2019 GREENHOUSE GAS EMISSIONS INVENTORY

CEMIG Corporate Inventory of GHG Emissions in 2019

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DELIVERABLE CEMIG Corporate Inventory of GHG Emissions in 2019

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SUMMARY

Low-carbon economy is pivotal to sustainable development, given the potential impacts that may result from Global Warming and Climate Change. Thus, means for allying economic development with protection of the climate system have been increasingly sought.

Founded in May 22, 1952, the Minas Gerais State Energy Company – CEMIG participates in more than 170 companies as well as in consortia and holding funds. This Brazilian group from the energy sector is widely recognized by its sustainable activities, having been a member of the Dow Jones Sustainability World Index (DJSI World) for 20 consecutive years.

Since 2014, CEMIG's impacts on the global climate system have been managed through inventorying of its greenhouse gas (GHG) emissions. The present study evaluated the company's GHG emissions in 2019.

In 2019, CEMIG's direct emissions (Scope 1) totalized 51,938.62 tCO_2e; emissions from electricity consumption and from losses in energy transmission and distribution (Scope 2) totalized 598,518.28 tCO_2e; and indirect emissions (Scope 3) totalized 6,451,461.79 tCO_2e. All these emissions are detailed in Table 1:

Table 1. Results of GHG emissions by scope and category in 2019 (tCO_2e)

Scope	Category	Emissions (tCO_2e)	Representativeness (%)
Scope 1	Stationary combustion	37,582.05	72.36%
	Mobile combustion	9,068.00	17.46%
	Fugitive emissions	5,239.42	10.09%
	Land-use change	49.16	0.09%
	Total Scope 1 emissions	**51,938.62**	-
Scope 2	Electricity consumption	3,153.68	0.53%
	Losses in T&D	595,364.60	99.47%
	Total Scope 2 emissions	**598,518.28**	-
Scope 3	Purchased goods and services	63.29	0.00%
	Employee commuting	215.47	0.00%
	Waste generated in operations	615.70	0.01%
	Downstream transport and distribution	22,699.24	0.35%
	Upstream transport and distribution	790.63	0.01%
	Use of sold goods and services	6,426,649.39	99.62%
	Business travel	428.07	0.01%
	Total Scope 3 emissions	**6,451,461.79**	-

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

The company's Scope1 emissions were mostly associated with consumption of diesel oil at the Igarapé thermal power plant (approximately 37 thousand tCO_2e). Scope 2 emissions, on the other hand, derived mostly from Losses in Transmission and Distribution (T&D) (99.47% representativeness). As for Scope 3 emissions, they were predominantly associated with the category Use of Sold Goods and Services (99.62% representativeness), due to the high amounts of electricity and natural gas commercialized by the company.

CEMIG GT was the main emitter of Scope 1 emissions in the CEMIG group, while CEMIG D was responsible for ca. 98% of the total Scope 2 emissions. CEMIG GT and GASMIG contributed equally with Scope 3 emissions (between 34% and 35%), followed by CEMIG D (30%).

Data on emissions by scope and by operating unit are shown in Table 2:

Table 2. Results of GHG emissions by operating unit in 2019 (tCO_2e)

Operating unit	Scope 1 (tCO_2e)	Scope 2 (tCO_2e)	Scope 3 (tCO_2e)
CEMIG D	11,457.46	587,856.21	1,949,452.19
CEMIG GT	40,107.30	10,627.96	2,240,377.74
CEMIG SIM	2.27	0.00	3.64
GASMIG	371.58	34.11	2,261,628.21
Total	**51,938.62**	**598,518.28**	**6,451,461.79**

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

1. INTRODUCTION

The problems arising from Global Warming and Climate Change render low-carbon economy a pivotal issue for sustainable development. For that, means for allying economic development with protection of the climate system have been gaining increasing attention.

Having been signed by several countries in the annual event hosted by the United Nations Framework Convention on Climate Change (UNFCCC), the 2015 Paris Agreement aims to restrict global warming to 2 ºC – ideally 1.5 ºC. For that, all government levels, as well the private sector, must commit to setting bold short and long-term targets that are in line with the creation of a zero net emissions future. This will require reducing to the closest as possible to zero all the emissions caused by anthropic action, such as those resulting from vehicular and industrial activities that utilize fossil fuels.

In that sense, it is of extreme relevance to quantify and manage greenhouse gas (GHG) emissions in the corporate environment by means of the GHG Emissions Inventory, an instrument which allows for knowing the profile of emissions resulting from the company's activities.

Elaborating a GHG Emissions Inventory has the following objectives:

- **Monitoring of GHG emissions:** Follow up and record the progress of emissions over time, which enables the identification of opportunities to gain operational efficiency and reduce costs;
- **Benchmarking:** Compare the emissions from each operating unit or from each sector of an organization;
- **Assessment of risks and opportunities:** Identify and mitigate the regulatory risks associated with future obligations related to carbon pricing or emission restrictions, as well as evaluate potential cost-effective opportunities for reducing emissions;
- **Target setting:** Subsidize the setting of targets to reduce GHG emissions and the planning of mitigation strategies;
- **Follow-up of results of mitigation measures:** Quantify all progress and improvement derived from strategic initiatives related to Climate Change;
- **Enrollment in climate footprint disclosure programs:** Allow for disclosing information on the company's climate performance (e.g. GHG Protocol, CDP, Corporate Sustainability Index (ISE), and Carbon Efficient Index (ICO_2)).

When applied to a company's value chain, the inventory also allows for an evaluation of the climate sustainability of external processes; e.g., production of raw material, use and disposal of products, and logistics of distribution.

Of the protocols and standards available to compile corporate GHG Emissions Inventories, the following were adopted in the present study:

- NBR ISO 14064 Standard; Brazilian Association of Technical Standards, 2007 (ABNT, 2007);
- Specifications in the Brazil GHG Protocol Program; Verification Specifications in the Brazil GHG Protocol Program; GHG Corporate Protocol – Brazil GHG Protocol Program (PBGHGP) – Fundação Getúlio Vargas; and World Resources Institute (FGV/GVces; WRI, 2011).

The protocols listed above have international credibility. The main reason to adopt them was to produce a report that would be comparable by both national and international standards.

It is worth noting that this inventory is subject to external assurance in compliance with the abovementioned protocols. The objective of third-party assurance is to obtain an independent statement on the quality of the inventory and on the consistency of the information contained in it, aiming to ensure to its users an accurate evaluation of the emissions standards of the company's value chain.

2. ADOPTED METHOD

The 2019 CEMIG Emissions Inventory was produced using CLIMAS[1], a calculation software developed by WayCarbon.

2.1 Accounting and reporting principles

The following principles guided the performance of this study, according to the guidelines of the Brazil GHG Protocol Program (FGV/GVces; WRI, 2011):

[1] CLIMAS is a GHG Emissions Inventory calculation software developed by WayCarbon that has a database with the most up-to-date emission factors available for each source type (e.g., Brazil GHG Protocol Program, for Brazil; and, when unavailable, internationally accepted references, such as the GHG Protocol, IPCC, EPA, and DEFRA).

- **Relevance**: Ensure that the GHG Emissions Inventory properly reflects the emissions by the analyzed process and that it meets the decision-making demands of its users.

- **Completeness**: Record all GHG emission sources and activities within the boundaries selected for inventorying. Document and justify any specific exclusions.

- **Consistency**: Use recognized and technically consubstantiated methods that allow for comparing the compiled emissions with emissions from other similar processes. Clearly document any alterations in the data, inventory boundaries, adopted methods, or other relevant factors for the analyzed period.

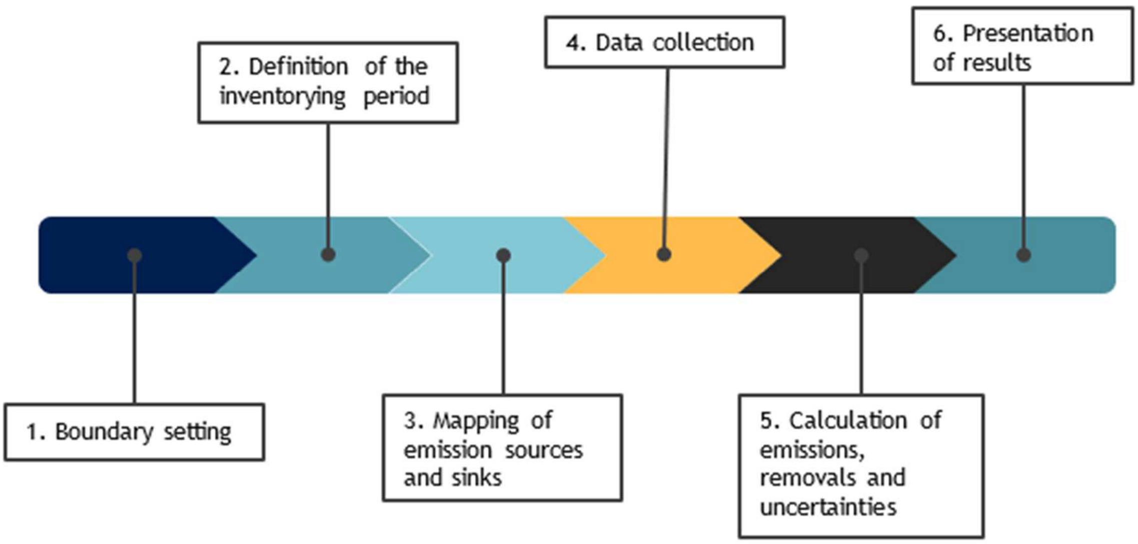
- **Transparency**: Treat all relevant issues coherently and factually, grounded on objective evidence. Disclose any relevant supposition, and make proper reference to the adopted calculation and recording methods, as well as to the data sources used.

- **Accuracy**: By means of using appropriate data, on either emission factors or estimates, ensure that the quantified GHG emissions are not under or overestimated. Reduce bias and uncertainty to the lowest possible level and obtain a degree of assurance that allows for safe decision-making.

2.2 Stages of inventorying

The conceptual stages used to compile this inventory are presented in the following flow chart and explained further below (Figure 1):

Figure 1. Flow chart of the methodological stages of inventorying



Source: Elaborated by the WayCarbon team.

First, the boundaries are set (Stage 1), i.e., the company's installations and activities that will be evaluated in the inventory are defined, thereby establishing the organizational boundary. Then, the reference period and base year are determined (Stage 2).

The GHG sources and sinks of the company are then identified (Stage 3) and later categorized and ranked. Posteriorly, data is collected (Stage 4). The collected data on emitting activities are used to calculate emissions (Stage 5), as are the emission factors (see below). At this stage, the inventory's uncertainties are also calculated. Lastly, results are compiled in an annual report (Stage 6).

The abovementioned stages were applied to the CEMIG GHG Emissions Inventory following the procedure described in the following sections.

2.3 Boundary setting

2.3.1 Organizational boundaries

There are two possible approaches to consolidate emissions and removals at the organizational level. Each of these approaches are defined below. The one used in this inventory is indicated.

☐ Equity share: The organization accounts for GHG emissions from operations according to its share of equity.

☑ Operational control: The organization accounts for 100% of GHG emissions from operations over which it has operational control.

In Minas Gerais state, CEMIG supplies energy to 8.5 million customers from 774 municipalities. The company's operations include energy generation, transmission and distribution; energy solutions; natural gas exploration and distribution; and data transmission, as shown below (CEMIG, 2020):

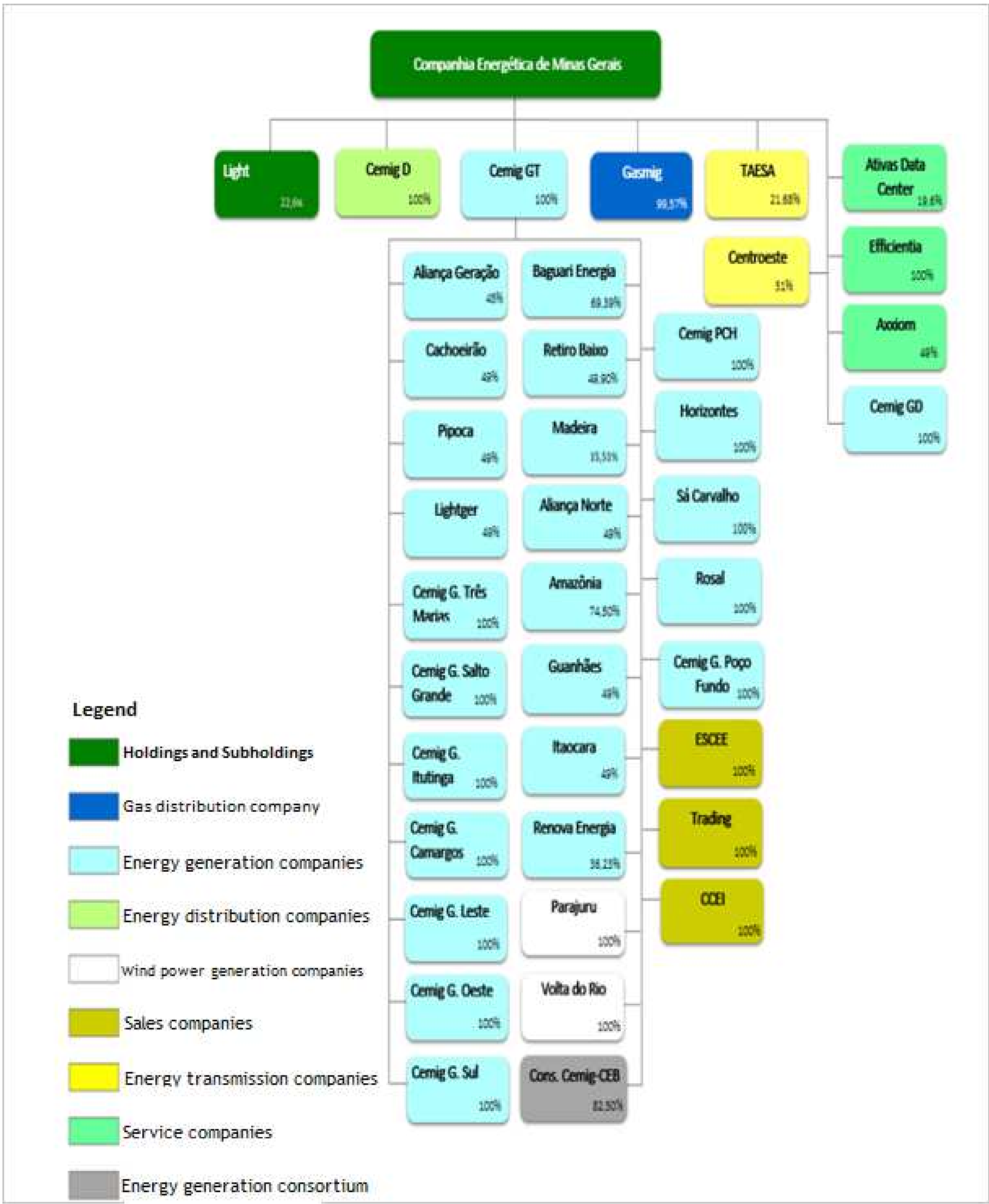
- **Generation:** 6,020 MW of installed capacity
- **Transmission:** 4,930 km of transmission lines
- **Distribution:** 539,807 km of distribution network
- **Gas:** 1,129,652,727 m³ sold

By the end of 2019, the CEMIG group held shares in 88 power plants, 81 of them hydroelectric (39 HPPs[2], 35 SHPs[3] and seven MHPs[4]), one solar power plant, and two wind farms (RAS, 2020). In 2019, the Condonga HPP and Igarapé TPP[5] were both deactivated (RAS, 2020).

The CEMIG corporate organization chart is shown below (Figure 2 and Table 3):

[2] HPP: Hydroelectric Power Plant
[3] SHP: Small Hydroelectric Power Plant
[4] MHP: Mini Hydroelectric Power Plant
[5] TPP: Thermal Power Plant

Figure 2. CEMIG corporate organization chart (base date: 12/31/2019)



Source: http://www.cemig.com.br/pt-br/a_cemig/quem_somos/Documents/Organograma-Grupo-Cemig.pdf

Table 3. Operational control and equity share of each of CEMIG's operating units

Sector	Operating unit	Operational control	Equity share (%)
Generation	CEMIG Geração e Transmissão S.A. (CEMIG GT)	Yes	100%
	CEMIG Geração Camargos S.A.	Yes	100%
	CEMIG Geração Itutinga S.A.	Yes	100%
	CEMIG Geração Leste S.A.	Yes	100%
	CEMIG Geração Oeste S.A.	Yes	100%
	CEMIG Geração Salto Grande S.A.	Yes	100%
	CEMIG Geração Sul S.A.	Yes	100%
	CEMIG Geração Três Marias S.A.	Yes	100%
	CEMIG PCH S.A.	Yes	100%
	Horizontes Energia S.A.	Yes	100%
	Rosal Energia S.A.	Yes	100%
	Sá Carvalho S.A.	Yes	100%
	Parajuru S.A.	Yes	100%
	Volta do Rio S.A.	Yes	100%
	CEMIG Geração e Distribuição S.A. (CEMIG GD)	Yes	100%
	CEMIG Geração Poço Fundo S.A.	Yes	100%
	Aliança Geração S.A.	No	45%
	Aliança Norte S.A.	No	49%
	Amazônia S.A.	No	74.50%
	Baguari Energia S.A.	No	69.59%
	Cachoeirão S.A.	No	49%
	Guanhães S.A.	No	49%
	Itaocara S.A.	No	49%
	Lighter S.A.	No	49%
	Madeira S.A.	No	15.51%
	Pipoca S.A.	No	49%
	Renova Energia S.A.	No	36.23%
	Retiro Baixo S.A.	No	49.90%
Generation consortium	Consórcio CEMIG – CEB S.A.	No	82.50%
Distribution	CEMIG Distribuição S.A. (CEMIG D)	Yes	100%
Gas distribution	GASMIG S.A.	Yes	99.57%
Transmission	TAESA S.A.	No	21.68%
	Centroeste	No	51.00%
Sales	ESCEE S.A.	Yes	100%
	Trading S.A.	Yes	100%
	CCEI S.A.	Yes	100%
Service	Efficientia S.A.	Yes	100%
	Ativas Data Center S.A.	No	19.60%
	Axxiom S.A.	No	49%
Subholding	Light S.A.	No	22.60%

Source: Elaborated by the WayCarbon team based on the CEMIG corporate organization chart.

Despite holding 100% of equity share, Sales companies (ESCEE S.A., Trading S.A., and CCEI S.A.) were not considered in the inventory, as CEMIG has no operational control over them. As for CEMIG Geração Poço Fundo, which also holds 100% of equity share, its emissions were accounted for within the emissions of CEMIG Geração e Transmissão S.A. (CEMIG GT).

CEMIG SIM is a merger between the former companies Efficientia (from the Service sector) and CEMIG Geração e Distribuição S.A. (CEMIG GD). Lastly, the units Parajuru and Volta do Rio are wind power generation companies located at Ceará state which have integrated the inventory as of 2019. Thus, the following operating units integrated the 2019 GHG Emissions Inventory of the CEMIG group (Table 4):

Table 4. CEMIG's operating units considered in the 2019 inventory

Operating unit	Operational control	Equity share (%)
CEMIG Geração e Transmissão S.A. (CEMIG GT)	Yes	100%
CEMIG Distribuição S.A. (CEMIG D)	Yes	100%
CEMIG SIM S.A.	Yes	100%
GASMIG S.A.	Yes	99.57%
CEMIG Geração Camargos S.A.	Yes	100%
CEMIG Geração Itutinga S.A.	Yes	100%
CEMIG Geração Leste S.A.	Yes	100%
CEMIG Geração Oeste S.A.	Yes	100%
CEMIG Geração Salto Grande S.A.	Yes	100%
CEMIG Geração Sul S.A.	Yes	100%
CEMIG Geração Três Marias S.A.	Yes	100%
CEMIG PCH S.A.	Yes	100%
Horizontes Energia S.A.	Yes	100%
Rosal Energia S.A.	Yes	100%
Sá Carvalho S.A.	Yes	100%
Parajuru S.A.	Yes	100%
Volta do Rio S.A.	Yes	100%

Source: Elaborated by the WayCarbon team.

2.3.2 Operational boundaries

The setting of operational boundaries takes into consideration the identification of GHG sources and sinks associated with the operations, by means of their categorization as direct or indirect emissions, employing the concept of Scope. Below, each of the three categories adopted by the GHG Protocol are defined, and the ones assessed in this inventory are indicated.

☑ Scope 1: Direct GHG emissions from sources that either belong to or are controlled by the organization.

☑ Scope 2: Indirect GHG emissions from purchased electricity that is consumed by the organization.

☑ Scope 3: A category whose reporting is optional; it encompasses all other indirect emissions that are not considered under Scope 2. Scope 3 emissions result from activities of the organization, but derive from sources that do not belong to or are not controlled by it.

2.3.3 Covered period

The present inventory covers emissions from activities held by CEMIG in 2019 (January 1st, 2019 through December 31st, 2019).

2.3.4 Base year

Base year is the reference timepoint in the past against which current atmospheric emissions can be consistently compared.

Recalculations must be retroactive to the base year whenever there is any change that lead to either increase or decrease in emissions, i.e., whenever the alteration compromises the consistency and relevance of analyses over time. The following cases may result in the need for recalculation of emissions:

- Significant structural changes that alter the inventory's boundaries: (i) mergers, acquisitions and divestments; (ii) outsourcing and insourcing of emitting activities; and (iii) change of the emitting activity to either inside or outside the geographical limits of the Program (GHG Protocol Brazil);
- Significant changes in the calculation method, or improvements in the accuracy of emission factors or activity data that result in a significant impact on the base year emissions data;
- Discovery of significant errors, or a number of cumulative errors, that lead to a significant change in the results.

In 2014, the Igarapé thermal power plant was activated with higher frequency, and its operational emissions then increased. As this unit started to burn a large volume of fuel oil, the Scope 1 emissions profile of the company changed thereafter.

In 2018, CEMIG set two targets of tCO_2e emissions. The first one consists in an absolute target based on the combined emissions from Scopes 1 and 2, while the second is an intensity target for Scope 2 emissions, based on emissions from total Losses in Electricity Transmission and Distribution. For this, 2022 was set as target year whereas 2017 was established as base year for total emissions.

In 2020, the company will propose a Science-Based Target (SBT), committing to limit global warming to a level below 2 °C. The base year will be established according to the reduction to be projected by the SBT method.

2.3.5 Greenhouse gases

According to the Brazil GHG Protocol Program, inventories must report emissions of the 7 types of GHGs that integrate the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Additionally, the Montreal Protocol includes ozone-layer depleting gases such as hydrochlorofluorocarbons (HCFCs), which also contribute to global warming.

Each GHG has an associated Global Warming Potential (GWP), which measures how much each gas contributes to global warming. The GWP is a relative value that compares the warming potential of a given amount of gas with that of the same amount of CO_2, which by convention has a GWP value of 1. GWP is always expressed in terms of CO_2 equivalent – CO_2e. Table 5 shows the GWP values used in the inventory:

Table 5. GWP of greenhouse gases

Gas	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298
Sulfur hexafluoride (SF_6)	22,800
Nitrogen trifluoride (NF_3)	17,200
PFCs	7,390 – 17,700
HFCs	12 – 14,800
HCFCs	5 – 14,400

Source: PBGHGP, 2020.

The CEMIG 2019 GHG Emissions Inventory considered emissions of CO_2, CH_4, N_2O, and SF_6 according to the mapped emission sources and available data. Additionally, the inventory also recorded the CO_2 emissions from biogenic sources[6].

The gases CO_2, CH_4, N_2O, and SF_6 are generated at CEMIG through the following processes:

- CO_2: Generated in the burning of fossil fuels (such as diesel, natural gas, kerosene, and liquefied petroleum gas) by mobile and stationary sources. CO_2 emissions at CEMIG may also derive from waste treatment and use of agricultural fertilizers;

[6] Biogenic Emissions in the GHG Emissions Inventory – CO_2 emissions resulting from the energetic use of biomass of renewable origin. In this study, the adopted definition of renewable biomass was the one elaborated by the Executive Board of the Clean Development Mechanism of the United Nations Framework Convention on Climate Change (EB 23, Appendix 18). This type of emission does not contribute to a long-term increase in CO_2 concentrations in the atmosphere, as it is part of the natural carbon cycle.

- CH_4: Generated in the burning of fuels by mobile and stationary sources; as fugitive emissions in the natural-gas distribution lines; and by organic matter decomposition in organic waste treatment processes;
- N_2O: Generated in the burning of fossil fuels (such as diesel, natural gas, kerosene and liquefied petroleum gas) by mobile and stationary sources. N_2O emissions at CEMIG may also derive from waste treatment and use of agricultural fertilizers;
- SF_6: Resulted from the leak of insulating gases.

2.3.6 Exclusions from the inventory

The Generation units CEMIG PCH, Camargos, Itutinga, Leste, Oeste, Salto Grande, Sul, Três Marias, Horizontes, Rosal, Sá Carvalho, Parajuru, and Volta do Rio record only the diesel oil consumption by generators (Scope 1 – stationary combustion), fuel consumption by fleet (Scope 1 – mobile combustion), fertilizer consumption (Scope 1 – land-use change), and commercialization of electricity (Scope 3 – use of sold goods and services). The other data (employee commuting, fugitive emissions, purchased electricity, waste generated in operations, upstream transport and distribution, and business travel) were thereby accounted for under the emissions from CEMIG GT.

The operating units CEMIG PCH S.A. and Horizontes Energia S.A. have no control over fleet-related information, as their fleet is entirely outsourced. Therefore, indirect emissions (Scope 3) associated with fuel consumption in such transport type were not accounted for. Analogously, the Generation units have no control over the amount of fuel consumed by sporadically used outsourced ships.

LPG consumption by forklift trucks (Scope 3 – purchased goods and services) as well as the gasoline, alcohol, diesel and VNG consumption by contractors (Scope 3 – downstream transport and distribution) are all applicable only to CEMIG D.

Emissions derived from CO_2 consumption by fire extinguishers (Scope 1 – fugitive emissions) were not recorded at CEMIG D, CEMIG GT or at the other Generation units (CEMIG PCH, Camargos, Itutinga, Leste, Oeste, Salto Grande, Sul, Três Marias, Horizontes, Rosal, Sá Carvalho, Parajuru, and Volta do Rio), since all these units lack a centralized management over the maintenance of this equipment. Such control is expected to be regularized in the next years.

Emissions from domestic waste (Scope 3 – waste generated in operations) in the CEMIG D facility at the Belo Horizonte Metropolitan Region were also not accounted for, yet they are to be reported in the next years; in the other CEMIG D facilities, the recording process of this data remains under development. From the 2020 inventory onwards, domestic-waste emissions at the Generation units (CEMIG PCH, Camargos, Itutinga, Leste, Oeste, Salto Grande, Sul, Três Marias, Horizontes, Rosal, Sá Carvalho, Parajuru, and Volta do Rio) will be accounted for as well.

Lastly, CO_2 removals by forestry and forest recovery were also not accounted for. The recording of this data is expected to be made as of the next year.

2.4 Identification or revalidation of sources and sinks

Emission sources were identified and ranked within the company's organizational structure. In the CLIMAS system, developed by WayCarbon, emission sources were mapped and each one was classified according to the attributes described below (Table 6):

Table 6. Description of attributes recorded for the input information database

Attribute	Description
Operating unit	Indicates the operating unit to which the source or sink belongs
Process	Indicates the process to which the source or sink belongs
Activity	Indicates the activity performed by the source or sink
Supervised item	A field where further details for identifying the source of emission are reported
Precursor	The substance which will originate the GHG emissions
Technology	The precursor-associated technology which originates GHG emissions
Operating parameter	Description of the input data
Unit of measurement	Unit of measurement of the consolidated input data
Responsible	The company's staff member which is in charge of data collection
Data source	The site, registry, reference or system from which the data is retrieved
Scope	Scope of the emission source, according to the GHG Protocol classification
Category	Category of the emission source, according to the GHG Protocol classification

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

The emission sources accounted for in the inventory, according to the ranking and organization elaborated in CLIMAS, are shown in Table 7.

Table 7. Emission sources in the inventory by scope, category and controlled data

Scope	Category	Controlled data
Scope 1	Stationary combustion	Natural-gas consumption by stationary sources
		Fuel oil consumption by stationary sources
		Diesel oil consumption by generators
	Mobile combustion	Diesel consumption by ships
		Gasoline consumption by ships
		Aviation kerosene consumption
		Alcohol consumption – company's own fleet
		Diesel consumption – company's own fleet
		Gasoline consumption – company's own fleet
		VNG consumption – company's own fleet

Scope	Category	Controlled data
	Fugitive emissions	Use of insulating gases – leak of SF_6
		CO_2 consumption by fire extinguishers
		Leak of natural gas in distribution
	Land-use change	Limestone consumption
		Nitrogen consumption in fertilizers
Scope 2	Purchased electricity	Losses in the T&D system
		Electricity consumption
Scope 3	Cat 1. Purchased goods and services	LPG consumption by forklift trucks
	Cat 4. Upstream transport and distribution	Diesel consumption by outsourced trucks (light, medium and heavy trucks)
		Distance covered to transport fuel to the operating unit
	Cat 5. Waste generated in operations	Mass of waste sent to landfills
		Mass of waste sent for incineration
		Mass of waste sent for co-processing
	Cat 6. Business travel	Air travels
	Cat 7. Employee commuting	Fuel consumption for employee commuting
	Cat 9. Downstream transport and distribution	Alcohol consumption by contractors
		Diesel consumption by contractors
		Gasoline consumption by contractors
		VNG consumption by contractors
	Cat 11. Use of sold goods and services	Commercialization of electricity and natural gas

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

As observed in Table 7, the processes defined in CLIMAS for the CEMIG inventory share a correlation with the categories established by the Brazil GHG Protocol Program[7] (PBGHGP). PBGHGP categories are shown in Appendix E – Categories in the Brazil GHG Protocol Program.

2.5 Data collection

The information used to compile the inventory was obtained through the following sequence of events:

1. Corporate managers identified the staff members responsible for managing the information needed for the GHG Emissions Inventory;
2. Staff members that monitor the operations assessed the best possible way to obtain data from the company's management systems (existing records in the CEMIG's ERP system, records in operational and control systems, invoices, or contracts);
3. The collected information was consolidated by focal points and ultimately sent to WayCarbon.

[7] Category definitions were obtained from documents published by FGV EAESP: "Nota Técnica: Classificação das emissões de gases de efeito estufa (GEE) de Escopo 1 nas respectivas categorias de fontes de emissão – versão 1.0" (available at: <http://mediadrawer.gvces.com.br/ghg/original/ghg-protocol_nota-tecnica_categorias-escopo-1_-v1.pdf>) and "Categorias de Emissões de Escopo 3 Adotadas pelo Programa Brasileiro GHG Protocol" (available at: <http://mediadrawer.gvces.com.br/ghg/original/ghg_ categorias_e3_definicoes_curta.pdf>).

WayCarbon developed specific spreadsheets for data collection at each focal point. CEMIG's focal points collected data throughout the year and reported the consolidated data to WayCarbon. The technical team at WayCarbon then performed a critical analysis of the data, compiled them and entered the operational data in the CLIMAS system.

2.6 Calculation of emissions

The CEMIG GHG Emissions Inventory was elaborated using CLIMAS, a calculation software developed by WayCarbon whose database has the most up-to-date emission factors available for each source type (e.g., Brazil GHG Protocol Program, for Brazil; and, when unavailable, internationally accepted references, such as the GHG Protocol, IPCC, EPA, and DEFRA[8]).

Generically, GHG emissions and removals were calculated individually for each source and sink, according to the following equation:

$$\boldsymbol{E_{i,g,y} = DA_{i,y} \cdot EF_{i,g,y} \cdot GWP_g}$$

Where:

- $\boldsymbol{i}$ index that denotes the activity of an individual source or skink;
- $\boldsymbol{g}$ index that denotes a GHG type;
- $\boldsymbol{y}$ reference year of the report;
- $\boldsymbol{E_{i,g,y}}$ emissions or removals of the GHG g that are attributable to the source or sink i during the year y, in tCO_2e;
- $\boldsymbol{DA_{i,y}}$ consolidated data on a given activity, relative to the source or sink i during the year y, in the unit u. As previously stated, the consolidated data on a given activity consists of all attributes recorded from each source/sink.
- $\boldsymbol{EF_{i,g,y}}$ emission factor of the GHG g applicable to the source or sink i in the year y, in t GHG g/u;
- $\boldsymbol{GWP_g}$ global warming potential of the GHG g, in tCO_2e/tGHG g.

[8] IPCC: Inter Intergovernmental Panel on Climate Change; EPA: Environmental Protection Agency; DEFRA: Department for Environment, Food and Rural Affairs.

The choice of the appropriate calculation method was made based on the availability of specific data and emission factors, combustion technologies used in the process, physical and chemical properties of materials, and operational performance data.

The technical team at WayCarbon is responsible for periodically updating CLIMAS with emission factors according to internationally established methods in order to compile GHG Emissions Inventories. Emission factors were based mainly on the following references (Table 8):

Table 8. References for emission factors

Reference	Description	Link
IPCC 2006	IPCC *Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme*, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). *Published: IGES, Japan.*	http://www.ipcc-nggip.iges.or.jp/public/2006gl/
PBGHGP 2020	Programa Brasileiro GHG Protocol, Ferramenta de Cálculo, versão 2020.1.	http://www.ghgprotocolbrasil.com.br/ferramenta-de-calculo
BEN 2019	Balanço Energético Nacional 2019: Ano base 2018 / Empresa de Pesquisa Energética. - Rio de Janeiro: EPE, 2019.	http://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2019
MCTIC 2020	MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES (MCTIC).	https://www.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/textogeral/emissao_corporativos.html

Source: Elaborated by the WayCarbon team.

The calculation methods and specific equations used for each type of emission in the CEMIG 2019 GHG Emissions Inventory are shown in detail in Appendix B – Calculation of Emissions and Uncertainties.

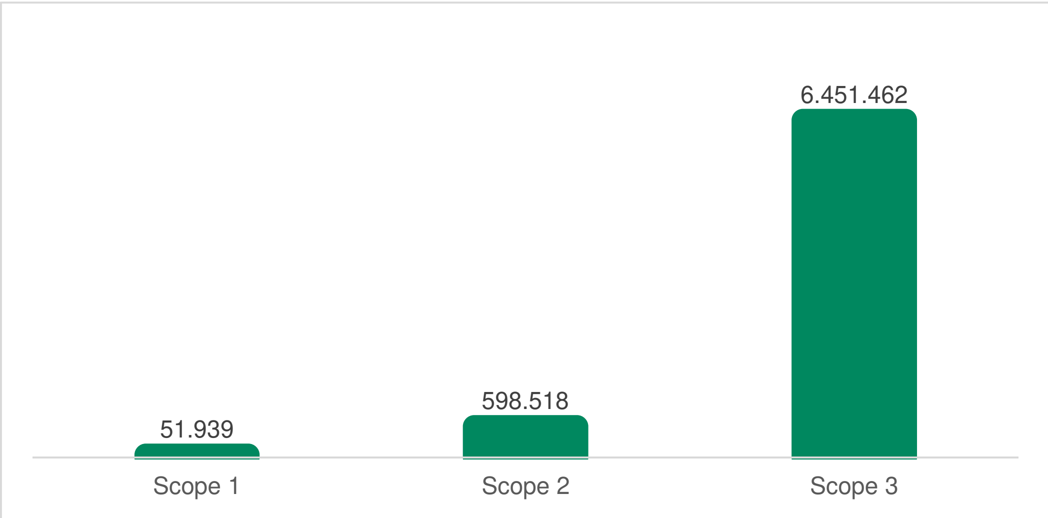
The emission factors used in the inventory as well as the calculation log[9] are available in the CLIMAS system as Excel® spreadsheets and also in Appendix C – GHG Inventory Emission Factors.

[9] The calculation log and emission factors of the inventory can be accessed via CLIMAS, through the following steps: a) access CLIMAS; b) click "*Emissões de GEE*" ['GHG emissions'] on the upper lef-hand corner of the screen; c) click "*Auditoria – Extrato de Fatores de Emissão*" ['Audit – Statement of Emission Factors']; d) choose the 2019 inventory and click "*Obter Extrato*" ['Obtain Statement']; e) in the last table, "*Fatores de emissão*" ['Emission Factors'], search for the emission source you wish to check using the search field and click the "*Ver*" ['See'] button on the right-hand side of the screen; f) click the button in the field "*Memorial de cálculo*" ['Calculation log'].

3. RESULTS

CEMIG's Scope 1, 2 and 3 emissions[10] in 2019 were 51,939 tCO_2e, 598,518 tCO_2e and 6,451,462 tCO_2e, respectively. Furthermore, 7,024 tons of CO_2 of renewable[11] origin were emitted (1,677 t of renewable CO_2 for Scope 1 and 5,347 t of renewable CO_2 for Scope 3). The company's Scope 1, 2 and 3 emissions in 2019 are shown in Figure 3:

Figure 3. GHG emissions in 2019 by scope (tCO_2e)



Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Table 9 shows CEMIG's GHG emissions by scope and category. In Scope 1, the category with highest representativeness was Stationary Combustion, which accounted for 72.36% of the total emissions in the scope (37,582.05 tCO_2e). Scope 2 emissions were represented mostly by Losses in T&D (595,364.60

[10] GHG emissions regulated by the Kyoto Protocol (carbon dioxide – CO_2, methane – CH_4 – nitrous oxide – N_2O and SF_6).
[11] CO_2 emissions resulting from the energetic use of biomass from renewable sources. In this study, the adopted definition of renewable biomass was the one elaborated by the Executive Board of the Clean Development Mechanism of the United Nations Framework Convention on Climate Change (EB 23, Appendix 18). This type of emission does not contribute to a long-term increase in CO_2 concentrations in the atmosphere.

tCO_2e), which contributed with 99.47% of emissions in that scope. As for Scope 3 emissions, they totalized 6,451,461.79 tCO_2e, of which the category Use of Sold Goods and Services represented 99.62%.

Table 9. GHG emissions by scope and category (tCO_2e)

Scope	Category	Emissions (tCO_2e)	Representativeness (%)
Scope 1	Stationary combustion	37,582.05	72.36%
	Mobile combustion	9,068.00	17.46%
	Fugitive emissions	5,239.42	10.09%
	Land-use change	49.16	0.09%
	Total Scope 1 emissions	**51,938.62**	-
Scope 2	Electricity consumption	3,153.68	0.53%
	Losses in T&D	595,364.60	99.47%
	Total Scope 2 emissions	**598,518.28**	-
Scope 3	Purchased goods and services	63.29	0.00%
	Employee commuting	215.47	0.00%
	Waste generated in operations	615.70	0.01%
	Downstream transport and distribution	22,699.24	0.35%
	Upstream transport and distribution	790.63	0.01%
	Use of sold goods and services	6,426,649.39	99.62%
	Business travel	428.07	0.01%
	Total Scope 3 emissions	**6,451,461.79**	-

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Emissions by Scope, operating unit and representativeness are shown in Table 10. CEMIG GT was the highest emitter of Scope 1 emissions, with 77.22% of representativeness in that Scope. Scope 1 emissions from CEMIG GT were mostly associated with the use of fuel oil at Igarapé TPP (37,210.91 tCO_2e of emissions thereat).

Scope 2 emissions from CEMIG D were dominant in relation to those from the other operating units, representing 98.22% of all emissions in the Scope. Scope 2 emissions were mainly associated with Losses in Transport and Distribution (both technical and non-technical losses).

CEMIG D, CEMIG GT and GASMIG showed similar contributions to Scope 3 emissions: 30.22%, 34.73% and 35.06%, respectively. Scope 3 emissions were mainly associated with commercialization of electricity and natural gas.

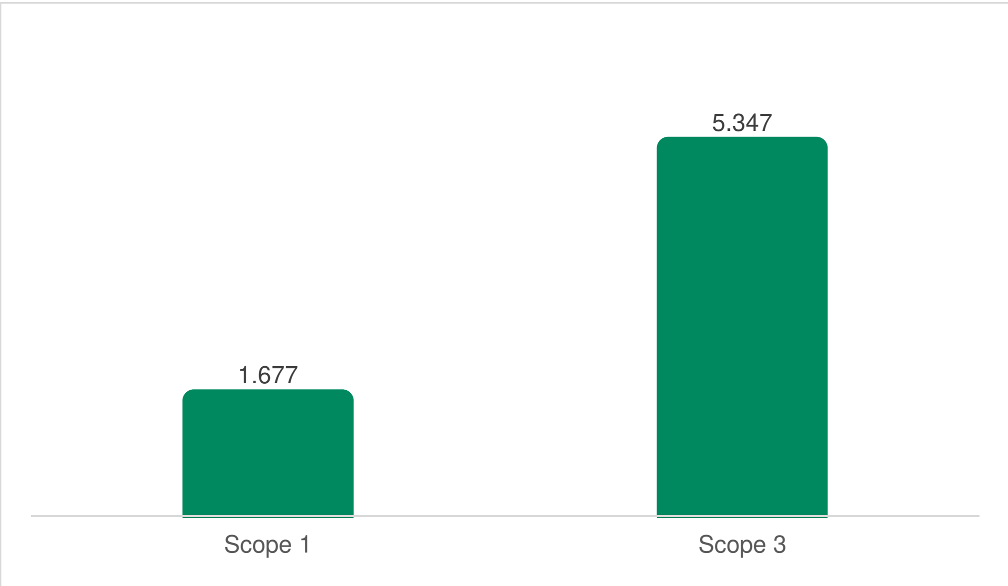
Table 10. Emissions by scope and operating unit in 2019 (tCO_2e)

Operating unit	Scope 1 (tCO_2e)	Contribution to Scope 1 (%)	Scope 2 (tCO_2e)	Contribution to Scope 2 (%)	Scope 3 (tCO_2e)	Contribution to Scope 3 (%)
CEMIG D	11,457.46	22.06%	587,856.21	98.22%	1,949,452.19	30.22%
CEMIG GT	40,107.30	77.22%	10,627.96	1.78%	2,240,377.74	34.73%
CEMIG SIM	2.27	0.00%	0.00	0.00%	3.64	0.00%
GASMIG	371.58	0.72%	34.11	0.01%	2,261,628.21	35.06%

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

The CO_2 emitted in the burning of renewable fuels such as ethanol or biodiesel is one that has been biologically sequestered (meaning that at any moment of its lifecycle, that CO_2 was assimilated by biomass). Emissions of this gas totalized 1,677 tons of renewable CO_2 and 5,347 tons of renewable CO_2 for Scopes 1 and 3 respectively, as shown in Figure 4.

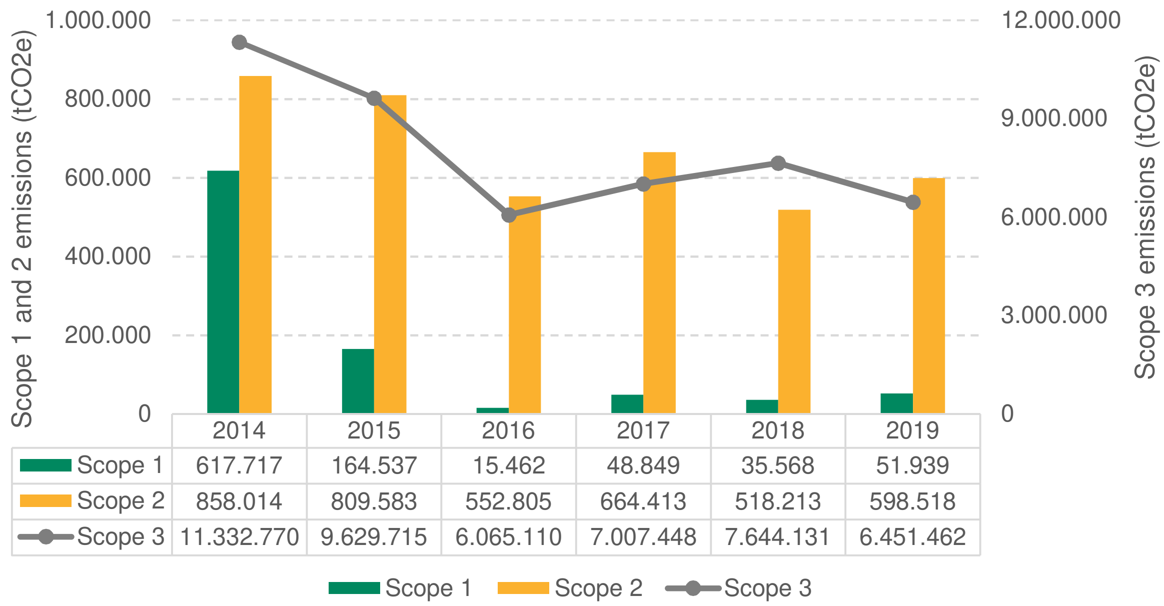
Figure 4. Renewable CO_2 emissions by scope (tons of renewable CO_2)



Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

While CEMIG has recorded its emissions since 2008, the year 2014 was the one that showed the worst scenario of emissions in the company's records. Therefore, the historical series presented in this report starts in 2014. Scope 1, 2 and 3 emissions from 2014 through 2019 are shown in Figure 5.

Figure 5. Historical data series of CEMIG's emissions (tCO_2e)



	2014	2015	2016	2017	2018	2019
Scope 1	617.717	164.537	15.462	48.849	35.568	51.939
Scope 2	858.014	809.583	552.805	664.413	518.213	598.518
Scope 3	11.332.770	9.629.715	6.065.110	7.007.448	7.644.131	6.451.462

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

In 2019, Scope 1, 2 and 3 emissions were reduced by 91.59%, 30.24% and 43.07% respectively in relation to 2014. Compared to the previous year (2018), Scope 1 and 2 emissions increased by 46.02% and 15.50% respectively, whereas Scope 3 emissions decreased by 15.60%.

The increase in Scope 1 emissions was mainly associated with the increased emissions at Igarapé TPP (approximately 16,000 tCO_2e), as well as with the incorporation of the new generation units into the inventory in 2019. The variation in Scope 2 emissions was directly related to the increased Losses in T&D (approximately an 80,000 tCO_2e increase). On the other hand, the reduction in Scope 3 emissions was due to the decrease in Use of Sold Goods and Services (commercialization of electricity and natural gas; approximately a 1,350 tCO_2e reduction).

Emissions from each emission source in the inventory are shown in Appendix D – Emissions by emission source.

3.1 Scope 1

CEMIG's Scope 1 emissions in 2019 totalized 51,938.62 tCO_2e, showing a 46.02% increase in relation to the previous year (2018 = 35,568 tCO_2e) and a 91.59% decrease in relation to 2014 (617,717 tCO_2e). Scope 1 emissions by category and representativeness are shown in Table 11:

Table 11. Scope 1 emissions by category (tCO_2e)

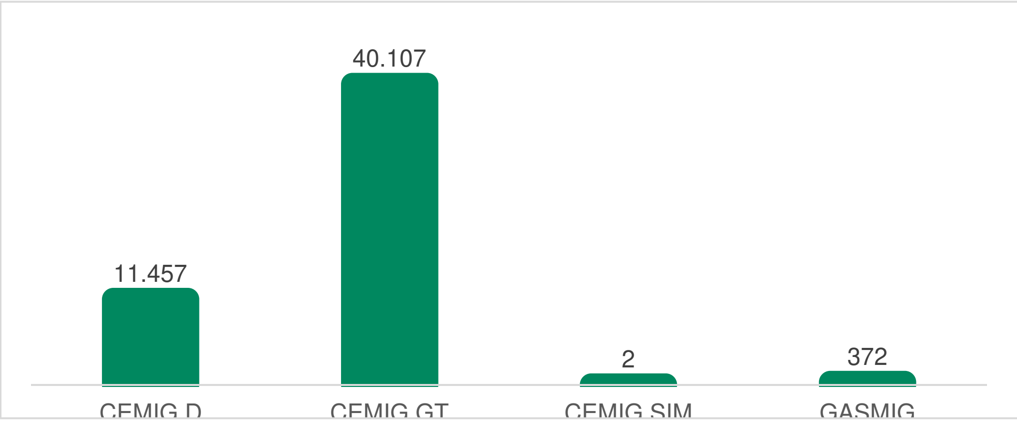
Scope	Category	Emissions (tCO_2e)	Representativeness (%)
Scope 1	Stationary combustion	37,582.05	72.36%
	Mobile combustion	9,068.00	17.46%
	Fugitive emissions	5,239.42	10.09%
	Land-use change	49.16	0.09%
	Total Scope 1 emissions	**51,938.62**	**-**

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Stationary Combustion was the category that contributed the most to Scope 1 emissions, with 37,582.05 tCO_2e. Within this category, fuel oil consumption at Igarapé TPP accounted for the emission of 37,210.91 tCO_2e. The category showed a 75% increase in emissions in relation to 2018. This was due to the fact that the entire fuel oil stock at the TPP had to be consumed, since the plant shut down its operations as of 2019.

Mobile Combustion emissions contributed with 9,068.00 tCO_2e in Scope 1, being mainly associated with diesel consumption by fleet (8,026 tCO_2e). Fugitive emissions totalized 5,239.42 tCO_2e, having derived mainly from the leak of SF_6 (4,958 tCO_2e). Land-use change, on the other hand, showed the lowest representativeness in Scope 1, with 49.16 tCO2e. The chart below shows CEMIG's GHG emissions in 2019 by operating unit (Figure 6):

Figure 6. Scope 1 emissions by operating unit (tCO_2e)



Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Scope 1 emissions derived mostly from CEMIG GT (77.22% of emissions), which uses fuel oil to produce energy at Igarapé TPP. CEMIG D ranked second in Scope 1 emissions (22.06%), which were due to diesel consumption by the company's own fleet and to leak of SF_6.

Emissions by precursor are shown in Table 12. The data reveals that fuel oil (71.64%), diesel (14.70%) and SF_6 (9.55%) were the main precursors of CEMIG's Scope 1 emissions.

Table 12. Scope 1 emissions by precursor (tCO_2e)

Precursor	Emissions (tCO_2e)	Representativeness (%)
Dolomitic limestone	9.00	0.02%
CH_4	280.85	0.54%
CO_2	0.02	0.00%
Diesel	7,635.80	14.70%
Hydrous ethanol	5.37	0.01%
Liquefied petroleum gas (LPG)	0.80	0.00%
Natural gas	12.50	0.02%
Vehicular natural gas (VNG)	80.70	0.16%
Gasoline	1,294.81	2.49%
Nitrogen in fertilizers	40.17	0.08%
Fuel oil	37,210.91	71.64%
Aviation kerosene	409.17	0.79%
SF_6	4,958.54	9.55%
Total Scope 1 emissions	**51,938.62**	**-**

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Table 13 shows the Scope 1 emissions from all Generation units inventoried in 2019. The units Camargos, Itutinga, Leste, Oeste, Salto Grande, Sul, Três Marias, Sá Carvalho, Parajuru, and Volta do Rio emitted GHGs resulting from Stationary Combustion (diesel consumption by generators) and Mobile Combustion (fuel consumption by fleet). In addition, Rosal also presents emissions from Land-Use Change (limestone and nitrogen consumption in fertilizers). Emissions at CEMIG PCH and Horizontes derived solely from Stationary Combustion. CEMIG GT alone accounted for 99.55% of all Scope 1 emissions, as this unit also contributed with emissions from other categories.

Table 13. Scope 1 emissions by operating unit (tCO_2e)

Operating unit	Emissions (tCO_2e)	Representativeness (%)
CEMIG GT	39,928.55	99.55%
Camargos	11.81	0.03%
CEMIG PCH	0.48	0.00%
Horizontes	0.05	0.00%
Itutinga	11.61	0.03%
Leste	11.87	0.03%
Oeste	9.90	0.02%
Parajuru - wind farm	26.11	0.07%
Rosal	23.35	0.06%
Sá Carvalho	2.56	0.01%
Salto Grande	14.12	0.04%
Sul	17.72	0.04%
Três Marias	8.58	0.02%
Volta do Rio - wind farm	40.60	0.10%
Total Scope 1 emissions - CEMIG's Generation units	**40,107.30**	-

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

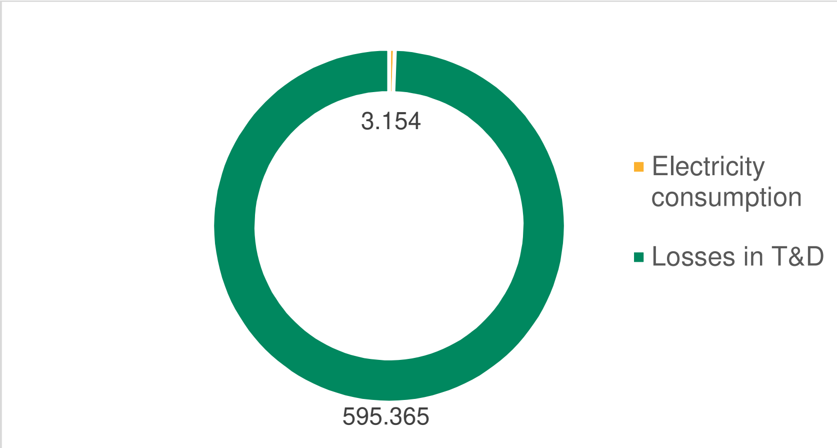
Aside from CEMIG GT, the wind farms Volta do Rio and Parajuru were the units that showed highest emissions (40.60 tCO_2e and 26.11 tCO_2e, respectively), followed by Rosal (23.35 tCO_2e). Emissions from Volta do Rio and Parajuru were mainly associated with Mobile Combustion, while those from Rosal were mostly related to nitrogen consumption in fertilizers.

3.2 Scope 2

CEMIG's Scope 2 emissions in 2019 totalized 598,518.28 tCO_2e, representing a 15.50% increase in relation to the previous year (518,212 tCO_2e in 2018) and a 30.24% reduction in relation to 2014 (858,014 tCO_2e).

Emissions from Losses in Transmission and Distribution (which represented 99.47% of Scope 2 emissions) showed an increase of approximately 15.56% in 2019 in relation to the previous year, due mostly to a refinement of the data, counting with higher monthly precision. Furthermore, in 2018 the grid mean emission factor showed a 1.35% increase compared with the previous year (0.0740 tCO_2e/MWh in 2018 against 0.0750 tCO_2e/MWh in 2019). Emissions resulting from Losses in T&D and from Electricity Consumption are shown in Figure 7.

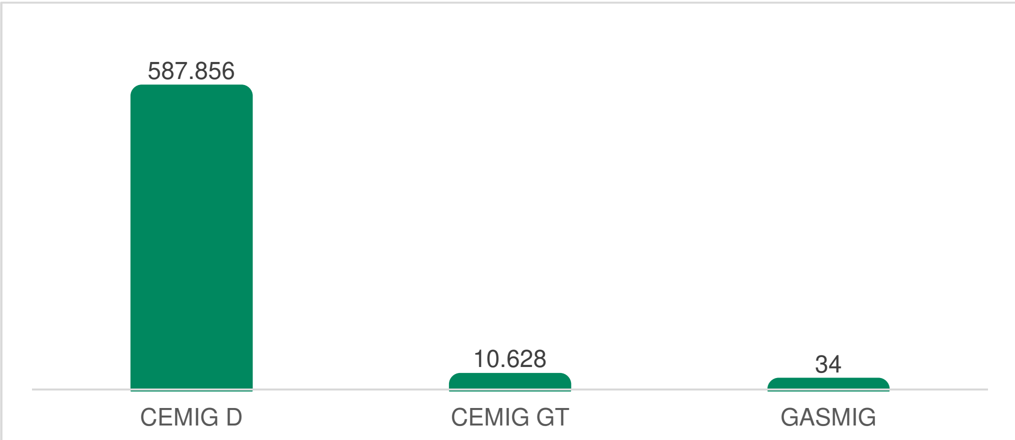
Figure 7. Scope 2 emissions by emission source (tCO_2e)



Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Scope 2 emissions by operating unit are shown in Figure 8. As a power distribution company, CEMIG D shows significantly higher emissions than other units (98.22% of the total Scope 2 emissions).

Figure 8. Scope 2 emissions by operating unit (tCO_2e)



Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

3.3 Scope 3

CEMIG's Scope 3 emissions in 2019 totalized 6,451,462 tCO2e, representing a 15.60% reduction in relation to the previous year (7,644,131 tCO2e in 2018) and a 43.07% reduction in relation to 2014 (11,332,770 tCO2e). Table 14 shows the company's GHG emissions by category and source over the last 6 years:

Table 14. Scope 3 emissions by category over the last 6 years (tCO_2e)

Category	2014	2015	2016	2017	2018	2019	Representativeness (%)
Employee commuting	586	600	591	494	112	215	0.00%
Waste generated in operations	-	-	-	-	338	616	0.01%
Downstream transport and distribution	5,729	12,851	13,241	19,871	13,700	22,699	0.35%
Upstream transport and distribution	817	373	548	575	673	791	0.01%
Use of sold goods and services	11,324,277	9,614,752	6,049,885	6,985,687	7,628,548	6,426,649	99.62%
Business travel	1,361	1,138	846	822	689	428	0.01%
Purchased goods and services	-	-	-	-	71	63	0.00%
Total	**11,332,770**	**9,629,714**	**6,065,111**	**7,007,449**	**7,644,131**	**6,451,462**	-

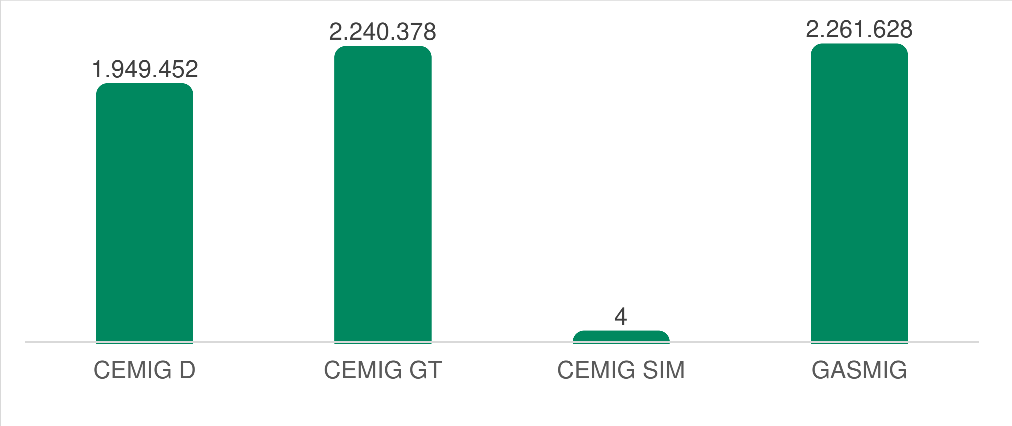
Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Scope 3 emissions were mainly associated with the commercialization of electricity and natural gas, which is categorized under Use of Sold Goods and Services. Emissions from this category represented almost the entirety of Scope 3 emissions (99.62% of the total).

The category Downstream Transport and Distribution accounts for emissions resulting from fuel consumption (alcohol, gasoline and diesel) by contractors hired by CEMIG D. For the 2019 Inventory, 15 contractors (75% of current contracts) provided this data voluntarily.

The units CEMIG D, CEMIG GT and GASMIG accounted for 30.22%, 34.73% and 35.06% of Scope 3 emissions, respectively. On the other hand, emissions from CEMIG SIM were irrelevant compared with those from the other units. Figure 9 shows the Scope 3 emissions by operating unit.

Figure 9. Scope 3 emissions by operating unit (tCO_2e)



Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Table 15 shows the precursors responsible for CEMIG's Scope 3 emissions. The data reveals that electricity (64.56%), natural gas (33.73%) and vehicular natural gas (1.32%) were the main precursors of Scope 3 emissions.

Table 15. Scope 3 emissions by precursor (tCO_2e)

Precursor	Emissions (tCO_2e)	Representativeness (%)
Diesel / Brazil	18,724.01	0.29%
Electricity / Brazil	4,165,042.75	64.56%
Hydrous ethanol	20.58	0.00%
Liquefied petroleum gas (LPG)	63.29	0.00%
Natural gas	2,176,346.22	33.73%
Vehicular natural gas (VNG)	85,260.42	1.32%
Gasoline / Brazil	4,960.75	0.08%
Aviation kerosene	428.07	0.01%
Industrial waste / Construction and demolition	4.16	0.00%
Industrial waste / Petroleum products, solvents and plastics	570.29	0.01%
Industrial waste / Sludge from wastewater treatment plants	7.85	0.00%
Urban solid waste / Wood	33.40	0.00%
Total Scope 3 emissions	**6,451,461.79**	**-**

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Table 16 shows the Scope 3 emissions from all Generation units inventoried in 2019. All units (Camargos, CEMIG PCH, Horizontes, Itutinga, Leste, Oeste, Parajuru, Rosal, Sá Carvalho, Salto Grande, Sul, Três Marias, and Volta do Rio) produced emissions from the category Use of Sold Goods and Services (commercialization of electricity).

Table 16. Scope 3 emissions by operating unit (tCO_2e)

Operating unit	Emissions (tCO_2e)	Representativeness (%)
CEMIG GT	2,090,436	93.31%
Camargos	3,804	0.17%
CEMIG PCH	10,119	0.45%
Horizontes	7,106	0.32%
Itutinga	3,097	0.14%
Leste	3,737	0.17%
Oeste	2,102	0.09%
Parajuru - wind farm	6,180	0.28%
Rosal	18,537	0.83%
Sá Carvalho	35,466	1.58%
Salto Grande	13,498	0.60%
Sul	3,482	0.16%
Três Marias	35,771	1.60%
Volta do Rio - wind farm	7,042	0.31%
Total Scope 3 emissions - CEMIG's Generation units	**2,240,378**	-

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

Emissions at CEMIG GT represented 93.31% of all Scope 3 emissions, since this unit also produced emissions from categories other than Use of Sold Goods and Services. Aside from CEMIG GT, the operating units Três Marias, Sá Carvalho and Rosal were the ones that showed highest emissions, with representativeness values of 1.60%, 1.58% and 0.83%, respectively.

4. UNCERTAINTY ANALYSIS

Compiling an emissions inventory requires using several calculation tools that are based on predictions, parameters and standard emission factors. The use of these tools may lead to a certain degree of uncertainty in the inventory's calculations.

To minimize such uncertainties, values based on official sources such as the consulted methods or market standards were used whenever possible, always taking into consideration the principles of conservative calculation, accuracy, and transparency.

Moreover, all sources of the parameters used were filed for ulterior analysis and checking by an external organization. This section presents a qualitative evaluation of the major uncertainties identified, as well as a quantitative assessment of the uncertainty in the calculation of emissions from each of the company's operating units.

The uncertainties associated with the inventory can be classified in two groups:

- **scientific uncertainty:** the uncertainty that arises when the science of the actual emission and/or removal process is not fully understood. E.g., the significant involvement of scientific uncertainty in the use of direct and indirect factors associated with global warming to estimate the emissions of several GHGs. Most factors used in this study were obtained from the IPCC.

- **estimation uncertainty:** the uncertainty that arises any time GHG emissions are quantified. Estimation uncertainty can be further classified in model uncertainty, when it is associated with the mathematical equations used to characterize the relationships between various parameters and emission processes; and parameter uncertainty, which is that associated with parameters introduced as inputs in estimation models.

According to recommendations in the IPCC Good Practice Guidance, inventories must not disclose emissions having any bias that could be identified and eliminated, and uncertainties must be minimized considering all the existing scientific knowledge and available resources.

These recommendations were followed throughout all stages of inventorying. In that sense, we cared to use the most recent calculation methods and emission factors provided by organizations of high credibility in the field of emissions calculation. Regarding the data used, special attention was paid to their conformity to reality (checking of the company's records and analysis of the data received) and a careful search was conducted for data in the units of measurement that would reduce the uncertainties associated with emissions.

The procedures adopted to calculate uncertainties are shown in Appendix B – Calculation of Emissions and Uncertainties. For CEMIG's 2019 GHG Emissions Inventory, the uncertainties were also calculated using CLIMAS. The results are shown in Table 17, where:

- **lower uncertainty** = lower limit of the 95% confidence interval, in %; and
- **upper uncertainty** = upper limit of the 95% confidence interval, in %.

Table 17. Results of uncertainties from the 2019 inventory

Category	Lower uncertainty	Upper uncertainty
Purchased electricity	0.00%	0.00%
Purchased goods and services	1.59%	3.03%
Stationary combustion	1.93%	2.51%
Mobile combustion	0.66%	0.58%
Employee commuting	0.72%	0.82%
Fugitive emissions	0.00%	0.00%
Land-use change	10.28%	26.12%
Waste generated in operations	1.47%	1.54%
Downstream transport and distribution	0.84%	0.77%
Upstream transport and distribution	1.10%	0.87%
Use of sold goods and services	0.44%	0.69%
Business travel	0.00%	0.00%
Total	**0.40%**	**0.62%**

Source: Elaborated by the WayCarbon team based on data from the CLIMAS software.

5. CORPORATE TARGETS

CEMIG is committed to mitigating emissions of gases that contribute to Climate Change, and thereby in 2018 the company set two targets for tCO_2e emissions. The first one consists in an absolute target based on the combined emissions from Scopes 1 and 2, while the second is an intensity target for Scope 2 emissions, based on emissions from total Losses in Electricity Transmission and Distribution.

For this, 2022 was set as target year whereas 2017 was established as base year for total emissions. For Scope 1 emissions, we adopted the following criteria: keeping the percentage of SF_6 emissions at a maximum 0.66% (SF_6 emissions (kg)/total installed stock (kg)); obtaining a maximum emission factor at Igarapé TPP of 0.88 t CO_2e/MWh (2017 factor); and reducing emissions from mobile sources by 10% in relation to 2017. Following this approach, the target set to 2019 for Scope 1 emissions was 56,663 tCO_2e. Thus, actual emissions were 9.09% below the set target, due mostly to the high efficiency of Igarapé TPP, which itself showed an emission factor of 0.82 tCO_2e/MWh, but also to the SF_6 emission factor, which showed a value of 0.48%.

For Scope 2 emissions, we adopted the following criteria: keeping electricity consumption under 156,773 GJ (2017 value); and recording no more than 11.23% of total losses in 2022.

CEMIG's direct emissions in 2019 totalized 51,939 tCO_2e, showing a 6.33% increase in relation to the company's direct emissions in 2017, which is the base year for the target. Between 2011 and 2019, electricity consumption reduced by 10.65%, dropping from 168,740 GJ to 150,766 GJ. In relation to the base year (2017), electricity consumption decreased by 3.83%.

The IPTD (Portuguese acronym for "Index of Technical Losses in Distribution") value in 2019 was 13,57% in relation to the total electricity injected in the distribution system. This result is above the target value (11.49% in 2019). Additionally, the 2019 result showed a slight increase in relation to 2018, when the IPTD was 12.82%.

6. RECOMMENDATIONS

In order for companies to adapt to a low-carbon economy, a virtuous cycle of analysis and process improvement must be developed. When carefully detailed and organized, such set of activities integrates the corporate plan for managing GHG emissions.

The pathway begins with a diagnosis of the current situation, by gathering technical knowledge on the subject of Climate Change mitigation and its application to the company. Once the company's impacts on Climate Change as well as their risks and opportunities to the business have been mapped, it is possible to evaluate process alternatives and select projects that reduce carbon intensity (GHG emissions by production). Then, a process must be structured to continuously follow up the company's climate performance, in order to assess the impact of the implemented projects and, based on the obtained results, update the diagnosis.

The GHG Emissions Inventory is the first step of the diagnosis and it must be continuously improved. The improvement strategies recommended to CEMIG are:

- expand the monitored emission sources, by calculating the emissions from other Scope 3 categories such as wastewater treatment, domestic waste, and refrigerant gases;
- implement a monthly information flow and follow up the impact on Climate Change on a monthly-basis as a form of environmental management;
- manage primary evidence, following it up in a system or via SharePoint.

Besides the inventory, there are other types of studies aimed to diagnose the company's situation in the context of a low-carbon economy, such as:

- calculation of impact indicators per product or service provided, thereby enabling the comparison with companies of diverse sizes and the evaluation of climate management efficiency;
- identification of risks and opportunities in regulatory scenarios, e.g., with mechanisms of carbon pricing.

The next steps are to plan and act on the Climate Change issue. That includes:

- sector benchmarking;
- defining a mitigation strategy;
- defining an adaptation strategy;
- defining a neutralization strategy.

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GLOSSARY

Base year: a specific historical period to compare GHG emissions and removals, as well as other related information.

Carbon dioxide equivalent (CO_2e): the unit used to compare the radiative forcing impact (global warming potential) of a given GHG with that of CO2.

Direct GHG emissions: GHG emissions by sources belonging to or controlled by the company. To establish the company's operational boundaries, the concepts of financial control and operational control may be adopted.

Emission factor or **GHG removal factor**: a factor that correlates activity data with GHG emissions and removals.

GHG emissions: the total mass of a GHG released to the atmosphere during a specific period.

GHG emissions inventory: a document which provides detailed information concerning the GHG sources and sinks and quantitative data regarding GHG emissions and removals during a given period.

GHG removals: the total mass of a given GHG removed from the atmosphere in a specific period.

GHG reservoir: any physical unit or component of the biosphere, geosphere or hydrosphere that is capable of storing or accumulating GHG removed from the atmosphere by a sink or GHG captured from a source. The total carbon mass contained in a GHG reservoir in a specific period can be referred to as the reservoir's carbon stock. A GHG reservoir may transfer its gases to another GHG reservoir. The capture of GHG from a source before the gases enter the atmosphere and their storage in a reservoir can be referred to as GHG capture and storage.

GHG sink: any physical unit or process that removes GHG from the atmosphere.

GHG source: any physical unit or process that releases GHG to the atmosphere.

Global warming potential (GWP): a factor that describes the radiative forcing impact of a mass unit of a given GHG, in relation to a mass unit of carbon dioxide (CO2) in a given period.

Greenhouse gas (GHG): an atmospheric constituent, of either natural or anthropogenic origin, that absorbs and emits radiation in specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, by the atmosphere and by clouds. E.g.: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF6).

Indirect GHG emissions related to energy consumption: GHG emissions from generation of electricity, heat or steam, either imported or consumed by the company.

Offset: credits to compensate for GHG emissions.

Organization: any company, corporation, enterprise, authority or institution – either a part or combination of –, incorporated or not, public or private, that has its own functions and administration.

Other indirect GHG emissions: indirect GHG emissions other than the indirect emissions related to energy consumption. These emissions result from the company's activities, but do not originate from sources owned or controlled by other companies.

Scope: the concept of scope was introduced by the GHG Protocol aiming to aid companies in defining their operational boundaries. Scopes are differentiated in three categories, being separated in direct and indirect emissions.

Scope 1: encompasses the category of direct GHG emissions of the company, i.e., those originating from sources belonging to or being controlled by the company within the defined boundaries. E.g., emissions from the burning of fossil fuels and from manufacturing processes.

Scope 2: encompasses the category of indirect GHG emissions related to external energy purchase. E.g., consumption of the electricity generated by power distribution companies from the Brazilian National Interconnected System (SIN, Portuguese acronym) and purchased thermal energy.

Scope 3: encompasses the category of indirect GHG emission by other sources, i.e., emissions that occur due to activities held by the company but originating in sources that do not belong to or are not controlled by it. E.g., transport of products in vehicles not owned by the company, use of vehicles by third-parties, transport of employees and business travel.

APPENDIX A - GHG PROTOCOL TABLES

Since reporting the emissions from international operating units is optional for the GHG Protocol, such emissions were separated from those originated in Brazilian facilities. Hence, the results presented in this section differ from those presented in the main body of the report. The aim of this section is to facilitate to CEMIG the reporting of its data to the public registry of emissions.

Table 1A. Summary of total emissions (tGHG)

	Escopo	Scope 1	Scope 2	Scope 3	Totals
Família de gás					
CH4		13.979132		331.546158	**345.525290**
CO2		46,340.253274	598,518.281463	6,440,259.459504	**7,085,117.994241**
N2O		0.974308		9.777443	**10.751751**
SF6		0.217480			**0.217480**
	Totals	**7,085,474.488762**			

Table 2A. Summary of total emissions (tCO_2e)

	Escopo	Scope 1	Scope 2	Scope 3	Totals
Família de gás					
CH4		349.478300		8,288.653950	**8,638.132250**
CO2		46,340.253274	598,518.281463	6,440,259.459504	**7,085,117.994241**
N2O		290.343784		2,913.678014	**3,204.021798**
SF6		4,958.544000			**4,958.544000**
	Totals	**51,938.619358**	**598,518.281463**	**6,451,461.791468**	**7,101,918.692289**

Table 3A. Scope 1 emissions by category (tCO_2e)

		Superfamília de gás	Kyoto
Escopo	Categoria		
Scope 1	Fugitive emissions		5,239.416000
	Land use change		49.161628
	Mobile combustion		9,067.996718
	Stationary combustion		37,582.045012
		Totals	**51,938.619358**

Table 4A. Scope 1 emissions by category – emissions and removals of biogenic CO_2

		Renewable CO2	
		Emissions (tGEE)	Removals (tGEE)
Scope 1	Mobile combustion	1,639.458526	0.000000
	Stationary combustion	37.854859	0.000000

Table 5A. Scope 2 emissions by category (tCO_2e)

		Superfamília de gás	Kyoto
Escopo	Categoria		
Scope 2	Electricity purchase		598,518.281463
		Totals	**598,518.281463**

Table 6A. Scope 3 emissions by category (tCO_2e)

		Superfamília de gás	Kyoto
Escopo	Categoria		
Scope 3	Business travel		428.070447
	Employee transportation (home - work)		215.467430
	Purchased goods and services		63.294566
	Transport and distribution (downstream)		22,699.236551
	Transport and distribution (upstream)		790.634060
	Use of goods and services sold		6,426,649.385894
	Waste generated in operations		615.702520
		Totals	**6,451,461.791468**

Table 7A. Scope 3 emissions by category – emissions and removals of biogenic CO_2

		Renewable CO2	
		Emissions (tGEE)	Removals (tGEE)
Scope 3	Employee transportation (home - work)	30.890583	0.000000
	Transport and distribution (downstream)	5,234.359819	0.000000
	Transport and distribution (upstream)	81.586432	0.000000

Table 8A. Emissions by operating unit (tCO_2e)

	Escopo	Scope 1	Scope 2	Scope 3	Totals
Unidade operacional					
CEMIG D		11,457.458517	587,856.208804	1,949,452.194899	**2,548,765.862220**
CEMIG GT		40,107.303504	10,627.962633	2,240,377.743058	**2,291,113.009195**
CEMIG SIM		2.274921		3.641319	**5.916240**
GASMIG		371.582416	34.110026	2,261,628.212192	**2,262,033.904634**
	Totals	**51,938.619358**	**598,518.281463**	**6,451,461.791468**	**7,101,918.692289**

APPENDIX B – CALCULATION OF EMISSIONS AND UNCERTAINTIES

B.1 FUEL CONSUMPTION BY MOBILE AND STATIONARY EQUIPMENT

The GHG emissions resulting from the burning of fossil fuels were calculated based on the fuel consumption, in volume, or on the distance covered, per fuel type and vehicle type, in 2018. When data is provided in terms of fuel consumption, GHG emissions from that given source are calculated according to the following equation:

$$E_{i,g,y} = C_{i,y} \cdot LHV_{i,y} \cdot EF_{i,g,y} \cdot GWP_g$$

Where:

- $\boldsymbol{i}$ index that denotes the fuel type;
- $\boldsymbol{g}$ index that denotes a GHG type;
- $\boldsymbol{y}$ reference year of the report;
- $\boldsymbol{E_{i,g,y}}$ emissions or removals of the GHG *g* that are attributable to the source *i* during the year *y*, in tCO_2e;
- $\boldsymbol{C_{i,y}}$ consumption of the fuel *i* during the year *y*, in the unit of measurement *u*, with *u* being given in m^3 or *kg*;
- $\boldsymbol{LHV_{i,y}}$ lower heating value of the fuel *i* during the year *y*, in the unit of measurement *TJ/u*;
- $\boldsymbol{EF_{i,g,y}}$ emission factor of the GHG *g* applicable to the fuel *i* in the year *y*, in tGHG g/*TJ*;
- $\boldsymbol{GWP_g}$ global warming potential of the GHG *g*, in tCO_2e/tGHG*g*.

In the cases where the input data is the covered distance, emissions are calculated by the following equation:

$$\boldsymbol{E_{i,g,y} = \frac{D_{i,j,y}}{FE_{i,j,y}} \cdot LHV_{i,y} \cdot EF_{i,g,y} \cdot GWP_g}$$

Where:

- $\boldsymbol{i}$ index that denotes the fuel type;
- $\boldsymbol{j}$ index that denotes the vehicle type;
- $\boldsymbol{g}$ index that denotes a GHG type;
- $\boldsymbol{y}$ reference year of the report;
- $\boldsymbol{E_{i,g,y}}$ emissions or removals of the GHG *g* that are attributable to the source *i* during the year *y*, in tCO_2e;
- $\boldsymbol{D_{i,j,y}}$ distance covered by the vehicle j that uses the fuel *i* during the year *y*, in km;
- $\boldsymbol{FE_{i,j,y}}$ fuel economy of the vehicle j, in the unit of measurement *u/km,* with *u* being given in m^3 or *kg*;
- $\boldsymbol{LHV_{i,y}}$ lower heating value of the fuel *i* during the year *y*, in the unit of measurement *TJ/u*;
- $\boldsymbol{EF_{i,g,y}}$ emission factor of the GHG *g* applicable to the fuel *i* in the year *y*, in tGHG g/*TJ*;
- $\boldsymbol{GWP_g}$ global warming potential of the GHG *g*, in tCO_2e/tGHG*g*.

The types of GHG emitted in fuel burning are CO_2, CH_4 and N_2O.

Gasoline and diesel consumption demand an additional calculation stage, since in 2019 the Brazilian law required that these fuels contained specific proportions of biofuels in their composition. For gasoline, the requirement was 27% of anhydrous ethanol, while for diesel the requirement was 10% until August 2019 and 11% from September onwards. To calculate the emissions resulting from consumption of these fuel types, the biofuel percentages were multiplied by the total consumption of the fuel mixture prior to the use of the equation described above.

The categories of this report that were calculated following the equations above were: fuel consumption by stationary equipment, fuel consumption by mobile equipment, outsourced transport, employee commuting and business travels (taxi, only).

B.2 ELECTRICITY CONSUMPTION

GHG emissions resulting from electricity consumption were calculated using data on the amount of electric energy consumed by operating unit, in MWh, in 2019. To calculate emissions, monthly consumption values were used due to the variation in emission factors of the Brazilian grid.

The GHG considered in the generation of electricity by the Brazilian grid is CO_2, and its emissions are calculated according to following equation:

$$\boldsymbol{E_{CO2,\mathrm{m,y}} = C_{m,y} \cdot EF_{CO2,\mathrm{m},y}}$$

Where:

- $\boldsymbol{m}$ month of electricity consumption;
- $\boldsymbol{y}$ reference year of the report;
- $\boldsymbol{E_{CO2,m,y}}$ CO_2 emissions that are attributable to the electricity consumption by the Brazilian grid in the month *m* of the year *y*, in tCO_2e;
- $\boldsymbol{C_{m,y}}$ electricity consumption by the Brazilian grid in the month *m* of the year *y*, in MWh;
- $\boldsymbol{EF_{i,g,y}}$ CO_2 emission factor applicable to the electricity of the Brazilian grid in the month *m* of the year *y*, in tCO_2/MWh.

The category ‘electricity consumption’ of this report was calculated by the above equation.

B.3 CONSUMPTION OF REFRIGERANT AND INSULATING GASES

GHG emissions resulting from consumption of refrigerant and insulating gases were calculated using data on the amount of gases consumed by operating unit, in kg, in 2019. The mass of consumed gases was multiplied by their respective global warming potentials so that their CO_2e could be obtained, according to the following equation:

$$E_{CO2e,g,y} = C_{g,y} \cdot GWP_g \cdot 1000$$

Where:

- y reference year of the report;
- g index that denotes a GHG type;
- $E_{CO2e,g,y}$ CO_2 emissions that are attributable to the consumption of the refrigerant gas g in the year y, in tCO_2e;
- C_y consumption of refrigerant gases in the year y, in kg;
- GWP_g global warming potential of the GHG g, in $tCO_2e/tGHGg$.

In the case of blends of refrigerant gases, emissions were calculated by multiplying the percentages of each refrigerant gas in the blend on the above equation.

The category 'fugitive emissions' of this report was also calculated by the above equation.

B.4 AIR TRAVEL

The first step to calculate GHG emissions from air travel is to record the distances covered by flights. The CLIMAS system has a function by which straight-line distances covered in air travels are calculated using their IATA[12] codes (e.g., GRU/FOR in the case of a trip from Guarulhos to Fortaleza). Additionally, a correction factor of 8% is applied, following the DEFRA recommendation, in order to estimate the real distance covered in the air travels, since the distances are in reality not travelled in a straight line. After distances are calculated, air travels are then classified as short-, medium- or long-haul flights.

The GHG emissions from short-, medium- and long-haul flights are calculated according to the following equations:

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[12] IATA (International Air Transport Association) is a simple identifier of codes from airports worldwide.

$$E_{CO2e,\mathrm{tr,y}} = Distance_{tr} \cdot pax \cdot EF_{CO2,tr,y}$$

$$E_{CH4,\mathrm{tr,y}} = Distance_{tr} \cdot pax \cdot EF_{CH4,tr,y}$$

$$E_{N2O,\mathrm{tr,y}} = Distance_{tr} \cdot pax \cdot EF_{N2O,tr}$$

Where:

- y reference year of the report;
- tr classification of the distance covered (short-, medium- or long-haul);
- $E_{CO2,tr,y}$ CO_2 emissions resulting from burning of fuels by the airplane that travelled the distance of type *tr* in the year *y*, in tCO_2;
- $E_{CH4,tr,y}$ CH_4 emissions resulting from burning of fuels by the airplane that travelled the distance of type *tr* in the year *y*, in tCH_4;
- $E_{N2O,tr,y}$ N_2O emissions resulting from burning of fuels by the airplane that travelled the distance of type *tr* in the year *y*, in tN_2O;
- $Distance_{tr}$ straight-line distance covered in the air travel of type *tr* corrected by a factor of 8%, in km;
- pax number of passengers that travelled the distance of type *tr*;
- $EF_{CO2,tr}$ CO_2 emission factor applicable to the burning of fuels by the airplane that travelled the distance of type *tr*, in tCO_2/pax.km;
- $EF_{CH4,tr}$ CH_4 emission factor applicable to the burning of fuels by the airplane that travelled the distance of type *tr*, in tCH_4/pax.km;
- $EF_{N2O,tr}$ N_2O emission factor applicable to the burning of fuels by the airplane that travelled the distance of type *tr*, in tN_2O/pax.km.

The emission factors ($EF_{CO2,tr}$, $EF_{CH4,tr}$ and $EF_{N2O,tr}$) have been removed from the emissions calculation tool of the 2019 Brazil GHG Protocol Program.

B.5 AGGREGATED AND OTHER NON-CO_2 EMISSIONS

The GHG emissions mapped from this source result from the use fertilizers in the soil, especially nitrogen fertilizers, limestone and urea. The input data needed to calculate these emissions is the total amount of fertilizers applied to the soil in the year, by type.

In the case of application of limestone (liming) and urea to the soil, CO_2 emissions are calculated according to the following equation:

$$\boldsymbol{E_{CO2,\mathrm{i,y}} = F_{i,y} \cdot FC_{\mathrm{i}} \cdot \frac{44}{12}}$$

Where:

- ***y*** reference year of the report (2019);
- ***i*** application of the fertilizer *i* (dolomitic limestone or urea);
- $\boldsymbol{E_{CO2,i,y}}$ CO_2 emissions that are attributable to application of the fertilizer *i* in the year *y*, in $t\ CO_2$;
- $\boldsymbol{F_{i,y}}$ amount of the fertilizer *i* used in the year *y*, in *t*;
- $\boldsymbol{FC_i}$ amount of C present in the molecular formula of the fertilizer *i*, in *t C/t*.

The compound considered to calculate emissions resulting from use of agricultural limestone was dolomitic limestone, since the information obtained from the Brazilian Association of Agricultural Limestone Producers (ABRACAL, Portuguese acronym) is not listed individually by liming type.

Besides CO_2 emission, the use of fertilizers in the soil, like urea and other nitrogen additives, also leads to emission of N_2O. Such emissions are calculated by the following equation:

$$\boldsymbol{E_{N2O,\mathrm{i,y}} = F_{i,y} \cdot (EF1_{\mathrm{i}} + EF4_i \cdot FracGasF_i + EF5_i \cdot FracLeach_i) \cdot F_{N_{\mathrm{i}}}} \cdot \frac{44}{28}$$

Where:

- ***y*** reference year of the report (2019);
- ***i*** application of the fertilizer *i*;
- $\boldsymbol{E_{N2O,i,y}}$ N_2O emissions that are attributable to application of the fertilizer *i* in the year *y*, in $t\ N_2O$;
- $\boldsymbol{F_{i,y}}$ amount of the fertilizer *i* used in the year *y*, in *t;*

- F_{N_i} amount of N present in the molecular formula of the fertilizer *i*, dimensionless;
- $EF1_i$ N factor considering additions, volatilization and displacement of N from fertilizer *i*, dimensionless (default value of 0.01, according to IPCC, 2006);
- $EF4_i$ Volatilization and re-deposition factor applicable to fertilizer *i*, dimensionless (default value of 0.01, according to IPCC, 2006);
- $EF5_{i,}$ Leaching/runoff factor applicable to fertilizer *i*, dimensionless (default value of 0.0075, according to IPCC, 2006);
- $FracGasF_i$ Factor of N loss by volatilization of NH_3 and NO_x for the fertilizer type *i*, dimensionless (default value of 0.1, according to IPCC, 2006);

$FracLeach_i$ Factor of N loss by leaching/runoff for the fertilizer type *i*, dimensionless (default value of 0.3 according to IPCC, 2006).

B.6 EMISSIONS FROM WASTE GENERATED IN OPERATIONS

Co-processing GHG emissions were calculated using data on the waste produced that was sent for co-processing in 2019, in tons. Emissions are calculated using the following equation:

$$E_{CO2,i,y} = m_{i,y} \,.\, CC_i \,.\, \frac{44}{12} + m_{i,y} \,.\, EF_{CH4,i} \,.\, GWP_{CH4} + m_{i,y} \,.\, EF_{N20,i} \,.\, GWP_{N2O}$$

Where:

- i waste type;
- y reference year of the report;
- $E_{CO2,i,y}$ CO_2 emissions resulting from co-processing of waste i during the year y, in tCO_2e;
- $m_{i,y}$ waste mass produced in the year y, in the unit of measurement u, with u being given in t;
- CC_i carbon content in waste i, dimensionless;
- $EF_{CH4,i}$ emission factor of CH_4 resulting from co-processing of waste i, in tCH_4;

- GWP_{CH4} global warming potential of CH_4, in tCO_2e/tCH_4;
- $EF_{N20,i}$ emission factor of N_2O resulting from co-processing of waste i, in tN_2O;
- GWP_{N2O} global warming potential of N_2O, in tCO_2e/tN_2O.

GHG emissions from waste incineration were calculated using data on the waste produced that was incinerated in 2019, in tons. Emissions are calculated using the following equation:

$$E_{CO2,i,y} = m_{i,y} \,.\, CC_i \,.\, \frac{44}{12} + m_{i,y} \,.\, EF_{CH4,i} \,.\, GWP_{CH4} + m_{i,y} \,.\, EF_{N20,i} \,.\, GWP_{N2O}$$

Where:

- i waste type;
- y reference year of the report;
- $E_{CO2,i,y}$ CO_2 emissions resulting from incineration of waste i during the year y, in tCO_2e;
- $m_{i,y}$ waste mass produced in the year y, in the unit of measurement u, with u being given in t;
- CC_i carbon content in waste i, dimensionless;
- $EF_{CH4,i}$ emission factor of CH_4 resulting from incineration of waste i, in tCH_4;
- GWP_{CH4} global warming potential of CH_4, in tCO_2e/tCH_4;
- $EF_{N20,i}$ emission factor of N_2O resulting from incineration of waste i, in tN_2O;
- GWP_{N2O} global warming potential of N_2O, in tCO_2e/tN_2O.

GHG emissions from landfills were calculated using data on the waste that was sent to landfills in 2019, in tons. The amount of CH_4 generated in landfills is estimated according to the following equations:

$$E_{CH4,y} = QR_y \cdot L_{0,y} \cdot (1 - OX_0)$$

$$L_{0,y} = MCF_0 \cdot DOC_{mean} \cdot DOC_f \cdot F_{CH4} \cdot \frac{16}{12}$$

$$DOC_{mean} = \sum (\%_{i,y} \cdot DOC_i)$$

Where:

- y reference year of the report;
- i waste type;
- $E_{CH4,y}$ CH_4 emissions attributable to decomposition of the waste disposed in landfills in year *y*, in *t* CH_4;
- AW_y amount of waste sent to landfills in year *y*, in *t*;
- $L_{0,y}$ methane generation potential in year *y*, in *t* CH_4/ *t waste*;
- OX_0 oxidation factor, dimensionless;
- MCF_0 methane correction factor based on landfill quality, dimensionless;
- DOC_{mean} mean value of industrial degradable organic carbon (default value of 0.04 according to IPCC 2006);
- DOC_i degradable organic carbon in waste *i*;
- $\%_{i,y}$ fraction of the amount of waste *i* in year *y*;
- $DOC_{f,y}$ fraction of waste that decomposes, dimensionless (default value of 50%, according to IPCC 2006);
- F_{CH4} fraction of methane in biogas, dimensionless (default value of 50%, according to IPCC 2006);
- **16/12** mass conversion of C into CH_4, 1.33;

Values of OX_0 and MCF_0 were obtained from IPCC 2006 for uncategorized landfills. Overall, there is no methane recovery in landfills or anaerobic reactors in Brazil, and thus such recovery was not considered in the inventory.

B.7 CALCULATION OF UNCERTAINTIES

The equations used to calculate combined uncertainties are provided below, as are estimates based on confidence intervals and the corrections that were made whenever necessary, according to the IPCC Good Practice Guidance (2006).

Combining uncertainties of components (not correlated) of a multiplication:

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots U_n^2}$$

Where:

- $\boldsymbol{U_{total}}$: the total percentage uncertainty in the product of quantities (half the 95 percent confidence interval expressed as percentage). To asymmetric confidence intervals, the value considered is the larger percentage difference between the mean and the confidence limit;
- $\boldsymbol{U_i}$: the percentage uncertainties associated with each of the quantities of a multiplication.

Combining uncertainties of components (not correlated) of an addition or subtraction:

$$U_{total} = \frac{\sqrt{(U_1.x_1)^2 + (U_2.x_2)^2 + \ldots + (U_n.x_n)^2}}{|x_1 + x_2 + \ldots + x_n|}$$

Where:

- $\boldsymbol{U_{total}}$: the total percentage uncertainty in the sum or subtraction of the quantities (half the 95 percent confidence interval expressed as percentage). To asymmetric confidence intervals, the value considered is the larger percentage difference between the mean and the confidence limit;
- $\boldsymbol{x_i}$ ***and*** $\boldsymbol{U_i}$: the uncertainty quantities and the percentage uncertainties associated with each one of the quantities in a multiplication.

By means of the propagation of uncertainty model described above, an estimate of half the 95% confidence interval was produced and expressed as a percentage of the inventory result. As the inventory uncertainty increases, the propagation approach detailed above systematically underestimates the uncertainty, except in cases where the quantification models are purely additive. Therefore, in cases where uncertainty is higher than 100% and lower than 230%, the uncertainty must be corrected by the procedures described below:

$$U_{corrected} = U.F_c$$

$$F_c = \left[\frac{(-0{,}720 + 1{,}0921.U - 1{,}63.10^{-3}.U^2 + 1{,}11.10^{-5}.U^3}{U}\right]^2$$

Where:

- $\boldsymbol{U_{corrected}}$: corrected total uncertainty (half the 95 percent confidence interval expressed as percentage);
- $\boldsymbol{U}$: uncorrected total uncertainty (half the 95 percent confidence interval expressed as percentage);
- $\boldsymbol{F_c}$: uncertainty correction factor.

To calculate the confidence intervals of the total result using the model based on the mean and on half the 95 percent confidence interval of the component quantities, a distribution must be assumed. If the model is purely additive and half the confidence interval is lower than 50%, a normal distribution is often an accurate estimate. In this case, a symmetric probability distribution can be assumed. For multiplicative models or in cases where uncertainty is higher than 50% for variables that must be non-negative, a lognormal distribution is typically an accurate assumption. In these cases, the probability distribution is not symmetric with respect to the mean. For such situations, the following equations were then used to calculate the upper and lower limits of the 95% confidence interval:

$$U_{low} = \left\{\frac{\exp[\ln(\mu_g) - 1{,}96.\ln(\sigma_g)] - \mu}{\mu}\right\}.100$$

$$U_{high} = \left\{\frac{\exp[\ln(\mu_g) + 1{,}96.\ln(\sigma_g)] - \mu}{\mu}\right\}.100$$

$$\sigma_g = exp.\left\{\sqrt{\ln\left(1 + \left[\frac{U}{100}\right]^2\right)}\right\}$$

$$\mu_g = exp.\left\{\ln(\mu) - \frac{1}{2}.\ln\left(1 + \left[\frac{U}{100}\right]^{-2}\right)\right\}$$

Where:

- $\boldsymbol{U_{low}}$: lower limit of the 95% confidence interval, in %;
- $\boldsymbol{U_{high}}$: upper limit of the 95% confidence interval, in %;
- $\boldsymbol{\mu_g}$: geometric mean;
- $\boldsymbol{\mu}$: arithmetic mean;
- $\boldsymbol{\sigma_g}$: geometric standard deviation;

- $\boldsymbol{U}$: symmetric total uncertainty of the 95% confidence interval, in %;

APPENDIX C - GHG INVENTORY EMISSION FACTORS

All calculation logs of emission factors can be found in the CLIMAS system. To access them, follow the steps below:

1. Access CLIMAS;
2. In “Emissões de GEE” [‘GHG Emissions’], select “Auditoria – Extrato de fatores de emissão” [‘Audit - Statement of emission factors’];
3. Choose the inventory and click “Obter extrato” [‘Obtain statement’] to generate the report;
4. In the last table (“Fatores de emissão”) [‘Emission factors’], select the emission factor in the columns “Tecnologia/Precursor” [‘Technology/Precursor’] and click the “Ver” [‘See’] button in the last column (“Medidas de fator”) [‘Factor measurements’];
5. In the new window, click “Memorial” [‘Log’] (last column) to verify how the emission factor was constructed and where its data was retrieved from.

Calculation logs have a detailed description, as in the following example:

tCO_2/Gm

Given:

Variable	Description	Value	Unit	Reference	Remark	Validity start	Validity end
FC	Diesel consumption in road bus	3, [-0.00%, +0.00%]	km/L	PBGHGP 2016	Sheet "Emission factors" (Fatores de emissão), Section 3, Table 8.		
EFCO2Diesel	CO2 emission factor for combustion of diesel oil	74100, [-2.02%, +0.94%]	kg/TJ	IPCC 2006	V2 CH3 table 3.5.2		
NCVdiesel	Net calorific value of diesel oil	43, [-3.72%, +0.70%]	TJ/Gg	IPCC 2006	V2 CH1 table 1.2		
DensityDiesel	Density of diesel oil	840, [-0.00%, +0.00%]	kg/m3	BEN 2015	Page 224, "Table VIII.9 – Specific Mass and Heating Values – 2014"		
FracBio	Percentage of biodiesel added to diesel in Brazil	0.07, [-0.00%, +0.00%]	Dimensionless	PBGHGP 2016		Nov/2014	

Then:

$$\frac{(1 - FracBio) \cdot DensityDiesel \cdot NCVdiesel \cdot EFCO2Diesel}{(FC \cdot 10^6)} = 829.7125200000^{+1.17\%}_{-4.24\%}$$

The major emission and conversion factors used to calculate scope 1, 2 and 3 emissions for the CEMIG 2019 GHG inventory are given in the sequence.

Table C1. Global Warming Potentials (GWPs)

Gas	GWP
CO_2	1
CH_4	25
N_2O	298
SF_6	22,800

Table C2. Emission Factors – Electricity – 2019

Country	$EFCO_2$ (t/MWh)	$EFCH_4$ (t/MWh)	EFN_2O (t/MWh)	Source
Brazil	0.0750	-	-	MCTIC, 2020

Table C3. Conversion Factors – Mobile Combustion

Transport data	Factor	Unit	Source
Diesel oil - commercial vehicle	10.5	km/L	PBGHGP 2020
Diesel oil - heavy truck	3.4	km/L	PBGHGP 2020
Diesel oil - light and medium trucks	5.6	km/L	PBGHGP 2020

Table C4. Emission Factors – Air Travel

Air travel	$EFCO_2$	$EFCH_4$	EFN_2O	Unit	Source
Air travel - long distance	94.851852	0.00037	0.003014	t/pax*Gm	PBGHGP 2020
Air travel - medium distance	76.768519	0.00037	0.002424	t/pax*Gm	PBGHGP 2020
Air travel - short distance	123.564815	0.004444	0.003915	t/pax*Gm	PBGHGP 2020
Air travel - cargo - short distance		0.000003	0.000034	kg/tkm	DEFRA 2016
Short-haul flights - international freight transportation	1.21094			kgGHG/tkm	DEFRA 2016
Short-haul flights - freight transportation	1.06176			kgCO_2/tkm	DEFRA 2016

Table C5. Specific Masses and Lower Heating Values (LHVs)

Precursor	Specific mass (kg/m³)	LHV (kcal/kg)	Source
Biodiesel (B100)	880	9,000	BEN, 2019
Hydrous ethanol	809	6,300	BEN, 2019
Natural gas	0.74	8,800	BEN, 2019
Automotive gasoline	742	10,400	BEN, 2019
Diesel oil	840	10,100	BEN, 2019
Aviation kerosene	799	10,400	BEN, 2019

Table C6. Emission Factors – Mobile and Stationary Sources

Precursor	$EFCO_2$	$EFCH_4$	EFN_2O	Unit	Source
Natural gas	56,100			kg/TJ	IPCC, 2006
Natural gas - mobile combustion		92.0	3.0	kg/TJ	IPCC, 2006
Biodiesel	2.431			tCO_2/m³	IPCC, 2006
Biodiesel - mobile combustion		0.000332	0.00002	tGHG/m³	IPCC, 2006
Biodiesel - stationary combustion - commercial / institutional		10.0	0.6	kg/TJ	IPCC, 2006

Precursor	$EFCO_2$	$EFCH_4$	EFN_2O	Unit	Source
Diesel oil	74,100			kg/TJ	IPCC, 2006
Diesel oil - mobile combustion		3.9	3.9	kg/TJ	IPCC, 2006
Diesel oil - stationary combustion - commercial / institutional		10.0	0.6	kg/TJ	IPCC, 2006
Ethanol	1.457			t/m^3	IPCC, 2006
Ethanol - mobile combustion		0.000384	0.000013	t/m^3	IPCC, 2006
Gasoline	69,300			kg/TJ	IPCC, 2006
Gasoline - mobile combustion		25.0	8.0	kg/TJ	IPCC, 2006
Aviation kerosene	71,500			kg/TJ	IPCC, 2006
Fuel combustion - civil aviation		0.5	2.0	kg/TJ	IPCC, 2006

APPENDIX D – EMISSIONS BY EMISSION SOURCE

Table D1. Scope 1 emissions by source (Kyoto - tCO_2e), with the respective responsible staff member

Operating unit	Parameter	Responsible	Emissions (tCO_2e)
CEMIG D	Alcohol consumption – company's own fleet	Ormindo Coutinho Filho	4.21
	S10 diesel consumption – company's own fleet		5,446.70
	S500 diesel consumption – company's own fleet		889.72
	Gasoline consumption – company's own fleet		891.88
	VNG consumption – company's own fleet		1.02
	Aviation kerosene consumption by the company's fleet	Vinicius Vieira Sales	338.23
	NG consumption by stationary sources (restaurant)	Pedro Henrick	3.28
	NG consumption by generators (Aureliano Chaves Bldg.)		3.26
	Diesel oil consumption by generators (headquarters)		1.19
	Use of insulating gases – leak of SF6	João Carlos Oliveira da Silva	3,871.21
	LPG consumption by forklift trucks	Júlio Henrique Costa Guimarães	0.80
	NG consumption by stationary sources (boilers and other equipment)		5.95
CEMIG GT	Alcohol consumption – company's own fleet	Ormindo Coutinho Filho	0.99
	Diesel consumption – company's own fleet		53.64
	S10 diesel consumption – company's own fleet		701.8
	S500 diesel consumption – company's own fleet		170.91

Operating unit	Parameter	Responsible	Emissions (tCO_2e)
	Gasoline consumption – company's own fleet		338.27
	Aviation kerosene consumption by the company's fleet	Vinicius Vieira Sales	70.94
	Limestone consumption	Clara Silva	9.00
	Diesel consumption – leased fleet		11.95
	Diesel consumption by ships		0.01
	Gasoline consumption – leased fleet		54.01
	Gasoline consumption by ships		0.11
	Nitrogen consumption in fertilizers		40.17
	Diesel oil consumption by generators		13.75
	Diesel oil consumption by generators (Generation)		2.58
	Fuel oil consumption by stationary sources	Tiago Brito	37,210.91
	Diesel oil consumption by stationary sources		324.58
	Diesel oil consumption by generators (Transmission)	Schubert / Ormindo	16.38
	Use of insulating gases – leak of SF6	Rômulo Miranda Teixeira	1,087.33
CEMIG SIM	Alcohol consumption – company's own fleet	Ormindo Coutinho Filho	0.02
	Gasoline consumption – company's own fleet		2.25
GASMIG	Alcohol consumption – company's own fleet	Augusto Vieira de Loiola	0.14
	CO_2 consumption by fire extinguishers		0.02
	Diesel consumption – company's own fleet		2.42
	Gasoline consumption – company's own fleet		8.31
	VNG consumption – company's own fleet		79.67
	Diesel oil consumption by generators		0.17
	Leak of natural gas in transport		280.85
TOTAL – Scope 1			**51,938.62**

Table D2. Scope 2 emissions by source (Kyoto - tCO_2e), with the respective responsible staff member

Operating unit	Parameter	Responsible	Emissions (tCO_2e)
CEMIG D	Electricity consumption	Danilo de Deus	2,816.16
	Losses in the Distribution system		585,040.05
CEMIG GT	Electricity consumption		303.41
	Losses in the Transmission system		103,24.55
GASMIG	Electricity consumption	Augusto Vieira de Loiola	34.11
TOTAL – Scope 2			**598,518.28**

Table D3. Scope 3 emissions by source (Kyoto - tCO_2e), with the respective responsible staff member

Operating unit	Parameter	Responsible	Emissions (tCO_2e)
CEMIG D	Commercialization of electricity	Danilo de Deus	1,925,237.85
	Alcohol consumption by contractors	Douglas Morais	20.58

	Diesel consumption by contractors		17,782.89
	Gasoline consumption by contractors		4,895.77
	Diesel consumption by outsourced trucks (light, medium and heavy trucks)	Bruno Tavora Palmeira	751.1
	LPG consumption by forklift trucks		60.13
	Diesel consumption for employee commuting	Ormindo Coutinho Filho	114.51
	Transport in short-haul air travels	Patricia Ferreira Peixoto	92.47
	Transport in long-haul air travels		52.45
	Transport in medium-haul air travels		111.74
	Mass of waste sent for incineration	Alessandra Chagas Daniel	2.87
	Mass of waste sent for co-processing		329.84
CEMIG GT	Commercialization of electricity	Danilo de Deus	2,239,804.90
	LPG consumption by forklift trucks	Bruno Tavora Palmeira	3.17
	Diesel consumption by outsourced trucks (light, medium and heavy trucks)		39.53
	Diesel consumption for employee commuting	Ormindo Coutinho Filho	35.98
	Gasoline consumption for employee commuting		64.98
	Transport in short-haul air travels	Patricia Ferreira Peixoto	52.73
	Transport in long-haul air travels		13.56
	Transport in medium-haul air travels		79.9
CEMIG GT	Mass of waste sent for incineration	Alessandra Chagas Daniel	0.22
	Mass of waste sent to landfills – sludge		7.85
	Mass of waste sent to landfills – wood		33.4
	Mass of waste sent to landfills – other		3.94
	Mass of waste sent for co-processing		237.58
CEMIG SIM	Transport in short-haul air travels	Patricia Ferreira Peixoto	2.27
	Transport in medium-haul air travels		1.37
GASMIG	Commercialization of NG (stationary combustion)	Augusto Vieira de Loiola	2,176,346.22
	Commercialization of NG (vehicular)		85,260.42
	Transport in short-haul air travels	Patricia Ferreira Peixoto	8.24
	Transport in long-haul air travels		6.96
	Transport in medium-haul air travels		6.38
TOTAL – Scope 3			**6,451,461.79**

APPENDIX E - CATEGORIES IN THE BRAZIL GHG PROTOCOL PROGRAM

The Brazil GHG Protocol Program defines the following emissions categories:

- **Stationary combustion (Scope 1):** GHG emissions resulting from fuel burning, which generates energy that is mainly used to produce steam or electricity. This energy is not used to fuel means of transport. E.g., furnaces, burners, heaters and generators.

- **Mobile combustion (Scope 1):** GHG emissions resulting from fuel burning, which generates energy that is used to produce movement and travel a given distance. E.g.: cars, motorcycles, trucks, buses, tractors, fork lifts, airplanes and trains.

- **Fugitive emissions (Scope 1):** GHG leaks, usually non-intentional, that occur during production, processing, transmission, storage or use of gas. E.g., fire extinguishers (CO_2) and leaks in refrigerant equipment and air conditioners (HFC or PFC).

- **Land-use change (Scope 1):** non-mechanical GHG emissions resulting from agricultural or stockbreeding activities, or from activities that promote any change in soil use.

- **Purchased electricity (Scope 2):** GHG emissions resulting from generation of electricity that was purchased by the company or related to the portion of electricity lost in the transmission and distribution systems.

- **Category 1: Purchased goods and services (Scope 3):** goods or services, purchased by the company from third parties, which generate GHG emissions.

- **Category 4: Upstream transport and distribution (Scope 3):** emissions from transport and distribution of products purchased or acquired by the company, in vehicles and installations that are not owned nor operated by it, as well as of other outsourced services of transport and distribution (including inbound and outbound logistics).

- **Category 5: Waste generated in operations (Scope 3):** includes emissions from treatment and/or final disposal of solid waste and wastewater resulting from the company's operations controlled by third-parties. This category considers all future emissions (along the process of treatment and/or final disposal) that result from the waste generated in the inventoried year.

- **Category 6: Business travel (Scope 3):** emissions from the transport of employees to activities related to the company's business, which is made by vehicles operated or owned by third-parties, such as airplanes, trains, buses, passenger automobiles or ships. This category considers all employees from entities and units that are operated, rented or owned by the company. It may also include employees from other relevant entities (e.g., outsourced service providers), as well as consultants and other individuals that are not employed by the company yet take transport to its facilities.

- **Category 7: Employee commuting (Scope 3):** emissions in this category include transport of employees from their homes to the workplace. They also include transport by car, bus, train and other modes of urban transportation.

- **Category 9: Downstream transport and distribution (Scope 3):** emissions from the transport and distribution of products sold by the company (if not paid for by it) between its operations and the final costumer, including retail and storage, in vehicles and third-party facilities.

- **Category 11: Use of sold goods and services (Scope 3):** emissions from the use of a given good or service sold by the company.

APPENDIX F - CERTIFICATE

STATEMENT

The Bureau Veritas Certification, established at Avenida Alfredo Egídio de Souza Aranha, 100, 4th floor, Torre C, Vila Cruzeiro, São Paulo / SP, enrolled in the National Registry of Legal Entities under No. 72.368.012 / 0002-65, states for appropriate action that CEMIG – Companhia Energética de Minas Gerais, established at Av. Barbacena, 1200 – 17th floor, wing A1, Belo Horizonte, Minas Gerais, entered in the CNPJ (National Register of Legal Entities) under number 17.155.730/0001-64, in the city of Belo Horizonte, Minas Gerais, is authorized to publish in all its titles and sites the excerpt of the Verification Declaration as drafted at following: **"Bureau Veritas Certification, based on the processes and procedures described in its Verification Report, adopting a reasonable level of confidence, declares that the Greenhouse Gas Inventory - 2019 inventoried year of the CEMIG – Companhia Energética de Minas Gerais, is precise, reliable and error-free or distortion-free and is an equitable representation of GHG data and information over the reference period, for the defined scope; was prepared in accordance with the specifications of NBR ISO 14064-1 and the Brazilian GHG Protocol Program. "**

Emissions Verified:
Scopes 1, 2 e 3 (em tCO_2e)

Approach	Scope 1	Scope 2	Scope 3	Total
Operational control	51.939	598.518	6.451.462	7.101.919

São Paulo, 13 de Abril de 2020

Bureau Veritas Certification

Lead Assessor

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