Instytut Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk

Strategic Research Unit

‘Conducting an analysis of the environmental footprint and carbon footprint for KGHM Polska Miedź S.A. products, including the preparation of environmental declarations’

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INTRODUCTION

The scope of work relating to the life-cycle assessment in the copper production sector for KGHM Polska Miedź S.A. encompasses the assessment of potential environmental risks arising from the production of copper, metals and other associated products. In line with the scope outlined above, the analysis focused on defining the objective (system boundaries), data inventory, assessment of potential environmental impact, and a hot-spot analysis for concentrates, copper cathodes, ETP copper wire rod, OFE copper wire (including CuAg alloy wire), silver, gold, selenium, nickel sulphate, copper sulphate, refined lead, sulphuric acid and iron silicate. The results obtained were used to prepare environmental declarations for the products listed.

I. LIFE CYCLE ASSESSMENT

1. Defining the purpose and scope of the LCA

The analysis involves calculating the environmental footprint for concentrates, copper cathodes, ETP copper wire rod, OFE copper wire (including CuAg alloy wire), silver, gold, lead, sulphuric acid, and granulated and crushed iron silicate produced by KGHM Polska Miedź S.A. in 2024. This is a 'cradle-to-gate' analysis, covering the life cycle of the analysed product portfolio from the extraction of primary raw materials (the 'cradle' stage), the transport of materials, the production of gold and silver at the Precious Metals Division, the production of lead at the Lead Division, the production of sulphuric acid at the Sulphuric Acid Plant, and the production of iron silicate. It also takes into account product-related greenhouse gas emissions from Scopes 1, 2 and 3, which have been expressed as CO_2 equivalents .

The calculations were carried out in accordance with ISO 14040, ISO 14044 and ISO 14067:2018.

Objective: The main objective of the LCA was to calculate the environmental footprint of the KGHM Polska Miedź S.A. product portfolio.

Time horizon of the analysis: 2024.

Geographical scope of the analysis: Poland (all processes falling within the organisational boundaries of the Lubin Mining Complex, the Polkowice-Sieroszowice Mining Complex, the Lubin Mining Complex, the ZWR plants, HM Legnica, HM Głogów I, HM Głogów II, HM Cedynia and the first tier of suppliers are carried out within Poland).

Technological scope of the analysis: the technology used in 2024 by KGHM POLSKA MIEDŹ S.A. for its Mining Plants, Ore Concentration Plants, Hydrotechnical Plant and Copper Smelters.

Unit of analysis: production of 1 Mg of concentrates, copper cathodes, ETP copper wire rod, OFE copper wire (including CuAg alloy wire), silver, gold, lead, sulphuric acid, granulated and crushed iron silicate produced by KGHM Polska Miedź S.A. in 2024, and an update of the results for concentrates, copper cathodes, ETP copper wire rod and OFE copper wire included in the KGHM Polska Miedź S.A. Product Portfolio in the quantity of 1 Mg in 2024.

System boundaries: the system boundaries are shown below (Figure 1.1).

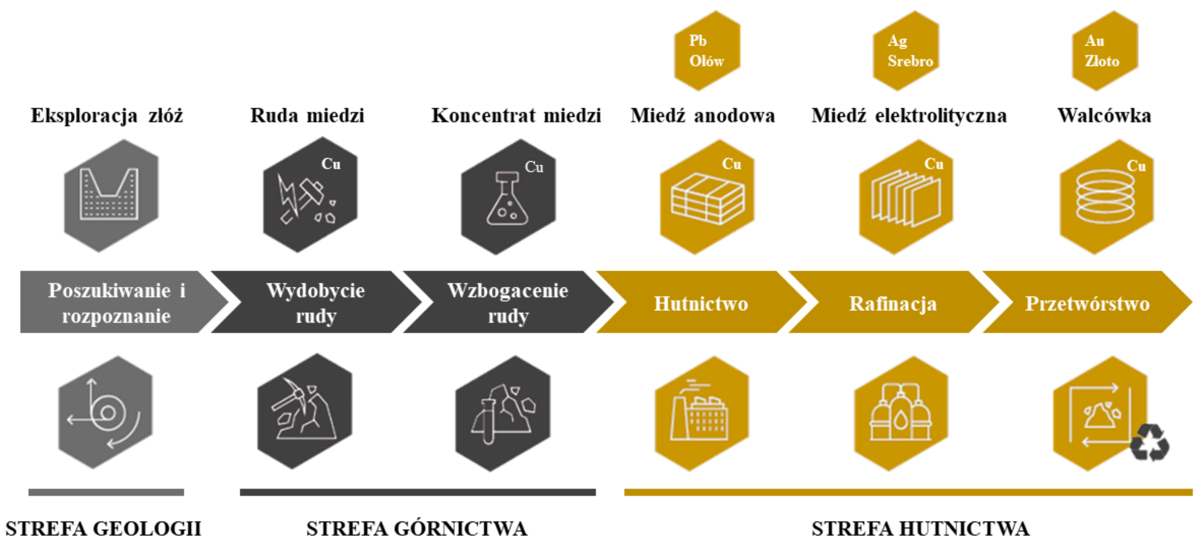

Figure1 .1 . System boundaries (compiled on the basis of the Integrated Report of KGHM Polska Miedź S.A. and the KGHM Polska Miedź S.A. Capital Group for 2022)

The boundaries of the system under analysis were defined on the basis of the actual processes carried out at the Mining Plants, Ore Concentration Plants and copper smelters of KGHM Polska Miedź S.A., based on the data received in this regard. The processes were therefore divided into the following sub-modules:

- Mining Operations
- Ore Concentration Plants,
- Hydrotechnical Plant,
- Smelters: Głogów I, II, Legnica, Cedynia.

Within the defined organisational boundaries, these processes are directly linked to the organisation's activities and are essential for the production of the products in the Portfolio.

Furthermore, within each of these, sub-processes have been identified relating to:

1) internal transport,
2) waste management.

2. Description of the organisation and product portfolio – KGHM POLSKA MIEDŹ S.A.

KGHM Polska Miedź S.A. is one of the world's largest and the largest in the European Union to produce copper from its own mining resources[1] . The Group carries out technologically advanced operations in the fields of exploration, mining, ore beneficiation, smelting and the processing of non-ferrous metals. The company has been operating continuously for over 60 years, serving as one of the pillars of the European raw materials sector and a key component of global supply chains for raw materials that are strategic to the energy and digital transitions.

The Group's operations span four continents – Europe, North America, South America and Asia. A key area of operation remains the Copper Basin , located in south-western Poland, which is home to some of the world's largest deposits of copper and silver ore. The Group controls approximately 40 million tonnes of copper ore reserves and employs over 34,000 people.

KGHM holds leading positions in global commodities markets – in 2022, the company was the eighth-largest copper producer in the world and the second-largest silver producer. The Group's products are used, amongst other things, in the energy sector, electromobility, electronics, construction, the aerospace industry, telecommunications and the renewable energy sector.

The company's strategy is based on the principles of sustainable development and the decarbonisation of industrial operations. KGHM has committed to achieving climate neutrality by 2050 and to reducing Scope 1 and 2 greenhouse gas emissions by 30 per cent by 2030 compared with the 2020 baseline. To this end, the Group is developing its own renewable

[1] KGHM Polska Miedź S.A. Integrated Report for 2022.

energy sources, including solar and wind projects, and is also analysing the potential for using small modular reactors (SMRs).

The Group's scope of operations includes:

- mining of copper and non-ferrous metal ores,
- copper smelting and processing,
- recovery and recycling of non-ferrous metals,
- the manufacture of products from copper and precious metals,
- recovery of metals associated with copper ores,
- manufacture of mining machinery and equipment,
- production of road aggregates,
- underground construction services,
- research, design and analytical activities,
- transport and logistics services.

KGHM's product portfolio covers a wide range of smelting, metallurgical and raw material products. The company's core product is copper cathodes with a copper content of at least 99.99 per cent, listed on global metals exchanges, including the London Metal Exchange (LME), the Shanghai Futures Exchange (SHFE) and the International Energy Exchange (INE). These cathodes form the basis for the production of products for the electrical engineering, energy and cable industries.

A second key product group is copper wire rod produced using Contirod® technology, used mainly in the cable and electrical machinery industries. KGHM also produces oxygen-free copper wires using UPCAST® technology, used, amongst other things, in the manufacture of specialised conductors, fire-resistant cables and electronic components.

Another key area of the Group's operations is the production of 99.99% pure electrolytic silver, certified by the London Bullion Market Association (LBMA) and COMEX. Silver is used, amongst other things, in the jewellery, electronics, photovoltaic and financial industries. The portfolio is complemented by gold produced in the form of investment and industrial bars.

KGHM also produces copper and molybdenum concentrates from overseas mining assets, including the Sierra Gorda mine in Chile and the Robinson mine in the USA. These products are a key component of the global raw materials market for heavy industry, the aerospace sector and high-tech industries.

Copper accounts for the largest share of the Group's revenue (around 68%), followed by silver (12%), gold (3%) and services and other products. 's largest sales markets are Poland, Germany, China, Italy, the Czech Republic and the United Kingdom, which confirms the company's strong export position and its importance for Europe's raw materials security.

The smelting operations of KGHM Polska Miedź S.A. are based primarily on the smelting of its own concentrates. The copper content of the concentrates is shown in Table 2.1.

Table2 .1 . Copper content in individual concentrates of KGHM Polska Miedź S.A. (2020 and 2024)

Product name	Copper content [%] (2020)	Copper content [%] (2024*)
'Lubin' concentrate	13.99%	13.7%
'Rudna' concentrate	26.27%	25.9%
'Polkowice' concentrate	24.43%	24.8%

* Management Board Report on the Activities of KGHM and the KGHM Group for 2024

The portfolio of products analysed and production volumes at individual branches are presented in Table 2.2.

Table2 .2 . Portfolio of analysed products from the Mining and Ore Concentration Plants and smelters of KGHM Polska Miedź S.A. (2020)

MINING AND ORE CONCENTRATION PLANTS		
'Lubin' concentrate	456,426,000	kg
'Rudna' concentrate	834,814,000	kg
'Polkowice' concentrate	448,551,000	kg
LEGNICA, GŁOGÓW I AND GŁOGÓW II COPPER SMELTERS		
'Legnica' cathode	123,306,222	kg
'Głogów I' cathode	205,275,569	kg
'Głogów II' cathode	230,170,016	kg
CEDYNIA COPPER SMELTER		
Wire rod	246,051,329	kg
OFE wires	11,100,621	kg
CuAg wires	3,002,318	kg

Source: Compiled by the authors based on data provided by KGHM S.A.

Table2 .3 .A. Portfolio of analysed products from the Mining and Ore Concentration Plants and smelters of KGHM Polska Miedź S.A. (2024)

MINING AND ORE CONCENTRATION PLANTS		
'Lubin' concentrate	447,507,000	kg
'Rudna' concentrate	863,041,000	kg
'Polkowice' concentrate	465,234,000	kg
LEGNICA, GŁOGÓW I AND GŁOGÓW II COPPER SMELTERS		
'Legnica' cathode	122,634,900	kg
'Głogów I' cathode	236,914,500	kg
'Głogów II' cathode	229,176,200	kg
CEDYNIA COPPER SMELTER		
Wire rod	271,488,581	kg
OFE wires	12,804,522	kg
CuAg wires	3,393,098	kg

Source: Compiled by the author based on data provided by KGHM S.A.

Production processes at each of KGHM's three smelters are based on different technologies. HM Legnica produces copper in the form of cathodes using shaft furnace technology and the processing of copper scrap. The smelter's facilities also include a Lead Refinery producing refined lead. At HM "Głogów I", the shaft furnaces were decommissioned in 2016 and the world's largest suspension furnace and electric furnace installation was commissioned, thereby creating the most modern copper smelting production line. At HM "Głogów II", copper is smelted using similar technology; consequently, production at both process lines of HM "Głogów" is currently based on single-stage smelting in a suspension furnace. The smelter's structure also includes a Precious Metals Division producing silver and gold, and a Lead Division producing raw lead. HM "Cedynia" is a copper rolling mill, processing electrolytic copper into wire rod using the Contirod method and into wire using Upcast technology. These products meet the needs of the most demanding markets[2] .

3. Assumptions, value choices and exclusions

- The processes are modelled on the basis of production data from 2024.
- ’s inventory data was available broken down by individual plant units , i.e. the production of concentrates, cathodes, silver, gold, sulphuric acid, copper and nickel sulphates, lead, wire rod, , CuAg and OFE wires . The breakdown into individual unit processes was carried out on the basis of various types of allocation (economic and mixed – a combination of mass allocation to the precious metals production stage, which was modelled using economic allocation), as described in the respective chapters. The option of expanding the system boundaries, known as *‘system* expansion’, for sulphuric acid or lead was also considered; however, these calculations were not carried out as one of the objectives of the study is to calculate the environmental footprint for each of the products analysed. Sales data from 2024 was used to calculate the individual shares. Information regarding operational data and direct primary flows was applied to total annual production and then converted to a per 1 Mg of product basis.
- Processes relating to employees’ commutes and business travel were excluded from this analysis, as were administrative processes.
- Data on electricity generation were modelled on the basis of data received from KGHM Polska Miedź S.A. concerning the purchase of electricity, broken down by licensed suppliers (Tauron Sprzedaż Sp. z o.o., Enea S.A., Energetyka Sp. z o.o., Alpiq SE), Energetyka Sp. z o.o. and KGHM’s own generation sources (modern combined cycle gas turbine units in Polkowice and Głogów). The modelling was carried out based on the composition of fuels and other primary energy sources consumed in electricity generation, as well as the emission levels for individual fuels and other primary energy sources for the aforementioned entities. An energy mix was prepared for KGHM Polska Miedź S.A. based on the volume of electricity purchased from individual suppliers. The dataset modelled in this way was used in the analysis. The structure is presented in Table 3.1. The analysis was carried out for two reference periods: 2020 and 2024.

Table3 .4 . Energy mix for KGHM Polska Miedź S.A. (2020)

Energy supplier	By volume of energy purchased	
	MWh	%
Tauron Sprzedaż Sp. z o.o.	614,880	23.33%
Enea S.A.	439,200	16.66%
TGE S.A.	573,959.1	21.77%
PGE S.A.	878,400	33.32%
Energetyka Sp. z o.o.	81,564.77	3.09%
Alpiq SE	48,055.552	1.82%
TOTAL	2,636,059.422	100%

[2] https://kghm.com/

Source: Compiled by the author based on data provided by KGHM S.A.

Table3 .5 .A. Energy mix for KGHM Polska Miedź S.A. (2024)

Energy supplier	By volume of energy purchased	
	MWh	%
Tauron Sprzedaż Sp. z o.o.	489,814.27	19.51
TGE S.A.	1,962,295.32	78.16
Energetyka Sp. z o.o.	58,383.68	2.33
TOTAL	2,251,493.26	100%

Source: Compiled by the author based on data provided by KGHM S.A.

The dataset obtained using the EF 3.0 Method (adapted) V1.02 / EF 3.0 normalisation and weighting set results in a lower environmental impact compared with the dataset *'Electricity, high voltage {PL}| market for | Cut-off, U'*, which represents the energy mix for Poland. A detailed comparison is presented in Table 3.2 (characterised results) and in Table 3.3 (weighted results). The analysis was carried out for two reference periods: the year 2020 and the year 2024.

Table3 .6 . Comparison of characterised results for impact category indicators for annual electricity generation ('KGHM mix' and Poland's energy mix) per 1 kWh (2020).

Impact category	Unit	ENVIRONMENTAL IMPACT PER 1 kWh of electricity in 2020	
		KGHM mix	Poland's energy mix
Climate change	kg CO_2eq	9.27E-01	9.97E-01
Ozone depletion	kg CFC-11 eq	5.13E-08	1.30E-08
Ionising radiation	kBq U-235 eq	1.38E-02	1.18E-02
Photochemical ozone formation	kg NMVOC eq	1.62E-03	2.46E-03
Particles	disease	1.82E-08	1.10E-08
Human health, non-carcinogenic factors	CTUh	1.50E-08	1.45E-08
Human health, carcinogenic factors	CTUh	3.12E-10	3.10E-10
Acidification	mol H+ eq	2.82E-03	7.18E-03
Aquatic eutrophication – fresh water	kg P eq	1.15E-04	1.34E-04
Aquatic eutrophication – marine water	kg N eq	5.27E-04	7.74E-04
Terrestrial eutrophication	mol N eq	4.93E-03	8.78E-03
Ecotoxicity to freshwater	CTUe	1.62E+01	1.27E+01
Land use	Pt	2.99E+00	2.03E+00
Resource depletion – water resources	m^3 depletion	1.77E-01	1.35E-01
Resource depletion – fossil fuels	MJ	1.32E+01	1.09E+01
Resource depletion – mineral resources and metals	kg Sb eq	4.44E-07	4.48E-07

Table3 .7 .A. Comparison of the characterised results of impact category indicators for annual electricity generation ('KGHM mix' and Poland's energy mix) per 1 kWh (2024).

Impact category	Unit	ENVIRONMENTAL IMPACT PER 1 kWh of electricity in 2024	
		KGHM mix	Poland's energy mix
Acidification	mol H+ eq	1.46E+00	6.64E+00

Impact category	Unit	ENVIRONMENTAL IMPACT PER 1 kWh of electricity in 2024	
		KGHM mix	Poland's energy mix
Climate change	kg CO_2 eq	6.22E+02	1.07E+03
Ecotoxicity to freshwater	CTUe	2.14E+03	2.19E+03
Particulate matter	disease inc.	6.19E-06	7.82E-06
Aquatic eutrophication – seawater	kg N eq	2.47E-01	7.63E-01
Aquatic eutrophication – freshwater	kg P eq	8.52E-02	4.35E-02
Terrestrial eutrophication	mol N eq	2.09E+00	8.41E+00
Human health, carcinogens	CTUh	1.00E-07	6.63E-08
Human health, non-carcinogenic factors	CTUh	7.31E-06	5.29E-06
Ionising radiation	kBq U-235	2.50E+00	4.78E+00
Land use	Pt	2.20E+03	8.94E+02
Ozone depletion	kg CFC-11	6.14E-06	1.07E-05
Photochemical ozone formation	kg NMVOC	8.04E-01	2.43E+00
Resource depletion – fossil fuels	MJ	8.79E+03	1.19E+04
Resource depletion – mineral resources and metals	kg Sb eq	1.61E-05	4.23E-06
Resource depletion – water resources	m^3 depriv.	1.09E+02	7.65E+01

3 Table 3. Comparison of weighted results for impact category indicators for annual electricity generation ('KGHM mix' and Poland's energy mix) per 1 kWh [mPt] (2020).

Impact category	ENVIRONMENTAL IMPACT PER 1 kWh of electricity in 2020	
	KGHM mix	Poland's energy mix
Climate change	2.41E-05	2.59E-05
Ozone layer depletion	6.04E-08	1.53E-08
Human health, carcinogens	1.64E-07	1.40E-07
Human health, non-carcinogenic factors	1.91E-06	2.90E-06
Particles, solid	2.73E-06	1.65E-06
Ionising radiation	1.20E-06	1.16E-06
Photochemical ozone formation	3.93E-07	3.90E-07
Acidification	3.15E-06	8.02E-06
Land-based eutrophication	2.00E-06	2.34E-06
Aquatic eutrophication – freshwater	7.98E-07	1.17E-06
Aquatic eutrophication – seawater	1.03E-06	1.84E-06
Exotoxicity to freshwater	7.31E-06	5.72E-06
Land use	2.90E-07	1.97E-07
Resource depletion – water resources	1.31E-06	1.00E-06
Mineral resources, fossil fuels	1.69E-05	1.40E-05
TOTAL	6.39E-05	6.70E-05

3 Table 3.A. Comparison of weighted results for impact category indicators for annual electricity generation ('KGHM mix' and Poland's energy mix) per 1 kWh [mPt] (2024).

Impact category	ENVIRONMENTAL IMPACT PER 1 kWh of electricity in 2024	
	KGHM mix	Poland's energy mix
Acidification	1.63E-03	7.41E-03
Climate change	1.73E-02	2.98E-02

Ecotoxicity to freshwater	7.24E-04	7.41E-04
Particulate matter	9.32E-04	1.18E-03
Aquatic eutrophication – seawater	3.74E-04	1.16E-03
Aquatic eutrophication – freshwater	1.48E-03	7.58E-04
Terrestrial eutrophication	4.39E-04	1.77E-03
Human health, carcinogens	1.23E-04	8.16E-05
Human health, non-carcinogenic factors	1.04E-03	7.55E-04
Ionising radiation	2.97E-05	5.67E-05
Land use	2.13E-04	8.66E-05
Ozone depletion	7.40E-06	1.29E-05
Photochemical ozone formation	9.41E-04	2.84E-03
Resource depletion – fossil fuels	1.13E-02	1.52E-02
Resource depletion – mineral resources and	1.91E-05	5.02E-06
Resource depletion – water resources	8.09E-04	5.68E-04
TOTAL	3.74E-02	6.25E-02

- At the Shaft Furnace Department of the Legnica Copper Smelter, the combustion of concentrate briquettes produces flue gas, which contains, amongst other things, combustible compounds such as CO, hydrocarbons and sulphur compounds (SO_2, CS_2, H_2S). In order for this gas to be desulphurised, it must be co-fired at the Legnica Combined Heat and Power Plant, thereby enabling energy recovery there. The post-combusted flue gases from the shaft furnaces are returned to HML. The energy recovered from the flue gas at the combined heat and power plant replaces the consumption of fossil fuels, thereby reducing the emission rate.
- The after-burning in the CHP plant’s boilers should be regarded as one of the components of the process gas treatment system for the shaft furnaces. Therefore, the flue gas produced by the combustion of concentrate briquettes should be attributed to its point of origin, namely the shaft furnaces.
- Mine water has been treated as an internal water circuit.
- Sulphuric acid production has been converted to 100% acid.
- Flotation tailings were modelled as inert waste, and the loads associated with the operations at Żelazny Most were allocated to flotation tailings on the basis of mass allocation.
- Heat and steam consumed in metallurgical processes were modelled as inputs to the system at each node, taking into account the relevant values. Heat recovery, on the other hand, was modelled as avoided heat and allocated to the departments where the heat recovery boilers are located.
- Internal material cycles were included in the inventory tables but are not taken into account in the assessment of the environmental footprint.
- Rock salt mined at the Polkowice-Sieroszowice Mining Plant has been modelled as an extension of the system boundaries.
- The production process in steelworks is a continuous one, and consequently the flow balance is not always reconciled – flows leaving a given node do not always reach the next node in their entirety – they may, for example, be stored and incorporated into the process at a later time. Of the key processes described in the LCA model at HML for a single year (processes classified as 1p), the process relating to the SOLINOX plant accounts for a significant proportion. In this process, it was therefore necessary to

apply a correction in the HML for the SOLINOX installation of 2.5% in the case of mixed allocation and 7% for economic allocation.

- The resulting carbon footprint is subject to the uncertainty of the measurement data, and its value may vary by +/- 5% from the figure given.

3.1.

In the case of mineral extraction and processing, the boundaries of the analysed system were defined on the basis of actual processes carried out at the Mining Plants and ZWR of KGHM Polska Miedź S.A., and on the basis of data obtained in this regard. The processes were therefore divided into the following sub-modules:

- mining plant,
- ore processing plant,
- hydrotechnical plant.

Within the defined boundaries, these processes are essential for the production of products from the Portfolio. Furthermore, within each of these, additional sub-processes have been identified relating to:

- internal transport,
- waste management.

In the case of integrated metallurgy carried out in steelworks, however, the system boundaries encompass the following processes:

- raw material transport,
- storage of raw materials,
- drying of concentrates,
- pre-treatment of secondary materials,
- smelting of copper matte,
- converter processing of copper matte,
- pyrometallurgical refining,
- copper electrolysis,
- processing of nickel sulphides and salts,
- production of sulphuric acid (sulphuric acid),
- slag management/processing (including iron silicate),
- production of Dore metal (recovery of tellurium and selenium[3] , pre-treatment for the production of Ag and Au),
- refining of Ag and Au (Ag, Au and PGM concentrates[4]),
- lead recovery.

Furthermore, the system encompasses processes that are essential for the manufacture of products from the Portfolio, namely:

- the production and supply of feedstock: copper concentrates (mining, processing, concentration), as well as secondary materials, including recycled materials,
- the production and supply of chemical and auxiliary materials,
- the production and supply of fuels,
- the generation and supply (transmission) of electricity and heat;

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[3] Not included in the analysis.
[4] ibid.

- transport of raw materials,
- waste management.

4. Life Cycle Inventory (LCI) analysis

All detailed inventory data were collected directly from the producer.

This chapter presents the final profiles for individual ZR and ZWR units and steelworks; these contain inventory data for individual processes as shown in the diagram (Figure 4.1).

Each table consists of two key elements: **inputs** (material and energy flows entering the unit process) and **outputs** (material and energy flows leaving the unit process). Intermediate flows and recirculations are excluded from the impact assessment analysis.

WEJŚCIA I WYJŚCIA		WEJŚCIA I WYJŚCIA		
PRZEPŁYW ZŁOŻONY (INNY NIŻ PODSTAWOWY)	PRZEPŁYW PODSTAWOWY	PRZEPŁYW POŚREDNI	WSPÓŁPRODUKT (CO-PRODUCT)	PRODUKT UBOCZNY
Materiał/surowiec lub energia wchodząca do procesu bezpośrednio ze środowiska (bez uprzedniego przetworzenia przez człowieka np. woda z jeziora) Materiał/surowiec lub energia wychodząca z procesu bezpośrednio do środowiska (nie podlegająca dalszemu przetworzeniu przez człowieka np. emisje do powietrza).	Materiał/surowiec lub energia wchodząca do procesu z innych procesów technologicznych/ systemów produktów (podlegająca uprzedniemu przetworzeniu przez człowieka np. woda z kranu) Materiał/surowiec lub energia wychodząca z procesu i trafiająca do innych procesów lub systemów produktów (podlegająca dalszemu przetworzeniu przez człowieka np. odpady do zagospodarowania).	Wyrób, materiał lub strumień energii pojawiający się pomiędzy jednostkowymi procesami badanego systemu produktu. Szczególnym przypadkiem strumienia pośredniego przez produkt pośredni, który stanowi wyjście z procesu jednostkowego będącego jednocześnie wejściem do innych procesów jednostkowych. Produkt pośredni to inaczej produkt główny na różnych stopniach przetworzenia. W bilansie materiałowo-energetycznym strumienie pośrednie są uwzględniane dla każdego procesu jednak w końcowej analizie nalicza się je tylko raz w celu uniknięcia wielokrotnego uwzględnienia tego samego aspektu.	Każdy z dwóch lub więcej wyrobów powstających w tym samym procesie jednostkowym lub systemie produktu. Współprodukty stanowią zamierzone efekty procesu produkcyjnego/ działalności organizacji. Zainstalowana linia technologiczna służy produkcji tych produktów. Znajdują się one w portfelu produktów i mają swoja określoną (często istotna) wartość ekonomiczną. Jeśli analizie podlega jeden z współproduktów, to należy wobec współproduktów zastosować procedurę alokacji.	Produkty, które powstają w danym procesie jednostkowym/ systemie produktu ale które stanowią zamierzonego efektu tego procesu/ działalności organizacji. Nawet jeśli posiadają wartość ekonomiczną (zazwyczaj niewielką), to powstają jako produkt uboczny. Zainstalowana linia technologiczna nie służy docelowo produkcji tych produktów. Produkty uboczne zazwyczaj nie stwarzają problemu alokacyjnego.

Figure4 .2 . Categories of inputs and outputs used in the identification and description of inventory table elements h

4.1.1.1. ***Allocation factors***

Allocation aims to distribute the potential environmental impact of a multi-product process amongst individual products. A mixed allocation method was applied – based on mass coefficients for the production stage up to the electrolysis process, and the products were then distributed according to their average nominal economic value, based on sales data from the last 10 years.

Tables 4.45–4.47 present the allocation coefficients, whilst Table 4.48 summarises the coefficients for both types of allocation at individual production nodes at HM Legnica.

4 ble 4.45. Allocation calculations for the shaft furnaces node

Flow	Quantity [kg]	Mass allocation
Copper ore	137,846,490	38.01%
Slag	206,364,400	56.90%
Pb concentrate	18,465,427	5.09%

Source: Own analysis based on data provided by KGHM S.A.

4 Table 46. Allocation calculations at the Converter Furnaces node

Flow	Quantity [kg]	Mass allocation
Converter Cu	117 210 056	50.85%
H_2SO_4	108,137,000	46.91%
Pb concentrate	5,157,060	2.24%

Source: Own analysis based on data provided by KGHM S.A.

Table4 . 47. Allocation calculations at the Hala wanien node

Stream	Quantity [kg]	Production value [thousand PLN]	Economic allocation
Cu cathodes	122,634,900	3,291,301.930	84.17%
Ag, Au slurry	728,000	572,530.340	14.64%
$CuSO_4$	5,394,000	38,643.238	0.99%
$NiSO_4$	717,000	7,761.78979	0.20%

Source: Compiled by based on data provided by KGHM S.A.

Table4 . 48. Allocation coefficients for the model at individual HML nodes

Flow	Model
Shaft furnaces	
Copper ore	38.01%
Slag	56.90%
Pb concentrate	5.09%
Converter furnaces	
Copper converter	50.85%
H_2SO_4	46.91%
Pb concentrate	2.24%
Tank hall	
Cu cathodes	84.17%
Ag, Au slurry	14.64%
$CuSO_4$	0.99%
$NiSO_4$	0.20%

Source: Author's own calculations

Tables 2.44–2.48 present the allocation coefficients, whilst Table 2.49 summarises the coefficients for both types of allocation at individual production nodes at HM Głogów 1.

Table 2.44. Allocation calculations for the Slurry Furnace node at

Stream	Quantity [kg]	Mass allocation
Cu blister	119,013,000	13.13%
Suspension slag	511,768,266	56.48%
H_2SO_4	275,360,000	30.39%

Source: Compiled by the authors based on data provided by KGHM S.A.

Table 2.45. Allocation calculations for the ‘ ’ electric furnace node

Flow	Quantity [kg]	Mass allocation
Cu-Fe-Pb alloy	105,916,000	18.71%
Iron silicate	448,800,970	79.29%
Pb-Zn concentrate	11,335,427	2.00%

Source: Own compilation based on data provided by KGHM S.A.

Table 2.46. Allocation calculations for the ‘ ’ converter furnaces node

Flow	Quantity [kg]	Mass allocation
Cu blister	95,240,423	77.43%
Pb dust (concentrate)	2,103,436	1.71%
Pb (post-production slag)	25,655,000	20.86%

Source: Own compilation based on data provided by KGHM S.A.

Table 2.47. Allocation calculations for the ‘ ’ anode furnaces node

Flow	Quantity [kg]	Mass allocation
Anode Cu	201,800,000	99.85%
Pb dust	299,728	0.15%

Source: Own analysis based on data provided by KGHM S.A.

Table 2.48. Allocation calculations for the ‘Hala wanien’ node

Flow	Quantity [kg]	Production value [thousand PLN]	Economic allocation
Copper cathodes	236,914,495	6,358,362,380	80.22%
Ag, Au slurry	1,982,427.422	1,559,065,723	19.67%
$NiSO_4$	811,120	8,780,673.546	0.10%

Source: Compiled by the authors based on data provided by KGHM S.A.

Table 2.49. Allocation coefficients for the model at individual HMGI nodes

Flow	Model
Suspension furnace	
Cu blister	13.13%

Suspension slag	56.48%
H_2SO_4	30.39%
Electric furnace	
Cu-Fe-Pb alloy	18.71%
Iron silicate	79.29%
PbZn concentrate	2.00%
Converter furnace	
Copper blister	77.43%
Pb dust (concentrate)	1.71%
Post-reduction slag Pb	20.86%
Anode furnace	
Anode Cu	99.85%
Pb dust	0.15%
Tank hall	
Copper cathodes	80.22%
Ag, Au slurry	19.67%
$NiSO_4$	0.10%

Source: Author's own work

Tables 2.67–1 present the allocation coefficients, whilst Table 2.72 summarises the coefficients for both types of allocation at individual production nodes in HM Głogów 2.

Table 2.67. Allocation calculations for the ' ' suspension furnace node

Flow	Quantity [kg]	Mass allocation
Cu blister	164,725,000	17.11%
Suspension slag	521,809,190	54.20%
H_2SO_4	276,300,000	28.70%

Source: Compiled by the authors based on data provided by KGHM S.A.

Table 2.68. Allocation calculations for the ' ' electric furnace node

Flow	Quantity [kg]	Mass allocation
CuFePb alloy	102 323 853	18.72%
Iron silicate	434,599,740	79.50%
PbZn concentrate	9,751,817	1.78%

Source: Own compilation based on data provided by KGHM S.A.

Table 2.69. Allocation calculations for the ' ' converter furnaces node

Flow	Quantity [kg]	Mass allocation
Cu blister	83,893,000	77.48%
Pb (concentrate)	1,947,211	1.80%
Pb (post-production slag)	22,430,940	20.72%

Source: Own compilation based on data provided by KGHM S.A.

Table 2.70. Allocation calculations for the ' ' anode furnaces node

Flow	Quantity [kg]	Mass allocation
Anode Cu	319 788 080	99.23%
Pb dust	2,483,227	0.77%

Source: Own analysis based on data provided by KGHM S.A.

Table 2.71. Allocation calculations for the ‘Hala wanien’ node

Flow	Quantity [kg]	Production value [thousand PLN]	Economic allocation
Cu cathodes	227,558,147	6,150,680,428	78.53%
Ag, Au slurry	2,126,706.5	1,672,532,962	21.35%
$NiSO_4$	831,570	9,002,052.35	0.11%

Source: Compiled by the authors based on data provided by KGHM S.A.

Table 2.72. Allocation coefficients for the model at individual HMGII nodes

Flow	Model
Suspension furnace	
Cu blister	17.11%
Suspension slag	54.20%
H_2SO_4	28.70%
Electric furnace	
CuFePb alloy	18.72%
Iron silicate	79.50%
PbZn concentrate	1.78%
Converter furnace	
Copper converter	77.48%
Pb concentrate	1.80%
Pb post-production slag	20.72%
Anode furnace	
Copper anode	99.23%
Pb dust	0.77%
Tank hall	
Copper cathodes	78.53%
Ag, Au slurry	21.35%
$NiSO_4$	0.11%

Source: Own compilation

II. ’S ENVIRONMENTAL IMPACT RESULTS

assumptions

System inclusions/exclusions: long-term emissions – excluded; infrastructure – included.

Characterisation: EF 3.0 Method (adapted) V1.03 / EF 3.0 normalisation and weighting set

Weighting: EF 3.0 Method (adapted) V1.03 / EF 3.0 normalisation and weighting set

1. Mining operations and ore processing plants

1.1. Results of the impact category indicators

In 2024, the three mines analysed produced a total of 1,769,721 Mg of copper concentrate (dry basis), of which 25.29% was produced at the Lubin Mine, 27.54% at Polkowice-Sieroszowice and 47.17% at the Rudna Mine. Production volumes and environmental impact per 1 Mg of concentrate for each mining site in 2024 are presented in Table 1.1.

Table1 .8 Production volumes and environmental impact of annual mining operations in 2024.

		MINES			
		LUBIN	POLKOWICE-SIEROSZOWICE	RUDNA	TOTAL [∑]
Concentrate production 2024 (dry weight)	Mg	447,507	487,400	834 814	1,769,721
	%	25.29%	27.54 %	47.17%	100.0
Environmental impact per 1 tonne of concentrate	Pt	0.168	0.197	0.197	-
Carbon footprint per 1 tonne of concentrate	kg CO_{2eq}	1,010.9695	1,309.3896	1,369.7308	-

Table 1.2 presents the results of the impact of concentrates in relation to unit production – 1 Mg.

Table1 .9 Weighted results of impact category indicators for 1 tonne of concentrates (2024) [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER ANNUAL PRODUCTION IN 2024					
	LUBIN		POLKOWICE-SIEROSZOWICE		RUDNA	
	Pt	%	Fri	%	Fri	%
Acidity	4.68E-03	2.78	1.11E-04	4.79	1.33E-04	4.97

Climate change	2.82E-02	16.73	1.07E-03	45.90	1.18E-03	44.28
Ecotoxicity to freshwater	1.08E-01	63.99	3.66E-05	1.57	4.10E-05	1.53
Particulate matter	7.45E-03	4.42	1.03E-04	4.43	1.29E-04	4.82
Aquatic eutrophication – seawater	2.51E-03	1.49	2.74E-05	1.18	3.91E-05	1.46
Aquatic eutrophication – freshwater	1.47E-03	0.87	7.13E-05	3.06	6.94E-05	2.60
Land-based eutrophication	2.32E-03	1.38	4.06E-05	1.75	5.60E-05	2.10
Human health, carcinogens	3.09E-04	0.18	7.65E-06	0.33	8.26E-06	0.31
Human health, non-carcinogenic factors	1.86E-03	1.10	5.48E-05	2.36	5.63E-05	2.11
Ionising radiation	6.14E-05	0.04	-5.44E-07	-0.02	2.22E-06	0.08
Land use	1.15E-03	0.68	1.23E-05	0.53	1.15E-05	0.43
Ozone depletion	3.14E-05	0.02	1.38E-06	0.06	2.26E-06	0.08
Photochemical ozone formation	4.68E-03	2.78	8.41E-05	3.62	1.09E-04	4.07
Depletion of resources – fossil fuels	2.00E-02	11.89	6.67E-04	28.68	7.79E-04	29.19
Resource depletion – Mineral resources and metals	1.86E-04	0.11	7.81E-06	0.34	6.77E-06	0.25
Resource depletion – water resources	-1.43E-02	-8.47	3.34E-05	1.44	4.55E-05	1.70
TOTAL	1.68E-01	100	2.33E-03	100	2.67E-03	100

Table 1.3 presents the characterised results of the impact category indicators for 1 tonne of concentrates.

Table1 .10 Characterised results of impact category indicators for 1 tonne of concentrate (2024)

IMPACT CATEGORIES	Unit	ENVIRONMENTAL IMPACT PER TONNE IN 2024

		LUBIN	POLKOWICE-SIEROSZOWICE	RUDNA
Acidification	mol H+ eq	4.20E+00	9.98E-02	1.19E-01
Climate change	kg CO_2 eq	1.01E+03	3.83E+01	4.24E+01
Ecotoxicity to freshwater	CTUe	3.18E+05	1.08E+02	1.21E+02
Particulate matter	Disease Inc.	4.95E-05	6.85E-07	8.55E-07
Aquatic eutrophication – seawater	kg N eq	1.66E+00	1.81E-02	2.58E-02
Aquatic eutrophication – freshwater	kg P eq	8.42E-02	4.09E-03	3.98E-03
Terrestrial eutrophication	mol N eq	1.11E+01	1.94E-01	2.67E-01
Human health, carcinogens	CTUh	2.50E-07	6.19E-09	6.69E-09
Human health, non-carcinogenic factors	CTUh	1.30E-05	3.83E-07	3.94E-07
Ionising radiation	kBq U-235 eq	5.17E+00	-4.59E-02	1.87E-01
Land use	Pt	1.19E+04	1.27E+02	1.19E+02
Ozone depletion	kg CFC-11 eq	2.60E-05	1.15E-06	1.88E-06
Photochemical ozone formation	kg NMVOC eq	4.00E+00	7.19E-02	9.29E-02
Resource depletion – fossil fuels	MJ	1.56E+04	5.21E+02	6.09E+02
Resource depletion – Mineral resources and metals	kg Sb eq	1.57E-04	6.58E-06	5.71E-06
Resource depletion – water resources	m^3 depletion	-1.92E+03	4.51E+00	6.13E+00

Tables 1.4–1.6 present the results for 1 tonne of concentrate from individual mines.

Table1 .11 Lubin Mine – results presented in tabular form

UNIT PROCESS	UNIT	LUBIN CONCENTRATE	LUBIN MINE				
			MINING OPERATION	ORE CONCENTRATION PLANT			
			Ore (result for the mine – extraction of 1 tonne of ore)	ZWRL	ZWRL_ WASTE	ZWRL_TRANS	WASTE POFLOT_ ZWRL
IMPACT CATEGORIES							
Acidification	mol H+ eq	4.20E+00	6.85E-02	1.74E+00	2.36E+00	7.36E-05	1.01E-01
Climate change	kg CO_2 eq	1.01E+03	2.53E+01	6.73E+02	2.97E+02	1.04E-02	4.14E+01
Ecotoxicity to freshwater	CTUe	3.18E+05	7.99E+01	2.18E+03	2.38E+03	8.16E-03	3.14E+05
Solid particles	disease inc.	4.95E-05	5.26E-07	1.20E-05	3.71E-05	2.26E-10	4.91E-07
Aquatic eutrophication – seawater	kg N eq	1.66E+00	1.21E-02	3.05E-01	7.21E-01	3.38E-05	6.34E-01
Aquatic eutrophication – freshwater	kg P eq	8.42E-02	2.42E-03	7.12E-02	4.53E-03	6.23E-09	8.46E-03
Land-based eutrophication	mol N eq	1.11E+01	1.31E-01	3.10E+00	7.80E+00	3.69E-04	1.60E-01
Human health, carcinogens	CTUh	2.50E-07	4.89E-09	1.26E-07	7.90E-08	4.49E-13	4.56E-08
Human health, non-carcinogenic factors	CTUh	1.30E-05	2.25E-07	6.97E-06	5.01E-06	1.13E-11	1.05E-06
Ionising radiation	kBq U-235 eq	5.17E+00	1.29E-01	3.18E+00	1.82E+00	1.14E-05	1.75E-01
Land use	Fri	1.19E+04	8.47E+01	2.25E+03	9.03E+03	1.48E-04	6.24E+02
Ozone depletion	kg CFC-11 eq	2.60E-05	5.95E-07	1.63E-05	9.09E-06	2.03E-10	6.91E-07
Photochemical ozone formation	kg NMVOC eq	4.00E+00	5.03E-02	1.20E+00	2.74E+00	1.06E-04	6.13E-02
Depletion of resources – fossil fuels	MJ	1.56E+04	3.49E+02	9.46E+03	5.59E+03	1.43E-01	5.99E+02
Resource depletion – Mineral resources and metals	kg Sb eq	1.57E-04	5.33E-06	1.11E-04	4.35E-05	2.24E-10	2.56E-06
Depletion of resources – water resources	m^3 depletion	-1.92E+03	8.99E+00	1.98E+02	-2.13E+03	5.91E-05	7.18E+00

1 table.12 Polkowice Mine – results presented in tabular form

UNIT PROCESS	UNIT	POLKOWICE CONCENTRATE	POLKOWICE MINE				
			MINING PLANT	ORE CONCENTRATION PLANT			
			Ore (result for the mine – extraction of 1 tonne of ore)	ZWRPS	ZWRPS_ WASTE	ZWRPS_TRANS	WASTE POFLOT_ ZWRPS
IMPACT CATEGORIES							
Acidification	mol H+ eq	4.80E+00	9.98E-02	2.46E+00	2.22E+00	1.59E-04	1.12E-01
Climate change	kg CO_2 eq	1.31E+03	3.83E+01	9.83E+02	2.80E+02	2.43E-02	4.59E+01
Ecotoxicity to freshwater	CTUe	3.53E+05	1.08E+02	2.90E+03	2.24E+03	2.02E-02	3.48E+05
Solid particles	disease inc.	5.29E-05	6.85E-07	1.74E-05	3.50E-05	5.07E-10	5.44E-07
Aquatic eutrophication – seawater	kg N eq	1.83E+00	1.81E-02	4.44E-01	6.81E-01	7.16E-05	7.02E-01
Aquatic eutrophication – freshwater	kg P eq	1.20E-01	4.09E-03	1.06E-01	4.28E-03	1.51E-08	9.37E-03
Terrestrial eutrophication	mol N eq	1.21E+01	1.94E-01	4.51E+00	7.37E+00	7.83E-04	1.77E-01
Human health, carcinogens	CTUh	3.06E-07	6.19E-09	1.81E-07	7.45E-08	8.66E-13	5.05E-08
Human health, non-carcinogenic factors	CTUh	1.59E-05	3.83E-07	1.00E-05	4.73E-06	2.69E-11	1.16E-06
Ionising radiation	kBq U-235 eq	2.45E+00	-4.59E-02	5.40E-01	1.72E+00	2.72E-05	1.93E-01
Land use	Fri	1.24E+04	1.27E+02	3.18E+03	8.53E+03	3.61E-04	6.90E+02
Ozone depletion	kg CFC-11 eq	3.58E-05	1.15E-06	2.65E-05	8.58E-06	4.66E-10	7.65E-07
Photochemical ozone formation	kg NMVOC eq	4.34E+00	7.19E-02	1.68E+00	2.59E+00	2.29E-04	6.79E-02
Depletion of resources – fossil fuels	MJ	1.92E+04	5.21E+02	1.32E+04	5.28E+03	3.39E-01	6.63E+02
Resource depletion – Mineral resources and metals	kg Sb eq	1.79E-04	6.58E-06	1.35E-04	4.11E-05	5.14E-10	2.84E-06
Depletion of resources – water resources	m^3 depletion	-1.87E+03	4.51E+00	1.33E+02	-2.01E+03	1.45E-04	7.95E+00

1 table.13 Rudna Mine – results presented in tabular form

UNIT OF MEASUREMENT	UNIT	Rudna CONCENTRATE	RUDNA MINE				
			MINING OPERATION	ORE CONCENTRATION PLANT			
			Ore (output for the mine – extraction of 1 tonne of ore)	ZWRR	ZWRR WASTE	ZWRR_TRANS	WASTE POFLOT_ ZWRR
IMPACT CATEGORIES							
Acidification	mol H+ eq	5.27E+00	0.118964	2.77E+00	2.39E+00	6.41E-05	1.06E-01
Climate change	kg CO_2 eq	1.37E+03	42.40286	1.03E+03	3.00E+02	1.72E-02	4.37E+01
Ecotoxicity to freshwater	CTUe	3.37E+05	120.9659	3.22E+03	2.41E+03	8.11E-03	3.31E+05
Solid particles	disease inc.	5.92E-05	8.55E-07	2.10E-05	3.76E-05	2.28E-10	5.18E-07
Aquatic eutrophication – seawater	kg N eq	1.96E+00	0.025821	5.63E-01	7.32E-01	2.80E-05	6.68E-01
Aquatic eutrophication – freshwater	kg P eq	1.19E-01	0.003982	1.06E-01	4.60E-03	8.56E-09	8.93E-03
Land-based eutrophication	mol N eq	1.38E+01	0.266568	5.68E+00	7.92E+00	3.06E-04	1.68E-01
Human health, carcinogens	CTUh	3.27E-07	6.69E-09	2.00E-07	7.97E-08	1.68E-12	4.81E-08
Human health, non-carcinogenic factors	CTUh	1.67E-05	3.94E-07	1.05E-05	5.08E-06	1.72E-11	1.10E-06
Ionising radiation	kBq U-235 eq	5.84E+00	0.186702	3.81E+00	1.84E+00	1.71E-05	1.84E-01
Land use	Fri	1.29E+04	118.7088	3.09E+03	9.17E+03	2.35E-04	6.58E+02
Ozone depletion	kg CFC-11 eq	4.62E-05	1.88E-06	3.62E-05	9.23E-06	3.96E-10	7.28E-07
Photochemical ozone formation	kg NMVOC eq	4.88E+00	0.092932	2.04E+00	2.78E+00	1.02E-04	6.47E-02
Depletion of resources – fossil fuels	MJ	2.08E+04	608.9584	1.45E+04	5.67E+03	2.27E-01	6.31E+02
Resource depletion – Mineral resources and metals	kg Sb eq	3.91E-04	5.71E-06	3.44E-04	4.42E-05	4.81E-10	2.70E-06
Depletion of resources – water resources	m^3 depletion	-1.99E+03	6.126205	1.65E+02	-2.16E+03	6.81E-05	7.57E+00

2. Copper smelters

2.1. Results for the ' ' impact category indicators

2.1.1. Cathodes

In 2024, the three smelters analysed produced a total of 588,725.60 Mg of cathodes, of which 20.83% were produced at HM Legnica, 40.24% at HM Głogów I, and 38.93% at HM Głogów II. Production volumes and environmental impact per 1 Mg of cathodes for individual copper smelters in 2024 are presented in the tables at2 .14 and2 .15 .

Table2 .14 Production volumes and environmental impact per 1 Mg of cathodes for individual smelters in 2024.

		Smelters		
		Legnica	Głogów I	Głogów II
Cathode production in 2024	Mg	122,634.90	236,914.50	229,176.20
	%	20.83	40.24	38.93
Environmental impact per 1 Mg of cathodes	Pt	0.183	0.367	0.425
Carbon footprint per 1 Mg of cathodes	$kgCO_2$ eq	1,260.72	1,829.76	1,776.61

Table2 .15 Weighted results for impact category indicators for steelworks production (2024), per 1 tonne of cathodes [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024					
	Legnica		Głogów I		Głogów II	
	Pt	%	Fri	%	Fri	%
Acidification	7.13E-03	3.88	8.70E-03	2.37	8.30E-03	1.95
Climate change	3.52E-02	19.17	5.10E-02	13.91	4.95E-02	11.66
Ecotoxicity to freshwater	5.93E-02	32.32	8.26E-02	22.53	8.01E-02	18.84
Particulate matter	4.43E-03	2.42	8.88E-03	2.42	7.92E-03	1.86
Aquatic eutrophication – seawater	2.02E-03	1.10	4.13E-03	1.13	3.72E-03	0.88
Aquatic eutrophication – freshwater	2.01E-03	1.10	3.17E-03	0.86	2.89E-03	0.68
Land-based eutrophication	2.14E-03	1.17	4.38E-03	1.19	4.17E-03	0.98
Human health, carcinogens	7.10E-04	0.39	5.89E-04	0.16	5.03E-04	0.12
Human health, non-carcinogenic factors	5.52E-03	3.01	3.83E-03	1.04	4.04E-03	0.95
Ionising radiation	1.68E-04	0.09	4.70E-04	0.13	4.36E-04	0.10
Land use	8.61E-04	0.47	1.25E-03	0.34	1.10E-03	0.26
Ozone depletion	4.68E-05	0.03	6.80E-05	0.02	5.90E-05	0.01
Photochemical formation of ozone	4.12E-03	2.25	7.93E-03	2.16	7.19E-03	1.69
Depletion of resources – fossil fuels	2.35E-02	12.82	3.67E-02	10.00	3.04E-02	7.16
Resource depletion – Mineral resources and metals	2.97E-02	16.18	1.46E-01	39.72	2.14E-01	50.40
Depletion of resources – water resources	6.64E-03	3.62	7.44E-03	2.03	1.04E-02	2.45

2.1.2. Silver

In 2024, a total of 1,316.28 Mg of silver was produced, of which 53.49% was in the form of silver ingots and 46.51% as silver granules . Production volumes and environmental impact per 1 Mg for both types of silver are presented in the tables2 .16 and2 .17 .

Table2 .16 Production volumes and environmental impact per 1 Mg of silver in the form of ingots and granules in 2024

		Silver	
		in ingots	granules
Silver production in 2024	Mg	898.41	417.87
	%	53.49	46.51
Environmental impact per 1 Mg of silver	Pt	25.329	25.333
Carbon footprint per 1 Mg of silver	$kgCO_2$ eq	121,535.49	121,554.89

Table2 .17 Weighted results of production impact category indicators (2024) per 1 tonne of silver in ingots and granules [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024	
	Silver in ingots and granules	
	Pt	%
Acidification	1.15E+00	2.28
Climate change	6.78E+00	13.38
Ecotoxicity to freshwater	1.06E+01	20.92
Particulate matter	1.07E+00	2.11
Aquatic eutrophication – seawater	4.94E-01	0.98
Water eutrophication – fresh water	3.99E-01	0.79
Terrestrial eutrophication	5.41E-01	1.07
Human health, carcinogens	7.92E-02	0.16
Human health, non-carcinogenic factors	5.93E-01	1.17
Ionising radiation	5.82E-02	0.12
Land use	1.54E-01	0.30
Ozone depletion	8.41E-03	0.02
Photochemical ozone formation	9.65E-01	1.90
Depletion of resources – fossil fuels	4.45E+00	8.78
Resource depletion – mineral resources and metals	2.21E+01	43.62

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024	
	Silver in ingots and granules	
	Pt	%
Resource depletion – water resources	1.23E+00	2.42

2.1.3. Gold

In 2024, a total of 2.71 Mg of gold was produced . Production volumes and environmental impact per 1 Mg of gold are presented in the tables2 .18 and2 .19 .

Table2 .18 Production volumes and environmental impact per 1 Mg of gold in bars in 2024

		Gold
Production in 2024	Mg	2.71
Environmental impact per 1 Mg of gold bullion	Pt	2,143.44
Carbon footprint per 1 Mg of gold bullion	$kgCO_2eq$	11,143,627

Table2 .19 Weighted results of production impact category indicators (2024) per 1 metric tonne of gold bullion [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024	
	Gold	
	Pt	%
Acidification	7.75E+01	3.62
Climate change	3.11E+02	14.50
Ecotoxicity to freshwater	4.27E+02	19.92
Particles	6.21E+01	2.90
Aquatic eutrophication – seawater	2.01E+01	0.94
Water eutrophication – freshwater	1.68E+01	0.79
Terrestrial eutrophication	2.20E+01	1.03
Human health, carcinogens	3.76E+00	0.18
Human health, non-carcinogenic factors	2.98E+01	1.39
Ionising radiation	2.39E+00	0.11
Land use	6.29E+00	0.29
Ozone depletion	3.43E-01	0.02
Photochemical ozone formation	4.08E+01	1.90
Resource depletion – fossil fuels	1.85E+02	8.63

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024	
	Gold	
	Pt	%
Resource depletion – mineral resources and metals	8.89E+02	41.48
Resource depletion – water resources	4.97E+01	2.32

2.1.4. Lead

In 2024, a total of 30,179.62 Mg of refined lead was produced . Production volumes and environmental impact per 1 Mg of lead are presented in the tables2 .20 and2 .21 .

Table2 .20 Production volumes and environmental impact per 1 Mg of refined lead in 2024.

		Lead
Lead production in 2024	Mg	30 179.62
Environmental impact per 1 Mg of refined lead	Pt	1.4
Carbon footprint per 1 Mg of refined lead	$kgCO_2eq$	7 111.42

Table2 .21 Weighted results of impact category indicators for refined lead production (2024) per 1 tonne [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024	
	Lead	
	Pt	%
Acidification	3.11E-02	2.22
Climate change	1.98E-01	14.17
Ecotoxicity to freshwater	2.47E-01	17.63
Particulate matter	3.79E-02	2.71
Aquatic eutrophication – seawater	1.30E-02	0.93
Water eutrophication – freshwater	9.65E-03	0.69
Terrestrial eutrophication	1.46E-02	1.04
Human health, carcinogens	3.68E-03	0.26
Human health, non-carcinogenic factors	2.96E-02	2.12
Ionising radiation	2.05E-03	0.15

Land use	4.12E-03	0.29
Ozone depletion	3.16E-04	0.02
Photochemical ozone formation	2.78E-02	1.99
Resource depletion – fossil fuels	1.31E-01	9.34
Resource depletion – mineral resources and metals	6.61E-01	47.23
Resource depletion – water resources	-1.10E-02	-0.79

2.1.5. Sulphuric acid

In 2024, the three smelters analysed produced a total of 659,797 Mg of sulphuric acid, of which 16.39% was produced at HM Legnica, 41.73% at HM Głogów I, and 41.88% at HM Głogów II. Production volumes and environmental impact, calculated per 1 Mg of sulphuric acid for individual copper smelters in 2024, are presented in the tables2 .22 and2 .23 .

Table2 .22 Production volumes and environmental impact per 1 Mg of sulphuric acid for individual smelters in 2024

		Smelters			
		Legnica	Głogów I	Głogów II	**Weighted average for Głogów 1 and Głogów 2**
Sulphuric acid production in 2024	Mg	108,137	275,360	276,300	-
	%	16.39	41.73	41.88	-
Environmental impact per 1 Mg of sulphuric acid	Pt	0.165	0.339	0.509	**0.424**
Carbon footprint per 1 Mg of sulphuric acid	$kgCO_2$ eq	1,018.76	1,402.893	1,584.61	**1,493.91**

Table2 .23 Weighted results of impact category indicators for steelworks production (2024) per 1 tonne of sulphuric acid [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024							
	Legnica		Głogów I		Głogów II		**Weighted average for Głogów 1 and Głogów 2**	
	Pt	%	Fri	%	Pt	%	**Fri**	**%**
Acidification	5.02E-03	3.05	7.00E-03	2.07	7.60E-03	1.49	**7.30E-03**	**1.72**
Climate change	2.84E-02	17.24	3.91E-02	11.54	4.42E-02	8.67	**4.17E-02**	**9.82**
Ecotoxicity to freshwater	8.65E-02	52.52	1.01E-01	29.88	8.89E-02	17.45	**9.50E-02**	**22.40**
Particulate matter	3.76E-03	2.28	8.41E-03	2.48	8.75E-03	1.72	**8.58E-03**	**2.02**
Aquatic eutrophication – seawater	1.63E-03	0.99	3.21E-03	0.95	3.25E-03	0.64	**3.23E-03**	**0.76**
Aquatic eutrophication – freshwater	1.44E-03	0.87	2.48E-03	0.73	2.73E-03	0.54	**2.61E-03**	**0.61**
Land-based eutrophication	1.75E-03	1.06	3.53E-03	1.04	4.13E-03	0.81	**3.83E-03**	**0.90**
Human health, carcinogens	5.65E-04	0.34	4.98E-04	0.15	4.45E-04	0.09	**4.71E-04**	**0.11**
Human health, non-carcinogenic factors	2.63E-03	1.60	3.28E-03	0.97	4.13E-03	0.81	**3.70E-03**	**0.87**
Ionising radiation	8.30E-05	0.05	4.58E-04	0.14	4.59E-04	0.09	**4.59E-04**	**0.11**
Land use	1.06E-03	0.64	1.32E-03	0.39	1.45E-03	0.28	**1.38E-03**	**0.33**
Ozone depletion	2.78E-05	0.02	4.75E-05	0.01	4.15E-05	0.01	**4.45E-05**	**0.01**
Photochemical formation of ozone	3.38E-03	2.05	6.21E-03	1.83	6.50E-03	1.28	**6.36E-03**	**1.50**
Depletion of resources – fossil fuels	1.57E-02	9.55	2.76E-02	8.14	2.48E-02	4.87	**2.62E-02**	**6.17**
Resource depletion – Mineral resources and metals	1.87E-02	11.35	1.43E-01	42.31	3.18E-01	62.50	**2.31E-01**	**54.45**
Depletion of resources – water resources	-5.96E-03	-3.62	-8.88E-03	-2.62	-6.33E-03	-1.24	**-7.60E-03**	**-1.79**

2.1.6. Iron silicate

In 2024, 206,364.40 Mg of shaft slag was produced at HML, 448,800.97 Mg of iron silicate in cast form (crushed iron silicate) at HMGI and 434,599.74 Mg of iron silicate in granulated form at HMGII . The environmental impact per 1 Mg of slag and iron silicate for individual copper smelters in 2024 is presented in the tables2 .24 and2 .25 .

Table2 .24 Production volumes and environmental impact per 1 Mg of shaft slag and iron silicate for individual smelters in 2024

		Steelworks		
		Legnica	Głogów I	Głogów II
Iron silicate production in 2024	Mg	206,364.40	448,800.97	434,599.74
	%	18.94	41.18	39.88
Environmental impact per 1 Mg of iron silicate	Pt	0.20	0.32	0.50
Carbon footprint per 1 Mg of iron silicate	$kgCO_2$ eq	1,403.77	1,498.19	1,816.17

Table2 .25 Weighted results of impact category indicators for the production of blast furnace slag and iron silicate in steelworks (2024), per 1 tonne [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024					
	Legnica		Głogów I		Głogów II	
	Pt	%	Fri	%	Fri	%
Acidification	5.71E-03	2.87	7.15E-03	2.22	8.08E-03	1.61
Climate change	3.91E-02	19.66	4.18E-02	13.01	5.06E-02	10.09
Ecotoxicity to freshwater	8.85E-02	44.43	9.09E-02	28.30	8.48E-02	16.89
Particulate matter	5.06E-03	2.54	8.06E-03	2.51	8.84E-03	1.76
Aquatic eutrophication – seawater	2.40E-03	1.20	3.17E-03	0.99	3.42E-03	0.68
Aquatic eutrophication – freshwater	1.78E-03	0.89	2.93E-03	0.91	3.22E-03	0.64
Land-based eutrophication	2.45E-03	1.23	3.52E-03	1.10	4.29E-03	0.85
Human health, carcinogens	8.95E-04	0.45	5.09E-04	0.16	4.81E-04	0.10
Human health, non-carcinogenic factors	3.97E-03	2.00	3.41E-03	1.06	4.41E-03	0.88
Ionising radiation	1.18E-04	0.06	4.24E-04	0.13	4.48E-04	0.09
Land use	1.71E-03	0.86	1.26E-03	0.39	1.45E-03	0.29
Ozone depletion	4.34E-05	0.02	4.66E-05	0.01	4.21E-05	0.01
Photochemical ozone formation	4.79E-03	2.41	6.29E-03	1.96	6.94E-03	1.38
Depletion of resources – fossil fuels	2.17E-02	10.89	3.06E-02	9.53	2.86E-02	5.70
Resource depletion – Mineral resources and metals	3.13E-02	15.70	1.29E-01	40.09	3.02E-01	60.18
Depletion of resources – water resources	-1.04E-02	-5.21	-7.66E-03	-2.38	-5.78E-03	-1.15

2.1.7. Selenium

In 2024, a total of 68.38 Mg of selenium was produced. Production volumes and environmental impact, calculated per 1 Mg of lead, are presented in Tables 2.13 and 2.14.

2 ble 2.13 Production volume and environmental impact per 1 Mg of selenium for individual smelters in 2024.

		Selenium
Selenium production in 2024	Mg	68.38
Environmental impact per 1 Mg of selenium	Pt	1.65
Carbon footprint per 1 Mg of selenium	$kgCO_2eq$	7,435.81

Table2 .14 Weighted results of impact category indicators for selenium production (2024) per 1 tonne [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024	
	Selenium	
	Pt	%
Acidification	2.11E-01	12.82
Climate change	2.07E-01	12.59
Ecotoxicity to freshwater	2.50E-01	15.20
Particulate matter	1.77E-01	10.75
Aquatic eutrophication – seawater	1.34E-02	0.81
Water eutrophication – freshwater	1.23E-02	0.75
Terrestrial eutrophication	1.53E-02	0.93
Human health, carcinogens	1.20E-02	0.73
Human health, non-carcinogenic factors	1.53E-02	0.93
Ionising radiation	2.89E-03	0.18
Land use	3.95E-03	0.24
Ozone depletion	2.74E-04	0.02
Photochemical ozone formation	3.89E-02	2.36
Resource depletion – fossil fuels	1.40E-01	8.52
Resource depletion – mineral resources and metals	5.14E-01	31.20
Resource depletion – water resources	3.26E-02	1.98

2.1.8. Copper sulphate

In 2024, a total of 5,394 Mg of copper sulphate was produced. Production volumes and environmental impact, calculated per 1 Mg of copper sulphate, are presented in Tables 2.15 and 2.16.

2 ble 15 Production volume and environmental impact per 1 Mg of copper sulphate in 2024

		Copper sulphate
Copper sulphate production in 2024	Mg	5,394
Environmental impact per 1 Mg of copper sulphate	Pt	0.049
Carbon footprint per 1 Mg of copper sulphate	$kgCO_2eq$	337

2 Table 16 Weighted results of impact category indicators for copper sulphate production (2024) per 1 tonne [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024	
	Copper sulphate	
	Pt	%
Acidification	1.91E-03	3.88
Climate change	9.40E-03	19.17
Ecotoxicity to freshwater	1.59E-02	32.32
Particulate matter	1.18E-03	2.42
Aquatic eutrophication – seawater	5.41E-04	1.10
Aquatic eutrophication – freshwater	5.39E-04	1.10
Terrestrial eutrophication	5.72E-04	1.17
Human health, carcinogens	1.90E-04	0.39
Human health, non-carcinogenic factors	1.48E-03	3.01
Ionising radiation	4.50E-05	0.09
Land use	2.30E-04	0.47
Ozone depletion	1.25E-05	0.03
Photochemical ozone formation	1.10E-03	2.25
Resource depletion – fossil fuels	6.29E-03	12.82
Resource depletion – mineral resources and metals	7.94E-03	16.18
Resource depletion – water resources	1.78E-03	3.62

2.1.9. Nickel sulphate

In 2024, the three smelters analysed produced a total of 2,359.69 Mg s of nickel sulphate , of which 30.39% was produced at HM Legnica, 34.37% at HM Głogów I, and 35.24% at HM Głogów II. Production volumes and environmental impact, calculated per 1 Mg of nickel sulphate for individual copper smelters in 2024, are presented in Tables 2.17 and 2.18.

2 ble 17 Production volumes and environmental impact per 1 Mg of nickel sulphate for individual smelters in 2024

		Smelters			
		Legnica	Głogów I	Głogów II	**Weighted average for Głogów 1 and Głogów 2**
Nickel sulphate production in 2024	Mg	717	811.12	831.57	**-**
	%	30.39	34.37	35.24	**-**
Environmental impact per 1 Mg of nickel sulphate	Pt	0.07	0.15	0.16	**0.16**
Carbon footprint per 1 Mg of nickel sulphate	$kgCO_2$ eq	512.37	732.84	685.84	**709.05**

2 Table 18. Weighted results of impact category indicators for smelter production (2024) per 1 tonne of nickel sulphate [Pt, %]

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024							
	Legnica		Głogów I		Głogów II		**Weighted average for Głogów 1 and Głogów 2**	
	Pt	%	Fri	%	Pt	%	**Fri**	**%**
Acidification	2.90E-03	3.88	3.48E-03	2.37	3.20E-03	1.95	**3.34E-03**	2.15
Climate change	1.43E-02	19.17	2.04E-02	13.91	1.91E-02	11.66	**1.98E-02**	12.70
Ecotoxicity to freshwater	2.41E-02	32.32	3.31E-02	22.53	3.09E-02	18.84	**3.20E-02**	20.56
Particulate matter	1.80E-03	2.42	3.56E-03	2.42	3.06E-03	1.86	**3.30E-03**	2.12
Aquatic eutrophication – seawater	8.23E-04	1.10	1.65E-03	1.13	1.44E-03	0.88	**1.54E-03**	0.99
Aquatic eutrophication – freshwater	8.19E-04	1.10	1.27E-03	0.86	1.11E-03	0.68	**1.19E-03**	0.76
Land-based eutrophication	8.70E-04	1.17	1.75E-03	1.19	1.61E-03	0.98	**1.68E-03**	1.08
Human health, carcinogens	2.88E-04	0.39	2.36E-04	0.16	1.94E-04	0.12	**2.15E-04**	0.14
Human health, non-carcinogenic factors	2.24E-03	3.01	1.53E-03	1.04	1.56E-03	0.95	**1.55E-03**	0.99
Ionising radiation	6.84E-05	0.09	1.88E-04	0.13	1.68E-04	0.10	**1.78E-04**	0.11
Land use	3.50E-04	0.47	4.99E-04	0.34	4.26E-04	0.26	**4.62E-04**	0.30
Ozone depletion	1.90E-05	0.03	2.72E-05	0.02	2.28E-05	0.01	**2.50E-05**	0.02
Photochemical formation of ozone	1.67E-03	2.25	3.17E-03	2.16	2.77E-03	1.69	**2.97E-03**	1.91
Resource depletion – fossil fuels	9.55E-03	12.82	1.47E-02	10.00	1.18E-02	7.16	**1.32E-02**	8.49
Resource depletion – Mineral resources and metals	1.21E-02	16.18	5.84E-02	39.72	8.27E-02	50.40	**7.07E-02**	45.42
Depletion of resources – water resources	2.70E-03	3.62	2.98E-03	2.03	4.02E-03	2.45	**3.51E-03**	2.25

3. Cedynia Copper Smelter

3.1. impact category indicators

In 2024, the Cedynia Smelter produced a total of 271,488,581 kg of wire rod and 16,197,620 kg of wire (including 12,804,522 kg of OFE wire and 3,393,098 kg of CuAg wire). Production volumes and environmental impact, calculated per 1 Mg of wire rod and OFE and CuAg wire for the Cedynia steelworks in 2024, are presented in the table at3 .26 .

Table3 .26 Production volumes and environmental impact of the Cedynia steelworks' annual operations in 2024.

		Cedynia Steelworks		
		Wire rod	OFE wire	CuAg wire
Production in 2024	kg	271,488,581	12,804,522	3,393,098
Environmental impact per 1 Mg of product	Pt	0.34	0.41	0.41
Carbon footprint per 1 Mg of product	$kgCO_2$ eq	1,782.71	2056.41	2056.64

Table3 .27 The results of the impact category indicators for 1 tonne of individual products from the Cedynia Steelworks (2024) are characterised

IMPACT CATEGORIES	Unit	ENVIRONMENTAL IMPACT PER TONNE IN 2024		
		Wire rod	OFE wire	CuAg wire
Acidification	mol H+ eq	7.51E+00	8.21E+00	8.21E+00
Climate change	kg CO_2 eq	1.78E+03	2.06E+03	2.06E+03
Ecotoxicity to freshwater	CTUe	2.23E+05	2.41E+05	2.41E+05
Particulate matter	disease inc.	4.93E-05	5.82E-05	5.82E-05
Aquatic eutrophication – seawater	kg N eq	2.31E+00	2.69E+00	2.69E+00
Aquatic eutrophication – freshwater	kg P eq	1.64E-01	2.08E-01	2.08E-01
Terrestrial eutrophication	mol N eq	1.80E+01	2.12E+01	2.12E+01
Human health, carcinogens	CTUh	5.00E-07	4.81E-07	4.81E-07
Human health, non-carcinogenic factors	CTUh	3.14E-05	3.06E-05	3.06E-05
Ionising radiation	kBq U-235 eq	3.19E+01	3.92E+01	3.92E+01
Land use	Pt	1.14E+04	1.33E+04	1.33E+04
Ozone depletion	kg CFC-11 eq	6.00E-05	5.49E-05	5.49E-05
Photochemical ozone formation	kg NMVOC eq	5.87E+00	6.78E+00	6.78E+00
Resource depletion – fossil fuels	MJ	2.66E+04	2.96E+04	2.96E+04
Resource depletion – Mineral resources and metals	kg Sb eq	1.14E-01	1.54E-01	1.54E-01
Resource depletion – water resources	m^3 depletion	1.17E+03	1.31E+03	1.31E+03

Table 3 .28 presents the characterised results for the production of wire rod, OFE wire and CuAg wire for data from 2024, expressed per 1 tonne.

Table 3 .28 . Production of wire rod, OFE wire and CuAg – weighted results of impact category indicators per 1 tonne of individual products at the Cedynia Steelworks (2024)

IMPACT CATEGORIES	ENVIRONMENTAL IMPACT PER 1 Mg in 2024					
	Wire rod		OFE wire		CuAg wire	
	Pt	%	Pt	%	Pt	%
Acidity	8.37E-03	2.45	9.15E-03	2.21	9.16E-03	2.21
Climate change	4.97E-02	14.53	5.73E-02	13.86	5.73E-02	13.86
Ecotoxicity to freshwater	7.55E-02	22.06	8.15E-02	19.70	8.15E-02	19.70
Particles	7.43E-03	2.17	8.76E-03	2.12	8.76E-03	2.12
Aquatic eutrophication – seawater	3.49E-03	1.02	4.08E-03	0.99	4.08E-03	0.99
Aquatic eutrophication – freshwater	2.86E-03	0.84	3.62E-03	0.88	3.62E-03	0.88
Land-based eutrophication	3.79E-03	1.11	4.45E-03	1.08	4.45E-03	1.08
Human health, carcinogens	6.17E-04	0.18	5.94E-04	0.14	5.94E-04	0.14
Human health, non-carcinogenic factors	4.49E-03	1.31	4.37E-03	1.06	4.37E-03	1.06
Ionising radiation	3.79E-04	0.11	4.65E-04	0.11	4.65E-04	0.11
Land use	1.11E-03	0.32	1.29E-03	0.31	1.29E-03	0.31
Ozone depletion	7.24E-05	0.02	6.62E-05	0.02	6.62E-05	0.02
Photochemical formation of ozone	6.87E-03	2.01	7.94E-03	1.92	7.94E-03	1.92
Depletion of resources – fossil fuels	3.41E-02	9.97	3.79E-02	9.17	3.79E-02	9.17
Resource depletion – Mineral resources and metals	1.35E-01	39.36	1.82E-01	44.08	1.82E-01	44.08
Depletion of resources – water resources	8.71E-03	2.55	9.75E-03	2.36	9.76E-03	2.36

Impact of the method on the results of the analysis

LCA analysis can be carried out using various calculation methods. For analyses carried out under European conditions, the EF 3.0 method and the CML-IA baseline are frequently used, amongst others. It is also possible to apply methods focused on a single impact category, such as IPCC 2021 GWP100, which is used to assess global warming potential. These methods differ in the scope of their impact categories, the way they are parameterised, and the characteristic factors adopted, which may lead to slight differences in the results of analyses concerning the same process. Furthermore, individual impact categories may be expressed in different units depending on the method used, which makes it difficult to compare results directly.

To illustrate the impact of the choice of calculation method on the results of the LCA analysis in the climate change category, carbon footprint calculations for the production of copper cathodes were carried out using three methods: the EF 3.0 Method (adapted) V1.03 / EF 3.0 normalisation and weighting set, CML-IA baseline V3.08 / EU25 and IPCC 2021 GWP100 V1.01. The results are summarised in Table 3.4.

Table3 .29 . Comparison of results in the climate change category for copper cathodes using the EF 3.0, CML-IA baseline and IPCC 2021 GWP100 methods

Method	HML cathode	HMGI cathode	HMGII cathode
EF 3.0 Method (adapted) V1.03 / EF 3.0 normalisation and weighting set	1 260.72	1 829.76	1 776.61
CML-IA baseline V3.08 / EU25	1,253.22	1,817.71	1,767.16
IPCC 2021 GWP100 V1.01	1,258.68	1,827.48	1,774.74

Based on the results obtained, it can be concluded that the choice of calculation method affects the carbon footprint value; however, the differences between the methods analysed are minor. The highest results for all the cathode types analysed were obtained using the EF 3.0 method, which was used to analyse the environmental footprint of KGHM Polska Miedź S.A.'s products based on data from 2024. The lowest values, however, were obtained using the CML-IA baseline method. The differences between the EF 3.0 and CML-IA baseline results are approximately 0.60% for the HML cathode, 0.66% for the HMGI cathode and 0.53% for the HMGII cathode, respectively. The results obtained using the IPCC 2021 GWP100 method are very similar to those of EF 3.0, although they are slightly lower.

In the EF 3.0 and IPCC 2021 methods, the GWP100 carbon footprint takes into account emissions associated with the fossil, biogenic and land-use change categories. In the CML-IA baseline method, the GWP100a indicator is analysed; this also refers to global warming potential over a 100-year horizon, but is based on slightly different characteristic factors. For this reason, the results obtained differ between methods, even though they relate to the same category of environmental impact. Consequently, when selecting a calculation method, one should take into account the purpose and scope of the analysis, the requirements of the recipient of the results, and the need to ensure their comparability and correct interpretation.3