# 2018 GREENHOUSE GAS EMISSIONS INVENTORY

Cemig corporate inventory of GHG emissions in 2018

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**CLIENT** CEMIG

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**DELIVERABLE** CEMIG corporate inventory of GHG emissions in 2018

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## DOCUMENT HISTORY

| Document name | Date | Nature of the review | Version of the CLIMAS results |
|---|---|---|---|
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| **CEMIG – GHG Inventory 2018-2019_05_03** | 05/03/2019 | Final English version | 4th version |

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# EXECUTIVE SUMMARY

Founded in May 22, 1952, the Minas Gerais State Energy Company – CEMIG is one of the major groups of the energy segment in Brazil, participating in more than 174 companies, as well as in consortia and holding funds. The mixed-economy, publicly-traded company is controlled by the Minas Gerais state government and has 140 thousand shareholders in 38 countries. The company's shares are negotiated in the São Paulo, New York and Madri Stock Markets.

CEMIG is currently a reference in the global economy, being widely recognized by its sustainable activities. The company has been a member of the Dow Jones Sustainability World Index (DJSI World) for 19 consecutive years.

CEMIG is also recognized by its size and high technical competence, being considered the largest integrated company of the electricity sector in Brazil. The company's activities cover 96% of the area of Minas Gerais state, serving 8.5 million consumers from 774 municipalities. It is also the largest energy provider for free clients in the country, holding 25% of the market; and one of the largest power-generating groups, controlling the operation of 87 power plants (83 hydroelectric, one thermoelectric, one photovoltaic and two wind farms), with an installed capacity of 6.07 Gigawatts.

CEMIG has a practically 100% renewable energy matrix, 4930 km of transmission lines and 532,569 km of distribution network.

The company operates in the areas of natural gas exploitation and distribution as well as data transmission. CEMIG's major business areas, however, are electricity transmission and distribution as well as energy solutions (as shown below).

- **Generation:** 7070 MW of installed capacity
- **Transmission:** 4930.56 km of transmission lines
- **Distribution:** 73,309 GWh of energy sold (of the entire holding)
- **Gas:** 1,104,745,283 $m^3$ sold

The greenhouse gas (GHG) emissions inventory is a management tool that allows for evaluating a company's impact on the global climate system. The present study evaluated CEMIG's GHG emissions in 2018.

In 2018, CEMIG's direct emissions (Scope 1) totalized 35,586.41 $tCO_2e$, while emissions from purchased electricity (Scope 2) totalized 518,212.79 $tCO_2e$ and indirect emissions (Scope 3) totalized 7,644,130.59 $tCO_2e$. These emissions are detailed in Table 1:

**Table 1. Results of GHG emissions by scope and category in 2018 (Kyoto - $tCO_2e$)**

| Scope | Category | Emissions ($tCO_2e$) | Representativeness (%) |
|---|---|---|---|
| Scope 1 | Agriculture and land-use change | 66.61 | 0.2% |
| | Stationary combustion | 21,434.25 | 60.3% |
| | Mobile combustion | 8920.18 | 25.1% |
| | Fugitive emissions | 5147.38 | 14.5% |
| | **Total scope 1 emissions** | **35,568.41** | - |
| Scope 2 | Electricity consumption | 3066.84 | 0.6% |
| | Losses in T&D | 515,145.95 | 99.4% |
| | **Total scope 2 emissions** | **518,212.79** | - |
| Scope 3 | Employee commuting | 111.64 | 0.0% |
| | Waste generated in operations | 337.61 | 0.0% |
| | Downstream transport and distribution | 13,699.89 | 0.2% |
| | Upstream transport and distribution | 673.44 | 0.0% |
| | Use of sold goods and services | 7,628,547.80 | 99.8% |
| | Business travel | 689.02 | 0.0% |
| | Purchased goods and services | 71.19 | 0.0% |
| | **Total scope 3 emissions** | **7,644,130.59** | - |

Scope1 emissions are mostly associated with consumption of fuel oil at Igarapé thermal power plant (ca. 21 thousand $tCO_2e$). As CEMIG is a major producer and distributor of electricity, its highest contributions to scope 2 emissions are the emissions resulting from Losses in Transmission and Distribution (T&D) (99.4% of scope 2 emissions). Scope 3 emissions are predominantly associated with the category of Use of Sold Goods and Services, due to the high amounts of electricity and natural gas commercialized by the company.

CEMIG GT is the main emitter of Scope 1 emissions in the CEMIG group, while CEMIG D is responsible for ca. 99% of the total Scope 2 emissions. CEMIG GT, CEMIG D and GASMIG contribute similarly to Scope 3 emissions.

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

**Table 2. Results of GHG emissions by operating unit in 2018 (Kyoto - $tCO_2e$)**

| Operating unit | Scope 1 ($tCO_2e$) | Scope 2 ($tCO_2e$) | Scope 3 ($tCO_2e$) |
|---|---|---|---|
| CEMIG D | 11,573.98 | 512,112.64 | 2,867,683.17 |
| CEMIG GT | 23,733.99 | 6066.63 | 2,511,141.29 |
| GASMIG | 245.59 | 33.52 | 2,204,883.37 |
| Efficientia | 2.92 | - | 0.59 |
| Rosal | 7.59 | - | 39,248.16 |
| Sá Carvalho | 4.33 | - | 21,174.03 |
| **Total** | **35.568,41** | **518.212,79** | **7.644.130,59** |

# 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. In that sense, quantifying and managing greenhouse gas (GHG) emissions in the corporate environment is of extreme relevance.

A Greenhouse Gas Emissions Inventory is the management tool that allows for quantifying the GHG emissions of a given company. By defining boundaries, identifying GHG sources and sinks, and recording their respective emissions or removals, the inventory allows for knowing the profile of emissions resulting from the company's activities.

The information generated by a Greenhouse Gas Emissions Inventory may fulfill 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), Carbon Efficient Index (ICO2)).

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 norms available to compile GHG corporate 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; 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 an external assurance in compliance with the protocols listed above. The objective of an assurance by third-parties is to obtain an independent declaration 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 emission standards of the company's value chain.

# 2. ADOPTED METHOD

The 2018 CEMIG Emissions Inventory was produced using CLIMAS, 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):

- **Relevance**: Ensure that the GHG 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 compiling the inventory. Document and justify any specific exclusions.

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

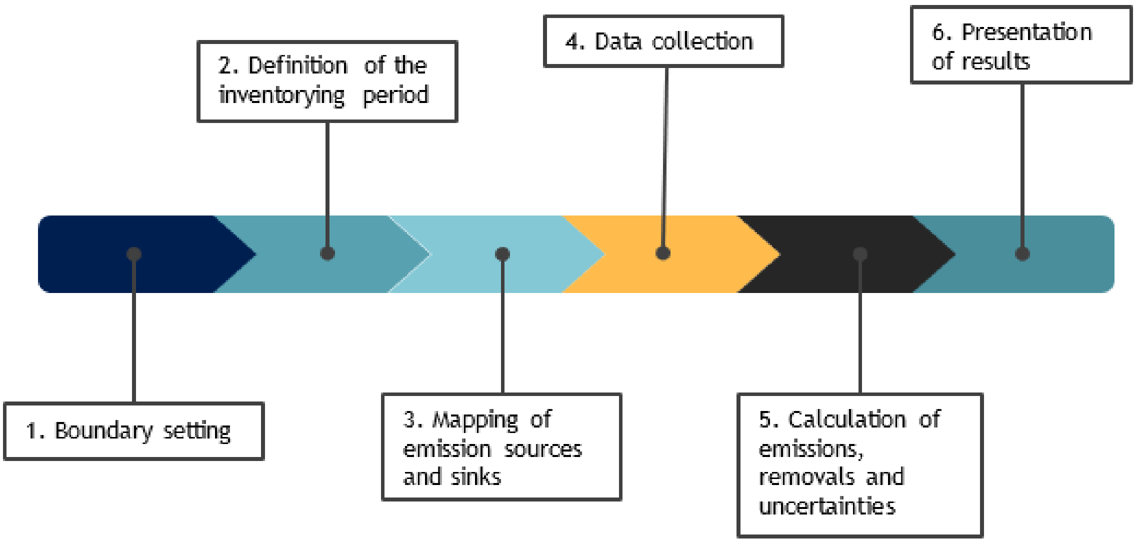
- **Transparency**: Treat all relevant issues coherently and factually, grounded on objective evidence. Disclose any relevant supposition, and make proper reference to the adopted calculation and recording methodologies, as well as to the used data sources.

- **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 processes.

## 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.**




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 below.

## 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.

The CEMIG group holds shares of 87 power plants (83 hydroelectric, one thermoelectric, one photovoltaic and two wind farms), with an installed capacity of 6.07 Gigawatts.

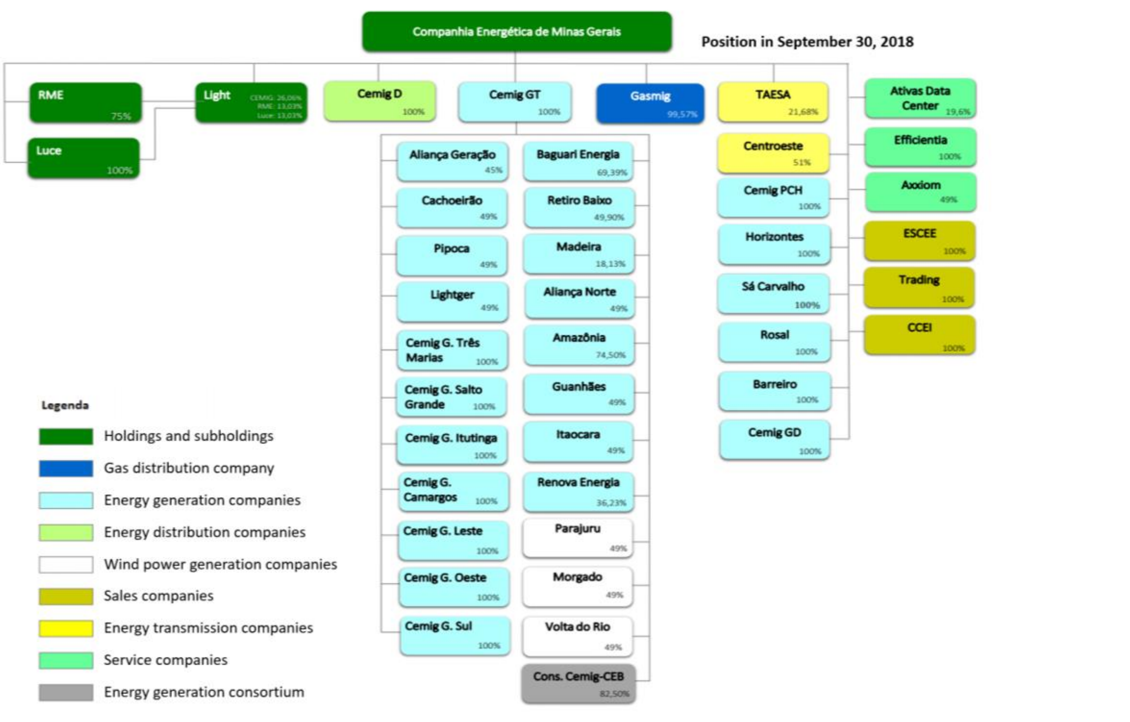
All 15 controlled companies recorded in the CEMIG 2018 GHG Emissions Inventory are presented in Table 3, along with their operational control and equity share. In 2018, GASMIG began to be evaluated in the GHG Emissions Inventory.

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

| Operating unit | Operational control | Equity share (%) |
|---|---|---|
| CEMIG Geração e Transmissão S.A. (CEMIG GT) | Yes | 100% |
| CEMIG Distribuição S.A. (CEMIG D) | Yes | 100% |
| Rosal Energia S.A. | Yes | 100% |
| Sá Carvalho S.A. | Yes | 100% |
| Efficientia S.A. | Yes | 100% |
| Gasmig S.A. | Yes | 100% |
| CEMIG PCH S.A. | Yes | 100% |
| Horizontes Energia S.A. | Yes | 100% |
| CEMIG Geração Camargos S.A. | Yes | 100% |
| CEMIG Geração Itutinga S.A. | Yes | 100% |
| CEMIG Geração Salto Grande S.A. | Yes | 100% |
| CEMIG Geração Três Marias S.A. | Yes | 100% |
| CEMIG Geração Leste S.A. | Yes | 100% |
| CEMIG Geração Oeste S.A. | Yes | 100% |
| CEMIG Geração Sul S.A. | Yes | 100% |

The CEMIG corporate organization chart and the operating units that were evaluated in this report are shown below (Figure 2):

**Figure 2. CEMIG corporate organization chart (date: 30/08/2019)**




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

### 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 2018 (January 1st, 2018 through December 31st, 2018).

### 2.3.4 Base year

The 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 methodology, 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, thus justifying the choice of 2014 as base year. 2014 was also chosen by the company for the establishment of reducing targets of Scope 1emissions.

### 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 – $CO2_e$. Table 4 shows the GWP values used in the CEMIG GHG Emissions Inventory:

**Table 4. 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 | 7390 – 17,700 |
| HFCs | 12 – 14,800 |
| HCFCs | 5 – 14,400 |

Source: PBGHGP, 2018.

The CEMIG 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[1].

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;
- $CH_4$: generated in the burning of fuels by mobile and stationary sources, fugitive emissions in the NG distribution lines and 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;

[1] Biogenic Emissions in the GHG 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.

- $SF_6$: leak of insulating gases.

### 2.3.6 Exclusions from the inventory

In 2018, CEMIG Telecomunicações S.A. was sold, and its emissions were therefore not recorded in this inventory. $CO_2$ emissions due to use of fire extinguishers were recorded only from CEMIG D, as the other operating units do not measure this data. Furthermore, this is not an expressive data to CEMIG, since the company's contribution with such emissions is very little representative compared with its other emission sources. $CO_2$ removals by forestry were also not recorded; this measurement will be accounted for from 2019.

## 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 5):

**Table 5. Description of attributes recorded for the instances of 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 employee which is responsible for data collection |
| **Data source*** | Site, registry, reference or system from which the data is obtained |
| **Scope** | Scope of the emission source, according to the classification in the *GHG Protocol* |
| **Category** | Category of the emission source, according to the classification in the *GHG Protocol* |

The emission sources recorded in the inventory, according to the ranking and organization elaborated in CLIMAS, are shown in Table 6:

**Table 6. Emission sources accounted in the inventory by scope, category and controlled data**

| Scope | Category | Controlled data |
|---|---|---|
| Scope 1 | Agriculture and land-use change | Limestone consumption |
| | | Nitrogen consumption in fertilizers |
| | Stationary combustion | NG consumption by stationary sources |
| | | Fuel oil consumption by stationary sources |
| | | Diesel oil consumption by generators |
| | Mobile combustion | Diesel 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 |
| | Fugitive emissions | Use of insulating gases – leak of SF6 |
| | | CO2 consumption by fire extinguishers |
| | | Leak of natural gas in transport |
| 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 for incineration |
| | | Mass of waste sent for co-processing |
| | Cat 6. Business travel | Air travels |
| | Cat 7. Employee commuting | Diesel 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 |
| | | Commercialization of NG |

As observed in Table 6, the processes defined in CLIMAS for the CEMIG inventory may be correlated to the categorization established by the Brazil GHG Protocol Program[2]. According to that program, categories are defined as follows:

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

[2] 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).

- **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.

## 2.5 Data collection

The information flow for compiling the inventory occurred according to the following sequence of activities:

1. Corporate managers identified the employees responsible for managing the information needed for the GHG inventory;

2. Employees 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.

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 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[3]).

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

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

Where:

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

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

The technical team at WayCarbon is responsible for periodically updating CLIMAS with emission factors according to internationally established methodologies, in order to compile GHG emissions inventories. Emission factors are mainly based on the following references (Table 7):

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

**Table 7. 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 2018 | Programa Brasileiro GHG Protocol, Ferramenta de Cálculo, versão 2018.1. | http://www.ghgprotocolbrasil.com.br/ferramenta-de-calculo |
| BEN 2015 | Balanço Energético Nacional 2015: Ano base 2014 / Empresa de Pesquisa Energética. - Rio de Janeiro: EPE, 2015. | http://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-127/topico-97/Relat%C3%B3rio%20Final%202015.pdf |
| MCTIC 2018 | MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES (MCTIC). | https://www.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/textogeral/emissao_corporativos.html |

The emission factors used in the inventory and calculation log[4] are available in the CLIMAS system and in APPENDICES C and D, as Excel™ spreadsheets.

The calculation methods and specific equations used for each type of emission in the CEMIG GHG Emissions Inventory are described below.

### 2.6.1 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:

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

Where:

[4] 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 2018 inventory and click "*Obter Extrato*" ['Obtain Statement']; e) in the last "*Fatores de emissão*" ['Emission Factors'] table, search for the emission source you wish to check using the search field and click the eye buttons on the right-hand side of the screen; f) click the button in the field "*Memorial de cálculo*" ['Calculation log'].

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

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

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

Where:

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

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 as of 2018 the Brazilian law requires that these fuels contain specific proportions of biofuels in their composition. For gasoline, the requirement was 27% of anhydrous ethanol, while for diesel the requirement was 8% until February 2018 and 10% from March of that year. 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 describe 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).

### 2.6.2 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 2018. 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:

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

Where:

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

### 2.6.3 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 2018. 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.

### 2.6.4 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[5] 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:

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

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

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

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

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 2018 Brazil GHG Protocol Program.

### 2.6.5 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:

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

Where:

- $y$ reference year of the report (2018);
- $i$ application of the fertilizer *i* (dolomitic limestone or urea);
- $E_{CO2,i,y}$ $CO_2$ emissions that are attributable to application of the fertilizer *i* in the year *y*, in *t* $CO_2$;
- $F_{i,y}$ amount of the fertilizer *i* used in the year *y*, in *t*;
- $FC_i$ 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:

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

Where:

- $y$ reference year of the report (2018);
- $i$ application of the fertilizer *i*;
- $E_{N2O,i,y}$ $N_2O$ emissions that are attributable to application of the fertilizer *i* in the year *y*, in *t* $N_2O$;
- $F_{i,y}$ amount of the fertilizer *i* used in the year *y*, in *t;*
- $F_{Ni}$ 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).

### 2.6.6 Incineration and co-processing emissions

Co-processing GHG emissions were calculated using data on the waste produced that was sent for co-processing, in tons, in 2018. Emissions are calculated using the following equation:

$$E_{CO2,w,y} = m_{w,y} \, . \, CC_w \, . \, \frac{44}{12} + m_{w,y} \, . \, EF_{CH4,w} \, . \, GWP_{CH4} + m_{w,y} \, . \, EF_{N2O,w} \, . \, GWP_{N2O}$$

Where:

- $w$ *type of waste;*
- $y$ *reference year of the report;*
- $E_{CO2,w,y}$ *$CO_2$ emissions resulting from co-processing of waste w during the year y, in $tCO_2e$;*
- $m_{w,y}$ *waste mass produced in the year y, in the unit of measurement u, with u being given in t;*
- $CC_w$ *carbon content in waste w, dimensionless;*
- $EF_{CH4,w}$ *emission factor of $CH_4$ resulting from co-processing of waste w, in $tCH_4$;*
- $GWP_{CH4}$ *global warming potential of $CH_4$, in $tCO_2e/tCH_4$;*
- $EF_{N2O,w}$ *emission factor of $N_2O$ resulting from co-processing of waste w, 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 tons, in 2018. Emissions are calculated using the following equation:

$$E_{CO2,w,y} = m_{w,y} \, . \, CC_w \, . \frac{44}{12} + m_{w,y} \, . \, FE_{CH4,w} \, . \, GWP_{CH4} + \, m_{w,y} \, . \, FE_{N20,w} \, . \, GWP_{N2O}$$

Where:

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

## 3. RESULTS

CEMIG's Scope 1, 2 and 3 emissions[6] in 2018 were 35,568.41 $tCO_2e$, 518,212.79 $tCO_2e$ and 7,644,130.59 $tCO_2e$, respectively. Furthermore, 3326.23 tons of $CO_2$ of renewable[7] origin were emitted (1409.27 t of renewable $CO_2$ for Scope 1 and 1916.97 t of renewable $CO_2$ for Scope 3).

The company's Scope 1, 2 and 3 emissions in 2018 are shown in Figure 3:

[6] GHG emissions regulated by the Kyoto Protocol (carbon dioxide – $CO_2$, methane – $CH_4$ – nitrous oxide – $N_2O$ and $SF_6$).
[7] $CO_2$ 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.

**Figure 3. GHG emissions in 2018 by scope (Kyoto - $tCO_2e$)**

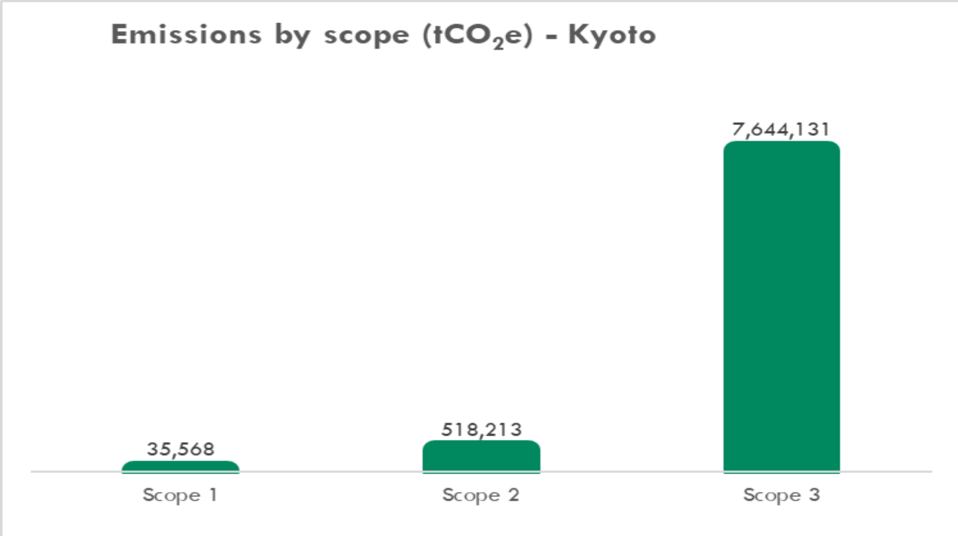



Table 8 shows CEMIG's GHG emissions by scope and category. In Scope 1, the category with lowest representativeness was Stationary Combustion, which accounted for 60.3% of the total emissions in the scope (21,434.25 $tCO_2e$). Scope 2 emissions are represented by Losses in T&D (515,145.95 $tCO_2e$) and Electricity Consumption (3066.84 $tCO_2e$), the two of which contributed with 99.4% and 0.6% of emissions in the scope, respectively. As for Scope 3 emissions, they totalized 7,644,130.59 $tCO_2e$, of which the category Use of Sold Goods and Services represented 99.8%.

**Table 8. GHG emissions by scope and category (Kyoto - $tCO_2e$)**

| Scope | Category | Emissions ($tCO_2e$) | Representativeness (%) |
|---|---|---|---|
| Scope 1 | Agriculture and land-use change | 66.61 | 0.2% |
| | Stationary combustion | 21,434.25 | 60.3% |
| | Mobile combustion | 8920.18 | 25.1% |
| | Fugitive emissions | 5147.38 | 14.5% |
| | **Total scope 1 emissions** | **35,568.41** | - |
| Scope 2 | Electricity consumption | 3066.84 | 0.6% |
| | Losses in T&D | 515,145.95 | 99.4% |
| | **Total scope 2 emissions** | **518,212.79** | - |
| Scope 3 | Employee commuting | 111.64 | 0.0% |
| | Waste generated in operations | 337.61 | 0.0% |
| | Downstream transport and distribution | 13,699.89 | 0.2% |
| | Upstream transport and distribution | 673.44 | 0.0% |
| | Use of sold goods and services | 7,628,547.80 | 99.8% |
| | Business travel | 689.02 | 0.0% |
| | Purchased goods and services | 71.19 | 0.0% |
| | **Total scope 3 emissions** | **7,644,130.59** | - |

Emissions by Scope, operating unit and representativeness are shown in Table 9. CEMIG GT was the highest emitter of Scope 1 emissions, with 66.73% of representativeness in that Scope. Scope 1 emissions from CEMIG GT are mostly associated with the use of fuel oil at Igarapé thermal power plant (emitting 21,220.24 $tCO_2e$ thereat).

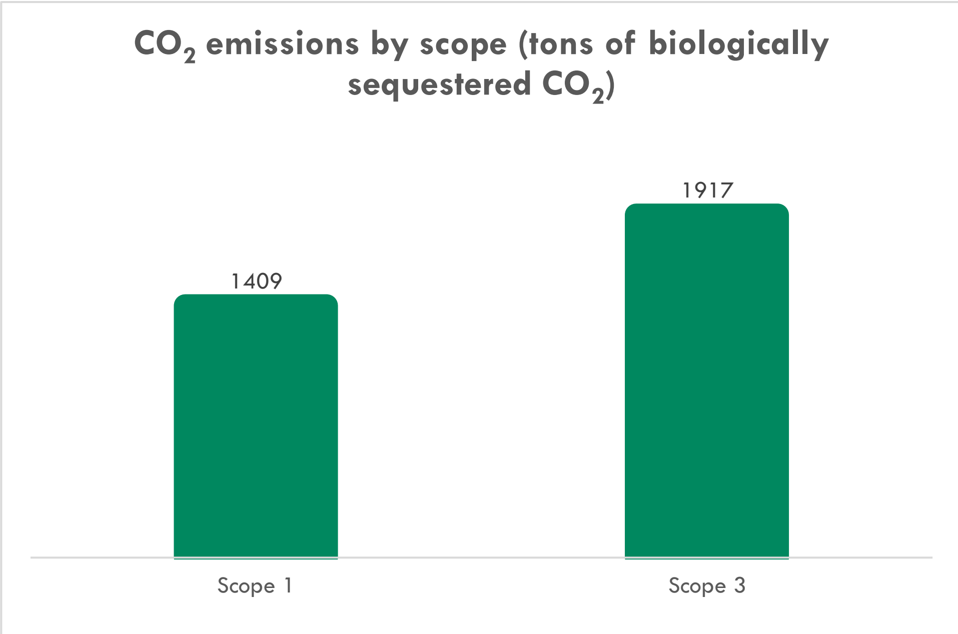
Scope 2 emissions from CEMIG D were dominant in relation to the other operating units, contributing with 98.82% of all emissions in this Scope. The contributions of CEMIG D, CEMIG GT and GASMIG to Scope 3 emissions were very similar: 37.51%, 32.85% and 28.84%, respectively. Scope 2 emissions are mainly associated with Losses in Transport and Distribution (both technical and non-technical losses), while Scope 3 emissions are almost exclusively associated with commercialization of electricity and natural gas.

**Table 9. Emissions by scope and operating unit in 2018 (Kyoto - $tCO_2e$)**

| 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 | 11,573.98 | 32.54% | 512,112.64 | 98.82% | 2,867,683.17 | 37.51% |
| CEMIG GT | 23,733.99 | 66.73% | 6066.63 | 1.17% | 2,511,141.29 | 32.85% |
| GASMIG | 245.59 | 0.69% | 33.52 | 0.01% | 2,204,883.37 | 28.84% |
| Efficientia | 2.92 | 0.01% | - | - | 0.59 | 0.00% |
| Rosal | 7.59 | 0.02% | - | - | 39,248.16 | - |
| Sá Carvalho | 4.33 | 0.01% | - | - | 21,174.03 | - |
| **Total** | **35,568.41** | | **518,212.79** | | **7,644,130.59** | |

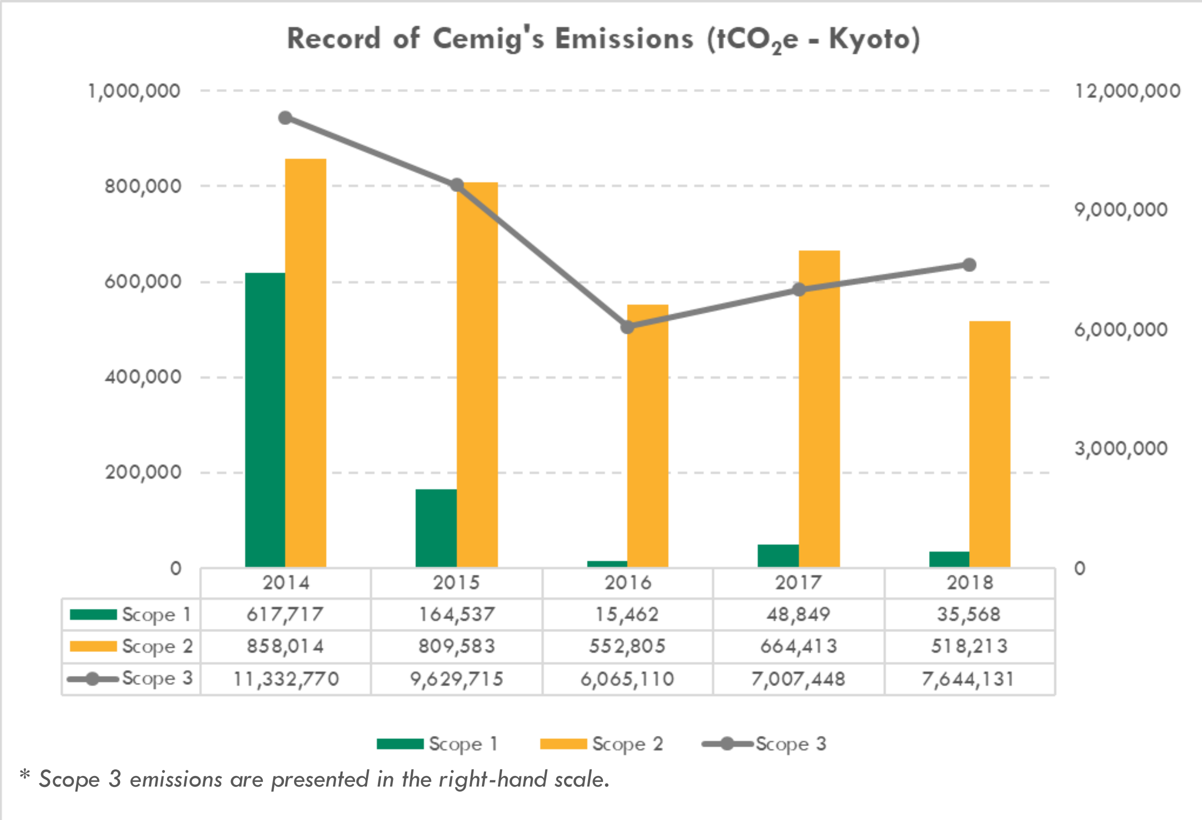
In the burning of renewable fuels, such as ethanol or biodiesel, the $CO_2$ emitted is biologically sequestered (i.e., at any moment of its lifecycle, $CO_2$ was captured by biomass). Emissions of this gas totalized 1409 tons of renewable $CO_2$ and 1917 tons of renewable $CO_2$ in Scopes 1 and 3 respectively, as shown in Figure 4.

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




Although CEMIG has recorded its emissions since 2008, the base year of the company's emissions is 2014 (the same year that was selected for target setting). Therefore, the historical series presented in this report starts in 2014. Scope 1, 2 and 3 emissions from 2014 through 2018 are shown in Figure 5. In 2018, Scope 1, 2 and 3 emissions decreased by 94.2%, 39.6% and 32.5% respectively in relation to the base year. When compared with 2017 data, Scope 1 and 2 emissions showed a reduction of 27.2%, and 22.0%, respectively. With GASMIG integrating the inventory from 2018, emissions due to commercialization of natural gas increased Scope 3 emissions in 2.1 million tons of $CO_2e$, which resulted in a 9.1% increase in emissions in relation to the previous year. If these emissions were not considered in the 2018 inventory, the data would show a 21.1% decrease in emissions in relation to the previous year.

**Figure 5. Historical data series of CEMIG's emissions (Kyoto – $tCO_2e$)**




Emission from each emission source in the inventory are shown in APPENDIX C.

## 3.1 SCOPE 1

CEMIG's Scope 1 emissions in 2018 totalized 35,568.41 $tCO_2e$, showing a 27.2% reduction in relation to the previous year (2017 = 48,849 $tCO_2e$) and a 94.2% reduction in relation to the base year (2014 = 617,717 $tCO_2e$).

**Table 10. Scope 1 emissions by category ($tCO_2e$ – Kyoto)**

| Category | Emissions ($tCO_2e$) | Representativeness (%) |
|---|---|---|
| Agriculture and land-use change | 66.61 | 0.2% |
| Stationary combustion | 21,434.25 | 60.3% |
| Mobile combustion | 8920.18 | 25.1% |
| Fugitive emissions | 5147.38 | 14.5% |
| **Total scope 1 emissions** | **35,568.41** | **-** |

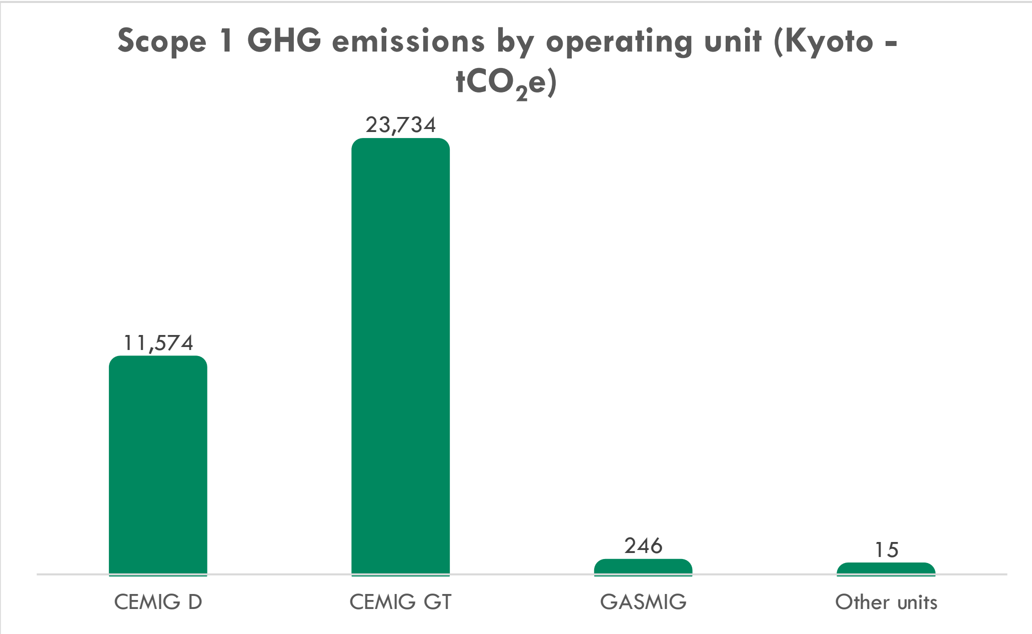
Scope 1 emissions by category and representativeness are shown in Table 10. In 2018, emissions from stationary combustion were mainly associated with oil consumption at Igarapé thermal power plant, with 21,220.24 $tCO_2e$ being emitted (representing 99.0% of emissions in this category). Despite being the major source of emissions in 2018, fuel oil showed a 35% decrease in emissions in relation to the previous year.

Stationary combustion emissions contributed the most in relation to the other categories, showing a 60.3% representativeness of Scope 1 emissions. However, this category also showed a 36.8% decrease in relation to 2017.

Mobile combustion emissions contributed with 25.1% of all Scope 1 emissions, being mainly associated with diesel consumption by the company's fleet (7186 $tCO_2e$). Fugitive emissions derived mainly from the leak of $SF_6$ in transmission and distribution systems, which contributed with 96.7% of the total emissions in this category. Agricultural emissions, on the other hand, showed low representativeness, as emissions from fertilizers are associated with secondary activities in power generation (less than 0.2% of Scope 1 emissions).

The chart below shows CEMIG's GHG emissions in 2018 by operating unit (Figure 6):

**Figure 6. Scope 1 GHG emissions by operating unit (Kyoto - $tCO_2e$)**




Scope 1 emissions derive mostly from CEMIG GT, which uses fuel oil to produce energy at Igarapé thermal power plant. However, CEMIG D also contributes significantly to Scope 1 emissions (32.4% of emissions), due to diesel consumption by the company's fleet (6303.53 $tCO_2e$) and to leak of $SF_6$ (4110.84 $tCO_2e$).

Emissions by precursor are shown in Table 11, which reveals that fuel oil (59.7%), diesel (20.8%) and $SF_6$ (14.0%) are the main precursors of CEMIG's emissions.

Table 11. GHG emissions by precursor ($tCO_2e$ - Kyoto)

| Category | Emissions ($tCO_2e$) | Representativeness (%) |
|---|---|---|
| Dolomitic limestone | 3.15 | 0.0% |
| CH4 | 171.50 | 0.5% |
| CO2 | 0.01 | 0.0% |
| Diesel / Brazil | 7394.45 | 20.8% |
| Hydrous ethanol | 3.56 | 0.0% |
| Liquefied petroleum gas (LPG) | 1.35 | 0.0% |
| Natural gas | 11.01 | 0.0% |
| Vehicular natural gas (VNG) | 74.38 | 0.2% |
| Gasoline / Brazil | 1323.20 | 3.7% |
| Nitrogen in fertilizers | 63.46 | 0.2% |
| Fuel oil | 21,220.24 | 59.7% |
| Aviation kerosene | 326.23 | 0.9% |
| SF6 | 4975.87 | 14.0% |
| **Total scope 1 emissions** | **35,568.41** | - |

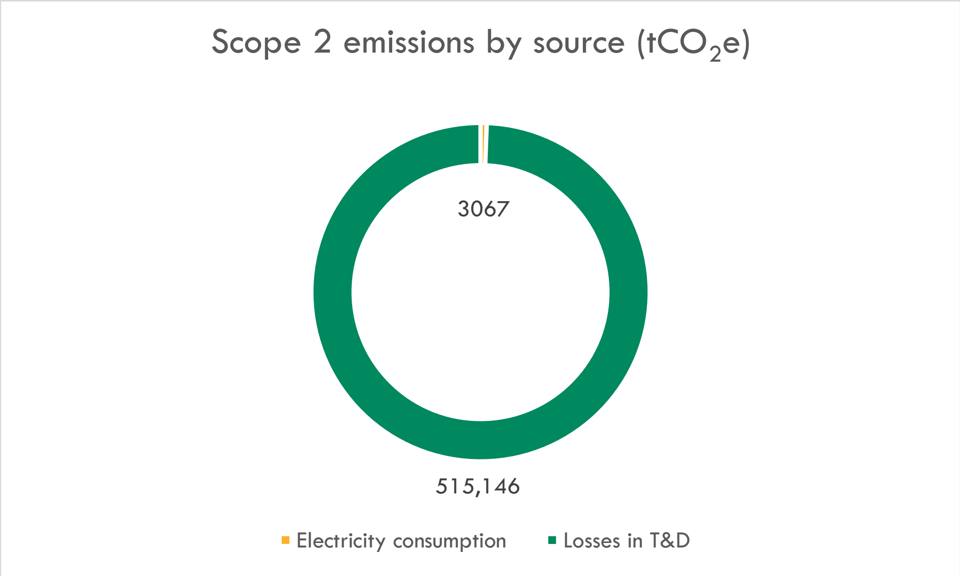
## 3.2 SCOPE 2

CEMIG's Scope 2 emissions in 2018 totalized 518,212.79 $tCO_2e$, representing a 22.0% reduction in relation to the previous year (664,413 $tCO_2e$ in 2017) and a 39.6% reduction in relation to the base year (858,014 $tCO_2e$ in 2014).

Emissions from Losses in Transmission and Distribution (which represented 99.4% of Scope 2 emissions) showed a reduction of ca. 2.2% in 2018 in relation to the previous year. Furthermore, in 2018 the grid mean emission factor[8] showed a 20% reduction in relation to the previous year (0.0927 $tCO_2e$/MWh in 2017 *vs* 0.0742 $tCO_2e$/MWh in 2018). These two aspects justify the 22% decrease in Scope 2 GHG emissions (comparing 2018 with 2017). Emissions resulting from Losses in T&D and from Electricity Consumption are shown in Figure 7.

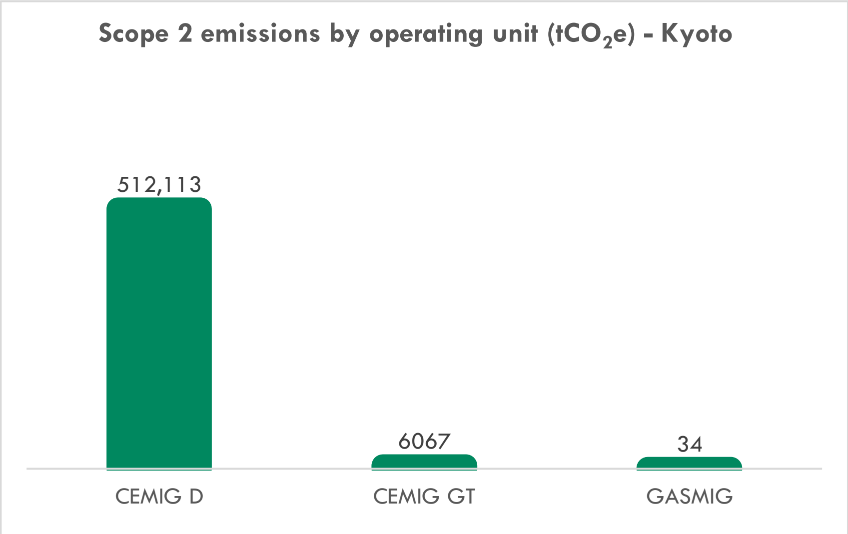
[8] **Mean anual factor of the Brazilian National Interconnected System (SIN, Portuguese acronym) ($tCO_2$/MWh):** 0.1355 (2014), 0.1244 (2015), 0.0817 (2016), 0.0927 (2017) and 0.074 (2018).

**Figure 7. Scope 2 emissions by emission source (Kyoto – $tCO_2e$)**




Scope 2 emissions by operating unit are shown in Figure 8. Being a power distribution company, CEMIG D has significantly higher emissions than other units (98.8% of the total Scope 2 emissions).

**Figure 8. Scope 2 GHG emissions by operating unit (Kyoto - $tCO_2e$)**



## 3.3 SCOPE 3

CEMIG's Scope 3 emissions in 2018 totalized 7644.130 $tCO_2e$, representing a 9.1% increase in relation to the previous year (7,007,448 $tCO_2e$ in 2017) and a 32.5% decrease in relation to the base year (11,332,770 $tCO_2e$ in 2017).

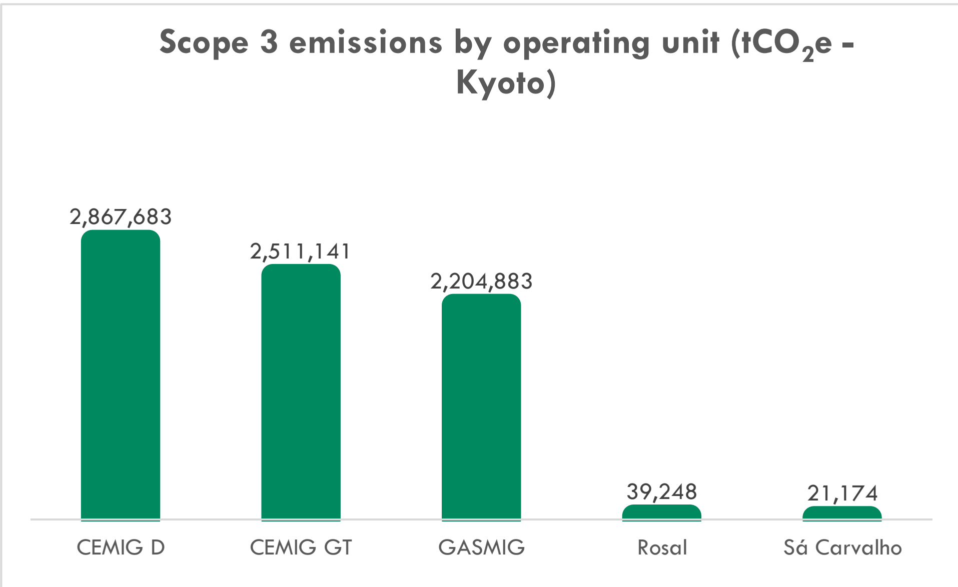
Table 12 shows the GHG emissions by category and source in the last 5 years:

**Table 12. Scope 3 emissions by category in the last 5 years (Kyoto - $tCO_2e$)**

| Category | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| Employee commuting | 586 | 600 | 591 | 494 | 112 |
| Waste generated in operations | - | - | - | - | 338 |
| Downstream transport and distribution | 5729 | 12,851 | 13,241 | 19,871 | 13,700 |
| Upstream transport and distribution | 817 | 373 | 548 | 575 | 673 |
| Use of sold goods and services | 11,324,277 | 9,614,752 | 6,049,885 | 6,985,687 | 7,628,548 |
| Business travel | 1361 | 1138 | 846 | 822 | 689 |
| Purchased goods and services | - | - | - | - | 71 |
| **Grand total** | **11,332,770** | **9,629,714** | **6,065,111** | **7,007,449** | **7,644,131** |

Scope 3 emissions are mainly associated with commercialization of electricity and natural gas, which are categorized under Use of Sold Goods and Services. Emissions associated with this category represent almost the total of Scope 3 emissions (99.8%). Since that energy is distributed by CEMIG D and CEMIG GT, the emissions from these units altogether account for 70.4% of Scope 3 emissions (Figure 9). Commercialization of natural gas by GASMIG is responsible for this unit's 28.8% representativeness of Scope 3 emissions.

**Figure 9. Scope 3 GHG emissions by operating unit (Kyoto – $tCO_2e$)**



## 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 methodologies 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 Entity. 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 operating unit of the company.

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 with 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, there was a great concern to use the most recent calculation methodologies 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 following paragraphs describe the procedures adopted to calculate combined uncertainties (IPCC, 2006).

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

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

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;
- $\boldsymbol{x_i \text{ and } U_i}$: 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:

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

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

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

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

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

Where:

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

- $\sigma_g$: geometric standard deviation;
- $I$: symmetric total uncertainty of the 95% confidence interval, in %;

For CEMIG's 2018 GHG emissions inventory, the uncertainties were also calculated using CLIMAS. The results are shown in the table below (Table 13).

**Table 13. Results of uncertainties from the 2018 inventory.**

| Category | Lower uncertainty | Upper uncertainty |
|---|---|---|
| Agriculture and land-use change | 35.10% | 99.96% |
| Purchased electricity | 0.00% | 0.00% |
| Purchased goods and services | 1.57% | 3.01% |
| Stationary combustion | 2.84% | 3.69% |
| Mobile combustion | 0.77% | 0.68% |
| Employee commuting | 1.02% | 0.81% |
| Fugitive emissions | 0.00% | 0.00% |
| Waste generated in operations | 0.87% | 1.84% |
| Downstream transport and distribution | 1.13% | 0.92% |
| Upstream transport and distribution | 1.19% | 0.94% |
| Use of sold goods and services | 1.24% | 1.90% |
| Business travel | 0.00% | 0.00% |
| **Total** | **1.16%** | **1.77%** |

## CORPORATE TARGETS

CEMIG is aware of its commitment to mitigate emissions of gases that contribute to global climate change, and the company has thereby set a corporate target of reducing its direct emissions (Box 1).

**Box 1. Corporate target of reducing direct emissions**

| Scope | % reduction in relation to the base year | Metric | Base year | Base year emissions ($tCO_2e$) | Target year |
|---|---|---|---|---|---|
| 1 | 8% | tCO2e | 2014 | 617,717 | 2021 |

In 2018, CEMIG's direct emissions totalized 35,568 tCO2e, which represents a 94.2% reduction in relation to direct emissions in 2014, the target base year.

With that same goal, CEMIG has also set a target of reducing its electricity consumption (Box 2).

**Box 2. Corporate target of reducing electricity consumption**

| Scope | % emissions from the Scope in the base year | % reduction in relation to the base year | Metric | Base year | Organizational boundaries | Target year |
|---|---|---|---|---|---|---|
| 2 | 0.8% | 4% | GJ | 2011 | Cemig GT and Cemig D | 2020 |

From 2011 through 2018, electricity consumption by the company decreased by 11.5%, going from 168,740 GJ in 2011 to 149,239 GJ in 2018.

**Box 3. Corporate target of reducing energy losses in the T&D system**

| Scope | % emissions from the Scope in the base year | Percent target | Metric | Base year | Organizational boundaries | Target year |
|---|---|---|---|---|---|---|
| 2 | 99.4% | Having a maximum 11.75% total energy loss | % of total calculated losses | 2018 | Cemig D | 2018 |
| 2 | 99.4% | By 2022, the set target is 11.23%, which will demand continuous efforts to ensure that the Company meets the regulatory limit for energy loss | % of total calculated losses | 2018 | Cemig D | 2022 |

The energy losses in the T&D system in 2018 were represented by an IPTD (Portuguese acronym for "Index of Technical Losses in Distribution") of 12.48% in relation to the total energy injected in the distribution system.

This result is above the target (11.75% in 2018). Nevertheless, the 2018 result showed a 1.76% reduction in relation to 2017, when the IPTD was 14.24%.

Additional information can be obtained in the company's Annual Sustainability Report: (http://www.cemig.com.br/en-us/Company_and_Future/Sustainability/Pages/reports.aspx).

## 5. 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 are 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 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
    - calculate the emissions from other Scope 3 categories, such as treatment of waste sent for the municipal waste treatment network, employee commuting and expanding the sources of business travels;
- 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 to diagnose the company's situation in the context of a low-carbon economy, such as:

- calculation of impact indicators by 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 following steps are planning and action on the Climate Change issue. That includes:

- sector benchmarking;
- defining the mitigation strategy and reduction targets;

- defining the adaptation strategy;
- defining the 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

It is important to note that since reporting the emissions from international operating units is optional for the GHG protocol, such emissions were separated from those originated in Brazilian facilities. Thereby, 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.

Summary of total emissions (tons of GHG)

| Gas | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| $CH_4$ | 8.910323 | | 140.608659 | 149.518982 |
| $CO_2$ | 30095.55918 | 5182012.789 | 7640354.851 | 8188663.199 |
| $N_2O$ | 0.920188 | | 0.874247 | 1.794435 |
| $SF_6$ | 0.21824 | | | 0.21824 |

Summary of total emissions (tons of equivalent CO2e)

| Gas | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| CH4 | 222.758075 | | 3515.216475 | 3737.97455 |
| CO2 | 30095.55918 | 518212.7887 | 7640354.851 | 8188663.199 |
| N2O | 274.216024 | | 260.525606 | 534.74163 |
| SF6 | 4975.872 | | | 4975.872 |
| Total | 35568.40527 | 518212.7887 | 7644130.593 | 8197911.787 |

Scope 1 emissions by category

| Scope | Category | Kyoto emissions |
|---|---|---|
| Scope 1 | Agriculture and land-use change | 66.60838 |
| | Stationary combustion | 21434.24582 |
| | Mobile combustion | 8920.175824 |
| | Fugitive emissions | 5147.37525 |
| Total | | 35568.40527 |

Scope 1 emissions by category – emissions and removals of biogenic $CO_2$

| Category | | Biogenic $CO_2$ | |
|---|---|---|---|
| | | Emissions (tGHG) | Removals (tGHG) |
| **Scope 1** | Stationary combustion | 19.581731 | 0 |
| | Mobile combustion | 1389.68758 | 0 |

Scope 2 emissions by category

| Scope | Category | Kyoto |
|---|---|---|
| **Scope 2** | Purchased electricity | 518212.7887 |
| **Total** | | 518212.7887 |

Values in $tCO_2$. Scope 2: Indirect emissions due to energy consumption

Scope 3 emissions by category

| Scope | Category | Kyoto |
|---|---|---|
| Scope 3 | Purchased goods and services | 71.190541 |
| | Employee commuting | 111.637776 |
| | Waste generated in operations | 337.612058 |
| | Downstream transport and distribution | 13699.88998 |
| | Upstream transport and distribution | 673.442054 |
| | Use of sold goods and services | 7628547.797 |
| | Business travel | 689.023784 |
| Total | | 7644130.593 |

Scope 3 emissions by category emissions and removals of biologically sequestered CO2

| | | Biologically sequestered CO2 | |
|---|---|---|---|
| | | Emissions (tGHG) | Removals (tGHG) |
| **Scope 3** | Employee commuting | 10.663382 | 0 |
| | Downstream transport and distribution | 1842.059161 | 0 |
| | Upstream transport and distribution | 64.242979 | 0 |

Emissions by operating unit

| Operating unit | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| CEMIG D | 11573.97978 | 512112.6363 | 2867683.165 | 3391369.781 |
| CEMIG GT | 23733.99373 | 6066.633333 | 2511141.288 | 2540941.915 |
| Efficientia | 2.92166 | | 0.588036 | 3.509696 |
| GASMIG | 245.587781 | 33.51905 | 2204883.367 | 2205162.474 |
| Rosal | 7.58733 | | 39248.15537 | 39255.7427 |
| Sá Carvalho | 4.334996 | | 21174.03 | 21178.365 |
| Total | 35568.40527 | 518212.7887 | 7644130.593 | 8197911.787 |

## APPENDIX B – 2018 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. go to "Emissões de GEE" ['GHG Emissions'] > "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 generated by the technology and precursor selection and click "ver" ['see'];
5. click the "*Memorial*" ['Log'] field button to verify how the emission factor was constructed and where the data used to construct it came 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 2018 GHG inventory are given below.

### A) Global warming potentials (GWP)

| Gas | GWP |
|---|---|
| **$CO_2$** | 1 |
| **$CH_4$** | 25 |
| **$N_2O$** | 298 |
| **$SF_6$** | 22800 |

### B) Emission factors – electricity – 2018

| Country | EFCO2 (t/MWh) | EFCH4 (t/MWh) | EFN2O (t/MWh) | Source |
|---|---|---|---|---|
| **Brazil** | 0.0742 | - | - | MCTIC, 2018 |

### C) Conversion factors – mobile combustion

| Transport data | Factor | Unit | Source |
|---|---|---|---|
| **Diesel oil - commercial vehicle** | 10.5 | km/L | PBGHGP 2016 |
| **Diesel oil - heavy truck** | 3.4 | km/L | PBGHGP 2016 |
| **Diesel oil - light and medium trucks** | 5.6 | km/L | PBGHGP 2016 |

### D) Emission factors – Air travel

| Air travel | EFCO2 | EFCH4 | EFN2O | Unit | Source |
|---|---|---|---|---|---|
| **Air travel - long distance** | 95.740741 | 0.00037 | 0.003045 | t/pax*Gm | PBGHGP 2018 |
| **Air travel - medium distance** | 78.074074 | 0.00037 | 0.002486 | t/pax*Gm | PBGHGP 2018 |
| **Air travel - short distance** | 129.648148 | 0.002222 | 0.004132 | t/pax*Gm | PBGHGP 2018 |
| **Air travel - cargo - short distance** | | 0.000003 | 0.000034 | kg/tkm | DEFRA 2016 |
| **Short-haul flights - international freight transportation** | 1.21094 | | | kgGHG/tkm | DEFRA 2015 |
| **Short-haul flights - freight transportation** | 1.06176 | | | kgCO2/tkm | DEFRA 2016 |

### E) Specific masses (source: BEN, 2015), net heating values – NHVs (source: BEN, 2015 and IPCC, 2006) and emission factors (source: IPCC, 2006) – mobile and stationary sources

| Precursor | Specific mass | Unit | NHV | Unit | EFCO2 | EFCH4 | EFN2O | Unit |
|---|---|---|---|---|---|---|---|---|
| **Natural gas** | 0.74 | kg/m3 | 48 | TJ/Gg | 56100 | | | kg/TJ |
| ***LPG*** | | | 47.3 | TJ/Gg | 63199 | 62 | 0.2 | kg/TJ |
| ***Natural gas - mobile combustion*** | | | | | 56100 | 92 | 3 | kg/TJ |
| **Biodiesel** | 880 | kg/m3 | 9000 | kcal/kg | 2.431 | | | $tCO2/m^3$ |
| ***Biodiesel - mobile combustion*** | | | | | | 0.000332 | 0.00002 | $tGHG/m^3$ |
| ***Biodiesel - stationary combustion - commercial / institutional*** | | | | | | 10 | 0.6 | kg/TJ |
| **Diesel oil** | 840 | kg/m3 | 43 | TJ/Gg | 74100 | | | kg/TJ |
| ***Fuel oil*** | | | 40.4 | TJ/Gg | 77400 | 3 | 0.6 | kg/TJ |
| ***Diesel oil - mobile combustion*** | | | | | | 3.9 | 3.9 | kg/TJ |
| ***Diesel oil - stationary combustion - commercial / institutional*** | | | | | | 10 | 0.6 | kg/TJ |

| Precursor | Specific mass | Unit | NHV | Unit | EFCO2 | EFCH4 | EFN2O | Unit |
|---|---|---|---|---|---|---|---|---|
| **Ethanol** | 809 | kg/m3 | 6300 | kcal/kg | 1.457 | | | t/m3 |
| ***Ethanol - mobile combustion*** | | | | | | 0.000384 | 0.000013 | t/m3 |
| **Gasoline** | 742 | kg/m3 | 44.3 | TJ/Gg | 69300 | | | kg/TJ |
| ***Gasoline - mobile combustion*** | | | | | | 25 | 8 | kg/TJ |
| **Aviation kerosene** | 799 | kg/m3 | 44.1 | TJ/Gg | 71500 | | | kg/TJ |
| ***Fuel combustion - civil aviation*** | | | | | | 0.5 | 2 | kg/TJ |

# APPENDIX C - EMISSIONS BY EMISSION SOURCE

**Table 1C. Scope 1 emissions by source and responsible (Kyoto - $tCO_2e$)**

| Operating unit | Parameter | Responsible | Emissions (tCO2e) |
|---|---|---|---|
| CEMIG D | Alcohol consumption – company's own fleet | Ormindo Coutinho Filho | 2.73 |
| | $CO_2$ consumption by fire extinguishers | Geraldo Vinicius Ferreira da Silva | 0.01 |
| | S10 diesel consumption – company's own fleet | Ormindo Coutinho Filho | 5238.55 |
| | S500 diesel consumption – company's own fleet | Ormindo Coutinho Filho | 1064.98 |
| | Gasoline consumption – company's own fleet | Ormindo Coutinho Filho | 959.57 |
| | NG consumption by stationary sources (restaurant) | Pedro Henrick | 0.96 |
| | NG consumption by generators (Aureliano Chaves Bldg.) | Pedro Henrick | 1.76 |
| | VNG consumption – company's own fleet | Ormindo Coutinho Filho | 3.75 |
| | Diesel oil consumption by generators (headquarters) | Narcilio Fernandes Lima | 0.23 |
| | Aviation kerosene consumption by the company's fleet | Ormindo Coutinho Filho | 190.60 |
| | Use of insulating gases – leak of SF6 | Charles | 4110.84 |
| CEMIG GT | Alcohol consumption – company's own fleet | Ormindo Coutinho Filho | 0.65 |
| | Limestone consumption | Clara Silva | 3.15 |
| | Diesel consumption by ships | Clara Silva | 5.44 |
| | S10 diesel consumption – company's own fleet | Ormindo Coutinho Filho | 696.76 |
| | S500 diesel consumption – company's own fleet | Ormindo Coutinho Filho | 179.22 |
| | Gasoline consumption – company's own fleet | Ormindo Coutinho Filho | 354.31 |
| | LPG consumption by forklift trucks | Júlio Henrique | 1.35 |
| | NG consumption by stationary sources (boilers and other equipment) | Júlio Henrique | 8.29 |
| | Nitrogen consumption in fertilizers | Clara Silva | 63.46 |
| | Fuel oil consumption by stationary sources | Tiago Brito | 21,220.24 |
| | Diesel oil consumption by stationary sources | Tiago Brito | 182.60 |
| | Diesel oil consumption by generators (Generation) | Clara Silva | 3.79 |
| | Diesel oil consumption by generators (Transmission) | Schubert | 14.08 |
| | Aviation kerosene consumption by the company's fleet | Ormindo Coutinho Filho | 135.64 |
| | Use of insulating gases – leak of SF6 | Rômulo Miranda Texeira | 865.03 |
| Efficientia | Alcohol consumption – company's own fleet | Caroline Alves da Cunha | 0.00 |
| | Gasoline consumption – company's own fleet | Caroline Alves da Cunha | 2.92 |
| GASMIG | Alcohol consumption – company's own fleet | Augusto Vieira de Loiola | 0.18 |
| | Diesel consumption – company's own fleet | Augusto Vieira de Loiola | 2.92 |
| | Gasoline consumption – company's own fleet | Augusto Vieira de Loiola | 0.35 |
| | VNG consumption – company's own fleet | Augusto Vieira de Loiola | 70.64 |
| | Leak of natural gas in transport | Augusto Vieira de Loiola | 171.50 |
| Rosal | Diesel consumption – company's own fleet | Aucione Modesto Ferreira | 3.58 |
| | Gasoline consumption – company's own fleet | Aucione Modesto Ferreira | 3.16 |
| | Diesel oil consumption by generators | Aucione Modesto Ferreira | 0.85 |
| Sá Carvalho | Gasoline consumption – company's own fleet | Aucione Modesto Ferreira | 2.89 |
| | Diesel oil consumption by generators | Aucione Modesto Ferreira | 1.44 |
| **Total** | | | **35,568.41** |

**Table 2C. Scope 2 emissions by source and responsible (Kyoto - $tCO_2e$)**

| Operating unit | Parameter | Responsible | Emissions ($tCO_2e$) |
|---|---|---|---|
| CEMIG D | Electricity consumption | Danilo de Deus | 3033.32 |
| | Losses in the D system | Danilo de Deus | 509,079.32 |
| CEMIG GT | Losses in the T system | Danilo de Deus | 6066.63 |
| GASMIG | Electricity consumption | Augusto Vieira de Loiola | 33.52 |
| **Total** | | | **518,212.79** |

**Table 3C. Scope 3 emissions by source and responsible (Kyoto - $tCO_2e$)**

| Operating unit | Parameter | Responsible | Emissions (tCO2e) |
|---|---|---|---|
| CEMIG D | Commercialization of electricity | Danilo de Deus | 2,852,486.60 |
| | Alcohol consumption by contractors | Érika Silveira | 3.24 |
| | Diesel consumption by contractors | Érika Silveira | 12,400.70 |
| | Diesel consumption by outsourced trucks (light, medium and heavy trucks) | Bruno Tavora Palmeira | 634.02 |
| | Diesel consumption for employee commuting | Ormindo Coutinho Filho | 89.31 |
| | Gasoline consumption by contractors | Érika Silveira | 1294.76 |
| | LPG consumption by forklift trucks | Bruno Tavora Palmeira | 67.63 |
| | VNG consumption by contractors | Érika Silveira | 1.19 |
| | Transport in short-haul air travels | - | 150.96 |
| | Transport in long-haul air travels | - | 104.17 |
| | Transport in medium-haul air travels | - | 144.79 |
| | Distance covered to transport fuel to the operating unit | Tiago Brito | 6.06 |
| | Mass of waste sent for incineration | Alessandra Chagas Daniel | 98.66 |
| | Mass of waste sent for co-processing | Alessandra Chagas Daniel | 201.09 |
| CEMIG GT | Commercialization of electricity | Danilo de Deus | 2,510,772.38 |
| | Diesel consumption by outsourced trucks (light, medium and heavy trucks) | Bruno Tavora Palmeira | 33.37 |
| | Diesel consumption for employee commuting | Ormindo Coutinho Filho | 22.33 |
| | LPG consumption by forklift trucks | Bruno Tavora Palmeira | 3.56 |
| | Transport in short-haul air travels | - | 128.81 |
| | Transport in long-haul air travels | - | 19.05 |
| | Transport in medium-haul air travels | - | 123.93 |
| | Mass of waste sent for co-processing | Alessandra Chagas Daniel | 37.86 |
| Efficientia | Transport in short-haul air travel | - | 0.50 |
| | Transport in medium-haul air travel | - | 0.09 |
| GASMIG | Commercialization of NG (stationary combustion) | Augusto Vieira de Loiola | 2,116,661.19 |
| | Commercialization of NG (vehicular) | Augusto Vieira de Loiola | 88,205.44 |
| | Transport in short-haul air travel | - | 2.63 |
| | Transport in long-haul air travel | - | 9.06 |
| | Transport in medium-haul air travel | - | 5.05 |
| Rosal | Commercialization of electricity | Danilo de Deus | 39,248.16 |
| Sá Carvalho | Commercialization of electricity | Danilo de Deus | 21,174.03 |
| **Total** | | | **7,644,130.59** |

## APPENDIX D – THIRD PART STATEMENT

### 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 Register of Legal Entities under No. 72.368.012 / 0002-65, for the proper purposes, Companhia Energética de Minas Gerais - CEMIG, established at Av. Barbacena, 1200 - Ed. Júlio Soares - Santo Agostinho - Belo Horizonte - MG - CEP: 30190-131 is authorized to publish in all its titles **"The 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 - year The 2018 inventory of Companhia Energética de Minas Gerais-CEMIG is accurate, reliable and free from error or distortion and is an equitable representation of GHG data and information on the reference period, for scoped definied; was prepared in accordance with the specifications of NBR ISO 14064-1. "**

**Emissions Verified:**

Scope 1, 2 e 3 (em $tCO_2e$)

| Approach | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| Operational control | 35.568 | 518.213 | 7.644.131 | 8.197.912 |

São Paulo, 08th May,2019.

| Lucia Nunes | Antonio Daraya |
|---|---|
| Bureau Veritas Certification | Lead auditor |

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