IBRAM
BRAZILIAN MINING

2024 INVENTORY OF **GREENHOUSE GAS EMISSIONS** IN THE MINERAL SECTOR

BASE YEAR 2022

2024 INVENTORY OF **GREENHOUSE GAS EMISSIONS** IN THE MINERAL SECTOR

BASE YEAR 2022

Brazilian Mining Institute - IBRAM

2024

SHIS QL 12 cj O (zero) casa 04, Lago Sul.
CEP:71.630-205 – Brasília/DF
Phone: (61) 3364-7272
Site:
http://www.ibram.org.br

TECHNICAL AND EXECUTIVE COORDINATING OFFICE

IBRAM - Brazilian Mining Institute
- Alexandre Valadares Mello
- Cinthia de Paiva Rodrigues
- Cláudia Franco de Salles Dias
- Julio Cesar Nery Ferreira
- Luisa Gouvêa Rates

PRODUCTION

WayCarbon
- Carolina Mendes
- Eloisa Casadei
- Higor Turcheto
- Matheus Fernandes

Graphic design, layout, cover and illustrations:

- Pablo Frioli

Photographs

The illustrations, tables and graphs with no indication of source were prepared by IBRAM.

GOVERNANCE

BOARD OF EXECUTIVES

Raul Jungmann
CEO of IBRAM

Fernando Azevedo e Silva
Vice-President of IBRAM

Alexandre Valadares Mello
Chief Executive for Associative Affairs and Climate Change

Julio Cesar Nery Ferreira
Chief Sustainability Officer

Paulo Henrique Leal Soares
Chief Communications Officer

Rinaldo César Mancin
Chief Institutional Relations Officer

Osny Vasconcellos
Chief Administrative and Financial Officer

BOARD OF DIRECTORS

TWO-YEAR PERIOD 2024-2025

Chairman of the Board:

- **Anglo American Brasil**
  Ana Sanches
  Acting Chairman

Vice-Chairman of the Board:

- **Lundin Mining**
  Ediney Maia Drummond
  Acting Vice-Chairman

Executive Board Members

- **Alcoa**
  Eduardo Doria - Acting Board Member
  Michelle Shayo - Substitute

- **Anglo American Brasil**
  Ivan de Araujo Simões Filho - Substitute

- **AngloGold Ashanti**
  Marcelo Pereira - Acting Board Member
  Othon de Villefort Maia - Substitute

- **ArcelorMittal**
  Wagner de Brito Barbosa - Acting Board Member
  Wanderley José de Castro - Substitute

- **BAMIN**
  Eduardo Jorge Ledsham - Acting Board Member
  Alexandre Victor Aigner - Substitute

- **Companhia Brasileira de Metalurgia e Mineração - CBMM**
  Eduardo Augusto Ayroza Galvão Ribeiro - Acting Board Member
  Ricardo Fonseca de Mendonça Lima - Substitute

- **Copelmi Mineração Ltda**
  Cesar Weinschenck de Faria - Acting Board Member
  Roberto da Rocha Miranda de Faria - Substitute

- **Embu S.A. Engenharia e Comércio**
  Daniel Debiazzi Neto - Acting Board Member
  Luiz Eulálio Moraes Terra - Substitute

- **Kinross Brasil Mineração S.A.**
  Gilberto Carlos Nascimento Azevedo - Acting Board Member
  Ana Cunha - Substitute

- **Lundin Mining**
  Luciano Antonio de Oliveira Santos - Substitute

- **Mineração Caraíba S.A.**
  Eduardo de Come - Acting Board Member
  Antonio Batista de Carvalho Neto - Substitute

- **Mineração Paragominas S.A. (HYDRO)**
  Anderson Baranov - Acting Board Member
  Paula Amelia Zanini Marlieri - Substitute

- **Mineração Rio Do Norte S.A. – MRN**
  Guido Roberto Campos Germani - Acting Board Member
  Vladimir Senra Moreira - Substitute

- **Mineração Taboca S.A**
  Newton A. Viguetti Filho - Acting Board Member
  Ronaldo Lasmar - Substitute

- **Mineração Usiminas S.A.**
  Carlos Hector Rezzonico - Acting Board Member
  Marina Pereira Costa Magalhães - Substitute

- **Minerações Brasileiras Reunidas - MBR**
  Octavio Bulcão - Acting Board Member
  Marcelo Sampaio - Substitute

- **Mosaic Fertilizantes**
  Adriana Kupcinskas Alencar - Acting Board Member
  Emerson Araken Martin Teixeira - Substitute

- **Nexa Resources**
  Jones Belther - Acting Board Member
  Guilherme Simões Ferreira - Substitute

- **Samarco Mineração S.A.**
  Rodrigo Alvarenga Vilela - Acting Board Member
  Felipe Starling - Substitute

- **Vale**
  Alexandre Silva D´Ambrosio - Acting Board Member
  Lauro Angelo Dias de Amorim - Substitute
  Marcello Magistrini Spinelli - Acting Board Member
  Vinícius Resende Domingues - Substitute
  Rafael Bittar - Acting Board Member
  Helga Paula Patrícia Franco - Substitute

PRESENTATION

The 2024 Inventory of Greenhouse Gas Emissions in the Mineral Sector (Base Year 2022), produced by the Brazilian Mining Institute (IBRAM), plays a significant role in guiding the future actions of the Brazilian mineral industry. It is important to emphasize that the mining industry must be part of the solution for Brazil and for the world to overcome the climate emergency.

Excessive greenhouse gas emissions intensify global warming and climate change, posing a major challenge for humanity. The Brazilian mining sector, led by IBRAM, has embraced the cause of energy transition and has intensified its actions in alignment with this goal. In this context, the mining industry has a fundamental role in seeking sustainable solutions, having the capacity of actively contributing to the reduction of GHG emissions and to the transition to a low-carbon economy.

One important aspect is the awareness that expanding the supply of minerals is essential for any strategy aimed at developing technology and equipment for the energy transition. Another relevant aspect is to establish the volume of emissions from the mineral sector as accurately as possible.

Thus, the GHG Inventory of the mineral sector is an important advancement, as it allows the industry to know and transparently disclose the level of its emissions and their main sources. Based on this information, it will be possible to define the best strategies for mitigating impacts and adopting increasingly sustainable practices.

The document covers both direct and indirect emissions, addressing everything from fossil fuel use to waste management. Furthermore, the inventory presents analyses of opportunities within the climate agenda, targets, and other recommendations for the mineral sector to effectively contribute to the decarbonization of the economy.

The realization of this inventory brings various benefits to mining companies, such as greater transparency and engagement with stakeholders, reduction of operational costs, strengthening of environmental responsibility and corporate reputation, in addition to new business opportunities in the national and international markets. Aware of its socio-environmental responsibility, the mining industry has been adopting various actions to reduce its GHG emissions, such as decreasing fossil fuel consumption, increasing energy efficiency, adopting renewable energy sources, conserving forests, managing waste sustainably, and promoting a circular economy. These initiatives are outlined in the ESG Agenda for Mining in Brazil, a guide for the sustainable and responsible development of the sector.

This Inventory represents another positive step in fulfilling the goals of this sectoral Agenda, demonstrating the commitment of mining companies associated with IBRAM to sustainability and the mitigation of climate change, reinforcing the essential role of the mineral industry in the sustainable development of the country.

Raul Jungmann,
President of IBRAM

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 Brazilian Mining Institute (IBRAM)

The Brazilian Mining Institute (IBRAM) is an entity that represents companies and institutions in Brazil's mining sector. Founded in 1990, it aims to promote sustainable and responsible mining, in addition to fostering the development of the Brazilian mining sector. In 2024, the entity has more than 200 members, including mining companies, mineral engineering companies, equipment manufacturers, among others.

IBRAM has strong operation in the field of environment, social and governance (ESG) of the mining sector, including activities related to operational safety, occupational health, mitigation of environmental impacts and local and future development of territories. On this topic, it develops projects and positions relevant to the sector, such as:

- **Zero Carbon Mining (ongoing):** Sectoral project focused on the decarbonization of the mining industry in Brazil. In partnership, IBRAM, the British Government in Brazil and the Mining Hub, launch projects to structure a decarbonization roadmap.

- **Inventories of greenhouse gas emissions for the years 2008 and 2011**: Project to account for emissions from selected typologies according to guidelines, with the purpose of obtaining the sector's emissions profile.

- **Resilient Mining:** A Guide for Mining to Adapt to the Impacts of Climate Change – IBRAM. Guidance and preparation of strategies that aim at reducing risks and exploring opportunities resulting from climate changes.

1.2 Mining sector in Brazil

The mining sector is highly relevant in the Brazilian economic scenario. According to data published in the Brazilian Mineral Yearbook of the National Mining Agency (ANM, 2024), the production marketed in Brazil in 2021 reached 227 million tons, and this value represents an increase of 15% in relation to 2020. In relation to 2022, the mining sector had a turnover of R$ 250 billion, having exported 258.2 million tons and generating 5 thousand direct and indirect jobs (IBRAM, 2022).

Brazil holds a large part of the mineral reserves, such as iron, aluminum, copper, tin and gold. The country also holds the third largest bauxite reserves in the world and is the second largest producer of iron ore, behind only Australia. Brazil also stands out for its reserves of minerals that will be important for the energy transition, such as niobium, of which it is the world's largest producer, with 94.1% of the world's share; lithium, of which it is among the six largest world producers (MME, 2023); and nickel, of which it is the third largest holder of reserves.

The figures on Brazil's mineral reserves for the main typologies are presented in Table 1.

Table 1: Brazil's mineral reserves

Tipology	Reserve (p) [em 10^3t]	Global share (p) [%]
Iron[1]	34.000.000	18,90%
Mineral Coal[1]	3.799.000	0,40%
Aluminum (Bauxite) [1]	2.700.000	8,40%
Phosphate[3]	1.600.000	2,30%
Manganese[2]	270.000	20,80%
Natural Graphite[1]	70.000	21,90%
Titanium[4]	43.000	6,10%
Rare Earths[2]	21.000	17,50%
Niobium[2]	16.000	94,10%
Nickel[2]	16.000	16,80%
Copper[2]	11.212	1,60%
Vermiculite[1]	6.600	14,10%
Zinc[2]	2.464	1,10%
Chromium[2]	2.451	0,50%
Zirconium[1]	2.319	3,10%
Potassium[3]	2.300	0,10%
Tin[2]	420	8,60%
Uranium[5]	245	0,00%
Vanadium[2]	120	0,50%
Lithium[2]	95	0,40%
Cobalt[2]	70	1,00%
Tantalum[2]	40	28,60%

Tipology	Reserve (p) [em 10³t]	Global share (p) [%]
Tungsten[2]	28	0,90%
Silver[2]	3,8	0,70%
Gold[2]	2,4	4,40%

Source: Adapted from the Mining Sector's Bulletin (MME, 2022).

Notes: 1 - Mineable Reserve of ore; 2 - Mineable Reserve in contained metal; 3 - Mineable Reserve in equivalent P_2O_5 or K_2O; 4 - Mineable Reserve of ilmenite + rutile; 5 - Resources; (p)preliminary data; n.d. data not available

In relation to its production chain, the mining sector can be divided into six main stages, which were considered as inventory limits:

a. **Prospecting:** search for mineral deposits;

b. **Mine research:** geological and geophysical studies to assess the economic viability of mineral extraction;

c. **Mining:** extraction of raw ore;

d. **Mineral processing:** processing of raw ore to separate minerals of interest from undesirable minerals;

e. **Transportation:** movement of processed ore to the marketing or export site;

f. **Mine closure:** conclusion of mining activities and recovery of areas used during the mineral extraction process.

2. OBJECTIVE

The Inventory of Greenhouse Gas (GHG) Emissions is the management instrument that allows an organization's impact on the global climate system to be evaluated by quantifying GHG emissions.

Mining is a process that involves several stages, with different contributions to GHG emissions. Therefore, monitoring and reporting the emissions is the main initiative to design the decarbonization strategy. This work assessed GHG emissions in Brazil's mining sector in 2022, focused on 27 mineral assets (typologies), using data provided by the mining companies that are part of IBRAM and other non-members, such as ABAL (Brazilian Aluminum Association) and SINDIROCHAS, for the provision of information on the relevant mineral typologies.

In this report, called the 2024 Inventory of GHG Emissions in the Mining Sector, it is possible to find the result consolidation methodology, the sector's emission profile, the indicators individualized by mineral assets and a brief context on the sector's decarbonization.

3. METHODOLOGY

3.1 Definition of mineral assets

IBRAM, together with associated companies and WayCarbon, considered the mineral assets, object of analysis and accounting of GHG emissions based on the following criteria:

- economic representativeness;
- representativeness by the amount of transacted ore;
- representativeness in number of companies per mineral asset and geographic distribution;
- availability of information from members;
- strategic relevance considering future scenarios, with special attention to critical and strategic minerals.

Of the 70 mineral assets listed in the ANM, 27 met the foregoing requirements and are listed in Table 2.

Table 2: Mineral assets considered in the 2024 Inventory of Greenhouse Gas (GHG) Emissions

Mineral assets			
Agalmatolite	Sand	Clay	Bauxite
Gravel	Limestone	Mineral Coal	Kaolin
Lead	Copper	Cobalt	Chromite
Spodumene (Lithium)	Tin	Iron	Phosphate
Gypsum	Magnesite	Manganese	Niobium
Nickel	Gold	Potassium	Silver
Ornamental rocks	Vanadium	Zinc	

3.2 Defining the scope of the inventory

The GHG (Greenhouse Gases) Protocol methodology was used for measurement of this Inventory's emissions. The GHG Protocol is a package of methodologies developed by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), used globally to account for and manage GHG emissions in a consistent manner across companies and reporting cycles, by defining standardized calculations, parameters (such as conversion factors and emission factors) and even a tool for calculation of process emissions in some sectors.

The GHG Protocol has nationalizations in different countries, that is, adaptations formally recognized by the methodology, which adapt emission factors according to local characteristics. In Brazil, we have the Brazilian GHG Protocol Program, which guides the use of emission factors on electricity supplied by the National Interconnected System (SIN) and fuels with renewable blends, such as diesel and gasoline.

Since it is widely used by companies globally, but mainly by companies in Brazil, the GHG Protocol, through its nationalization, the Brazilian GHG Protocol Program, has proven to be the most coherent methodology to be used in this work. Thus, we have below the descriptions of the main aspects of aggregation of information, as requested by the guideline.

3.2.1 Organizational boundary

Two approaches are possible for consolidation of the emissions at the organizational level. Below, each of these approaches is defined and the option used in this inventory is indicated.

- **Corporate Participation:** the organization assumes the GHG emissions of operations in accordance with its corporate participation.

- **Operational Control:** the organization is responsible for the totality of the GHG emissions from operations over which it has operational control.

The operational control approach, today, is the most relevant practice for recording and communication of GHG inventories by several companies, and its reporting is mandatory for companies that disclose their inventories in the Public Emission Registry. The IBRAM study considered the inventories of companies that adopt this operational boundary approach.

3.2.2 Operational boundary

The definition of operational boundaries takes into account the identification of GHG emission sources associated with operations through their categorization into direct or indirect emissions, using the Scope concept. Below, each of the three categories adopted by the GHG Protocol is defined and the options covered in this inventory are indicated.

- **Scope 1:** Direct GHG emissions from sources that belong to or are controlled by the inventorying organization.

- **Scope 2:** Indirect GHG emissions from the acquisition of electricity that is consumed by the inventorying organization.

- **Scope 3:** Indirect GHG emissions related to operations of the inventorying organization's value chain.

The 2024 Inventory of GHG Emissions in the Mining Sector considered Scopes 1, 2 and 3.

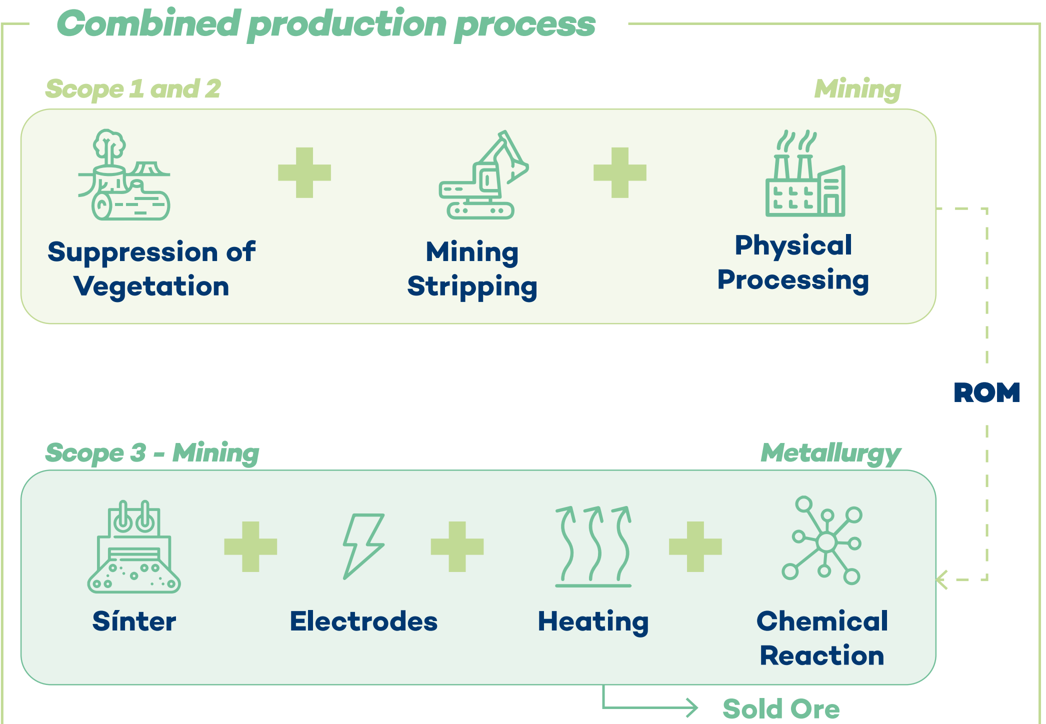
For consolidation of the inventory, the main sources of emission were mapped, considering the stages of mineral processing and related to the categories of GHG Protocol emissions, which is a globally used emission management and calculation methodology, presented in Figure 1

Figure 1: Operations and sources of GHG emissions in the mining sector

STAGE	ACTIVITY	EMISSION CATEGORY
Stripping and opening of mining front	• Removal of vegetation cover to reach the rock and perforation stage.	• Change of use of the soil • Stationary and mobile combustion (use of heavy vehicles)
Extraction	• Detonation for extraction of minerals; • Digging and transport	• Stationary and mobile combustion (digging machines and trucks) • Electric power consumption
Processing	• ROM treatment; • Set of processes for separation and obtainment of the concentrate.	• Stationary combustion • Electric power consumption (fragmentation, milling, concentration)
Movement of machines and internal transport	• Support machinery for processing and transport of the concentrate ore	• Stationary and mobile combustion • Use of fuels • Electric power consumption
Recovery of open areas	• Set of operations necessary for mine discontinuation	
Completion of these areas		

As most of the participants that took part in this inventory have mining and metallurgy processes, the separation of these emissions was carried out by type of activity, so that the operational limit of the inventory contains only the mining process, accounting for emissions beyond the mining stage in Scope 3 of the 2024 Inventory of GHG Emissions of the Mining Sector. This adaptation is described in Figure 2 and was carried out for a clear view of the emissions of the mining sector, containing only the activities of this sector.

Figure 2: Division between scopes of the mining and metallurgy sector



Source: WayCarbon

3.2.3 Definition of emission sources

The emission categories, which correspond to the classification of GHG emissions of the GHG Protocol according to the characteristics of their emitting sources, were defined and aligned with the participants in meetings of the Work Group. These are presented in Table 3.

Table 3: Definitions of scopes and categories

Scope	Category	Definition
Scope 1	Stationary combustion	GHG emissions from the combustion of fuel, which generates energy, generally used to produce water vapor or electrical energy in stationary equipment. This energy is not used for means of transportation
	Mobile combustion	GHG emissions from the combustion of fuel, which generates energy used to produce movement and travel a distance
	Fugitives	GHG releases, generally unintentional, that do not pass through chimneys, drains, exhaust pipes or other functionally equivalent opening
	Agriculture and changes in use of the soil	Non-mechanical emissions from agriculture, livestock activities or changes in use of the soil. Mechanical emissions from agriculture or livestock activities must be accounted for in the categories “Stationary combustion” or “Mobile combustion”
	Solid waste and liquid effluents	GHG emissions from the treatment of Solid waste and liquid effluents
	Industrial processes	GHG emissions from the chemical or physical transformation of some material, with the exception of its combustion. In general, these emissions arise from industrial production processes, but do not result from the burning of fuels.

Scope	Category	Definition
Scope 2	Acquisition of electrical energy – Location	GHG emissions using as emission factor the average emissions for generation of electrical energy in a given electrical system (grid), considering its geographic limit and a given period
	Acquisition of electrical energy – Market	GHG emissions from the generation of electrical energy acquired by the inventorying company, considering the specific energy supply source (such as renewable sources, among others)
Scope 3	Category 1 - Purchased Goods and Services	All emissions that occur in the life cycle (extraction, production and transportation) of the products (goods and services) purchased or acquired, up to the point of receipt by the inventory organization that are not accounted for in another Scope 3 category
	Category 2 - Capital goods	All emissions that occur in the life cycle (extraction, production, transportation) of the capital goods purchased or acquired, up to the point of receipt by the inventorying organization
	Category 3 - Activities related to fuel and energy not included in Scopes 1 and 2	Relative emissions extraction, production and transportation of fuels and energy purchased and consumed by the inventorying organization in the inventory year, which are not accounted for in Scopes 1 and 2 (i.e., excluding combustion of fuels or consumption of electricity)
	Category 4 - Transportation and distribution (upstream):	Emissions from transportation and distribution of products (excluding fuels and energy products - see category 3) purchased or acquired by the inventorying organization in the inventory year in vehicles and facilities that are not owned or operated by the organization, as well as from other outsourced transportation and distribution services (including both inbound and outbound logistics)

Scope	Category	Definition
Scope 3	Category 5 - Waste generated in the operations	Includes emissions from the treatment and/or final disposal of Solid waste and liquid effluents arising from the inventorying organization's operations in the inventory year, carried out in facilities owned or controlled by third parties
	Category 6 - Business trips	Emissions from transportation of employees for activities related to the inventorying organization's business, carried out in vehicles operated by or owned by third parties, such as aircraft, trains, buses, passenger cars and vessels
	Category 7 - Displacement of employees (home-work)	Emissions caused by displacement of employees between their homes and their workplaces in different modes of transport not operated or owned by the inventorying organization
	Category 8 - Leased assets (the organization as lessee)	Emissions from the operation of assets leased by the inventorying organization (lessee) and which were not included in its Scopes 1 and 2
	Category 9 - Transportation and distribution (downstream)	Emissions from the transportation and distribution of products sold by the inventory organization (if not paid for by the inventory organization) between its operations and the end consumer, including retail and storage, in third-party vehicles and facilities
	Category 10 - Processing of sold products	Emissions from the processing of intermediate products, carried out by another organization, after their sale by the inventorying organization
	Category 11 - Use of sold goods and services	Emissions from the final use of goods and services sold by the inventorying organization in the inventory year. All emissions throughout the useful life of the product are accounted for in the inventoried year
	Category 12 - End-of-life treatment of sold products	Emissions from the final disposal and treatment of sold products in the inventoried year by the inventorying organization at the end of their useful life

Scope	Category	Definition
Scope 3	Category 13 - Leased assets (the organization as lessee)	Emissions from the operation of assets owned by the inventorying organization (lessor) and leased to other entities in the inventory year, not included in Scopes 1 and 2 of the inventorying organization
	Category 14 - Franchises	Emissions from franchising operations in the inventory year, not included in Scopes 1 and 2 of the inventorying organization (franchiser)
	Category 15 - Investments	Emissions from investment operations (including equity investments, debt investments and project financing) in the inventory year, not included in Scopes 1 and 2

3.2.4 Greenhouse gases considered

The 2024 Inventory of GHG Emissions of the Mining Sector included the three most representative gases covered by the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4) and nitrogen oxide (N_2O). In addition, the inventory also computed CO_2 emissions from renewable sources (biogenic), which are treated separately because they do not contribute to the greenhouse effect.

Each GHG has an associated Global Warming Potential (GWP), which represents the global warming impact of each gas in reference to CO_2, the reference gas and with a GWP equal to 1. Therefore, by bringing the gases to the same base, it is possible to consolidate the result in tCO_2e (tons of equivalent carbon dioxide).

The 2024 Inventory of Greenhouse Gas Emissions in the Mining Sector followed the GWP values from the Assessment Report (AR) Five (5) of the Intergovernmental Panel on Climate Change (IPCC). The Table 4 presents the GWP values used.

Table 4: Global Warming Potential (GWP) of GHGs considered in the inventory

Gás	Potencial de Aquecimento Global (AR-5)
CO_2	1
CH_4	28
N_2O	265

Source: IPCC (2013)

3.2.5 Information reference year

All information collected considered the calendar year 2022. This decision was made jointly with the participants, considering that the availability of data from the participating companies was representative for that year, and the availability of updated data from the Brazilian Mineral Yearbook (ANM, 2024) – used to extrapolate emissions to the national scenario – for that year, demonstrating that it is the most up-to-date year possible for consolidation of the inventory.

3.3 Calculation of emissions from the Brazilian mining sector

The 2024 Inventory of GHG Emissions of the Mining Sector was consolidated based on emissions from mining companies and entities participating in this process. The information was requested in the format determined above, that is, GHG emissions from their mining and processing operations separately, for the year 2022, segregated by GHG Protocol categories.

In addition to the data related to GHG emissions, participants were asked to provide:

- **Transacted ore (ROM - Run-of-Mine):** Quantity of raw ore, excluding the amount of waste rock, produced in the year. This is considered the amount obtained directly from the mine, without undergoing any type of processing.
- **Ore sold:** Quantity of ore after all processing, which will be sold to the end customer.
- **Waste rock:** Soil and rocks discarded directly from the operation, not being sent to the processing stage. It originates from the surface removed from the mine or from the subsoil.

This data was used to calculate indicators and to extrapolate the results of the participants to the entire Brazilian mining sector. Using the GHG emissions and production data submitted, an indicator of tons of CO2e (tCO2e) emitted by each ton of the typology analyzed was generated. This indicator was subsequently multiplied by Brazil's total production in 2022, according to data from the Brazilian Mineral Yearbook (ANM, 2024), to estimate the absolute emissions of the Brazilian mining sector.

In order to fully understand the impact of mineral production, it was decided to quantify Scope 3 for the first time in a sectoral inventory of the mining sector. Therefore, for preparation of this report, participants were asked to report all Scope 3 categories they quantified, so that there was an evaluation of their representativeness. Since not all mining companies include this Scope in their inventories, sectoral studies that demonstrated the relevance of the consideration of category 10 (product processing) were considered. Therefore, this was the category selected for measurement in this Inventory, being considered by two means, depending on the availability of data: either the emissions calculated by the mining company, and an indicator generated for extrapolation, or estimated (based on the ore sold) for those that did not report it.

It is worth noting that the current analysis, carried out according to data received from mining companies, is based on a sample of 50% of the sector's total gross production, according to the Brazilian Mineral Yearbook. When extrapolating the results of this portion to the total, a methodological approach consistent with sector practices was applied, although this analysis has limitations in terms of public data and involves the adoption of assumptions.

Despite the increased uncertainty of the results, due to the application of these calculation assumptions, the exercise of consolidating these results is highly relevant for understanding the emissions profile of the sector and its chain, and assists in strategic decision-making for the sector and mining companies.

3.4 Data collection

Data collection was carried out through the CLIMAS platform, developed by WayCarbon for ESG information management. Use of the system guarantees important features to the project, such as data confidentiality, systematic management of data collection and reduction of the occurrence of manual calculation errors and ease in the continuity of future inventories, due to the existence of a base already parameterized in the system.

The release of the information that made up the inventory was the responsibility of each participant. During this stage, WayCarbon was available to clarify and resolve doubts, but no individual checks were made on the integrity and consistency of the data. These were only checked to ensure the completeness and coherence of the responses. In addition, the methodological consistency of the emission factors and calculations among the participating inventories was not assessed.

Specifically for ornamental rocks, due to the absence of corporate inventories, data collection was carried out through a form in which companies filled out fuel and electricity consumption data so that emissions could be calculated.

Mining companies that did not have a GHG inventory for the year 2022 and, therefore, were unable to report their emissions, only released production data and had their emissions estimated from literature data and extrapolated based on the results published in the Brazilian Mineral Yearbook.

4. RESULTS

Using all the assumptions mentioned in the methodology and the data received from the participants for each mineral asset, calculations, adjustments and validations were made that led to the general overview of greenhouse gas emissions for mineral extraction.

The results presented below represent an estimate of GHG emissions for the national scenario, classified as Scope 1, 2 and 3, which was made by extrapolating the emissions reported by mining companies to the total production of each type of mineral asset, according to data from the ANM's Brazilian Mineral Yearbook for the year 2022. It is worth noting that discrepancies were observed in the data reported by mining companies in relation to those available in the government database, without the reason being possible to identify.

4.1 Consolidated results for the Brazilian mining sector

For the year 2022, the main results for Scope 1 and 2 emissions are shown below. Scope 3 emissions will be described below.

- direct Scope 1 emissions, from combustion processes, soil use change, among others, totaled 11,298,225.77 tCO_2e, representing 88% of the total inventory;

- Scope 2 emissions, from purchased electricity and considered by Location, were in the order of 844,913.91 tCO_2e, representing 12% of the total inventory;

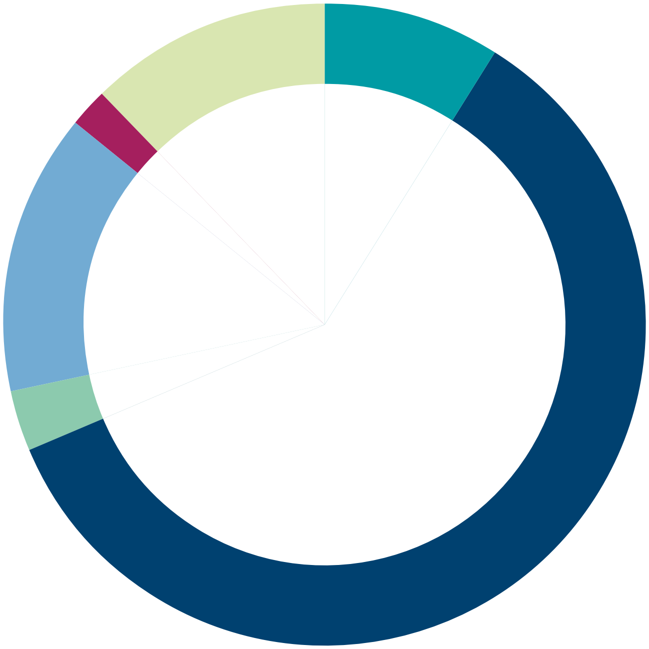
In Table 5 it is not possible to verify the result for scopes 1 and 2, which was 12,771,155.03 tCO_2e.

Table 5: Emissões do Scope 1 e 2 do setor mineral nacional

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**11.298.225,77**	**100,0%**	**93%**
Stationary combustion	1.194.399,14	10,6%	10%
Mobile combustion	7.550.657,29	66,8%	62%
Fugitives	445.339,60	3,9%	4%
Change of use of the soil	1.783.999,09	15,8%	15%
Industrial processes	305.016,84	2,7%	3%
Solid waste and liquid effluents	18.813,80	0,2%	0%
Scope 2	**844.913,91**	**100,0%**	**12%**
Energy - Location	844.913,91	100,0%	7%
Total (Scopes 1+2)	**12.143.139,67**	**100,0%**	**100%**

Evaluating Scope 1, it is possible to identify that the categories of mobile combustion and change of use of the soil were the most representative, with 62% and 15% of the total emissions of the inventory, respectively, which is coherent with the sector's operation macro profile (movement of large diesel-powered machines for mineral extraction and the need of change of vegetation for cleaning of the soil). Figure 3 Presents a graphical representation of each category of the emissions.

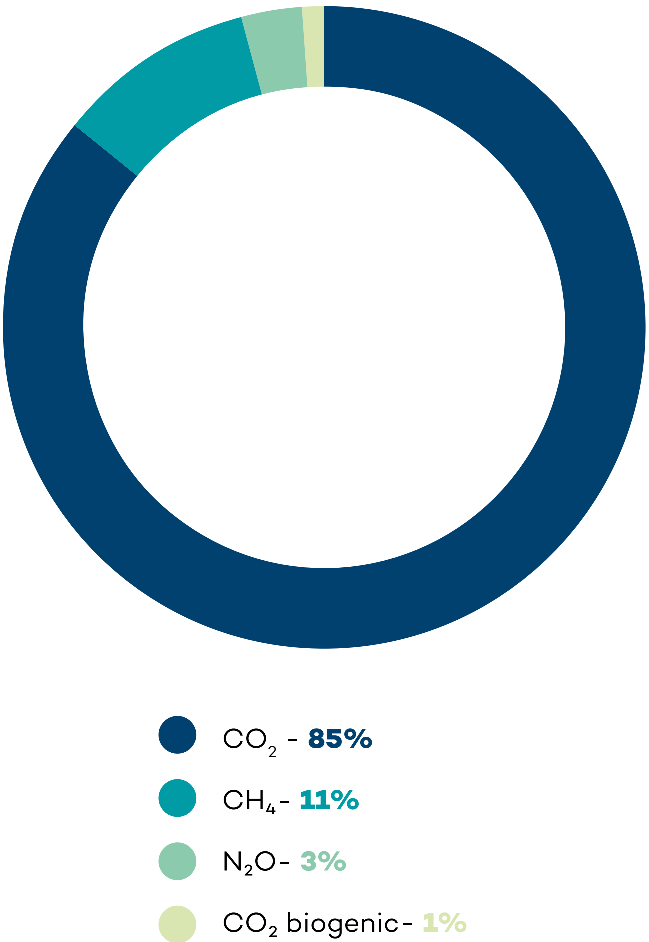
Figure 3: Representativeness of the mining sector's emission categories (%)



- Mobile combustion - **62%**
- Change of use of the soil - **15%**
- Energy - Location - **7%**
- Stationary combustion - **10%**
- Fugitive - **4%**
- Industrial processes - **2%**
- Solid wastes and liquid effluents - **0%**

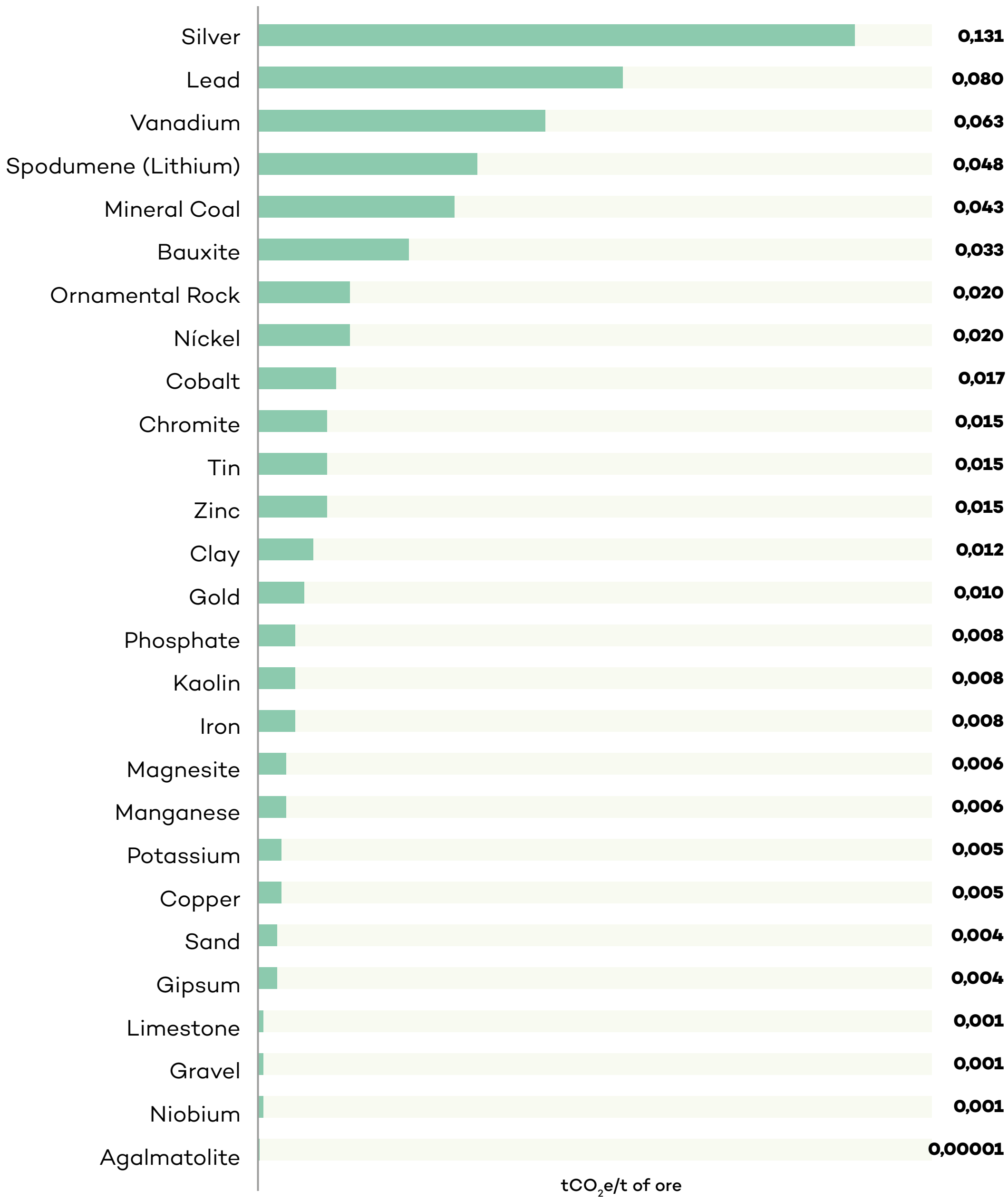
In what refers to gases, it is noted that in Figure 4 that CO_2 is the predominant gas in the mining sector, with 85% of the total emissions in CO_2e. Next, we have CH_4, with 10%, and N_2O, with 3% of the total emissions in CO_2e. Biogenic emissions represented 1%.

Figure 4: Representativeness of each GHG in the mining sector's result



In dealing with the result by typology, the emission intensity of Scopes 1+2 per ton of ore is presented in Figure 5.

Figure 5: Emission intensity of Scopes 1+2 per ton of ore for each typology

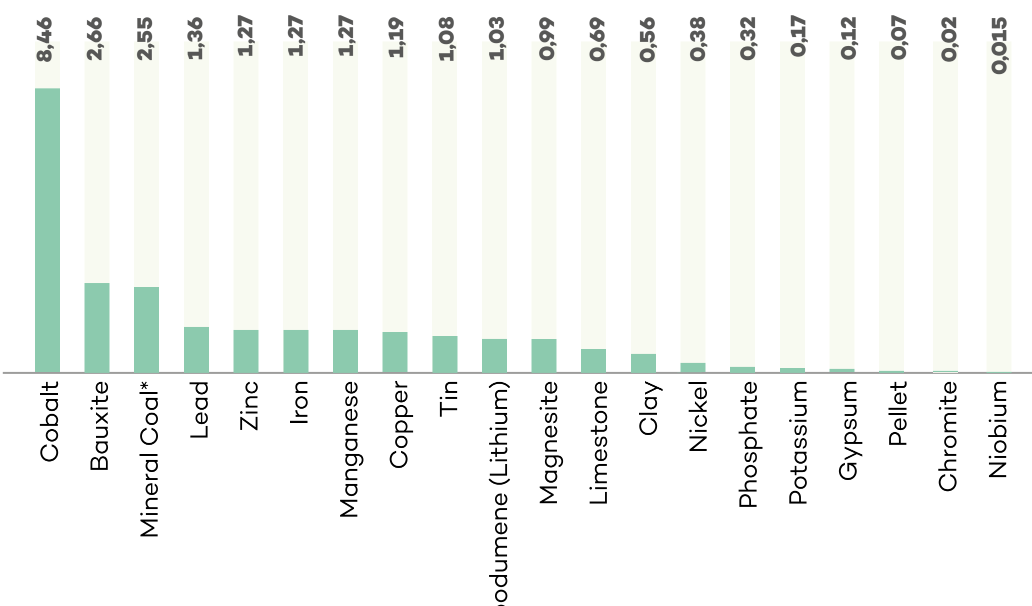


Indirect emissions of Scope 3 were estimated for the first time, and it has its consolidation carried out based on emissions reported by the participants and through estimations of market calculation. It is important to identify that they are a limited part of this Scope and, therefore, it must not be compared with the others through representativeness assessments.

The emissions from product processing (category 10 of Scope 3) summed up to a total of 762,252,033 tCO2e. In these emissions, the emissions from category 11 (use of the product) were also considered for mineral coal, given that this is the most representative category of this mineral asset, at the expense of product processing.

With the data from the typologies reported using premises and those reported by the mining companies, it is possible to carry out a graph of emission indicators (Figure 6):

Figure 6: Intensity of emissions from product processing (Category 10 of Scope 3) for each considered typology



* For Coal, the emissions from burning of the product (category 11) were calculated

4.2 Results from direct emissions (Scopes 1 and 2) of typologies calculated with data from the mining companies

4.2.1 Agalmatolite

Agalmatolite, composed mainly of pyrophyllite and muscovite, two aluminum phyllosilicates, is used as a filler in the paint industry, as well as ceramic, refractory, plastic, paper, cellulose, among others (CETEM, 2008). It was considered for the first time in the sectoral inventory of the mining industry, therefore, there are no comparative data for this typology. Table 6 presents the emissions of Scopes 1 and 2 referring to agalmatolite production.

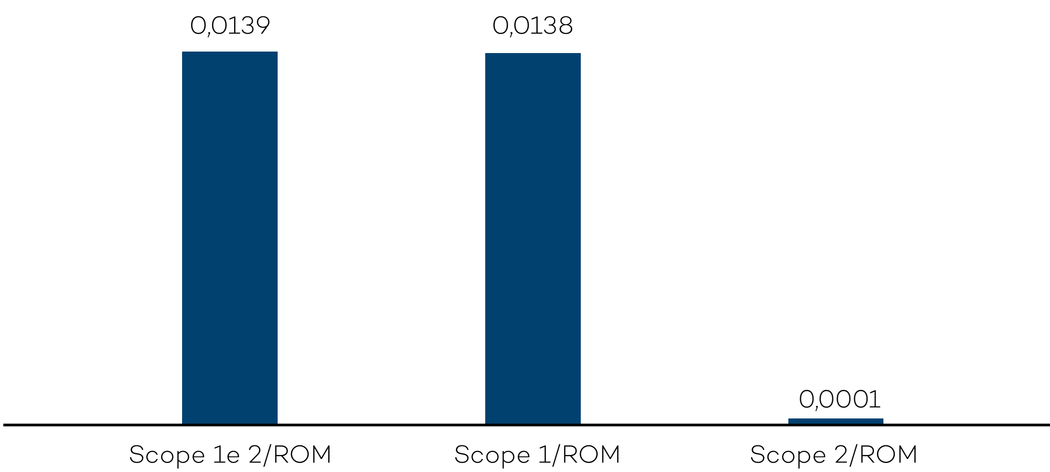
Table 6: Scope 1 e 2 – Agalmatolite

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**111,00**	**100,0%**	**99,5%**
Stationary combustion	-	0,0%	0,0%
Mobile combustion	111,00	100,0%	99,5%
Fugitives	-	0,0%	0,0%
Change of use of the soil	-	0,0%	0,0%
Industrial processes	-	0,0%	0,0%
Solid waste and liquid effluents	-	0,0%	0,0%
Scope 2	**0,56**	**100,0%**	**0,5%**
Energy - Location	0,56	100,0%	0,5%
Total (Scopes 1+2)	**19.144,55**	**404.989,21**	**100,0%**

The analysis of the data from the inventory reported in this report for the typology allows 99.5% of the emissions to be noted originate from mobile combustion, and that 0.5% have its origin in electric power consumption.

Finally, in relation to production, the reported data were 8,140.61 tons. Since ANM did not include this typology in the latest reports, it was not possible to identify whether the data accounted for here represent the national production of the mineral asset and, therefore, it was not possible to carry out extrapolation of the data. Figure 7 presents the indicators in tCO_2e per ton produced.

Figure 7: Indicators – Agalmatolite (tCO_2e/ton of ore)



4.2.2 Sand

Sand emissions were considered for the second time in a mining inventory. Previously, the emissions from this typology were accounted for using secondary data, but for 2022, primary data from participating mining companies were used, increasing the precision of the information. The emissions of Scopes 1 and 2 summed up to a total of 349,893.74 and 55,09547 tCO_2e, respectively.

Table 7 presents the results found, as well as the extrapolation based on ANM's data, which considered reported tCO_2e indicator direct emissions/t of ROM, to reach the total emissions referring to the total national sand movement in 2022.

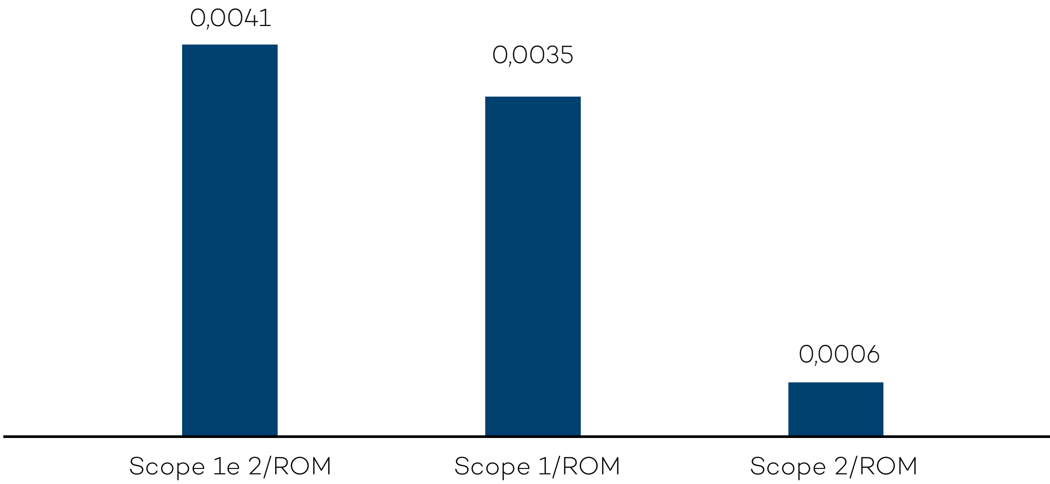
Table 7: Scope 1 e 2 – Sand

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**349.839,74**	**100,0%**	**86,4%**
Stationary combustion	227.745,62	65,1%	56,2%
Mobile combustion	122.148,12	34,9%	30,2%
Fugitives	-	0,0%	0,0%
Change of use of the soil	-	0,0%	0,0%
Industrial processes	-	0,0%	0,0%
Solid waste and liquid effluents	-	0,0%	0,0%
Scope 2	**55.095,47**	**100,0%**	**13,6%**
Energy - Location	55.095,47	100,0%	13,6%
Total (Scopes 1+2)	**404.989,21**	**100,0%**	**100,0%**

Scope 1 represents 86.4% of total direct emissions, and in this, stationary and mobile combustion stand out (65% and 35% of scope 1, respectively). Scope 2 represented 13.6% of the emissions.

The emission indicators can be seen in Figure 8.

Figure 8: Indicators - Sand (tCO_2e/tons of ore)



4.2.3 Clay

For the first time, the clay production emissions were considered in the sectoral inventory of the mining sector. Table 8 shows the emissions of Scopes 1 and 2 (location approach) of this typology referring to 100% of the clay movement in 2022.

Table 8: Scope 1 e 2 – Clay

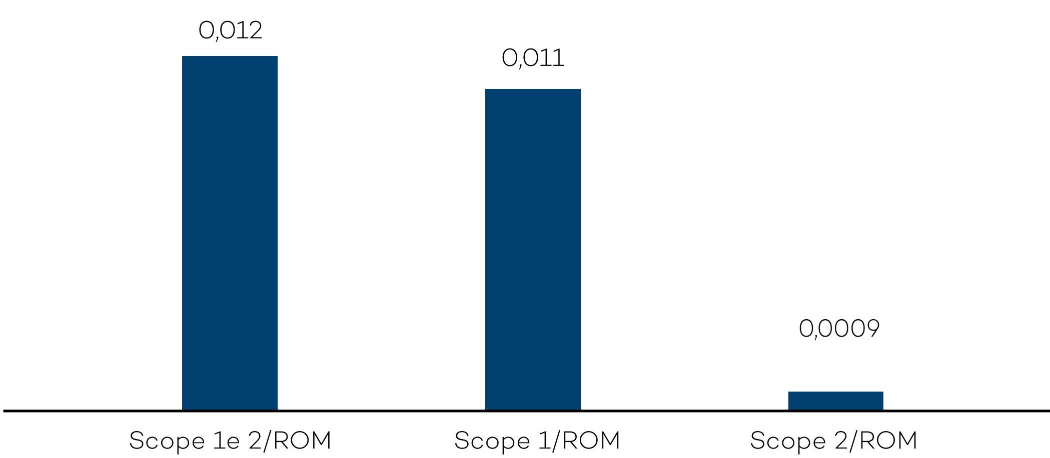
Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**514.652,79**	**100,0%**	**92,5%**
Stationary combustion	-	0,0%	0,0%
Mobile combustion	514.652,79	100,0%	92,5%
Fugitives	-	0,0%	0,0%

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Change of use of the soil	-	0,0%	0,0%
Industrial processes	-	0,0%	0,0%
Solid waste and liquid effluents	-	0,0%	0,0%
Scope 2	**41.627,66**	**100,0%**	**7,5%**
Energy - Location	41.627,66	100,0%	7,5%
Total (Scopes 1+2)	**556.280,45**	**100,0%**	**100,0%**

Scope 1 represents 92.5% of the direct emissions. This which is formed in its totality by the mobile combustion category. Now the approach used for clay for Scope 2 was that of location, and the emissions corresponded to 7.5%.

In what refers to production, the value accounted for was 53,414.06 tons. Figure 9 presents the indicators in tCO_2e per ton produced.

Figure 9: Indicators – Clay (tCO2e/tons of ore)



4.2.4 Bauxite

For this Inventory, the bauxite report was carried out through the Brazilian Aluminum Association (Abal). For this typology, Scope 2 was considered using the location approach, as it was the only reported data. Table 9 presents the results referring to the total national movement in 2022.

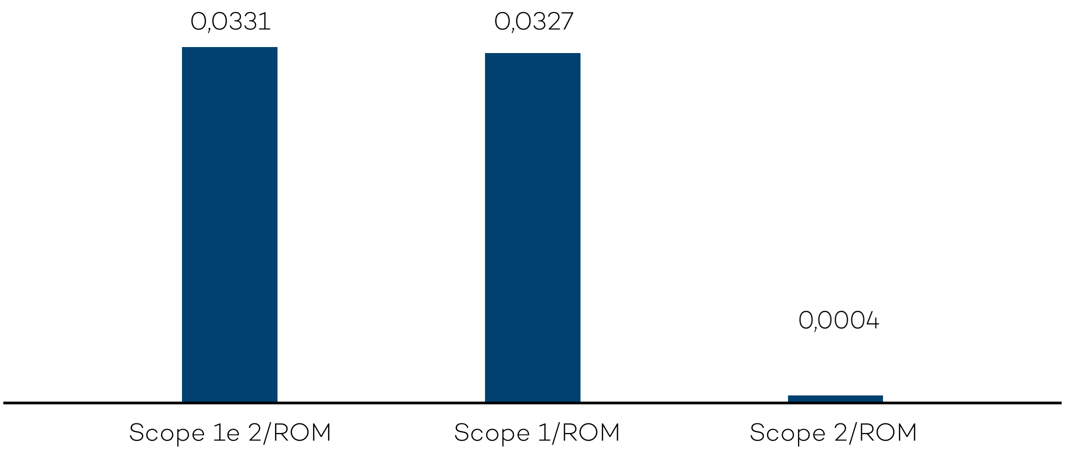
Table 9: Scope 1 e 2 – Bauxite

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**1.448.909,05**	**100,0%**	**98,8%**
Stationary combustion	532.782,44	36,8%	36,3%
Mobile combustion	239.787,85	16,5%	16,4%
Fugitives	3.091,23	0,2%	0,2%
Change of use of the soil	666.359,14	46,0%	45,5%
Industrial processes	-	0,0%	0,0%
Solid waste and liquid effluents	6.888,39	0,5%	0,5%
Scope 2	**16.976,33**	**100,0%**	**1,2%**
Energy - Location	16.976,33	100,0%	1,2%
Total (Scopes 1+2)	**1.465.885,38**	**100,0%**	**100,0%**

For this typology, the predominance of Scope 1 is noted, which represents almost 99% of the total direct emissions, with emphasis on the categories of change of use of the soil (45% of the total), which had not been reported in previous inventories, and stationary combustion (36% of the total). Scope 2 represented 1.2% of the emissions.

In relation to production, the total bauxite produced, according to ANM data, was 44,273,311.47 tons. The emission indicators can be seen in Figure 10

Figure 10: Indicators – Bauxite (tCO2e/tons of ore)



4.2.5 Limestone

Not having been accounted for in previous inventories, the emissions from limestone production collected in this work summed up to a total of 239,931.89 tCO2e. Table 10 presents the emissions of Scopes 1 and 2 for the total national movement in 2022.

Table 10: Scope 1 e 2 – Limestone

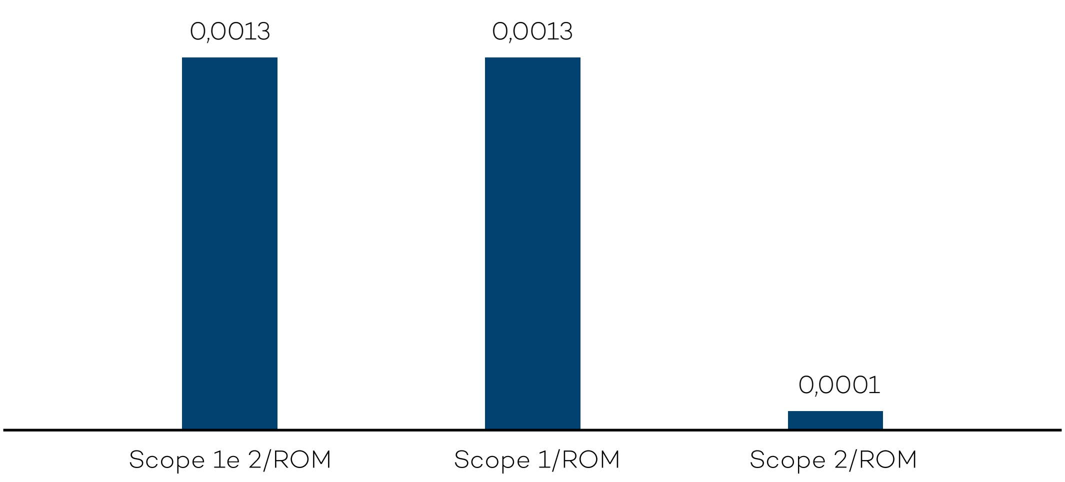
Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**224.804,25**	**100,0%**	**93,7%**
Stationary combustion	6.397,52	2,8%	2,7%
Mobile combustion	218.406,73	97,2%	91,0%
Fugitives	-	0,0%	0,0%
Change of use of the soil	-	0,0%	0,0%

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Industrial processes	-	0,0%	0,0%
Solid waste and liquid effluents	-	0,0%	0,0%
Scope 2	**15.127,65**	**100,0%**	**6,3%**
Energy - Location	15.127,65	100,0%	6,3%
Total (Scopes 1+2)	**239.931,89**	**100,0%**	**100,0%**

The results allow 94% of the emissions that are related to Scope 1 and 6% to Scope 2 to be observed, taking into account that 91% originate from mobile combustion and the other 2.5% from stationary combustion.

In what refers to production, the ANM disclosed the total of 179,147,725.53 tons of ROM produced in 2022. Figure 11 presents the results from indicators.

Figure 11: Indicators – Limestone (tCO_2e/tons of ore)



4.2.6 Mineral Coal

In 2022, the reported emissions for Scopes 1 and 2 (location approach) summed up to a total of 430,514.45 and 3,604.39 tCO_2e, respectively. Table 11 presents the results referring to the total national movement of mineral coal in 2022.

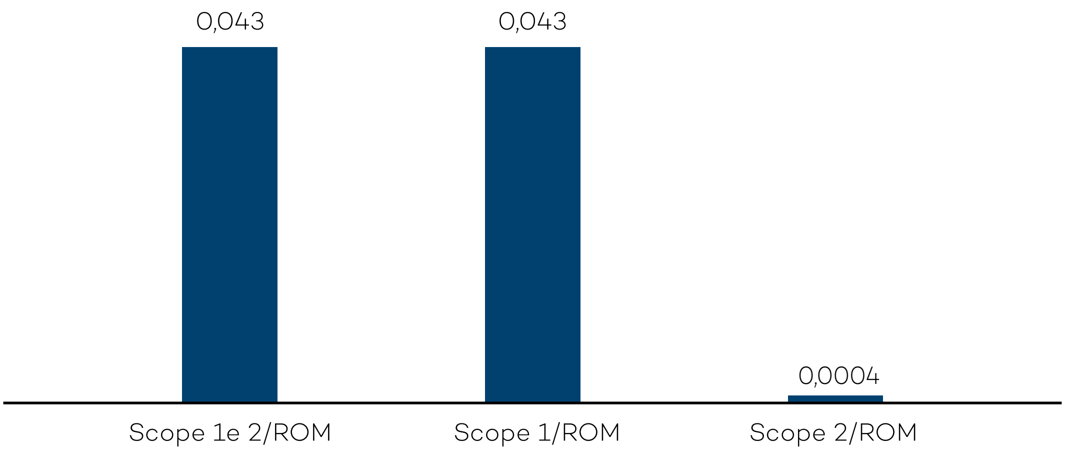
Table 11: Scope 1 e 2 – Mineral Coal

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**430.514,45**	**100,0%**	**99,4%**
Stationary combustion	443,54	0,0%	0,0%
Mobile combustion	11.597,95	1,1%	1,1%
Fugitives	418.455,25	98,8%	98,3%
Change of use of the soil	-	0,0%	0,0%
Industrial processes	-	0,0%	0,0%
Solid waste and liquid effluents	17,71	0,002%	0,002%
Scope 2	**3.604,39**	**100,0%**	**0,3%**
Energy - Location	3.604,39	100,0%	0,3%
Total (Scopes 1+2)	**434.118,83**	**-**	**100,0%**

It is possible to note that 99% of the emissions of Scope 1 are related to fugitive emissions. This happened as methane emissions were reported from the seam gas, which is a gas rich in methane that is emitted from deep mines.

In relation to production, it was 10,052,628.70 tons in 2022, according to data from ANM. The emission indicators can be seen in Figure 12.

Figure 12: Indicators – Mineral Coal (tCO2e/tons of ore)



4.2.7 Copper

For the third time, Copper emissions were considered in a sectoral inventory of the mining industry. It is possible to observe that Scope 1 is responsible for the majority of emissions of this typology, 92%, while Scope 2 represented 8%. Table 12 presents emissions segregated by category, referring to the national total in 2022.

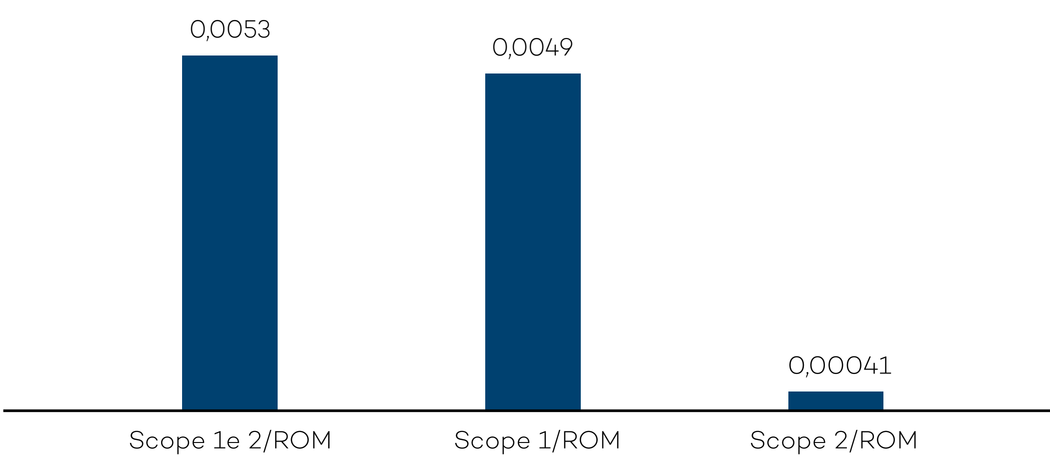
Table 12: Scope 1 e 2 - Copper

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**416.321,74**	**100%**	**92%**
Stationary combustion	585,62	0%	0%
Mobile combustion	404.982,98	97%	90%
Fugitives	2.816,13	1%	1%

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Change of use of the soil	-	0%	0%
Industrial processes	7.937,01	2%	2%
Solid waste and liquid effluents	-	0%	0%
Scope 2	**34.309,64**	**100%**	**8%**
Energy - Location	34.309,64	100%	8%
Total (Scopes 1+2)	**450.631,38**	**-**	**100%**

Finally, the analysis of emission indicators are in Figure 13.

Figure 13: Comparison of emission indicators - Copper (tCO2e/tons of ore)



4.2.8 Chromite

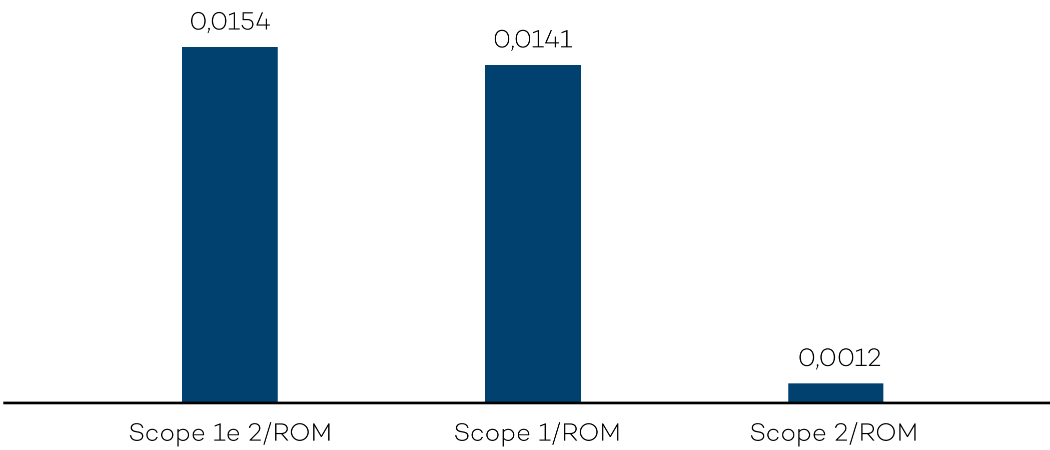
Chromite is being considered for the first time in the sectoral inventory of the mining industry. Table 13 presents the results of emissions referring to the total national movement of chromite in 2022.

Table 13: Scope 1 e 2 – Chromite

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**20.111,42**	**100%**	**92%**
Stationary combustion	-	0%	0%
Mobile combustion	20.111,42	100%	92%
Fugitives	-	0%	0%
Change of use of the soil	-	0%	0%
Industrial processes	-	0%	0%
Solid waste and liquid effluents	-	0%	0%
Scope 2	**1.776,52**	**100%**	**8%**
Energy - Location	1.776,52	100%	8%
Total (Scopes 1+2)	**21.887,94**	**-**	**100%**

Direct emissions from Scope 1 of chromite are composed exclusively of the mobile combustion category. In relation to production, the national production of Chromium was used, which is viable, since according to CETEM (2005), chromite is the only economically usable chromium mineral. Moreover, the ANM database only contains data for chromium. Based on the data, emission indicators were defined for scopes 1 and 2 in accordance with ROM production, which can be seen in Figure 14.

Figure 14: Indicators – Chromite (tCO2e/tons of ore)



4.2.9 Spodumene (Lithium)

Spodumene is being considered for the first time in the sectoral inventory of the mining industry. Table 14 presents the results of emissions referring to the total national movement of spondumene in 2022.

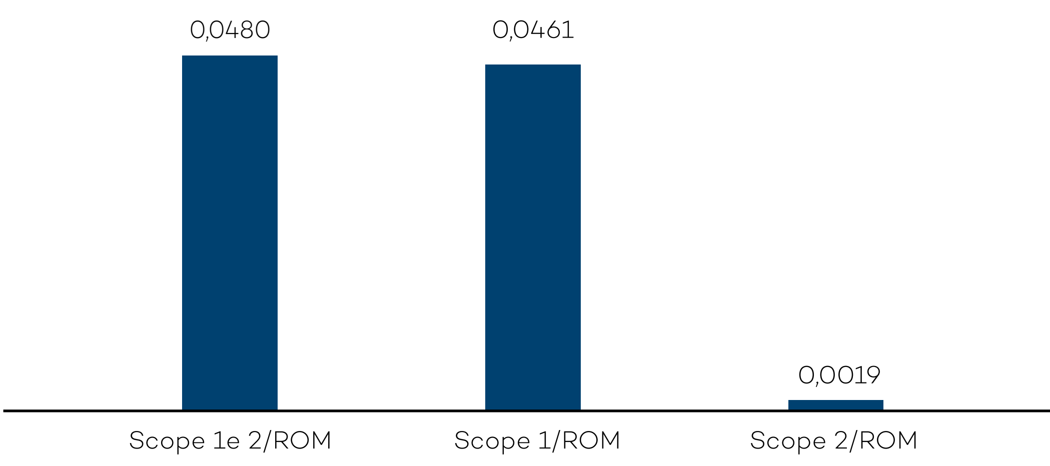
Table 14: Scope 1 e 2 - Spodumene

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**41.841,16**	**100%**	**96%**
Stationary combustion	3.938,86	9%	9%
Mobile combustion	37.902,30	91%	87%
Fugitives	-	0%	0%
Change of use of the soil	-	0%	0%

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Industrial processes	-	0%	0%
Solid waste and liquid effluents	-	0%	0%
Scope 2	**1.733,92**	**100%**	**4%**
Energy - Location	1.733,92	100%	4%
Total (Scopes 1+2)	**43.575,08**	**-**	**100%**

The emissions of Scope 1 of this typology comes from the mobile (91%) and stationary (9%) combustion categories. Scope 2 in turn, represents 4% of the emissions. In relation to production, the reported data were 703,787.17 tons, which corresponds to 77.5% of the national production. Based on the reported data, emission indicators were defined for scopes 1 and 2 in accordance with ROM production, which can be seen in Figure 15.

Figure 15 Indicators – Spodumene (Lithium) (tCO_2e/tons of ore)



4.2.10 Tin

Tin is being considered for the first time in the sectoral inventory of the mining industry. Table 15 presents the results of emissions referring to the total national movement of tin in 2022.

Table 15: Scope 1 e 2 - Tin

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**262.969,62**	**100%**	**100%**
Stationary combustion	43.468,26	17%	17%
Mobile combustion	54.628,56	21%	21%
Fugitives	1,16	0%	0%
Change of use of the soil	154.054,03	59%	59%
Industrial processes	8.932,15	3%	3%
Solid waste and liquid effluents	1.885,45	1%	1%
Scope 2	**-**	**0%**	**0%**
Energy - Location	-	0%	0%
Total (Scopes 1+2)	**262.969,62**	**-**	**100%**

In relation to Scope 1, all categories had their emissions accounted for, of which change of use of the soil, and mobile and stationary combustion were those of major representativeness. Together, these categories represent 96% of Scope 1. No emissions were reported for Scope 2.

Based on the emissions data and the national production from ANM, the emission indicator was calculated which is 0.012 tCO_2e/ton of ROM.

4.2.11 Iron

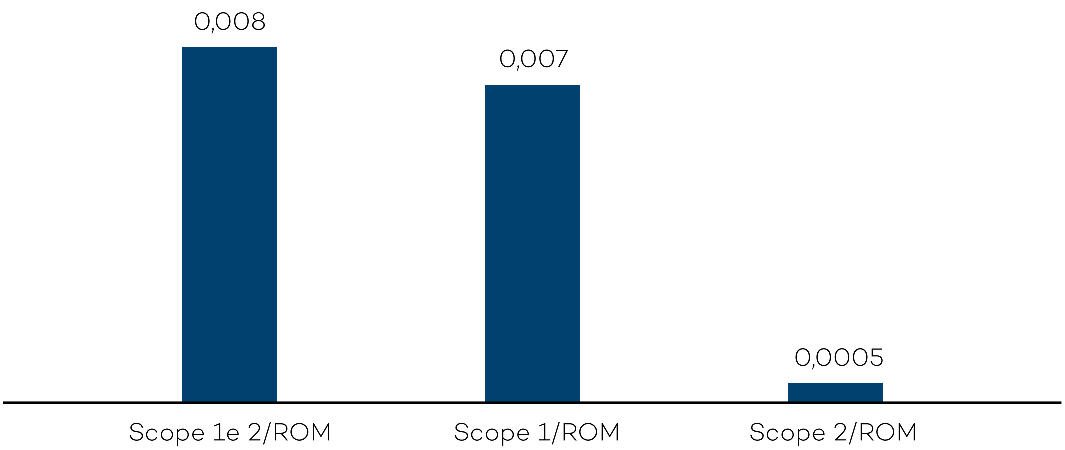
Iron has its emissions accounted for since the preparation of the 2008 Inventory. In 2022, the reported emissions of iron summed up to a total of 4,186,047.89 tCO_2e, considering the location approach for Scope 2. Table 16 presents the results of emissions referring to the total national movement of iron in 2022.

Table 16: Scope 1 e 2 – Iron

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**3.893.325,31**	**100,0%**	**93,0%**
Stationary combustion	60.718,51	1,6%	1,5%
Mobile combustion	3.442.393,13	88,4%	82,2%
Fugitives	18.389,79	0,5%	0,4%
Change of use of the soil	366.600,71	9,4%	8,8%
Industrial processes	330,36	0,009%	0,008%
Solid waste and liquid effluents	4.892,82	0,1%	0,1%
Scope 2	**292.722,57**	**100,0%**	**7,0%**
Energy - Location	292.722,57	100,0%	7,0%
Total (Scopes 1+2)	**4.186.047,89**	**-**	**100%**

It is noted that the main points of attention is the mobile combustion, originating from the consumption of fuels for the movement of machines, followed by the change of use of the soil, which represent currently 9% of the total emissions. Scope 2 represents 7% of the total emissions. The production emission intensity calculations are presented in Figure 16.

Figure 16: Indicators - Iron (tCO2e/tons of ore)



4.2.12 Phosphate

In 2022, the reported emissions for Scopes 1 and 2 (location approach) summed up to a total of 323,480.23 tCO2e. Table 17 presents the results of emissions referring to the total national movement of phosphate in 2022.

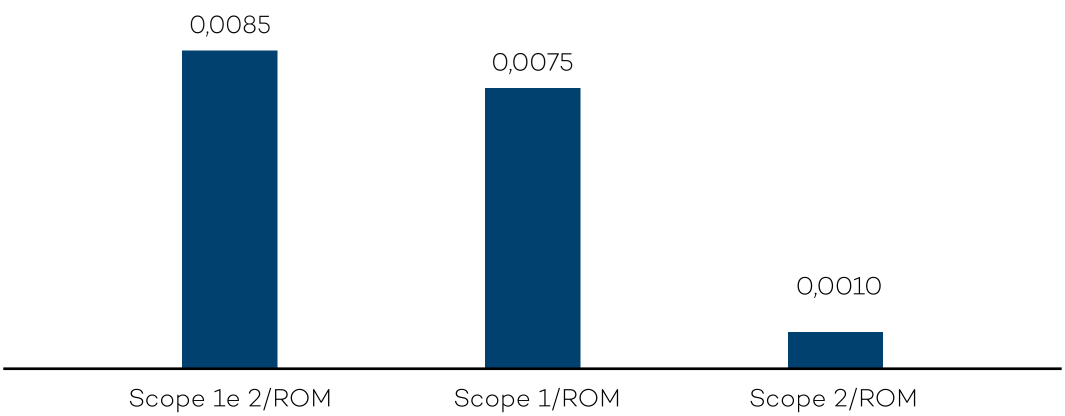
Table 17: Scope 1 e 2 – Phosphate

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**285.168,35**	**100,0%**	**88,2%**
Stationary combustion	11.654,22	4,1%	3,6%
Mobile combustion	197.462,28	69,2%	61,0%
Fugitives	1.483,92	0,5%	0,5%
Change of use of the soil	73.342,55	25,7%	22,7%
Industrial processes	184,19	0,1%	0,1%

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Solid waste and liquid effluents	1.041,18	0,4%	0,3%
Scope 2	**38.311,88**	**100,0%**	**11,8%**
Energy - Location	38.311,88	100,0%	11,8%
Total (Scopes 1+2)	**323.480,23**	**-**	**100,0%**

Finally, the analysis of emission indicators are in Figure 17.

Figure 17: Indicators – Phosphate (tCO_2e/tons of ore)



4.2.13 Magnesite

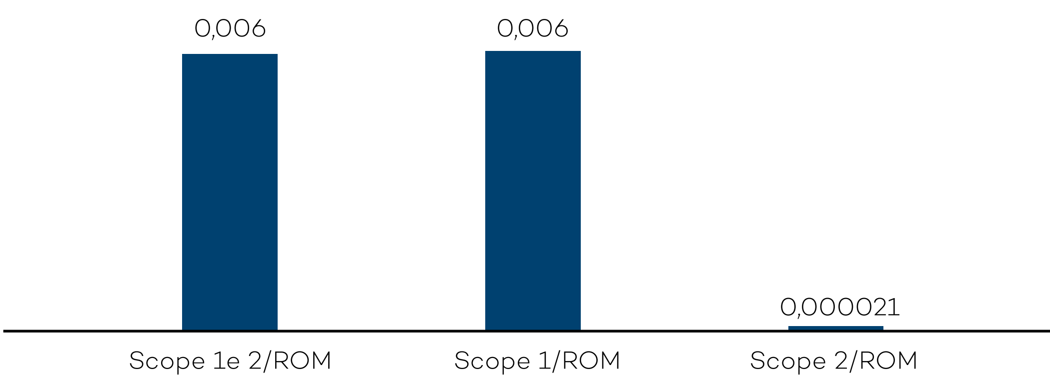
The magnesite typology is being considered for the first time in the sectoral inventory of the mining industry. In 2022, the reported emissions for Scopes 1 and 2 (location approach) summed up to a total of 61,638.32 tCO_2e. Table 18 presents the results of emissions referring to the total movement of magnesite in 2022. It is important to point out that the extrapolation of magnesite was carried out based on the "dolomite and magnesite" data from ANM. For this typology, only mobile combustion emissions were reported.

Table 18: Scope 1 e 2 - Magnesite

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**61.436,47**	**100%**	**100%**
Stationary combustion	-	0%	0%
Mobile combustion	61.436,47	100%	99,7%
Fugitives	-	0%	0%
Change of use of the soil	-	0,0%	0%
Industrial processes	-	0,0%	0%
Solid waste and liquid effluents	-	0,0%	0%
Scope 2	**201,86**	**100%**	**0%**
Energy - Location	201,86	100%	0,3%
Total (Scopes 1+2)	**61.638,32**	**-**	**100%**

Based on the data, emission indicators were defined for scopes 1 and 2 in accordance with ROM production, which can be seen in Figure 18.

Figure 18: Indicators – Magnesite (tCO_2e/tons of ore)



4.2.14 Niobium

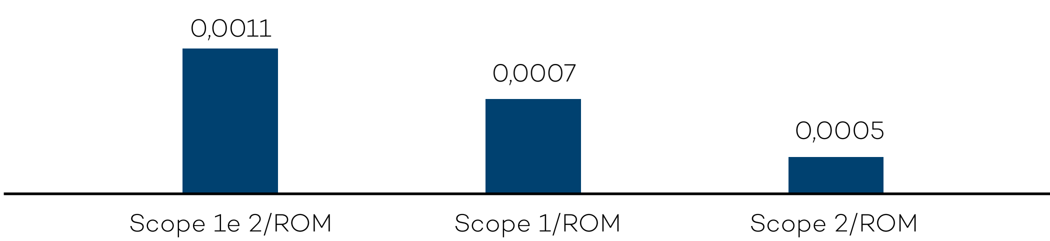
In 2022, the reported emissions for Scopes 1 and 2 (location approach) summed up to a total of 19,529.86 tCO_2e. Table 19 presents the results of emissions referring to 100% movement of niobium in 2022.

Table 19: Scope 1 e 2 - Niobium

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**61.436,47**	**100%**	**100%**
Stationary combustion	-	0%	0%
Mobile combustion	61.436,47	100%	99,7%
Fugitives	-	0%	0%
Change of use of the soil	-	0,0%	0%
Industrial processes	-	0,0%	0%
Solid waste and liquid effluents	-	0,0%	0%
Scope 2	**201,86**	**100%**	**0%**
Energy - Location	201,86	100%	0,3%
Total (Scopes 1+2)	**61.638,32**	**-**	**100%**

The emission indicators are in Figure 19.

Figure 19: Indicators – Niobium (tCO_2e/tons of ore)



4.2.15 Nickel

In 2022, the reported emissions for Scopes 1 and 2 (location approach) summed up to a total of 242,658.43 tCO_2e. Table 20 presents the results of emissions referring to the total movement of nickel in 2022.

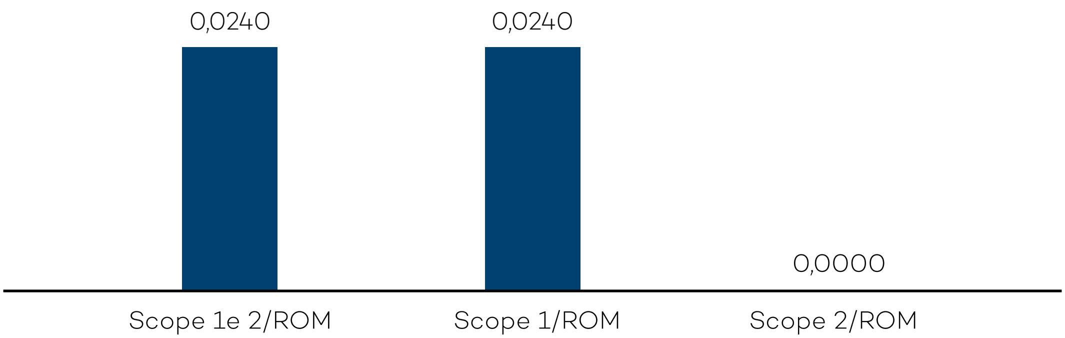
Table 20: Scope 1 e 2 - Nickel

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**242.658,43**	**100%**	**100%**
Stationary combustion	56.156,69	23%	23%
Mobile combustion	30.405,37	13%	13%
Fugitives	1,06	0%	0%
Change of use of the soil	155.944,61	64,3%	64%
Industrial processes	-	-	-
Solid waste and liquid effluents	150,71	0,1%	0%
Scope 2	**1,32**	**100%**	**0%**
Energy - Location	1,32	100%	0%
Total (Scopes 1+2)	**242.659,75**	**-**	**100%**

It is possible to note that 64% of the emissions of Scope 1 are related to change of use of the soil. This happened, as one of the mining companies that reported data had the license only for the execution of stripping, which is the movement of the surface layer of the soil, which resulted in large emissions in this category.

The emission indicators are in Figure 20.

Figure 20: Indicators – Nickel (tCO2e/tons of ore)



4.2.16 Gold

In 2022, the emissions of Gold summed up to a total of 2,412,104.63 tCO_2e, considering the location approach for Scope 2. Table 21 presents the results of emissions referring to 100% movement of gold in 2022.

Table 21: Scope 1 e 2 – Gold

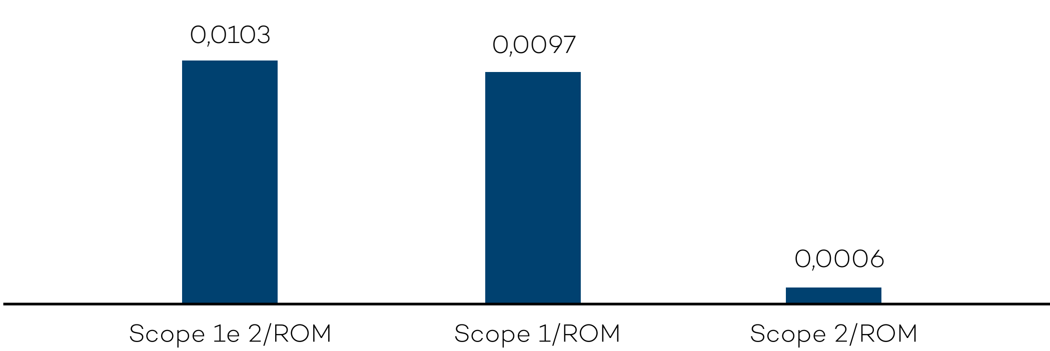
Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**2.277.692,22**	**100%**	**94%**
Stationary combustion	130.627,26	6%	5%
Mobile combustion	1.502.616,99	66%	62%
Fugitives	1,39	0%	0%
Change of use of the soil	367.686,00	16,1%	15%
Industrial processes	272.940,79	12,0%	11%
Solid waste and liquid effluents	3.819,79	0,2%	0%

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 2	**134.412,41**	**100%**	**6%**
Energy - Location	134.412,41	100%	6%
Total (Scopes 1+2)	**2.412.104,63**	**-**	**100%**

As well as for Iron, the most representative emission categories for Gold are mobile combustion (62% of the total emissions) and change of use of the soil (15%). The industrial processes category has a representativeness of 11%. These emissions are those that do not originate from combustion, and may be associated with the use of chemical products and reduction processes, for example.

The production emission indicators are in Figure 21.

Figure 21: Indicators – Gold (tCO_2e/tons of ore)



4.2.17 Potassium

Potassium emissions are accounted for since the preparation of the first inventory conducted in 2008. Table 22 presents the results of emissions referring to 100% movement of potassium in 2022.

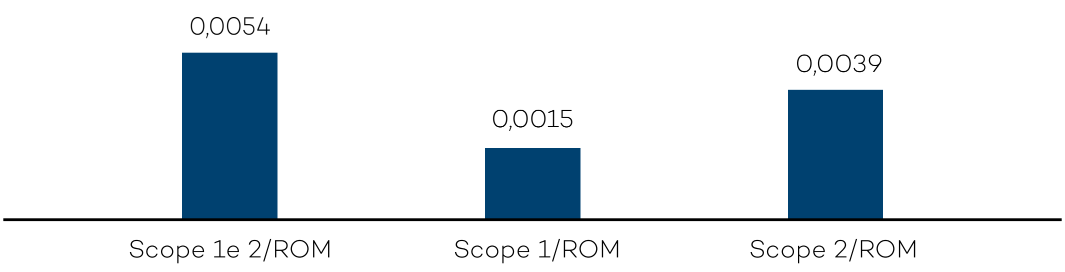
Table 22: Scope 1 e 2 – Potassium

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**3.926,32**	**100%**	**28%**
Stationary combustion	84,38	2%	1%
Mobile combustion	3.841,94	98%	27%
Fugitives	-	-	-
Change of use of the soil	-	-	-
Industrial processes	-	-	-
Solid waste and liquid effluents	-	-	-
Scope 2	**10.112,16**	**100%**	**72%**
Energy - Location	10.112,16	100%	72%
Total (Scopes 1+2)	**14.038,48**	**100%**	**%**

The use of electrical energy showed to be relevant for this typology, representing 72% of the total emissions of Scopes 1 and 2. The acquisition of electrical energy had already been pointed out as important for potassium in previous inventories of the mining sector.

The emission indicators are in Figure 22.

Figure 22: Indicators – Potassium (tCO2e/tons of ore)



4.2.18 Vanadium

Vanadium had its emissions accounted for, for the first time in an inventory of the mining industry. The collected data corresponded to the total national production, according to the report of ANM. Therefore, there was no extrapolation of data for this typology. In 2022, the emissions summed up to a total of 85,810.23 tCO_2e, considering the location approach for Scope 2 (Table 23).

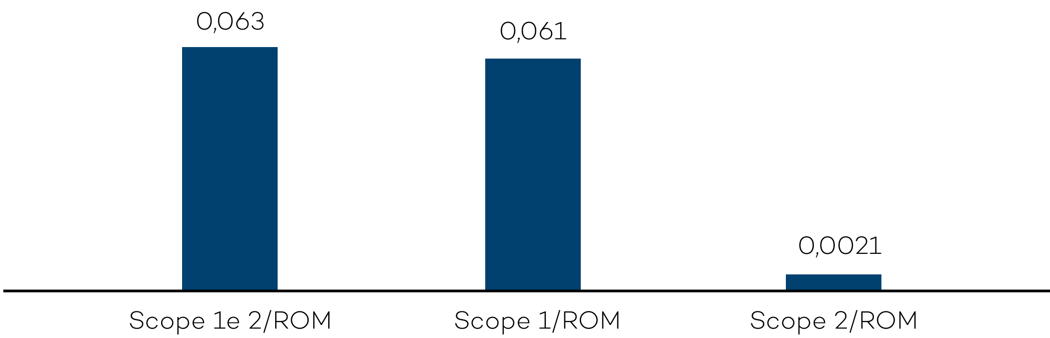
Table 23: Scope 1 e 2 – Vanadium

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**82.979,95**	**100%**	**97%**
Stationary combustion	51.444,01	62%	60%
Mobile combustion	17.039,70	21%	20%
Fugitives	96,94	0%	0%
Change of use of the soil	-	-	-
Industrial processes	14.366,79	17,3%	17%
Solid waste and liquid effluents	32,52	0,0%	0%
Scope 2	**2.830,28**	**100%**	**3%**
Energy - Location	2.830,28	100%	3%
Total (Scopes 1+2)	**85.810,23**	**-**	**100%**

When analyzing the results, it is possible to observe that 83% of the emissions in Scope 1 come from combustion processes, mainly stationary combustion, which represents 62% of the direct emissions of this typology. Scope 2, in turn, summed up to a total of 2,830.28 tCO_2e, representing 3% of the total.

Based on production data and emissions, the emission indicators were calculated and are shown in Figure 23.

Figure 23: Indicators – Vanadium (tCO_2e/tons of ore)



4.2.19 Zinc

In 2022, the reported emissions summed up to a total of 43,131.30 tCO_2e, considering the location approach for Scope 2. Table 24 presents the results of emissions referring to 100% movement of zinc in 2022.

Table 24: Scope 1 e 2 – Zinc

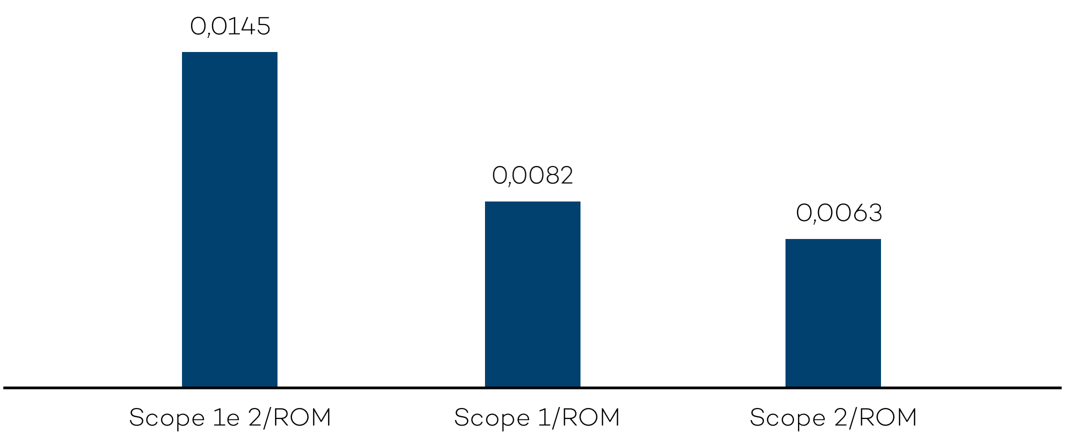
Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**24.385,01**	**100,0%**	**56,5%**
Stationary combustion	338,09	1,4%	0,8%
Mobile combustion	22.623,17	92,8%	52,5%
Fugitives	1.000,91	4,1%	2,3%
Change of use of the soil	12,06	0,05%	0,03%
Industrial processes	325,55	1,3%	0,8%
Solid waste and liquid effluents	85,23	0,3%	0,2%

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 2	**18.746,29**	**100,0%**	**43,5%**
Energy - Location	18.746,29	100,0%	43,5%
Total (Scopes 1+2)	**43.131,30**	**-**	**100,0%**

In Scope 1, the predominance of the mobile combustion category is noted, which represents 92.8% of this scope. Notwithstanding, by analyzing Scopes 1 and 2 together, the high representativeness of the acquisition of electricity in Scope 2 is noted, configuring a point of attention for this typology, with 43.5% of the total emissions.

The production emission indicators are in Figure 24.

Figure 24: Indicators – Zinc (tCO_2e/tons of ore)



4.3 Results from direct emissions (Scopes 1 and 2) of typologies calculated with primary data

4.3.1 Ornamental rocks

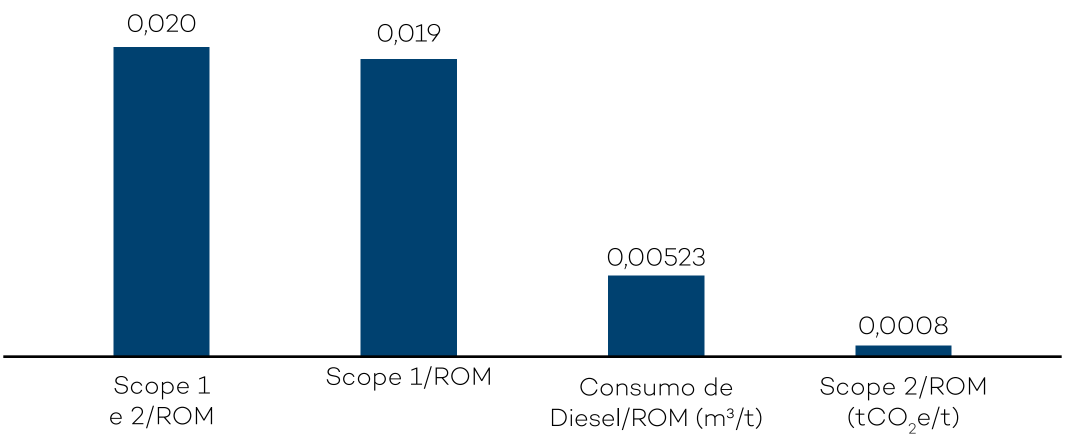
Ornamental rocks (marble, granite and quartzite) had their emissions accounted for, for the first time in 2011. On that occasion, Scope 1 emissions were estimated using literature data. In this inventory, primary production data, fuel and electrical energy consumption were collected to calculate Scope 1 and 2 emissions for this typology, which were later extrapolated to national production. The result is presented in Table 25.

Table 25: Scope 1 e 2 - Ornamental rocks

Scope	Result (tCO_2e)	Representativeness in the scope itself	Representativeness all in all
Scope 1	**92.352,41**	**100%**	**13%**
Stationary combustion	67.906,67	74%	71%
Mobile combustion	24.445,74	26%	25%
Fugitives	-	0%	0%
Change of use of the soil	-	0%	0%
Industrial processes	-	0%	0%
Solid waste and liquid effluents	-	0%	0%
Scope 2	**3.752,23**	**100%**	**4%**
Energy - Location	3.752,23	100%	4%
Total (Scopes 1+2)	**96.104,64**	**-**	**100%**

For the first time, electrical energy consumption data were collected from this mineral asset. The results showed that Scope 2 represented 4% of the total emissions. The emission indicators of Scopes 1 and 2, as well as diesel consumption, are in Figure 25.

Figure 25: Indicators - Ornamental rocks (tCO_2e/tons of ore)



4.4 Results from direct emissions (Scopes 1 and 2) of typologies calculated with premises

4.4.1 Gravel

Emissions from gravel were accounted for, for the first time in 2011. This estimation took place that year through a survey of data using the Scope of emissions from a sand and gravel extraction mining company. The data came grouped in such a way that it was necessary to use the total movement of each of the typologies, gravel and sand, to estimate the total emissions by mineral typology.

This year, in turn, the emissions of Scope 1 and 2 were estimated using information on fuel and electricity consumption from Ecoinvent, which is a database where it is possible for the lyfe cycle evaluation (LCE) of various products to be obtained. The data proved to be coherent with the standard operation, since it is known that the combustion of equipment, such as vehicles and machinery, and the electrical power consumption are sources of representative emissions for the activity. Table 26 presents the premises used.

Table 26: Premises used to estimate the gravel emissions

Diesel consumption per kg of ROM (MJ)	Electrical power consumption per kg of ROM (kWh)	Movement of ROM (t)
(kWh)	Movimentação de ROM (t)	266.000.000,00

The emission factors (EF) of commercial diesel oil were made available by the GHG Protocol and the electrical power consumption from GRID were made available by MCTI (Table 27).

Table 27: Emission factors (EF) of Scope 1 - Gravel

Diesel EF ($kgCO_2e/MJ$)	Electrical power EF (2022) ($kgCO_2e/kWh$)
0,074	0,04

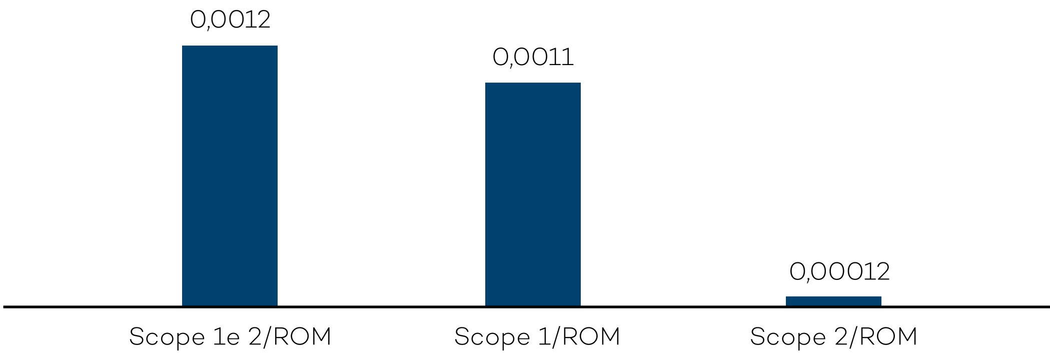
In possession of the information, the direct emissions for gravel were calculated. The result is presented in Table 28.

Table 28: Emissions of Scopes 1 and 2 - Gravel

Scope 1 ($kgCO_2e$)	Scope 2 ($kgCO_2e$)	Total ($kgCO_2e$)
290.565,66	30.771,03	321.336,69

The emission indicators are in Figure 26.

Figure 26: Indicators - Gravel (tCO_2e/tons of ore)



4.4.2 Cobalt

The cobalt emissions were estimated for the first time in a sectoral inventory of the mining industry. No data of emissions were obtained referring to this typology and, in this case, the emissions were estimated considering the diesel oil and energy consumption per ton of ROM produced, using data available in Ecoinvent. Now the production data came from a large mining company. Table 29 presents the premises used in the calculation.

Table 29: Premises used to estimate the Cobalt emissions

Diesel consumption per t of ROM (MJ)	Electrical power consumption per t of ROM (kWh)	Movement of t of ROM
12,34	367,00	2.434.000,00

The emission factors were obtained using the GHG Protocol calculation tool, and these are presented in Table 30.

Table 30: Emission factors (EF) used to estimate the cobalt emissions

Diesel EF ($kgCO_2e/MJ$)	Electrical power EF (2022) ($kgCO_2e/kWh$)
0,074	0,04

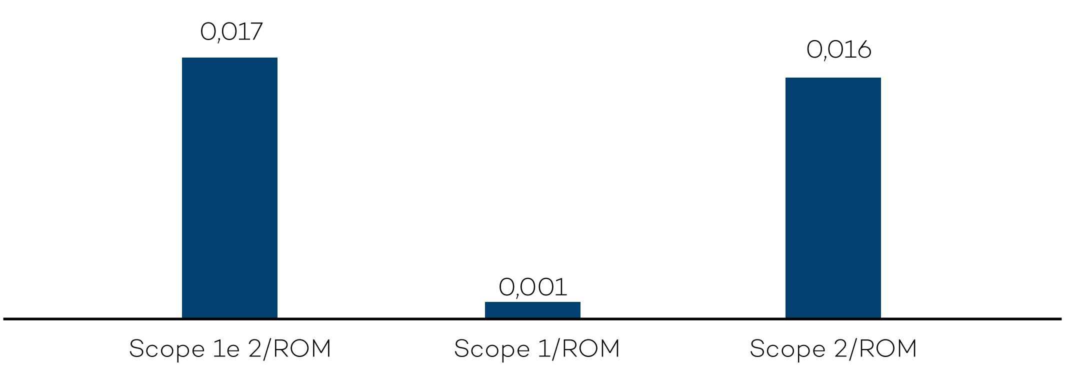
The analysis of the results of the emissions (Table 31) showed that 94% of the emissions are allocated in Scope 2 and 6% in Scope 1. The emissions summed up to a total of 40,281.60 tCO_2e.

Table 31: Emissões dos Scope 1 e 2 - Cobalt.

Scope1	Scope2	Total
2.231,93	38.049,67	40.281,60

Finally, the emission indicators per ton of ROM produced were obtained and are presented in Figure 27.

Figure 27: Indicators – Cobalt (tCO_2e/tons of ore)



4.4.3 Gypsum

Gypsum had its emissions estimated for the first time in 2011. On that occasion, the emissions were estimated based on fuel consumption per ton of ROM. This information was obtained through the class association. This occurred in 2011 because it was not possible to obtain data in relation to individual production from the companies and/or the corresponding emissions.

This year, for similar reasons, the emissions were also estimated based on fuel consumption. This estimate continues to be possible, since it is known that the total emissions of this typology come mainly from the combustion of mobile equipment, such as vehicles and machinery (Table 32). The emission factor considered was that of commercial diesel oil made available by the GHG Protocol

Table 32: Premises used to estimate the Gypsum emissions

Diesel consumption per t of ROM (L/ton)	Movement of t of ROM	Diesel consumption in liters - Total
1,3	5.155.339,54	6.873.786,05

In possession of the information, the direct emissions for Gypsum were calculated. The result is presented in Table 33.

Table 33: Emissions of Scope 1 - Gypsum

Diesel EF (kg CO_2e/L)	Scope 1 (tCO_2e)
2,63	18.143,63

The emission indicators was 0,0035 tCO_2e/tons of ore

4.4.4 Lead

It also had its emissions estimated for the first time in a sectoral inventory of the mining industry, like the previous typologies. The calculations for lead were also made using the premises obtained using the Ecoinvent database. Table 34 presents the premises used in the calculation.

Table 34: Premises used to estimate the Lead emissions

Diesel consumption per t of ROM (t)	Electrical power consumption per t of ROM (kWh)	Movement of t ofROM
0,020	436,45	2.971.892,15

The emission factors were obtained using the GHG Protocol calculation tool, and these are presented in Table 35.

Table 35: Emission factors (EF) used to estimate the lead emissions

Diesel EF (tCO_2e/t)	Electrical power EF (2022) ($kgCO_2e/kWh$)
3,142309095	0,04

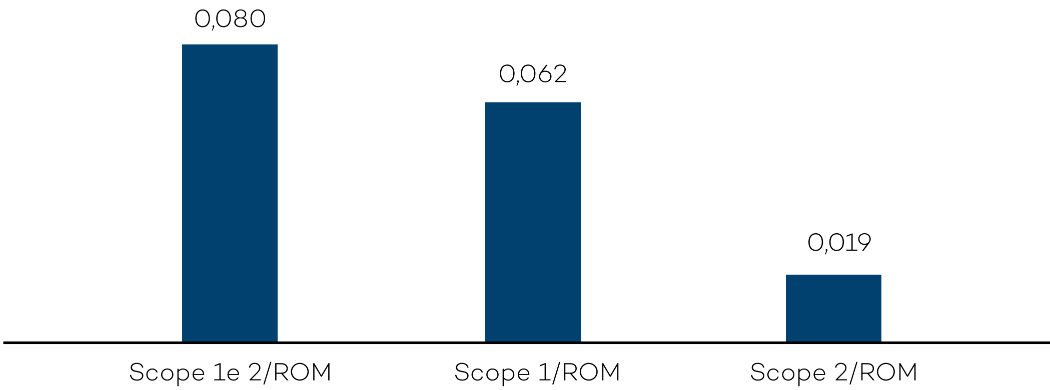
The analysis of the calculations of the emissions (Table 36) showed that 77% of the emissions are allocated in Scope 1 and 23% in Scope 2. The emissions summed up to a total of 238,721.90 tCO_2e.

Table 36: Emissões dos Scopes 1 e 2 - Lead

Scope1	Scope2	Total
183.472,35	55.249,55	238.721,90

Finally, the emission indicators per ton of ROM produced were obtained and are presented in Figure 28.

Figure 28: Indicators – Lead (tCO_2e/tons of ore)



4.4.5 Silver

Silver had its emissions estimated for the first time in a sectoral inventory of the mining industry. Similarly to what happened with gypsum, no emission data were obtained referring to this typology. Although, given its relevance and with the intention of encompassing the largest possible number of typologies in this report, the silver emissions were estimated considering the energy diesel oil consumption (KWh) per ton of ROM produced. These data were obtained using Ecoinvent. Table 37 presents the premises used in the calculation.

Table 37: Premises used to estimate the Silver emissions

Diesel consumption per t of ROM (t)	Electrical power consumption per t of ROM (kWh)	Movement of t ofROM
1495	466,02	936.265,37

In turn, the emission factors were obtained using the GHG Protocol calculation tool, and these are presented in Table 38.

Table 38: Emission factors (EF) used to estimate the Silver emissions

Diesel EF (kgCO_2e/MJ)	Electrical power EF (2022) (kgCO_2e/kWh)
0,074309667	0,04

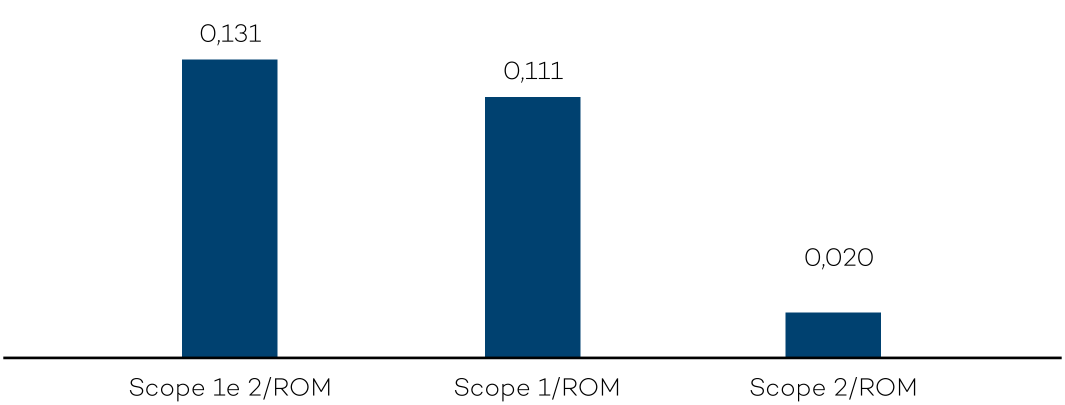
The analysis of the calculations of the emissions (Table 39) showed that 85% of the emissions are allocated in Scope 1 measured here using the fuel consumption, and 15% in Scope 2. The emissions summed up to a total of 122,597.67 tCO_2e.

Table 39: Emissions of Scopes 1 and 2 - Silver

Scope1	Scope2	Total
104.012,48	18.585,19	122.597,67

Finally, the emission indicators per ton of ROM produced were obtained and are presented in Figure 29.

Figure 29: Indicators – Silver (tCO_2e/tons of ore)



4.4.6 Kaolin

Kaolin has its emissions accounted for since the 2008 Inventory. In the 2011 inventory, due to a lack of collection data, its emissions were estimated from the results found for 2008, assuming at that time that there was no significant change in the process that could alter the indicator. For the year 2022, the emissions were estimated using information on electrical power consumption from Ecoinvent, and this is because according to the literature, Kaolin mining only uses electricity and heat. Table 40 presents the premises used.

Table 40: Premises used to estimate the Kaolin emissions

Electrical power consumption per t of ROM (kWh)	Movement of t ofROM
0,18	2.968.686,23

The emission factor was obtained using the GHG Protocol calculation tool, and these are presented in Table 41.

Table 41: Emission factors (EF) used to estimate the kaolin emissions

Electrical power EF (2022) ($kgCO_2e/kWh$)
0,04

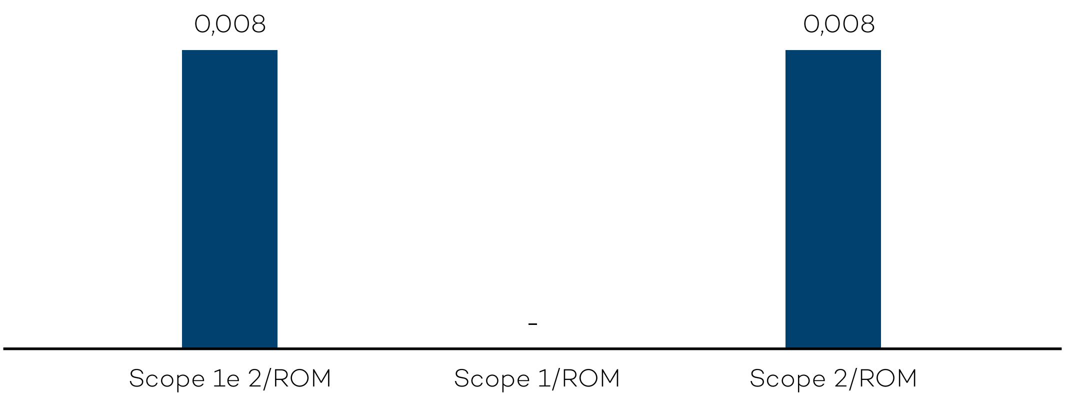
Due to the premise present in the database, only the emissions of Scope 2 for Silver were calculated, whose result is in Table 44

Table 42: Emissions of Scope 2 - Silver

Scope2	Total
22.761.507,33	22.761.507,33

The emission indicators are in Figure 30.

Figure 30: Indicators – Kaolin (tCO_2e/tons of ore)



4.4.7 Manganese

For the third time, manganese emissions are being accounted for in an inventory of the mining industry. However, this year no data were reported for this typology, due to this it was decided to use the indicators from the 2011 inventory, assuming that there were no changes in production rounds that could impact the emissions. Table 43 presents the values used.

Table 43: Premises used to estimate the Manganese emissions

Scope 1/ROM	Scope 2/ROM	ROM
0,00628	0,00008	2.259.826,20

The analysis of the calculations of the emissions (Table 44) showed that 99% of the emissions are allocated in Scope 1 and 1% in Scope 2. The emissions summed up to a total of 14,370.02 tCO_2e.

Table 44: Scope 1 e 2 - Manganese

Scope1	Scope2	Total
14.188,61	181,41	14.370,02

4.5 Results from indirect emissions (Scope 3)

According to a survey conducted by the Carbon Disclosure Project (CDP) (CDP, 2023), the representativeness of Scope 3 in the total emissions of the mining and metallurgy sectors reaches 92%. Although the two sectors may be considered jointly, the CDP document highlights the importance of category 10, processing of sold products, for the mining sector, given its activity of supply of inputs for transformation into other products.

4.5.1 GHG emissions from category 10 (processing of sold product)

Emissions from category 10 correspond to the transformation of ore into other products. For most typologies, this category represents emissions from the metallurgy stage, where there is high energy consumption and chemical transformations capable of releasing greenhouse gases. The calculations were structured as follows:

- For 6 of the 27 typologies, the result was reported by the companies, together with the mass of processed ore;
- For the other 12 typologies, the emissions were estimated based on literature data. In this case, it was necessary to use premises to define a specific processing for each metal that would be the most representative for that typology.

This processing was defined in communication with the mining companies that reported Scope 1 and 2 data, with IBRAM and data from the Mining Summary;

- For 8 typologies, processing emissions were not considered as it was understood that these do not undergo significant transformations and, consequently, representative emissions, in their most common use, including vanadium, for which no references were found in the literature on GHG emissions from its most common processing.

- For 1 typology, mineral coal, calculations were carried out for the use of the product, referring to category 11 of Scope 3, at the expense of processing (category 10). This decision was made considering that the main use of coal is burning, whose emissions are included in category 11.

For all typologies, the emission results were extrapolated to the national scenario using the 2022 processed ore production, as disclosed by ANM in the Brazilian Mineral Yearbook. Although this data reflects the mass processed in the country, it is possible that these processing emissions may have not occurred entirely within the national territory, since the processes involved in the processing chain may partially occur abroad.

The classifications of each typology are in Table 45.

Table 45: Consideration of Category 10 of each typology

Classification	Typology
Data reported by the companies	Clay
	Chromite
	Tin
	Nickel
	Iron
	Magnesite

Classification	Typology
Calculations using the premises and literature data	Bauxite
	Spodumene (Lithium)
	Niobium
	Potassium
	Limestone
	Gypsum
	Lead
	Cobalt
	Manganese
	Zinc
	Phosphate
	Copper
	Mineral Coal*
Were not considered	Agalmatolite
	Ornamental Rocks
	Sand
	Gravel
	Kaolin
	Vanadium
	Gold
	Silver

* For Coal, emissions from burning the product were calculated, which corresponds to category 11

For the typologies whose emissions were calculated using the premises, the emission factor due to production of the generated product after processing was sought and a mass balance was performed to calculate the result per mass of ore. Table 46 contains all the information referring to the premises adopted for these typologies.

Table 46: Processing data used in the typologies considered using premises

Typology	Assumed processing	Source	Reference	Exclusions or adaptations	Emission factor (tCO2e/t product)	Ore mass per product mass	Final result (tCO2e/t ore)
Bauxite	Aluminum	IAI, 2023, Ecoinvent	Global emission factor	Bauxite mining and refinement. Ecoinvent data were used for execution of mass balance	12.400	4.653	2.665
Spodumene (Lithium)	Lithium Carbonate	Ecoinvent	lithium carbonate production, from spodumene | Allocation: Cut-off - RoW. Base Version: 3.9.1	Mining	8.527	8.299	1.027
Niobium	Ferroniobium	Dolganova et al., 2019	Study developed in Brazil.	Mining (approximately 40% of the total result)	4.560	2.200	2.073
Potassium	Potassium Chloride	Ecoinvent	potassium chloride production | Allocation: Cut-off - RoW. Base Version: 3.9.1	Mining	0.382	2.209	0.173
Limestone	Cement	SNIC, 2021; Ecoinvent	Study developed in Brazil	Ecoinvent data were used for execution of mass balance	0.565	0.824	0.686
Gypsum	Plaster	Ecoinvent, ANM	gypsum plasterboard production | Allocation: Cut-off - RoW. Base Version: 3.9.1	Mining Summary Data (ANM, 2019) used for the mass balance	0.146	1.250	0.117
Lead	Primary lead	Ecoinvent	primary lead production from concentrate | Allocation: Cut-off - RoW. Base Version: 3.9.1	Mining and flotation	2.265	1.663	1.362
Cobalt	Cobalt sulfate	Zhang et al., 2021	Study based in China	Mining (approximately 5% of the total result). It is assumed that 0.25 t of cobalt (mineral) is needed for every 1 t of cobalt sulfate.	33.820	0.250	8.455
Manganese	Ferromanganese	Ecoinvent	ferromanganese production, high-coal, 74.5% Mn | Allocation: Cut-off - RoW. Base Version: 3.9.1	Mining and concentration	2.956	2.330	1.269
Zinc	Primary zinc	Ecoinvent	primary zinc production from concentrate | zinc | Allocation: Cut-off - RoW. Base Version: 3.9.1	Mining	1.691	1.327	1.274
Phosphate	P2O5 (32%)	Ecoinvent	phosphate rock, beneficiated | Allocation: Cut-off - RoW. Base Version: 3.9.1	Mine infrastructure process and land use flows	0.101	0.320	0.032
Copper	Copper Cathode	Ecoinvent	electrorefining of copper, anode | copper, cathode | Allocation: Cut-off - RoW. Base Version: 3.9.1	Mining and concentration	3.942	3.306	1.193
Mineral Coal*	Burning in stationary combustion	GHG Protocol Brazil - tool version 2023.0.3	National Metallurgical Coal - Stationary Combustion		2.554	1.000	2.554

* For Coal, emissions from burning the product were calculated, which corresponds to category 11

In Table 47, we have the absolute emissions from processing of the product of the typologies considered in the 2024 Inventory of Greenhouse Gas Emissions in the Mining Sector.

Table 47: Absolute emissions from processing of the product of the typologies considered in the 2024 mining sector inventory

	Typology	Mass beneficiated in 2022 (ANM, 2024)	Extrapolated emissions (tCO_2e)
Calculated from the reported data	Clay	6.203.334,530	3.488.010,181
	Chromite	565.574,810	8.752,979
	Tin	13.399,216	14.522,951
	Iron	411.427.979,580	522.571.688,691
	Pellet	41.565.435,18***	3.113.187,32
	Magnesite	16.654.359,460	16.467.600,812
Calculated from premises and literature data	Bauxite	31.608.693,910	84.227.601,246
	Spodumene (Lithium)	143.719,730	147.663,913
	Niobium	3.925.240,849	8.135.953,759
	Potassium	301.876,820	52.148,483
	Limestone	141.610.807,153	97.146.801,896
	Gypsum	3.203.473,810	373.550,674
	Nickel	360.615,890	676.130,066
	Lead	29.416,770	40.065,864
	Cobalt	167.818,150*	1.418.902,458
	Manganese	1.344.154,960	1.705.317,078
	Zinc	417.963,820	532.560,542
	Phosphate	9.719.980,680	3.067.699,902
	Copper	1.024.424,510	1.221.692,110
	Mineral Coal**	6.985.388,420	17.842.182,074
	Total	**677.105.840,10**	**762.252.033,00**

* The same premise used for ROM, as it is not included in ANM.

** Considering emissions from burning.

*** Sum of the production of two large mining companies.

4.5.2 Scope 3 completeness assessment

In its Scope 3 Emissions Accounting and Reporting Guidance, the ICMM provides a reference for representative emissions within Scope 3, that is, categories that tend to be relevant in the Scope for each group of metals. The definition of these emissions aims to help companies, especially those that do not yet calculate Scope 3, to prioritize the calculation of categories according to their materiality and, subsequently, evaluate their inclusion in the GHG inventory.

In this case, the completeness assessment aims to identify whether, within each typology, those categories classified as relevant by the ICMM were considered and, therefore, should receive priority for future inclusion in the emissions report. The ICMM provides recommendations by metal categories, presented in Table 48.

The expansion of scope 3 is becoming increasingly strategic, as it allows for a complete and transparent view of GHG emissions. This facilitates the identification of opportunities for emission reduction, risk management in the supply chain and reputational strengthening of mining, promoting long-term sustainability and competitiveness for the entire value chain.

One mechanism that can be used in this process is screening, which is a more simplified analysis, usually using financial data due to its availability, to assess the materiality of an emissions category and decide whether to include it in the calculation.

Table 48: Definitions of metal categories, according to ICMM

Bulky Metals	Metal ores, metal oxides, metallurgical coal, thermal coal and, mainly, unprocessed minerals - may include iron.
Base Metals	Primary non-ferrous metals, such as copper, aluminum, lead, nickel, tin and zinc, as well as related metal alloys, which may or may not include iron.
Precious Metals	Main commodities include gold, silver and platinum group metals, as well as diamonds and similar products.
Diversified Minerals	Combine bulky, base metals and/or precious metals. In this work, we consider those typologies that would not fit into the other categories.

In the Bulk Metals category, we have Iron and Coal and the assessment is in Table 49. For Iron, it is noted that most of the most relevant categories according to the ICMM were reported (Categories 1 – Purchased Goods and Services; Category 3 – Activities related to fuel and energy not included in Scopes 1 and 2; and Category 10 – Processing of the sold product).

The exception would be Category 11 – Use of goods and services sold, for which it is necessary to assess the applicability for this specific typology, since the emissions of this category are dependent on the processing and the final product.

For coal, it is noted that there was no reporting of the categories that the ICMM considers most relevant, especially Category 11 – Use of goods and services sold, which would include emissions from burning this product, since this is the priority use of coal. Screening can be used to assess the materiality of the categories before proceeding to the calculation by activity data and to improve the input data.

Table 49: Scope 3 completeness assessment for Bulky Metals

	Bulky Metals		
	ICMM (Reference)	Iron	Mineral Coal
Category 1 - Purchased Goods and Services			
Category 2 - Capital goods			
Category 3 - Activities related to fuel and energy not included in Scopes 1 and 2			
Category 4 - Transportation and distribution (upstream)			
Category 5- Waste generated in the operations			
Category 6 - Business trips			
Category 7 - Displacement of employees (home-work)			
Category 8 - Leased assets (the organization as lessee)			
Category 9 - Transportation and distribution (downstream)			
Category 10 - Processing of sold products			
Category 11 - Use of sold goods and services			
Category 12 - End-of-life treatment of sold products			
Category 13 - Leased assets (the organization as lessee)			
Category 14 - Franchises			
Category 15 - Investments			

Key

	Typically **greater than 5%** of total Scope 3 emissions
	Typically **around 5%** of total Scope 3 emissions
	Typically **less than 5%** of total Scope 3 emissions
	There was no reporting by the companies

In Table 50, we can see the reference of representativeness of each category for Base Metals, according to the ICMM, and the reports for Nickel, Copper and Zinc. For this type of materials, the ICMM categorizes Category 10 - Processing of sold products and Category 11 - Use of sold goods and services as the most possibly relevant.

In the case of nickel, the calculation of Category 10 - Processing of sold products is observed, which is of extreme importance given its possible processing. The representativeness of this category was reflected in the companies' reporting, where this was the only category with relevance greater than 5% of the total of Scope 3. Just as the case for iron, the calculation of Category 11 - Use of sold goods and services is not carried out. As these emissions depend on the use of the product produced from nickel, it is necessary to assess if this typology would have relevant emissions in this category.

In the case of zinc, Category 4 - Transportation and distribution (upstream), was the most relevant in the companies' report. For the ICMM, this would represent around 5% of the total of Scope 3. For this type of metals, the expansion of scope 3 could start with the categories Category 10 - Processing of sold products and Category 11 - Use of sold goods and services, for better identification of the representativeness of this scope within the total emissions of this typology. In addition, a screening of the categories that the ICMM places with a representativeness of around 5% is recommended, with emphasis for Category 9 - Transportation and distribution (downstream), whose calculation can be prioritized given the current representativeness of Category 4, which also concerns transportations. This simplified assessment can be performed through the estimation of routes and modes, for example.

For copper, low adherence of Scope 3 is perceived. Just as the case for zinc, the calculation of Scope 3 can begin with Category 10 - Processing of sold products, followed by a screening of Category 11 - Use of sold goods and services and the categories that ICMM places with a representativeness of around 5%. This analysis can be performed using publicly available financial data and databases.

Table 50: Scope 3 completeness assessment for Basic Metals

	Basic Metals			
	ICMM (Reference)	Nickel	Copper	Zinc
Category 1 - Purchased Goods and Services				
Category 2 - Capital goods				
Category 3 - Activities related to fuel and energy not included in Scopes 1 and 2				
Category 4 - Transportation and distribution (upstream)				
Category 5- Waste generated in the operations				
Category 6 - Business trips				
Category 7 - Displacement of employees (home-work)				
Category 8 - Leased assets (the organization as lessee)				
Category 9 - Transportation and distribution (downstream)				
Category 10 - Processing of sold products				
Category 11 - Use of sold goods and services				
Category 12 - End-of-life treatment of sold products				
Category 13 - Leased assets (the organization as lessee)				
Category 14 - Franchises				
Category 15 - Investments				

Key

	Typically **greater than 5%** of total Scope 3 emissions
	Typically **around 5%** of total Scope 3 emissions
	Typically **less than 5%** of total Scope 3 emissions
	There was no reporting by the companies

In Table 51, we can see the reference of representativeness of each category for Precious Metals, according to the ICMM, where Gold is the only typology that comprises this group. For Gold, it is observed that the most relevant category was Category 1 - Purchased Goods and Services, which the ICMM also pointed out as important. However, it is possible to identify the possibility of implementing the report of Category 3 - Activities related with fuel and energy not included in Scopes 1 and 2, through emission factors of the life cycle of fuels and energy accounted for in Scopes 1 and 2, and the categories of Category 4 - Transportation and distribution (upstream) and Category 9 - Transportation and distribution (downstream) through freight-related financial data.

Table 51: Avaliação de completude do Scope 3 para Metais Preciosos

	Precious Metals	
	ICMM (Reference)	**Gold**
Category 1 - Purchased Goods and Services		
Category 2 - Capital goods		
Category 3 - Activities related to fuel and energy not included in Scopes 1 and 2		
Category 4 - Transportation and distribution (upstream)		
Category 5- Waste generated in the operations		
Category 6 - Business trips		
Category 7 - Displacement of employees (home-work)		
Category 8 - Leased assets (the organization as lessee)		
Category 9 - Transportation and distribution (downstream)		
Category 10 - Processing of sold products		
Category 11 - Use of sold goods and services		
Category 12 - End-of-life treatment of sold products		
Category 13 - Leased assets (the organization as lessee)		
Category 14 - Franchises		
Category 15 - Investments		

Key	
(dark blue)	Typically **greater than 5%** of total Scope 3 emissions
(teal)	Typically **around 5%** of total Scope 3 emissions
(light green)	Typically **less than 5%** of total Scope 3 emissions
(pale yellow)	There was no reporting by the companies

For diverse metals (Table 52), generally low adherence to Scope 3 is observed. The ICMM places the following categories as the most relevant: Category 1 - Purchased Goods and Services, Category 3 - Fuel and energy-related activities not included in Scopes 1 and 2, Category 10 - Processing of sold products and Category 11 - Use of sold goods and services.

Sand is the typology with the largest number of calculated Scope 3 categories (7). In comparison with the categories considered relevant by the ICMM, it is noted that there was no reporting of Category 10 - Processing of sold products and Category 11 - Use of sold goods and services. As sand has many varied uses, from glass production to use in civil construction, the representativeness of these categories depends on the use of fuels and energy in the processing of each company, and this is an important stage for the assessment for possible inclusion in Scope 3.

In tin, the calculation of 7 categories was also carried out, which include Category 1 - Purchased Goods and Services and Category 10 - Processing of sold products, flagged as relevant by the ICMM. An expansion of Scope 3 could be guided by a calculation of Category 3 - Fuel and energy-related activities not included in Scopes 1 and 2, using life cycle factors from the data used in Scopes 1 and 2, and an assessment of Category 11 - Use of sold goods and services that may consider the use of the final product produced from tin.

Phosphate also presents a good coverage of Scope 3, with 6 calculated categories. Although part of the categories considered as relevant for the ICMM have already been considered, there is an opportunity of evaluating Category 1 - Purchased Goods and Services, possibly through a screening of financial data, and mainly Category 10 - Processing of sold products, which may be relevant for this category due to the fact that one of the common processing of phosphate is the production of fertilizers.

For Niobium and Bauxite, the calculation of Category 1 - Purchased Goods and Services, which was considered as relevant to the ICMM is worth noting. For these typologies, an expansion of Scope 3 could start with the calculation of Category 10 - Processing of sold products, which may be relevant, most especially in the case of bauxite, as the processing of aluminum has important associated emissions.

For Magnesite, Clay and Chromite, only the calculation of Category 10 - Processing of sold products is observed. A screening of the following categories is recommended: Category 1 - Purchased Goods and Services, which can be carried out through financial purchase data; Category 3 - Fuel and energy-related activities not included in Scopes 1 and 2, which tends to be relevant for those typologies whose mining is energy-intensive; and Category 11 - Use of sold goods and services, which may be relevant depending on the use given to the final product of each category.

These observations also apply to Agalmatolite, Potassium, Limestone and Vanadium, but to these is added the importance of evaluation of Category 10 - Processing of sold products, which may be relevant because it concentrates emissions from metallurgical and industrial processes for transformation of mineral typologies.

Table 52: Scope 3 completeness assessment for Different Metals

	Diferent Metals			
	ICMM (Reference)	**Phosphate**	**Magnesite**	**Bauxite**
Category 1 - Purchased Goods and Services				
Category 2 - Capital goods				
Category 3 - Activities related to fuel and energy not included in Scopes 1 and 2				
Category 4 - Transportation and distribution (upstream)				
Category 5- Waste generated in the operations				
Category 6 - Business trips				
Category 7 - Displacement of employees (home-work)				
Category 8 - Leased assets (the organization as lessee)				
Category 9 - Transportation and distribution (downstream)				
Category 10 - Processing of sold products				
Category 11 - Use of sold goods and services				
Category 12 - End-of-life treatment of sold products				
Category 13 - Leased assets (the organization as lessee)				
Category 14 - Franchises				
Category 15 - Investments				

	Diferent Metals			
	ICMM (Reference)	Tin	Sand	Niobium
Category 1 - Purchased Goods and Services				
Category 2 - Capital goods				
Category 3 - Activities related to fuel and energy not included in Scopes 1 and 2				
Category 4 - Transportation and distribution (upstream)				
Category 5- Waste generated in the operations				
Category 6 - Business trips				
Category 7 - Displacement of employees (home-work)				
Category 8 - Leased assets (the organization as lessee)				
Category 9 - Transportation and distribution (downstream)				
Category 10 - Processing of sold products				
Category 11 - Use of sold goods and services				
Category 12 - End-of-life treatment of sold products				
Category 13 - Leased assets (the organization as lessee)				
Category 14 - Franchises				
Category 15 - Investments				

	Diferent Metals			
	ICMM (Reference)	**Clay**	**Chromite**	**Agalmatolito**
Category 1 - Purchased Goods and Services				
Category 2 - Capital goods				
Category 3 - Activities related to fuel and energy not included in Scopes 1 and 2				
Category 4 - Transportation and distribution (upstream)				
Category 5- Waste generated in the operations				
Category 6 - Business trips				
Category 7 - Displacement of employees (home-work)				
Category 8 - Leased assets (the organization as lessee)				
Category 9 - Transportation and distribution (downstream)				
Category 10 - Processing of sold products				
Category 11 - Use of sold goods and services				
Category 12 - End-of-life treatment of sold products				
Category 13 - Leased assets (the organization as lessee)				
Category 14 - Franchises				
Category 15 - Investments				

	Diferent Metals			
	ICMM (Reference)	Potassium	Vanadium	Limestone
Category 1 - Purchased Goods and Services				
Category 2 - Capital goods				
Category 3 - Activities related to fuel and energy not included in Scopes 1 and 2				
Category 4 - Transportation and distribution (upstream)				
Category 5- Waste generated in the operations				
Category 6 - Business trips				
Category 7 - Displacement of employees (home-work)				
Category 8 - Leased assets (the organization as lessee)				
Category 9 - Transportation and distribution (downstream)				
Category 10 - Processing of sold products				
Category 11 - Use of sold goods and services				
Category 12 - End-of-life treatment of sold products				
Category 13 - Leased assets (the organization as lessee)				
Category 14 - Franchises				
Category 15 - Investments				

Key

	Typically **greater than 5%** of total Scope 3 emissions
	Typically **around 5%** of total Scope 3 emissions
	Typically **less than 5%** of total Scope 3 emissions
	There was no reporting by the companies

5. RECOMMENDATIONS

The inventory of GHG emissions is the first stage for an institution's climate impact management and it must be continually improved to represent the most trustworthy emissions from the operations, in addition to being the basis for a well-structured diagnosis. For this reason, points for improvement were identified for future inventories:

- Increase gradually the number of mineral assets included in the inventory, to stimulate the increase of maturity on the matter among the companies and to identify the emission profile of other typologies.

- Expand the categories and sources of emissions calculated in companies' GHG inventories for all Scopes, in order to increase the reliability and accuracy of the results.

- Focus on expansion of the accounting of emissions for Scope 3, mainly for critical minerals, whose importance tends to grow significantly in the coming years due to government policies and market movements, but also for all other types, using the guidelines of the ICMM (International Council on Mining and Metals) (ICMM, 2023) as guide.

- Identify the best estimation or extrapolation format for Scope 3 categories, whereas for some categories the variation is directly related to production (such as transportation and distribution and use of the sold product, among others) and, for others, the variation has no direct relation with production (employee displacement and business trips, for example).

- Segregate the emissions within the categories by activity, according to their relevance to the sector, such as stripping and the use of explosives, but maintaining comparability with the emission categories of the GHG Protocol. This process further helps in the comparison of previously conducted GHG inventories of the mining sector, as well as with inventories of companies in the sector, in addition to providing inputs for specific mining sources.

- Refine the accounting of fugitive emissions from coal, most especially methane emissions from deep mining explorations, which can be quite representative for a part of the mines in Brazil.

- Strengthen the use of emission indicators using the total transacted mass, considering the waste rock, as the ROM emissions indicator can be over-estimated or underestimated due to the different variations in waste rock depending on the mining phase, such as change in the mining front.

- Prepare an inventory of withdrawals from the sector, considering the accounting of carbon stocks in the soil and from green mining areas.

- Stimulate the preparation of sectoral inventories by mineral assets through their related associations, in order to expand the participation of institutions in the methodology and in the refinement of results.

These recommendations aim at continuous improvement of the companies' reporting for the sectoral report, adding quality and precision of data for strategic decision-making for the sector.

6. FINAL CONSIDERATIONS

Considering the current impacts of climate changes and the significant increase of emissions over time, companies are increasingly being encouraged to carry out the decarbonization of their processes. The 2024 Inventory of GHG Emission of the Mining Sector represents a major step and an important instrument for this that the process be initiated by corporations and monitored by institutions such as sectoral associations and institutes.

In addition to sectoral motivation, there are market pressures, mainly from investors, and from government regulations, such as laws, decrees and carbon taxations. For Brazil, in particular, the last few years have seen major movement on the subject, with the need to comply with the Nationally Determined Contribution (NDC) – determined in the Treaty of Paris, the alignments on the creation of the Brazilian carbon market, the review of the National Climate Change Policy, the preparation of Sectoral Plans for Adaptation and Mitigation of GHG Emissions and the holding of COP30 in Belém do Pará, in Brazil, in 2025. These government mechanisms are translated into legal obligations for institutions, generating greater relevance on the subject and greater urgency in the preparation of an inventory of GHG emissions and its deployments, such as decarbonization.

Analyzing by sector, as technological advances and innovative initiatives continue to be developed, it is likely that mining may become less carbon-intensive in the future. A survey of decarbonization initiatives from direct emissions (of Scope 1 and Scope 2) for the sector, separated in relation to to their origin was conducted. In Figure 31, it is possible to identify the listed technologies, an assessment of barriers and the estimated measurement of current applicability in the industry and their potential of reduction. The intention is that there may be an evaluation, mainly of the barriers, which can be worked on sectorally or through advocacy of the companies, so that there may be an acceleration of technology release processes, if the potential of reduction is relevant for the sector.

The technologies were identified based on the main source of emissions of the sector, mobile combustion, in accordance with a review of the sector's main publicly available decarbonization plans.

Regarding the possible execution barriers, we highlight that the main ones are:

- Need for development of a regulatory framework, as in the case of hydrogen, especially green hydrogen, which does not have yet all aspects of its production fully authorized and regulated.

- The need for change of equipment, generating a major cost for companies in the update of their physical assets, and the availability of modern and fully accessible equipment for use, such as large electric vehicles, and the infrastructure necessary for their use and maintenance.

Thus, we can observe that most of the technologies have minimal applicability or very close to the minimal applicability in the mining industry, demonstrating the relevance of alignment with the Government on the urgency of release of technologies for the sector and green financing, but also of innovation and sustainable development groups among the institutions or even in the governance of the companies.

Now the measurement of the impact of technologies in terms of potential of reduction and possible barriers was carried out by taking into account:

- the total replacement of the technology currently used by companies;
- the precursors associated with each one and;
- the emission factors.

In the evaluation of the main results of this analysis, it is possible to identify that, considering the estimated premises, electrification is still a highly relevant item for reduction of emissions, as wells as the replacement of fossil fuels. Green hydrogen also has high potential of reduction, but there is still a need for development of the legal structure and technological adaptations for its production.

The issue of production efficiency may be the most financially viable for mining companies in the short term, whereas logistic optimizations can be carried out with low implementation cost and that sensing systems may have a lower cost than deep-set changes in assets or fuels.

Considering the sources covered by this inventory, a survey was also conducted on decarbonization opportunities for the main link of the mining value chain and an important source of Scope 3 emissions, which is metallurgy. These include:

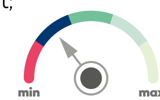
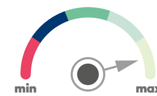
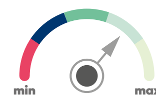
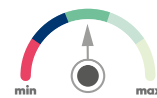
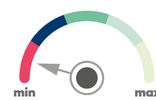
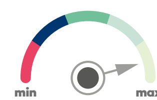
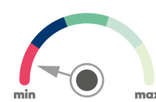
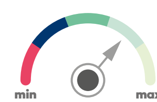
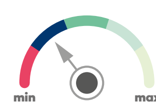
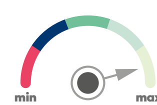
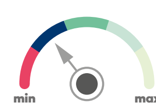
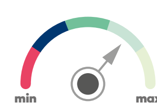
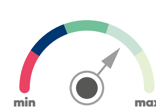
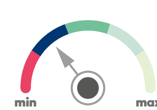
- circular economy (mainly the use of recycled scrap), identified as the most available activity for industrial decarbonization;

- next, change in production processes (such as electrification of equipment and change of fuels, or change of production routes) may be the target of significant reductions in the medium term;

- the transportation of sold products (such as fuel change) can be considered for medium to long-term projects, whereas the sector still seeks alternative fuels and legal approvals;

- reaching CCUS (Carbon Capture, Use and Storage) – and this is still very dependent on legal approvals and high financial investment, and it must be considered for medium to long-term plans.

Figure 31: Possibilities of decarbonization actions for the mining sector

	Description	Possible barriers in execution	Applicability in the industry	Potential of reduction
Green Hydrogen	Less carbon-intensive energy source for mining trucks and equipment	• Costs of electrolysis and transport; • Other fuels with lower cost; • Need of change of equipment. • Need of robust regulatory and methodological framework		
Renewable power and consumption optimization	Acquisition of electric power of renewable sources and processes for optimization/reduction of power consumption.	• Need of purchase of certificates; • Need of change of equipment by others that are more efficient.		
Electrification of equipment and fleet	Replacement of diesel motors by electric power with low carbon, such as batteries end electricity from renewable sources.	• Need of change of equipment; • Increase of electrical power consumption; • Loading time of vehicle batteries; • Availability of vehicles and capacity		
Use of Autonomous Vehicles	Autonomous vehicles in the mining sector allows optimization when reducing fuel consumption and minimizing emissions, as these vehicles can be programmed to operate more efficiently.	• Need of change of equipment; • Need of training for monitoring of these vehicles.		
Replacement of fossil fuels	Replacement of fossil fuels, such as diesel and gasoline, with ethyl alcohol, biomethane and HVO (green diesel).	• Less efficiency of less carbon-intensive fuels, if compared with the conventional ones* • Increase of acquisition costs in relation to conventional fuels.		
More efficient production processes	Sensing, control and automation system of mine processes Industry 4.0 or intelligent manufacturing	• Need of acquisition and implementing of equipment and vehicles that allow its automation and control remotely		
	Optimization of loading time in the queues; replacement of trucks that circulate in mines using long-distance conveyor belts.	• Need of equipment change		

7 REFERENCES

ANEPAC - National Association of Construction Aggregate Producing Entities. Construction Aggregates. Available at: <https://anepac.org.br/agregados-para-construcao/>. Accessed on: 12 March 2024

ANM – National Mining Agency. Brazilian Mining Yearbook, 2024. Available at: <https://dados.gov.br/dados/conjuntos-dados/anuario-mineral-brasileiro-amb>. Accessed on: 12 March 2024

ANM – National Mining Agency. Brazilian Mining Summary, 2019. Available at: < https://www.gov.br/anm/pt-br/assuntos/economia-mineral/publicacoes/sumario-mineral/sumario-mineral-brasileiro-2018>. Accessed on: 12 March 2024

CDP. [S. l.], 25 Jan. 2023 Available at: https://cdn.cdp.net/cdp-production/cms/guidance_docs/pdfs/000/003/504/original/CDP-technical-note-scope-3-relevance-by-sector.pdf. Accessed on: 10 Oct. 2023

CETEM. Agalmatolite. 2008 Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1033/1/03.AGALMATOLITO%20proposta%20Paulo%20Tomedi.pdf. Accessed on: 12 March 2024

CETEM. Chromite. 2005 Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1052/1/16.CROMITA.pdf. Accessed on: 19 March 2024.

Dolganova, I., Bosch, F., Bach, V., Baitz, M., & Finkbeiner, M. (2019). Life cycle assessment of iron niobium. The International Journal of Life Cycle Assessment, 25, 611–619.

Ecoinvent Version 3 - Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B., 2016. The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, [online] 21(9), pp.1218–1230. Available at: <http://link.springer.com/10.1007/s11367-016-1087-8> Accessed on: 19 March 2024.

IAI - International Aluminium Institute. Greenhouse Gas Emissions Intensity - Primary Aluminium. 2023 Available at: https://international-aluminium.org/statistics/greenhouse-gas-emissions-intensity-primary-aluminium/. Accessed on: 01 March 2024.

IBRAM. Mining performance takes a downswing in 2022, but sector creates more jobs and will increase investments to US$50 billion by 2027. Available at: <https://ibram.org.br/noticia/desempenho-da-mineracao-tem-queda-em-2022-mas-setor-cria-mais-empregos-e-aumentara-investimentos-para-us-50-bi-ate-2027/>. Accessed on: 4 Apr. 2024.

International Council on Mining and Metals (ICMM). Scope 3 Emissions Accounting and Reporting Guidance. 2023 Available at: <https://www.icmm.com/website/publications/pdfs/environmental-stewardship/2023/guidance_scope-3-reporting.pdf?cb=69120>. Accessed on: 10 Oct. 2023.

Ministry of Mines and Energy (MME). Mining Sector Bulletin 2002. 2022 Available at: <https://www.gov.br/mme/pt-br/assuntos/secretarias/geologia-mineracao-e-transformacao-mineral/publicacoes-1/boletim-do-setor-mineral/boletim-do-setor-mineral-2013-1-sem2022.pdf/@@download/file#:~:text=A%20Secretaria%20de%20Geologia%2C%20Minera%C3%A7%C3%A3o,alcan%C3%A7ou%20quase%20850%20mil%20postos>. Accessed on: 4 Apr. 2024.

Ministry of Mines and Energy (MME). Brazil's potential of minerals for energy transition is highlighted at the largest global event in the sector, in Canada. 2023 Available at: <https://www.gov.br/mme/pt-br/assuntos/noticias/potencial-brasileiro-de-minerais-para-transicao-energetica-e-destaque-no-maior-evento-mundial-do-setor-no-canada>. Accessed on: 4 Apr. 2024.

PBGHG Protocol. Accounting, quantification and publication of corporate inventories of greenhouse gas emissions. 2008 Available at: https://hdl.handle.net/10438/15413. Accessed on: 4 March 2024.

SNIC - National Union of the Cement Industry. Roadmap – Carbon Neutrality. 2023 Available at: <https://hdl.handle.net/10438/15413>. Accessed on: 4 March 2024

Zhang, T., Bai, Y., Shen, X., Zhai, Y., Ji, C., Ma, X., & Hong, J. (2021). Cradle-to-gate life cycle assessment of cobalt sulfate production derived from a nickel–copper–cobalt mine in China. The International Journal of Life Cycle Assessment, 26, 1198–1210.

IBRAM
BRAZILIAN MINING

/InstitutoBrasileirodeMineracao

/ibrammineracao

@ibram_mineracao

InstitutoBrasileirodeMineração/videos

https://ibram.org.br

ibram@ibram.org.br

WAY CARBON

@WayCarbon

/waycarbon