaic energy at KK while also developing solutions to further reduce the use of fossil fuels and consequently GHG emissions. These efforts include the assessment of bio reductants as a substitute for coke in the shaft furnace, as well as the use and continuous expansion of waste heat recovery systems to improve overall energy efficiency. To ensure the credibility and transparency of the results, this LCA was independently verified by TÜV Süd.

1 copperalliance.org/wp-content/uploads/2023/05/ICA-LCI-GlobalSummary-202305-F.pdf

CIRCULAR ECONOMY

Circular economy means keeping raw materials in circulation and reusing them over and over again – this is exactly what MWB has been doing for over 100 years. We extract high-purity copper from scrap and other secondary raw materials, which can be reused an infinite number of times without any loss of quality. This closes the loop: products made from our copper drive future technologies such as e-mobility, renewable energies and smart cities – and return to us as raw materials at the end of their life cycle. In doing so, we save up to 85% of energy and enable maximum CO_2 reduction along the value chain compared with production using primary raw materials.

RENEWABLE ENERGY

At MWB the company relies entirely on electricity from renewable sources. We therefore take responsibility for the environment and the future. Three company-owned hydroelectric power plants supply clean energy directly on site. In addition, we operate several photovoltaic systems, which we are continuously expanding. In this way, we use the power of the sun and water to operate our production sustainably. Through this consistent use of renewable energies, we are significantly reducing our Scope 2 emissions. This means less CO_2, more climate protection and an important contribution to the circular economy.

REDUCTION OF FOSSIL FUEL EMISSIONS

We consistently focus on measures to increase energy efficiency, thereby reducing the use of fossil fuels. One example is the reduction process in the anode furnace at MWB, which is powered entirely by biomass from sustainable sources. In addition, our plants are equipped with modern heat recovery systems. We use the recovered energy to generate steam and hot water. In this way, we save resources, reduce emissions and make our production particularly energy-efficient and environmentally friendly.

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Critical Review Statement

CRS-4232946

Add value.
Inspire trust.

The „Life Cycle Assessment of Montanwerke Brixlegg for the production of Copper" study report, dated 03 February 2026,

prepared by
Sphera Solutions, Inc.,

on behalf of
Montanwerke Brixlegg AG
Werkstraße 1, 6230 Brixlegg, Austria,

was critically reviewed in accordance with ISO/TS 14071:2014 regarding compliance with the requirements of ISO 14040/44:2006. We hereby confirm:

Results

- The Life Cycle Assessment (LCA) was conducted in compliance with ISO 14040 and ISO 14044.
- The methods used and the modelling of the product system are consistent with these standards.
- The methods used to carry out the LCA are scientifically and technically valid.
- The data used are appropriate and reasonable in relation to the goal of the study.
- The interpretations reflect the limitations identified and the goal of the study.
- The study report is transparent and consistent.

The life cycle assessment (LCA) and the corresponding Life Cycle Inventory (LCI) cover the acquisition of copper scrap until the completion of the production process of copper cathodes, copper billets and the by-products gold, platinum-palladium, silver and nickel-sulphate ("cradle to exit-gate" / "partial"). The transportation of the products to the clients/users, subsequent manufacturing processes, the use of the products, and the end-of-life treatment are not included.

This statement on the critical review applies only to the aforementioned life cycle assessment and in conjunction with the critical review report.

TÜV SÜD Industrie Service GmbH
Validation and Verification Body
Westendstrasse 199, 80686 Munich, Germany

Munich, 11 February 2026

LCA-Reviewer: Daniel Wittl

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